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**Assessing prey and competitor/predators of pink salmon fry, Submitted Under the BAA**

Project Number: 02-452 -BAA

Restoration category: Research

Proposer: Prince William Sound Science Center



Lead Trustee Agency: NOAA
Cooperating Agencies: ADF&G (matching), OSRI (matching)

Alaska SeaLife Center: No

Duration: 2nd year of 2

Cost FY02: $36.4K
Cost FY03: $0K

Geographic Area: Prince William Sound

Injured Resource/Service: Pink Salmon, Walleye pollock, Pacific herring

## ABSTRACT

EVOS TC-funded research showed that macro zooplankton and adult walleye pollock densities are the primary biological forcing variables affecting pink salmon fry survival. A program to make these estimates was initiated in spring 2000 by a partnership of organizations including OSRI, SERVS and ADF&G. EVOS TC provided additional funds to expand this effort in 2001, including interaction with another EVOS TC project that is studying the use of pristine concentration in mussels to estimate pink salmon fry survival. We propose to finalize the survey design in 2002 and recommend procedures as a potential element in GEM, OSRI or a combined institutional monitoring program.

## INTRODUCTION

The annual run of pink salmon, which is composed of up to 90% hatchery fish, is a valued resource to the residents of Prince William Sound (Thomas et al. 1991; Thomas and Mathisen 1993). Commercial fishers, processors, shippers and managers depend upon forecasts of pink salmon returns, which require estimating juvenile survival, for efficient and sustainable use of the resource. Cooney (1993) and Willette et al. (1999a,b) have shown that plankton density is important to pink salmon fry growth and survival. Recognizing the importance of plankton to fry survival, the hatcheries in the Sound use a net sampling program to determine release strategies. However, Cooney et al. (1995) noted that the data from this plankton-watch program was not always consistent with other measures of productivity.

The absence of quantitative information on prey and predator densities has been a traditional limiting factor to describing the mechanisms that affect juvenile marine fish survival (Cushing 1974; Jones 1973). As part of the SEA program, new mechanistic models to predict pink salmon fry survival in the Sound using both plankton and predator densities as model input hindcasted survival as measured by wire-coded tag recoveries with remarkable accuracy (Willette et. al in preparation, Mason and Patrick, unpublished). The consistency of these results place increasing pressure on fisheries science to develop quantitative methods to monitor predator and prey conditions that juvenile fish are exposed to in their early life history.

Thomas et al. (1998) and Kirsch et al. (2000) demonstrated acoustic-plankton net techniques to synoptically measure zooplankton prey and fry predator densities along the outmigration route of pink salmon fry in PWS. As part of its nowcast-forecast (NF) program, the Oil Spill Recovery Institute (OSRI) sponsored the continued development of these methods with the goal of prediction the survival of dominant age-0 fishes in the Sound. This resulted in incorporating SEA methods in a two-stage, multi-frequency sampling design, which uses the acoustics to locate patches of plankton for optimization of the net sampling effort. The TC joined as a co-sponsor of this research and development in 2001. This allowed for the expansion of the field survey effort from three cruises to five and a 50% increase in spatial coverage. The increased spatial coverage allowed comparisons between the direct acoustic observations of plankton densities and fish with the measure of pristane build up in mussels.

The goal for FY02 is to formalize the predator-prey sampling design to document conditions in juvenile fish rearing areas and recommend monitoring approaches suitable for a cooperative GEM program.

## NEED FOR THE PROJECT

### A. Statement of the problem

One of the original questions sought by the SEA program was to explain why the survival of juvenile salmon fluctuated dramatically after the oil spill. Pink salmon suffered major

declines in 1992 and 1993. Declines in abundance may have resulted from changes to habitat, food supply, predator and competitor populations, genetic degradation, the commercial fishery and management, or unknown natural events. In 1990, GLOBEC scientists concluded that only with the development of new population measurement techniques and survival models, would it be possible to forecast accurately enough to separate the effects of natural from anthropogenic forcing on animal populations (Cullen 1989). The OSRI monitoring program resulted from the development of new predictive tools for pink salmon survival that grew out of the SEA program. Specifically, the abundance of spring prey and predators is critical input for assessment of pink salmon marine survival. Since restoration is an anthropogenic impact by definition, improving predictive capability is the path for designing more effect and accurate restoration activities and developing a GEM program that contributes to the future improvement of conservation and sustainable use of the pink salmon stocks of Prince William Sound.

FY00 Findings

The F00 field studies of the OSRI monitoring program produced two substantive findings. First, the results demonstrated that a three-frequency acoustic system, supported by plankton net samples and CTD measurements, can provide a viable methodology, combining high quantification with the extremely high sampling power that is required to obtain sufficient detail in a reasonable time and cost framework. Second, the study revealed how challenging the sampling requirements were for more conventional sampling approaches. A comparison of the acoustic and net sampling approaches showed that the acoustic system approached an acceptable level of precision at a rate about 30,000 times faster than an equivalent effort with conventional zooplankton net sampling. However, even at this much higher sampling power, it is difficult to achieve the required temporal and spatial coverage within the economic limitations that are necessary for a long-term monitoring program (assumed to be under $100K/year including vessel costs). The optimization strategies that were applied in the FY00 design resulted in an additional 200-fold increase in sampling efficiency. This improvement resulted in an approach that was marginally cost effective. However, further increases in efficiency are required to ensure the long-term cost effectiveness of the monitoring effort. It is hoped that the additional information to be obtained during the expanded FY01 effort will provide the ingredients necessary for a final incremental increase in efficiency.

In addition to the need for further increases in survey efficiency, some additional advancements in data analysis methods are needed and some potential biases need to be explored. Most of these objectives should be accomplished in the FY01 effort with only minor adjustments in FY02.

EVOS TC has invested considerably (seven years) in the use of pristane concentrations in mussels as a measure of marine productivity, and more recently as a measure of the survival of hatchery-released pink salmon. While such indices can provide valuable insights, there are inherent dangers. Unless the mechanism of a correlation is well understood, the predictive capability can break down and lead to error. The danger is

well articulated by Cullen (1989), a GLOBEC planning document, "Many correlations between population variability and associated biological and physical variables have been reported. However, these correlations are generally unsuccessful predictors of population variability and, hence, of limited usefulness..... As a consequence of having available only a correlative understanding of the fluctuations in marine populations, policy formulation in global fisheries, climate effects, and pollution can be addressed with neither confidence or vigor." Unlike pristane, acoustics provides a direct measure of biomass, both of the zooplankton and the zooplankton-feeding fishes whose abundance and behavior are implicit in the pristane abundance. Near-synoptic comparisons between the acoustic observations and the pristane monitoring should produce some quantitative understanding of the mechanism behind the pristane values, increase its usefulness as an indicator, and decrease the dangers inherent in such correlative measures.

## B. Rationale/Link to Restoration

As the Restoration effort transitions into the GEM program, meaningful and cost effective monitoring methods and applications will be required for GEM to carry out its stated mission and goals. As pointed out by the NRC review of the GEM planning document, that process can be "messy". There are several elements that are key to a successful monitoring program. As pointed out by the NRC review, the selected species must be based on implicit or explicit hypotheses about ecosystem function and what is important to monitor to gain knowledge of that system. *Neocalanus*, the largest zooplankton biomass that we measured in Prince William Sound, is also the primary documented prey of pink salmon fry so stands out under the NRC's criteria. Further, *Neocalanus* is an input to models that have been developed for pink salmon production. The NRC adds, "species may be selected because they are of great human interest or of particular commercial value". Again, while *Neocalanus* has no specific commercial value, its abundance is paramount in the success of pink salmon, which is clearly of considerable commercial value and human interest.

What is not pointed out in the NRC review document, but is possibly the most critical factor in the success of any monitoring program, including GEM, is the ability to measure a parameter with sufficient precision to detect meaningful change. In the pursuit to improve predictions of animal population change, we must have the ability to measure the change to verify the prediction. This need is implicit in the GLOBEC planning documents. The National Science Foundation GLOBEC program pointed out that one of the primary failures in past marine research was the use of sparse, discrete measurements, often with nets to estimate abundance. GLOBEC recommended the use of acoustical-optical, quasi-continuous measurement technologies to resolve confounding temporal and spatial variation. The SEA and OSRI programs followed this advice and have been highly successful at making lasting contributions. This project also adheres to this principal and in doing so should make a lasting contribution to the GEM program.

## C. Location

Research will be conducted in Prince William Sound where the fishing industry in the communities of Cordova, Valdez, Tatitlek, Chenega Bay, Whittier and Seward will benefit. Transfer of this technology to outlining areas could result in benefits throughout Alaskan coastal communities.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Traditional and scientific knowledge has led to the development of regional applications of new acoustic methods. Local and Native fishermen were responsible for first applications of new quantitative acoustic technologies for fish stock assessment and research: 1) after the herring collapse in 1993 (Gerald McCune, Cordova District Fishermen United, personal communication), 2) after the pink salmon collapse in 1993 (R.J. Kopchak and Jim Gray, Cordova fishermen, personal communication) and 3) at the beginning of the walleye pollock commercial fishery in 1995 (Jay Stinson, Alaska Draggers Assoc., personal communication). After repeated applications over the last eight years, management is slowly integrating this technology into its harvest management practices in the Sound. However, the transition from research and development to management applications is slow and rarely has sufficient funding. Full implementation of the information from technological advances made during the SEA program and continuing research projects will require leadership and vision from sponsors who are dedicated to the improvement of environmental information systems. There in lies the importance of funding institutions such as the TC, OSRI, the North Pacific Research Boarch and others to develop science plans that carryout the implementation phase of the research, else the public are likely to lose the benefits of the research and development. With continuation of funding for implementation there is the opportunity to use PWS as a example for monitoring and predicting animal population change, thus influencing neighboring bioregions such as Kodiak and Cook Inlet to seek similar capability and promote the transfer of new technologies.

The following procedures have worked well for developing the SEA, OSRI and Science Center programs: 1) discusing problems with the Board of Directors, who collectively represent fishers, federal, state and local managers, univerisity and independent researchers, private industry and the public, 2) consulting with community representatives during the conception and design of the project to seek input, 3) advertising all vessel charters and employment opportunities in communities near where the work is to be performed, 4) visiting local communities during the course of the field work via our educational outreach programs, and where appropriate, base field work out of the villages using local lodging and/or vessels, 5) providing information to the community through the publication and distribution of newsletters that use non-technical language on project results, 6) the posting of non-technical information on our web page, 7) the presentation of research results as seminars during the year in the community, 8) acknowledging all contributions appropriately, 9) applying the results of the research in

ways designed to benefit local communities, people, and cultural practices and 10) living in and becoming part of the community we serve.

## PROJECT DESIGN

### A. Objectives

- Measure macrozooplankton density, distribution and abundance in PWS during the spring using echointegration-plankton net techniques,
- Make synoptic measurements of dominant fry predators,
- Collaborate with other researchers to integrate the predator-prey information with physical oceanography information from the OSRI nowcast-forecast program and make this available to modelers for predicting pink salmon fry survival,
- Exchange information on zooplankton and fish distribution and density with the pristane project to test assumptions, underlying mechanisms and compare results.
- Finalize and document a cost-effective, long-term monitoring program to be incorporated in GEM, OSRI Nowcast/forecast and/or other institutional programs.

### B. Methods

Acoustic and ground-truthing procedures: Acoustic methodology for zooplankton assessment is well developed. Major publications include: Holliday and Peiper 1980; Greenlaw and Pearcy 1985; Peiper et al. 1990; GLOBEC 1990a,c; Stanton et al. 1994, 1996; Wiebe et al. 1997; Thomas and Kirsch 2000a,b. Specific application in Prince William Sound is described in Kirsch et al. (2000). The results of the F00 monitoring are reported in Thorne (2000a) and Thorne and Thomas (2000a,b).

The application of multiple frequencies allows use of scattering models (Holliday and Piper 1980; Greenlaw and Pearcy 1985; Peiper et al. 1990; Stanton et al. 1994, 1996) to improve assessment accuracy. Although a variety of acoustic frequencies have been used in Prince William Sound, from 38 kHz to 1 mHz, comparable applications (acoustic/net sampling applications on *Neocalanus* spps. copepods) were previously limited to single frequency studies, either 120 kHz or 420 kHz (Thomas et al. 1998; Kirsch et al. 2000; Thorne and Thomas 2000a,b). This project uses three frequencies simultaneously, 38 kHz, 120 kHz and 420 kHz. The 420 kHz can detect most calanoid copepod zooplankton (Fig. 1). The 120 kHz frequency can detect *Neocalanus* size zooplankton very effectively (Fig. 2). The 38-kHz frequency is primarily meant for fish, although the surveys in May 2000 found that 38 kHz also detected zooplankton with larger target strengths (Fig. 3). We have found that frequencies higher than 420 kHz (720 kHz and 1 mHz) are impractical in PWS during the spring because the high sound attenuation in plankton layers severely limits the range and volume of the sampling.

In FY00, we used a BioSonics 38 kHz DT4000 with a 6-degree transducer, a 120 kHz BioSonics Model 101 with a 7-degree transducer and a BioSonics 420 kHz Model 102 with a 6-degree transducer. The systems were calibrated with standard targets following

procedures of Foote and MacLennan (1982). All three systems were mounted on a single towing vehicle. Triggering for all three was synoptic at one per second, driven by the DT system. The DT4000 stores raw digital echo information directly on computer hard-drive. The data were analyzed using BioSonics Echo Integration Analyzer Program Version 4.0. The 420 kHz data were analyzed in real-time using a BioSonics Model 221 Echo Signal Processor. The 120 kHz data were recorded on DAT and later processed using the BioSonics ESP. We are integrating DT (Digital Transducer) technology at 120 kHz and 430 kHz for F01.

The basic echo integration analysis produces estimates of volume backscattering. Estimation of absolute density from volume backscattering measurement requires estimates of species composition and average backscattering cross-section. Species composition information is obtained from the net sampling. Backscattering models for zooplankton are described in several publications (Holliday and Peiper 1980, Greenlaw and Pearcy 1985, Peiper et al. 1990, Stanton et al. 1994, 1996). Kirsch et al. (2000) specifically estimated the reflection characteristics of copepods, pteropods and euphausids in PWS at 420 kHz and details the absolute density estimation procedure. Results from the May 2000 surveys show that the three-frequency volume backscatter combined with the plankton nets readily allows estimation of the absolute densities of the various zooplankton components (Table 1).

Backscatter from fish is readily detected and separated from zooplankton backscatter in most cases. Backscatter from schooled or layered fish aggregations is far higher than for zooplankton. When individual fish targets are present within a zooplankton scattering layer, the fish signals appear as high, narrow spikes above the more homogenous zooplankton backscatter. In most cases, it is relatively easy to estimate fish densities in the presence of zooplankton by simple thresholding. The separation is greatly facilitated with digital transducer technology. With this technology, raw signal data can be rapidly examined at various thresholds and the echo integration component from different signal levels can be measured. This procedure can also be done with recorded analog data, as was the case for the FY00 surveys, but the procedure is more time consuming. For data that is analyzed in real-time, the best procedure is to echo integrate over small space/time scales and carefully edit out returns from fish. This procedure works except where fish densities are too low to make an obvious contribution to the backscatter, but in those case the error from misappropriation is minor. The transition to DT technology, which will began in YF01 and be completed in FY02, will greatly facilitate data analysis and decrease analysis time.

No direct sampling for fish targets is envisioned in this program, at least for the near future. Sufficient pattern classification information is available from historic observations to separate components into adult pollock, juvenile pollock and forage fish categories with reasonable accuracy. In five years of intensive midwater trawling during April and May, we found that 95% or more of the large fish targets in the plankton layers to be walleye pollock (Thomas et al. 1997; 1998). Acoustic backscattering cross-section information is available for these categories for biomass estimation (Thorne 1983a) of schools and layers. Echo counting techniques can provide numerical abundance

estimates with high accuracy (Thorne 1983b). Trends in observed fish abundance will be compared with annual biomass estimates of adult herring and adult pollock conducted by OSRI monitoring programs for those species (Thorne 2000b). The May 2000 surveys showed high densities of both adult and juvenile pollock in central PWS early in May. Fish densities in the Knight Island/Perry Passage area were very low until the end of the month when the abundance increased slightly. The increase corresponded with a decrease in abundance in the central basin (Fig. 4).

Past sampling of the zooplankton in the Sound during April and May has shown that *Neocalanus* spps. copepods dominate the assemblage (Cooney 1993; Cooney et al. 1995). They are the primary large zooplankton scatter in the surface layers until late May (Thomas et al. 1998; Kirsch et al. 2000). Our plankton net sampling is conducted primarily to verify that the composition of the early spring zooplankton assemblage is dominated by *Neocalanus* spps. copepods. During the FY00 surveys, three to five zooplankton samples were taken within each 4-transect cluster. The zooplankton sampling was a 50 m vertical tow using a 0.335-mm 0.5 m-ring net, following procedures of Cooney et al. (1995). Samples are preserved in the field in 10% seawater formalin. Zooplankton analysis follows standard procedures (Coyle et al. 1990). Samples are processed for to identify and quantify the species composition and dominant zooplankters. The FY00 sampling verified the predominance of *Neocalanus* (Table 2). Changes in the zooplankton composition were clearly reflected in changes the backscattering ratios among the three frequencies and corresponded to changes predicted from existing scattering models.

Some minor additions will be added to the program either in FY01 or FY02 to investigate the potential of some biases. The 0.5 m ring net vertical tows appear to be very effective for documenting the zooplankton community, and signal classification appears to be sufficient to document both juvenile and adult fishes. Weaknesses in the current program are lack of information on the vertical stratification and (possibly) lack of sampling capability for larval and juvenile fishes. The backscatter from larval and juvenile fishes, such as pollock, might confound the acoustic assessment of zooplankton if these targets are at high enough concentrations. Although, previous studies indicate that larval fishes are not present until after the May sampling window, these studies have relied on using nets, such as the MOCNESS, that may not be able to sample some juvenile fishes due to avoidance. In FY01-02, we plan to sample with an RMT to resolve this question.

Physical data acquisition: Temperature and salinity data were acquired using a SeaBird Electronics Model 19.03 CTD. Typically, 6-7 CTD stations were taken each cruise and were arrayed to provide inshore/offshore and north/south trends. This information is incorporated into the seasonal physical Oceanographic sampling database funded by the OSRI nowcast-forecast program. A Princeton Ocean Model (POM) is used to assimilate the physical monitoring data and produce nowcast-forecasts of physical structure (current velocities, direction, temperature, salinity, and density) in the Sound. A workshop was held in December 2000 to determine a 10-year plan to improve and fill the large gaps in the present physical observation system. By superimposing the distribution of predators and prey populations on this physical data, the actual physical conditions experienced by

these animal populations are estimated accurately enough to incorporate as parameters into the population, bioenergetics growth models. Simulations with the POM are also being conducted to reconstruct the distributions we observe on the surveys. These simulations and observations should help us determine if the *Neocalanus* spps. copepods are originating from the Sound or the Gulf (Kline 1999).

Survey design: The methods follow those developed and applied on the OSRI, SERVS, PWSAC and ADF&G program in spring 2000. Effort centers on the early marine life history period of the pink salmon, since the overwhelming consensus of evidence is that this stage is crucial to total survival. This follows the rationale of the PWSAC Plankton-Watch program, which is designed to guide pink salmon fry releases by monitoring food availability. The *Neocalanus* spps. copepod life history strategy anticipates the timing of the spring bloom by placing the earliest life stages in the water column before plant production is initiated each spring (Cooney et al. 1995), providing an ideal food source for pink salmon fry. Peak abundance of *Neocalanus* spps. copepods in the upper 50 m occur during the month of May. In June, *Neocalanus* spps. copepods migrate to deeper waters. The proposed monitoring program is designed to cover this critical period. Three surveys were conducted during May 2000. EVOS funding is allowing temporal expansion of this project to five surveys between mid-April and mid-June in 2001.

The FY00 zooplankton survey design was six groups or clusters of four transects (Figure 5). Three clusters (twelve transects) extended along central PWS from Bligh Island to the Hinchinbrook Entrance and three more clusters along the primary pink salmon out-migration corridor west and north of Knight Island, extending to Perry Island. This initial design was based on several criteria: (1) coverage of the historic area of juvenile pink salmon out-migration and hatchery locations, (2) contrast between the traditional western outmigration route and the eastern side or main basin of Prince William Sound, and (3) an area that could be covered within a two-day survey. Transects were designed to be able to contrast near-shore and offshore areas as well as north/south trends. Strong gradients in abundance were observed, with highest densities in the southern portions of Knight Island. The lowest abundance of zooplankton was consistently observed along the west shore. EVOS funding is supporting a spatial expansion of this project to nine groups or clusters of four transects that will achieve a better understanding of the over-winter areas/sources of zooplankton, incorporate sampling near more hatcheries and sample adjacent to the mussel-bed areas where pristane is being measured (Fig. 6).

The tactical procedure is to complete the acoustic data collection along a four-transect cluster, locate patches of high density zooplanktgon, then backtrack to subsample the patches with nets and the water conditions with a CTD. Usually these station locations are where the higher zooplankton densities were observed, but low-density locations were also selected for contrast. This general pattern approximates proportional sampling and will be refined in future surveys. A recent analysis of our two-stage, proportional sampling shows that we have achieved a 15,000-fold increase in efficiency over traditional discrete-only sampling designs. Zooplankton data collection is limited to daytime hours due to the long daylight hours and the presence of benthic nekton species at the surface during the night.

Pristane links: The initial studies of pristane concentrations in mussels have indicated a positive correlation with marine survival of hatchery pink salmon (Jeff Short, NMFS, pers. comm.). The hypothetical mechanism for this is:

- the pink salmon fry feed on pristane-rich *Neocalanus* spps. copepods;
- the pink salmon fry are the dominant zooplantivores in mussel bed habitats;
- the pink salmon fry defecate pristane-rich feces near the mussel beds,
- the pristane-rich feces are ingested by mussels,
- the pristane accumulates in the mussel tissues in proportion to the amount of feeding by the fry on the copepods.

The acoustic survey will not measure pink salmon fry directly, but it will document the inshore-offshore gradients of *Neocalanus* spps. copepods, herring and other fishes, which should provide supporting data for interpretation of the pristane data. First, high occurrences of juvenile herring and sand lance in the nearshore during the summer is well documented (Stokesbury et al. 2000) and could possibly swamp the effects of pink salmon fry on the mussel beds. Acoustic surveys can determine if these fishes are in the mussel bed habitats where pristane concentrations are measured. It is possible that other fishes may only be inshore at night when they come to the surface and spread out so some nocturnal sampling will be required (Thomas et al. 1995). Second, we will be able to compare the distribution of zooplankton and fish to pristane levels in the mussels. This information should help to resolve questions on zooplankton and pristane origin.

In addition, there are also some assumptions that the pristane index makes that will require new information. Willette et al. (1999a,b) also suggested that the availability of *Neocalanus* spps. copepods inshore were a critical factor in pink salmon survival. However, in our FY00 surveys we frequently observed pink salmon fry feeding on patches of copepods in the middle of the Perry Island and Knight Island passages. It is obvious that the pink fry must cross these passages to migrate so we are not sure at this time what portion of the population resides offshore. Also most of the historical sampling of the pink salmon fry has been based upon visually locating the fry at the surface along the shoreline and then seining them (Mark Willette, ADF&G, personal communication).

Our FY01-02 surveys will include special sampling at key pristane stations around AFK Hatchery, Applegate Island, Brass Beach, Esther Island, Fairmont Island, Fox Farm, Herring Point, Pt. Eleanor, Perry Island and Point Pakenham.

Estimating fry survival: Historically, fisheries models have not used predator-prey information to predict returns (Ricker 1975). However, with the development of the bioenergetics model (Hewitt and Johnson 1992) and it's application at the population level (Beauchamp et al. 1995), modeling of population bioenergetics became a numerical process driven by temperature and food, which are measured environmental parameters. With predation being a function of size and size a function of growth, survival is a function of growth. Thus the linking of predator numbers in the environment with the population bioenergetics is the accepted numerical approach to solving for survival.

SEA research has shown that calanoid copepods and adult walleye pollock are the primary prey and predator, respectively of the pink salmon fry in the Sound (Willette et al. 1999a,b; Thomas et al. 1997). Thus, making synoptic measures of the temperature, density of calanoid copepods and adult walleye pollock in the marine rearing areas of the Sound offers the best approach to solving population survival questions for the PWS pink salmon.

In FY02, we will collaborate with physical oceanographers and modelers to make the information on predator-prey and physical conditions available for modeling excercises. Since neither of the Principal Investigators in this proposal are modelers, we will work to collaborators in ADF&G, OSRI and other grant recipients to make forecasts. Assimilation of the measurement data can be into spreadsheet formats that are common in fisheries management or into more complex numerical solutions such as the pink salmon fry model developed during the SEA program (Mason and Patrick, unpublished). First, we have had discussions with Steve Moffit (Cordova ADF&G), who has assumed Mark Willette's responsibilities for forecasting pink salmon returns. Steve will be using Mark's spreadsheet to forecast pink survival, and we will be providing Steve with prey and predator numbers to assimilate and compare results with the traditional method.

Second, we have already made contact with the GLOBEC program researchers to encourage use of our data to estimate the nearshore survival of fry. Since estimation of nearshore marine mortality is a prerequisite for separating ocean mortality from total mortality as measured by marked fish returns, this monitoring program in the Sound provides critical measurement data for estimating nearshore marine mortality. We have had discussions with David Beauchamp, University of Washington, to facilitate cooperation.

Third, we will collaborate with the numerical modelers on a specific OSRI modeling project. Since the mechanisms for the SEA pink salmon model have been described (Willette et al in press), we will attempt to work with the OSRI modeling effort to provide information needed to forecast fry survival. However, as an FY02 OSRI program, the PI's and their approaches have yet to be defined and are subject to change.

Finally, Jeff Short has developed a Pristane index model as a surrogate to the magnitude of pink salmon feeding on calanoid copepods, which is a surrogate to survival. As stated earlier, this model has several assumptions that we can evaluate with direct measures of copepod and fish abundance. Given that total mortality will be determined the following year by adult pink salmon returning to the Sound, the data we collect will be useful to four independent modeling groups to compare expected survival estimates.

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

OSRI, SERVS and ADF&G provided approximately 110K to conduct the FY00 surveys. This level increased to 160K in FY01, with the added sponsorship of the TC. This

program makes extensive use of the measurement and computing equipment purchased and used on past EVOS TC and OSRI research projects at minimal costs to upgrade and maintain.

## SCHEDULE

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

Oct 1 – Dec 31, 01: Complete analysis and reporting of FY01 sampling program

Jan 1 - Mar 31, 02: Review of databases and models for program and survey design; design and begin refinements of measurement systems, design and begin assembling processing system for making near-real time estimates of abundance, attend EVOS workshop

Apr 1 - Jun 30: Implementation of FY02 field surveys; continue data analysis.

July 1 - Sep 30: Report, evaluate and refine survey design, make initial predictions of recruitment, and finalize sampling for future implementation, develop manuscript for publication in a peer reviewed journal

### B. Project Milestones and Endpoints

FY02 Report on the spring FY02 predator-prey surveys with estimates of future pink Survival. Completion and documentation of proposed future monitoring design.

### C. Completion Date

FY02 (September 2002) with annual report on April 15, 2002.

## PUBLICATIONS AND REPORTS

An annual report will be prepared to meet the Council's requirements for work done in 2002. Several peer-reviewed articles are anticipated from the results of the two years of work for publication in professional journals.

## PROFESSIONAL CONFERENCES

Presentations are planned for the International Council for Exploration of the Seas: Fisheries Acoustics Symposium, PICES, the American Fisheries Society Meetings and the World Fisheries Congress.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project is directly interacting with EVOS Trustee Council projects on physical oceanography modeling and observations, pristane measurement, and stable isotope analysis. We will also make use of preceding Council research through the designation of common field sites and sampling design. This project will also make use of data generated in the SEA, APEX and NSP projects as well as seek the input of researchers involved in other projects within the region.

## PRINCIPAL INVESTIGATORS

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Responsibilities: Dr. Thorne will be responsible for project administration and acoustic sampling, analysis and writing. He has vast experience working as a PI on research projects for over 25 years while at the University of Washington and at BioSonics Inc. He is well published with over 50 peer-reviewed manuscripts and holds is a Research Full Professor at the University of Washington. He is PI on the continuation of this TC project and participated as a subcontractor to the University of Alaska Fairbanks on the APEX research program.

Dr. Thomas will be responsible for project coordination, survey design and field logistics, data analysis and writing, and interfacing with OSRI physical oceanography and modeling projects. He has been working as a PI on research projects for over 20 years while at the University of Washington and at the PWS Science Center. He is well published with over 60 peer-reviewed manuscripts and is an Affiliate Full Professor at the University of Miami and the University of Alaska at Fairbanks. He is a PI on the continuation of this project and has been a PI on past EVOS TC research projects.

C.V.s for both investigators are attached. Please address all correspondence related to this proposal to Richard E. Thorne.

## KEY PERSONNEL

| | |
|---|---|
| Field assistants (staff): | Assists with all aspects of fieldwork and sampling. |

## LITERATURE CITED


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Table 1. Scattering Characteristics of Various Components in Plankton Net Samples

| | Volume Backscattering | | Target Strength (dB) | | | |
|---|---|---|---|---|---|---|
| Frequency | KI/P | Main | Large Copepods | Small Copepods | Pteropods | Oikopleura |
| 420 | 1.4E-07 | 1.4E-07 | -97 | -113 | -95 | -107 |
| 120 | 2.5E-07 | 1.3E-07 | -98 | -120 | -95 | -94 |
| 38 | 1.7E-07 | 6.0E-08 | -102 | -150 | -115 | -95 |

Table 2. Characteristics of Plankton Net Samples in Knight Island/Perry Passage and the Main Basin of Prince William Sound

| | % Biomass Composition | | | | | Length (mm) | | |
|---|---|---|---|---|---|---|---|---|
| Location | Small copepods | Large copepods | Oikopleura | Pteropod | Other | Large Copepod | Pteropod | Euphausid |
| KI/P | 19.8 | 73.2 | 4.5 | 0.1 | 2.5 | | | |
| Main | 35.6 | 58.4 | 1.0 | 0.7 | 4.2 | | | |
| Average | 27.8 | 65.8 | 2.6 | 0.3 | 3.5 | 3.80 | 1.48 | 3.26 |

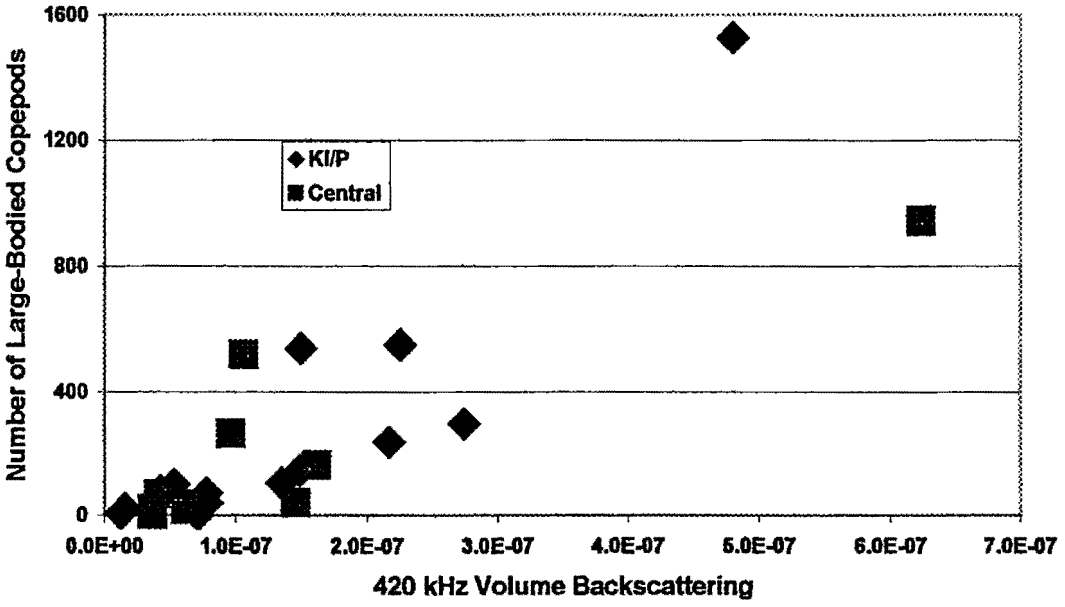


Figure 1. Relationship between 420 kHz volume backscattering and plankton net catches of large copepods in Knight Island Passage and the main (central) basin of Prince William Sound, May 2000

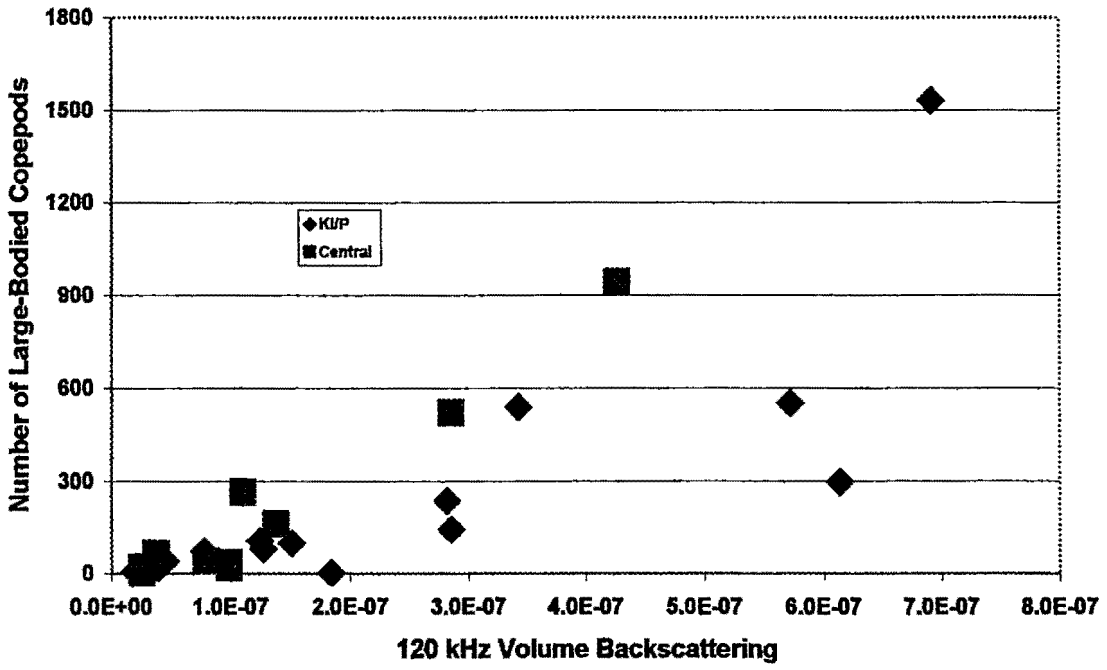


Figure 2. Relationship between 120 kHz volume backscattering and plankton catches of large copepods in Knight Island Passage and the main (central) basin of Prince William Sound, May 2000

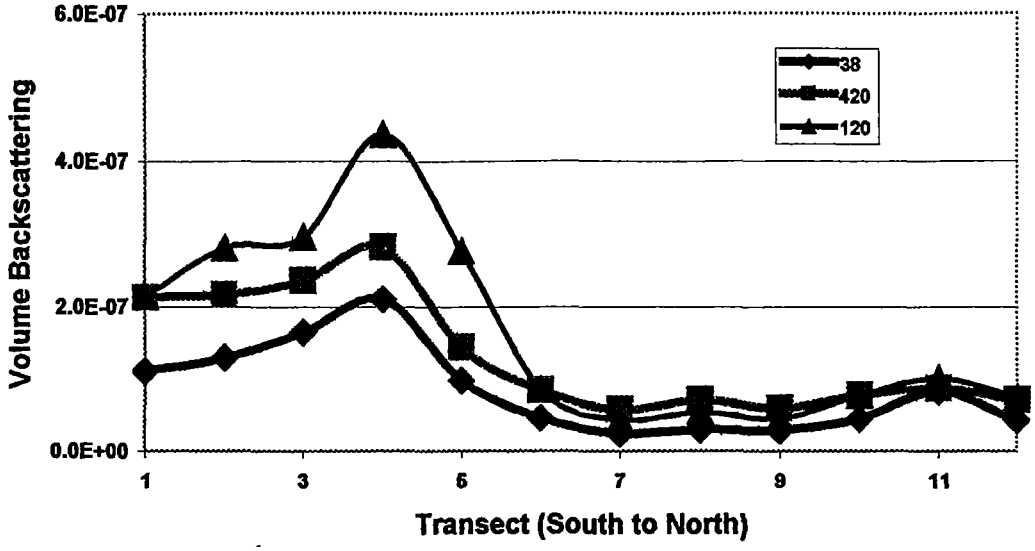


Figure 3. Distribution of scattering from three frequencies, Knight Island/Perry Passage, PWS, May 13, 2000

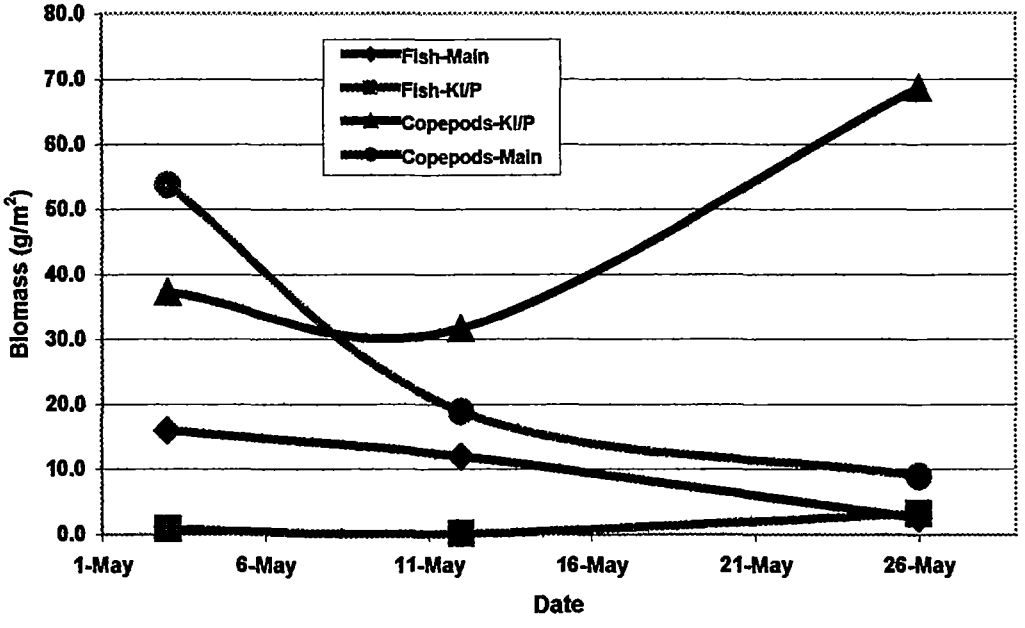


Figure 4. Changes in biomass of large copepods and fish in Knight Island/Perry Passage and the main basin of Prince William Sound during May 2000

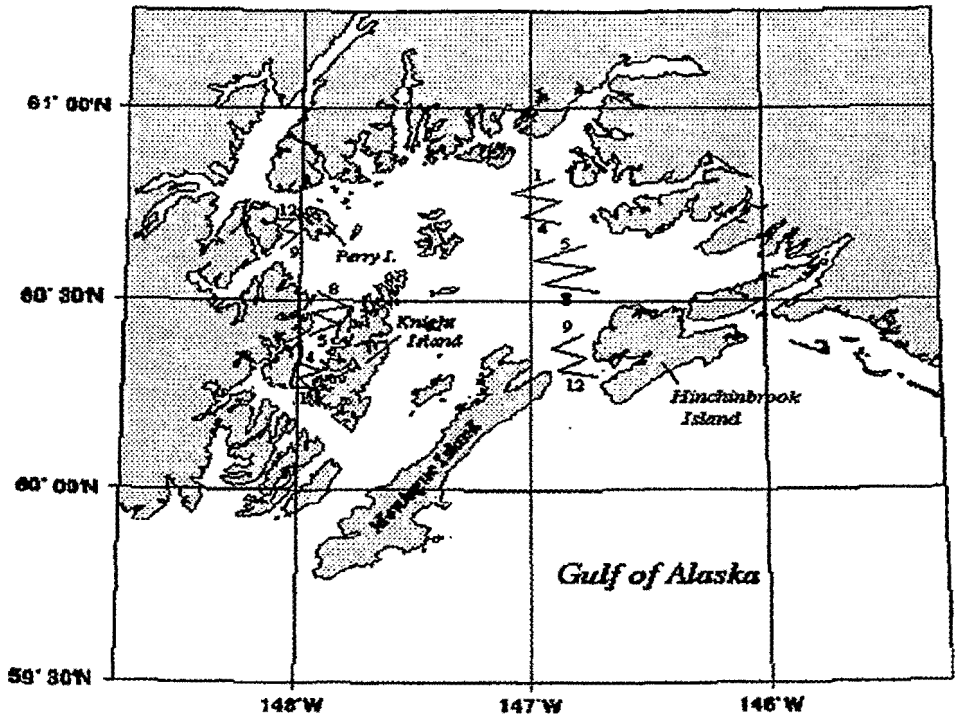


Figure 5. Schematic of approximate transect locations for the May 2000 surveys in Prince William Sound.

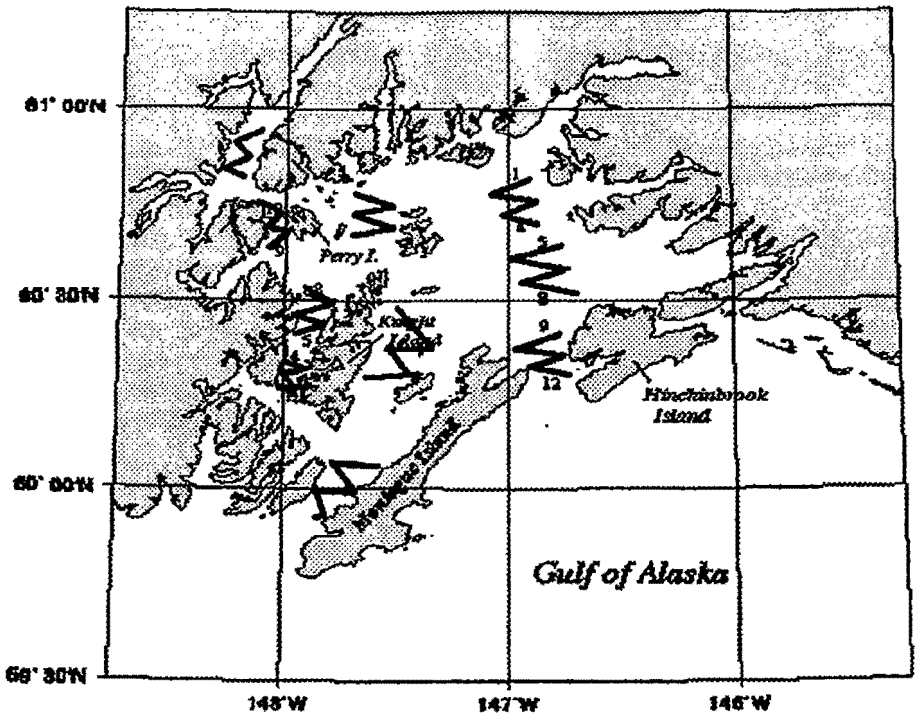


Figure 6. Schematic of approximate general transect locations for the 2001 surveys in Prince William Sound. Specific intertidal sampling at Pristane sampling stations is not shown.

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Employment History

| | |
|---|---|
| Prince William Sound Science Center | Senior Scientist 2000-present |
| BioSonics, Inc.<br>4027 Leary Way NW<br>Seattle, WA 98107<br>(206) 782-2211 | Vice President 1996-1999<br>Manager Technical Services 1991-1999<br>Senior Scientist 1988-1999 |
| University of Washington<br>School of Fisheries<br>Fisheries Research Institute<br>Seattle, WA | Affiliate Research Professor 1991-Present<br>Research Professor1981-1990 (LOA 1988-1990)<br>Research Associate Professor 1976-1981<br>Senior Research Associate 1970-1976 |
| Commercial Fisher (salmon and albacore) | 1957-1968 |

Academic Background

Ph.D., Fisheries-1970, University of Washington, School of Fisheries
MS Degree-1968, University of Washington, Department of Oceanography
B.S. Degree-1965, University of Washington, Department of Oceanography

PUBLICATIONS:

Thomas, G.L, J. Kirsch and R.E. Thorne in review. *Ex-situ* target strength measurements of Pacific herring *Clupea pallasi* and Pacific sand lance *Ammodytes hexapterus* North American Journal ofFisheries Management.

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1993-95, Associate Professor (affiliate), University of Alaska Fairbanks, Fairbanks, AK
1984-89, Assistant to Leader, Fish Coop Unit, University of Washington, Seattle, WA
1976-92, Assist. Professor (research)/Fish.Biol./Res.Assoc, FRI, Univ. of Wash., Seattle, WA
1973-76, Pre-doc. Research Assoc., College of Fisheries, FRI/FCU, Univ. Wash., Seattle, WA
1972-73, Research Associate, Scripps Institute of Oceanography, La Jolla, CA
1971-72, Biological Technician, GS-5, Southwest Fisheries Center, NMFS, La Jolla, CA

**Academic Honors**
1999 - Outstanding Service Award, Prince William Sound Science Center
1990 - Outstanding Service Award, U.S. Fish and Wildlife Service, Region 1.
1986 - Outstanding Service Award, North Pacific International Chapter, Amer. Fish. Soc.
1976 - Ellis Memorial Scholarship, College of Fisheries, University of Washington
1974 - Tacoma Sportsmen's Scholarship, College of Fisheries, University of Washington

**Professional Memberships**
American Fisheries Society (life member)
American Institute of Fisheries Research Biologists
American Association for the Advancement of Science

**Public Service**
1998-01 Board Member, Cordova Medical Center, Cordova AK
Served on many science review panels, chaired several symposia and edited proceedings, peer reviewed proposals and journal papers, supported and mentored over 20 graduate students. Two of four Ph.D. students are faculty at major research universities.

**Other experience**
1965-73, Deckhand on Southern California sport-fishing charters
1983-1993 Commercial Fisher, intermittent and seasonal (Bristol Bay salmon gillnetting, Gulf of Alaska long-lining for blackcod and halibut, West coast trolling for albacore, Nearshore jigging for rockfish)
1978-present, Fisheries Consultant, hydroacoustics, stock assessment, environmental impact

**Publications**


Thomas, G.L, J. Kirsch and R.E. Thorne in review. *Ex-situ* target strength measurements of Pacific herring *Clupea pallasi* and Pacific sand lance *Ammodytes hexapterus* North American Journal ofFisheries Management.

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Technical Reports: I am author on over 100 technical reports.

**FY 01 EXXON VALDEZ TI EE COUNCIL PROJECT BUDGET**
October 1, 2000 - September 30, 2001

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 |
|---|---|---|
| Personnel | $0.0 | $0.0 |
| Travel | $0.0 | $0.0 |
| Contractual | $53.3 | $36.4 |
| Commodities | $0.0 | $0.0 |
| Equipment | $0.0 | $0.0 |
| Subtotal | $53.3 | $36.4 |
| General Administration | $3.7 | $2.5 |
| Project Total | $57.0 | $38.9 |
| Full-time Equivalents (FTE) | 4.0 | 2.5 |
| Other Resources | $160.0 | $135.0 |

LONG RANGE FUNDING REQUIREMENTS

| Estimated FY 2003 | Estimated FY 2004 | Estimated FY 2005 |
|---|---|---|
| $0.0 | $0.0 | $0.0 |

Dollar amounts are shown in thousands of dollars.

Comments:

**FY 02**

Prepared:

Project Number: 02-452 ~BAA
Project Title: Assessing prey and competitor/predators of pink salmon fry, Submitted Under the BAA
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

**FY 01 EXXON VALDEZ T EE COUNCIL PROJECT BUDGET**

October 1, 2000 - September 30, 2001

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 |
|---|---|---|
| Personnel | $29.4 | $20.7 |
| Travel | $1.5 | $3.4 |
| Contractual | $10.5 | $3.5 |
| Commodities | $1.2 | $1.0 |
| Equipment | $0.0 | $0.0 |
| Subtotal | $42.6 | $28.6 |
| Indirect | $10.7 | $7.8 |
| Project Total | $53.3 | $36.4 |
| Full-time Equivalents (FTE) | 4.0 | 2.5 |
| Other Resources | $160.0 | $135.0 |

LONG RANGE FUNDING REQUIREMENTS

| Estimated FY 2003 | Estimated FY 2004 | Estimated FY 2005 | | |
|---|---|---|---|---|
| $0.0 | | | | |

Dollar amounts are shown in thousands of dollars.

Comments:

The total EVOS TC share of the requested project is approximately 21%

*Salary rate for G.L. Thomas reflects research time at 20% reduction from administrative costs
**OSRI, is contributing $50,000 to this project
***SERVS is providing 15 days of vessel charter, valued at $5,000 per day, for $75,000 of in-kind support
****ADF&G is contributing personnel time, equipment and supplies valued at $10,000 of in-kind support
*****PWSAC, CDFU and fishermen are also expected to contribute in-kind services to this program

**FY 02**

Prepared:

Project Number: 02-452
Project Title: Assessing prey and competitor/predators of pink salmon fry, Submitted Under the BAA
Name: Prince William Sound Science Center
Agency: NOAA

FORM 4A
Non-Trustee
SUMMARY

11.445

**FY 01 EXXON VALDEZ T EE COUNCIL PROJECT BUDGET**

October 1, 2000 - September 30, 2001

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | | Budgeted | Costs | Overtime | FY 2002 |
| R.E. Thorne | co-Principal Investigator | | 1.0 | 11.0 | | 11.0 |
| G.L. Thomas | co-Principal Investigator | | 0.5 | 11.4 | | 5.7 |
| Other | Technician | | 1.0 | 4.0 | | 4.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 2.5 | 26.4 | 0.0 | |
| | | | | | **Personnel Total** | $20.7 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| Description | | Price | Trips | Days | Per Diem | FY 2002 |
| Annual Meeting | | 0.5 | 1 | 5.0 | 0.2 | 1.5 |
| EVOS and collaborative workshops | | 0.5 | 1 | 7 | 0.2 | 1.9 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | **Travel Total** | $3.4 |

**FY 02**

Prepared:

Project Number: 02-452
Project Title: Assessing prey and competitor/predators of pink salmon fry, Submitted Under the BAA
Name: Prince William Sound Science Center
Agency: NOAA

FORM 4B
Personnel
& Travel
DETAIL

**FY 01 EXXON VALDEZ TI EE COUNCIL PROJECT BUDGET**
October 1, 2000 - September 30, 2001

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 2002 |
| tele, communications, fax, etc. | 0.4 |
| maintenance | 0.1 |
| Vessel Charters | 3.0 |
| **Contractual Total** | $3.5 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 2002 |
| supplies | 1.0 |
| **Commodities Total** | **$1.0** |

**FY 02**

Project Number: 02-452
Project Title: Assessing prey and competitor/predators of pink salmon fry, Submitted Under the BAA
Name: Prince William Sound Science Center
Agency: NOAA

FORM 4B
Contractual & Commodities DETAIL

Prepared:

**FY 01 EXXON VALDEZ T EE COUNCIL PROJECT BUDGET**
October 1, 2000 - September 30, 2001

| New Equipment Purchases: | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | FY 2002 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| 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 | |
| 420, 120 and 38 kHz echosounding systems | | |
| Towfin and harnesses | | |
| Plankton nets | | |
| CTD | | |
| Processing hardware and software | | |

**FY 02**

Prepared:

Project Number: 02-452
Project Title: Assessing prey and competitor/predators of pink salmon fry, Submitted Under the BAA
Name: Prince William Sound Science Center
Agency: NOAA

FORM 4B
Equipment
DETAIL

02457

**Monitoring the fall-winter juvenile and adult herring biomass to track the recovery of the Prince William Sound herring stock Submitted under the BAA**

Project Number: 02457-BAA

Restoration category: Research

Proposer: Prince William Sound Science Center



Lead Trustee Agency: NOAA
Cooperating Agencies: ADF&G ($20K in-kind matching)
OSRI ($40K in matching)

Alaska SeaLife Center: No

Duration: 1st year of 2

Cost FY02: $80.4K
Cost FY03: $80K

Geographic Area: Prince William Sound

Injured Resource/Service: Pacific herring

## ABSTRACT

The herring population in Prince William Sound has declined about fifty-fold since the 1989 oil spill and is in a virtual state of collapse. Recent infrared scanning surveys have revealed intense predator activity on overwintering aggregations of herring, which includes several predators that are either threatened or oil-damaged species. EVOS is implicated as a factor in this decline. A limited monitoring program has been maintained by OSRI and ADF&G. Because of the critical stage of this resource and its importance to the health of the Sound, we are requesting support from EVOS TC to expand the survey effort by including fall surveys of adults and juveniles as a measure of mortality and an early indicator of future recovery.

## INTRODUCTION

The Pacific herring (*Clupea pallasi*) population in Prince William Sound, Alaska, is in crisis. Population levels declined from over 100,000 tons to about 7,000 tons from 1992 to 2000. Preliminary evidence from 2001 surveys indicates the population may have dropped to levels below 3,000 and may be seriously endangered. Further, a major factor in the decline is predation by Steller sea lions, humpback whales, killer whales and many seabirds, whose own populations are at serious risk.

EVOS TC funded some herring survey effort as part of the Sound Ecosystem Assessment (SEA) Program, beginning in 1994. The herring assessment was an aspect of the Nekton and Plankton Acoustics Program, which implemented a large-scale observational program to improve population-level measurement and the understanding of population responses to ecosystem change. The immediate goal was to develop a new generation of observation data for management and research purposes. The long-range goal was to assist in the development and testing of numerical models to improve the prediction of herring population changes in Prince William Sound (SEA 1993). The absence of accurate and repeatable techniques to measure adult and juvenile herring biomass had limited research to discern the underlying mechanisms that affect the population (Thomas 1992, Thomas et al. 1997).

With the end of the SEA Program in 1999, the Oil Spill Recovery Institute (OSRI) and ADF&G initiated a limited program to continue monitoring age 3+ Pacific herring biomass in overwintering areas of PWS. The findings of that program in 2000 are as follows (Thorne 2000): (1) the population level of the PWS herring is the lowest ever recorded, (2) the predation intensity on the adult herring population by marine mammals is far greater than previously documented, (3) the vulnerability of the herring to an oil spill is far greater than previously recognized. The estimated population of adult herring for all of PWS in FY00 was 7,281 metric tons, with a 95% confidence interval of 5,898 to 8,664.

In FY00, the infrared system revealed an intensive and previously undocumented nighttime feeding activity by Steller sea lions, humpback whales and various seabirds on the herring (Thomas and Thorne In Press). A limited retrospective analysis of historic fall and spring acoustic surveys using recently acquired target strength information suggests that the current population may be exposed to a level of over-winter mortality that would seriously jeopardize population recovery.

The infrared system also observed the presence of herring at the surface, a phenomenon previously hypothesized (Thorne and Thomas 1990) but not documented. Such behavior provides a plausible mechanism for previously unexplained, circumstantial evidence of damage to the PWS herring population from the 1989 oil spill. The nightly surface excursions, a highly concentrated adult distribution over an extended period of time, and a highly concentrated spawn deposition all combine to produce an extreme vulnerability to oil spills.

Details of the F00 OSRI herring monitoring study are given in Appendix 1.

Subsequent surveys appear to confirm fears of further reduction. In Dec 00, very high predator activity was observed on the major overwintering herring concentration in Zaikof Bay. In March 01, only about 2000 tons of adult herring were located, including record low levels in normal overwintering areas of Zaikof and Rocky Bays. Steller sea lions were widely distributed throughout PWS, and both Stellers and humpback whales were observed working on juvenile herring concentrations in lieu of adults. It appears very possible that the PWS ecosystem is on the verge of a major crisis that may even exceed that of the initial EVOS impact.

There are three critical measurements that are necessary to monitor the health of the herring population in PWS: (1) annual tracking of the adult population level, (2) monitoring of the overwintering mortality of the adult population, and (3) annual tracking of the juvenile population level. The first provides for the adult population trends. This parameter has been consistently measured over the past eight years, including the last two years by the cooperative OSRI/ADF&G monitoring program. These measurements both detected the collapse and determined the processes underlying the collapse (Thomas and Thorne 2000a).

The second measurement, overwintering mortality, is needed to document and monitor one of the apparent reasons for the collapse, marine mammal predation during the extended overwintering period (Thomas and Thorne 2000b). Although the importance of the process was recognized very early in 2000, and despite repeated requests to funding agencies, no funding has yet been made available for this measurement. This is a regrettable situation considering the magnitude of the herring decline, the role of important marine mammals in this collapse, and the lack of quantitative data on these critical events. The management agencies that formulate and carryout marine resource policy in Alaska have a responsibility to sponsor such critical monitoring.

The third parameter, annual tracking of juvenile herring abundance, both provides a measure of the juvenile to adult mortality and a forecast of recruitment. Although the capability to make this measurement was demonstrated in the SEA program in 1995, no monitoring of this critical parameter has been conducted in PWS. Ironically, the only funds that were made available for expanded herring monitoring in PWS in F01 came from the Pollock Conservation Cooperative, and that only provided for a limited winter-period monitoring of Steller sea lion predation on herring and pollock.

This proposal requests matching funds for EVOS TC to expand the current OSRI/ADF&G program to include a fall surveys of both adult and juvenile herring to obtain this critically needed information.

## NEED FOR THE PROJECT

### A. Statement of the problem

One of the original questions sought by the SEA program was to explain why the herring abundance fluctuated dramatically after the oil spill. Declines in abundance may have resulted from changes to habitat, food supply, predator and competitor populations, genetic degradation, the commercial fishery and management, or unknown natural events. The premise of the SEA program and the subsequent OSRI Nowcast/Forecast program is that these changes can only be understood by the application of a sound monitoring program. Critical to that success is the ability to detect change through accurate and well-conceived measurement programs. The herring monitoring in PWS exemplifies that approach. High speed acoustic/optical technologies were developed following recommendations of the GLOBEC program (Cullen 1989, GLOBEC 1991a,b,c). Further improvements were achieved through the application of optimization techniques (Thorne and Thomas 2000). Substantial understanding of the factors affecting the herring population in PWS was obtained as a result of repeated accurate measurements since 1993. Continued focus at the population level of distribution resulted in detection of major factors affecting decline, including predator activity and behavioral characteristics that increased vulnerability to damage from surface pollution including oil spills (Thorne 2000).

The current decline of the population to historic lows adds urgency to the need to further understand and address these declines. In particular, expansion of monitoring efforts to the juvenile population is critical as it appears the predation intensity is switching to juveniles as a result of the extremely depressed adult population. Monitoring of juvenile populations will both provide a framework for increased understanding of herring population processes and a forecast of future recruitment to the adult population.

### B. Rationale/Link to Restoration

It is apparent that the EXXON VALDEZ oil spill was a factor in the precipitous decline of herring to crisis levels (Thomas and Thorne 2000a, Thorne 2000). The decline threatens the health of many oil-damaged, recovering species who rely on herring as a food supply. Documentation of the herring population levels is critical. Determination and tracking of marine mammal predation is essential. Expansion of monitoring to juveniles will increase our understanding of the processes and provide needed forecast of future recruitment. In addition, the juvenile herring themselves are a major resource for recovering species and may be suffering increasing damage. This project provides the observational data that is necessary to track annual changes in the herring biomass, study mortality mechanisms and predict future recruitment to determine recovery of the stock. It also provides "best-available" technology and information to agencies for management purposes (Thomas et. al 1997). Successful restoration of herring would promote the recovery of the commercial fishery and related services and will also assist recovery of seabirds, marine mammals and other foragers such as salmon shark, halibut, eagles, lingcod, and more. The ultimate goal of the observations is to increase the capability to predict natural changes that are occurring with the herring population. This capability is

a prerequisite to the assessment of anthropogenic impacts, such as those caused by an oil, assessment of restoration, and prediction of herring recovery (Cullen 1988; SEA 1993).

The restoration work of EVOS TC is in transition into the GEM monitoring program. For the past two years, herring monitoring has been the providence of the OSRI/ADF&G program, but herring are of obvious important within the scope of the GEM program. The current OSRI/ADF&G monitoring program exemplifies the qualities specified in the National Academies National Research Council review of the GEM program. The review specifically lists herring as a key species, Prince William Sound as the preferred geographical focus and stresses the need for "long-term monitoring: detection of change and understanding the causes of change" . We assume that GEM will undertake some responsibility for this resource in the future. The expansion to juvenile herring provides an additional element to monitoring needs that should aid GEM program development.

### C. Location

Research will be conducted in Prince William Sound. Communities that may benefit include Whittier, Valdez, Cordova, Tatitlek, Chenega Bay and Port Graham. All communities in the oil spill area could benefit by development of a successful restoration technique.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The following procedures have worked well for developing the SEA, OSRI and Science Center programs: 1) discusing problems with the Board of Directors, who collectively represent fishers, federal, state and local managers, univerisity and independent researchers, private industry and the public, 2) consulting with community representatives during the conception and design of the project to seek input, 3) advertising all vessel charters and employment opportunities in communities near where the work is to be performed, 4) visiting local communities during the course of the field work via our educational outreach programs, and where appropriate, base field work out of the villages using local lodging and/or vessels, 5) providing information to the community through the publication and distribution of newsletters that use non-technical language on project results, 6) the posting of non-technical information on our web page, 7) the presentation of research results as seminars during the year in the community, 8) acknowledging all contributions appropriately, 9) applying the results of the research in ways designed to benefit local communities, people, and cultural practices and 10) living in and becoming part of the community we serve.

## PROJECT DESIGN

### A. Objectives

Implement a cost-effective observational program to annually estimate the distribution, abundance and condition of juvenile and adult herring in PWS and predict future recruitment.

### B. Methods

Acoustic surveys have been conducted on herring populations for several decades (MacLennan and Simmonds 1992, Thorne 1977a,b, Thorne et al. 1983). Methods for pre-spawning herring were developed during the late 1970's (Trumble et al. 1983). The most effective survey techniques are based on three-stage sampling: (1) location of the school or schools is detected by widespread surveys, (2) intense small-scale surveys are conducted over the limited area encompassing the concentration, and (3) net sampling is conducted on the concentration for biological information, including species and size composition.

For Prince William Sound, concentrations of herring are located by a combination of aerial surveys and sonar surveys. The aerial surveys look for evidence of bird and marine mammal activity that is often associated with feeding on herring schools as well as herring spawn when seasonally appropriate. Sonar surveys allow very rapid coverage of areas looking for herring schools. Once an area of herring abundance is located, the sonar survey delineates the boundaries of the concentration. Then a series of closely-spaced transects are run with the acoustic assessment system. Sonar monitoring continues at this stage to ensure that the survey covers the extent of the herring concentration. Biological information is obtained using a commercial herring purse seine. Several scientific acoustic systems have been used in the surveys. Current applications have primarily been BioSonics Digital Transducer (DT) scientific echosounders with transducers mounted on a 1.2 m fin. BioSonics Visacq (DT) software provides real-time digital signal acquisition, and a Magellan DLX-10 GPS receiver provides precise transect locations. The acoustic systems are field calibrated with a standard target (tungsten carbide) prior to surveys to verify system performance parameters (Foote et al. 1987).

Recent acoustic data have been analyzed using BioSonics Analyzer Program, version 4.02. The target strength values for analysis are based on the mean length of herring captured in purse seine samples taken at various locations (Thorne 1983). A value of -32.2 dB/kg was applied for the spring 2000 data. Minor adjustments and some retrospective analyses will be made as a result of target strength studies recently conducted (Thomas, Kirsch and Thorne, in review). Density estimates (biomass per unit surface area) are made for each transect. The mean density for each survey is calculated from the estimates along each transect, weighted by transect length (Seber 1973, p 6.). The surface areas covered by each survey are measured by plotting the transect endpoints from the GPS data, and abundance estimates are derived by multiplying the mean density

per unit surface area by the total surface area of the survey. Confidence intervals for the biomass estimates are calculated from the variation among estimates from replicate surveys (Seber 1973, Cochran 1977, Scheaffer, Mendenhall and Ott 1986).

An infrared survey of predators was initiated in the spring 2000 survey using a Texas Instruments "Nightsight" scanner. A Ratheon M200 Nightsight system was recently purchased for the study with funds provided by the Pollock Conservation Cooperative (PCC) through the University of Alaska, Fairbanks.

A detailed description of the methodology is provided in Appendix 1.

Similar methods will be applied to juvenile surveys. In 1995, SEA also successfully accomplished an acoustic survey of the distribution of age 0 herring using these techniques. Juvenile herring, like the adults, are distributed in limited areas during the extended overwinter period. Investigation conducted during the SEA program indicated that the October-November time period was the most favorable for juvenile surveys.

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

OSRI and ADF&G are providing approximately 60K annually to conduct the spring surveys of adult herring, and both are committed to long-term monitoring of the herring biomass. PCC provided $40K to support infrared monitoring of predators on both pollock and herring during F01. We seek EVOSTC partnership for FY02 and FY03 surveys. This program makes extensive use of the measurement and computing equipment purchased and used on past EVOS TC research at minimal costs to upgrade and maintain.

## SCHEDULE

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

Oct. –Nov 01: Conduct fall survey of adult and juvenile herring

Jan - Mar 02: Analysis and reporting. Attend EVOS workshop.

Apr 1 - Jun 30: Continue data analysis and submit preliminary reports

Jul 1 - Sep 30: Annual Reporting

### B. Project Milestones and Endpoints

FY02 Report on the fall distribution and abundance of adult and juvenile herring.

FY03 Report on the fall distribution and abundance of adult and juvenile herring. Final Report

## C. Completion Date

End of FY03 (September 2003).

## PUBLICATIONS AND REPORTS

An annual report will be prepared to meet the Council's requirements for work done in F02. Several peer-reviewed articles are anticipated from past herring work and some may incorporate the first year's work as well. In the second year, we will prepare manuscripts presenting results for publication in professional journals.

## PROFESSIONAL CONFERENCES

Presentations are planned for the International Council for Exploration of the Seas: Fisheries Acoustics Symposium, the American Fisheries Society Meetings and the World Fisheries Congress.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project will make use of preceding Council research through the designation of common field sites and sampling design. This project will also make use of data generated in the SEA, APEX and NSP projects as well as seek the input of researchers involved in other projects within the region.

## PRINCIPAL INVESTIGATORS

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Responsibilities: Dr. Thorne will be responsible for project administration and acoustic sampling, analysis and writing. He has been working as a PI on research projects for over 30 years while at the University of Washington and at BioSonics Inc. He participated as a subcontractor to the

University of Alaska Fairbanks on the APEX research program.

Dr. Thomas will be responsible for project coordination, field logistics, data analysis and writing running and refinement of the Nekton model. He has worked as a PI on past EVOS TC research programs.

C.V.s for both investigators are attached. Please address all correspondence related to this proposal to Richard E. Thorne.

## KEY PERSONNEL

| | |
|---|---|
| Project biologist/field manager (staff): | Primary responsibility for field scheduling and logistics, equipment and data management, assists with analyses and report writing. |
| Field assistants (staff): | Assists with all aspects of fieldwork and sampling. |

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# APPENDIX- 1

# Assessment of the Herring Population in Prince William Sound During Spring 2000

by
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Annual Progress Report to the Oil Spill Recovery Institute
**Contract # 00-10-03**
**December 21, 2000**


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## ABSTRACT

**An acoustic/infrared survey of the population of adult Pacific herring (*Clupea pallasi*) in Prince William Sound (PWS) was conducted during early spring 2000. The findings of the study are as follows: (1) the population level of the PWS herring is the lowest ever recorded, (2) the predation intensity on the adult herring population by marine mammals is far greater than previously documented, (3) the vulnerability of the herring to an oil spill is far greater than previously recognized. The estimated population of adult herring for all of PWS was 7,281 metric tons, with a 95% confidence interval of 5,898 to 8,664. The infrared system revealed an intensive and previously undocumented nighttime feeding activity by Steller sea lions, humpback whales and various seabirds on the herring. A limited retrospective analysis of historic fall and spring acoustic surveys using recently acquired target strength information suggests that the current population may be exposed to a level of over-winter mortality that would seriously jeopardize population recovery. The infrared system also observed the presence of herring at the surface, a phenomenon previously hypothesized but not documented. Such behavior provides a plausible mechanism for previously unexplained, circumstantial evidence of damage to the PWS herring population from the 1989 oil spill. The nightly surface excursions, a highly concentrated adult distribution over an extended period of time, and a highly concentrated spawn deposition all combine to produce an extreme vulnerability to oil spills. It is incumbent upon OSRI, and other organizations with similar responsibilities, to factor this extreme vulnerability into prevention, response and recovery plans.**

# Assessment of the Herring Population in Prince William Sound During Spring 2000

## INTRODUCTION

The Pacific herring (*Clupea pallasi*) population in Prince William Sound (PWS), Alaska, is both a valuable resource for fishermen and a crucial part of the ecosystem. Historically, herring in PWS were managed by a combination of recruitment models, egg deposition estimates and test fishing. Acoustic surveys were initiated in fall 1993 after these traditional techniques predicted a large return in spring 1993 that failed to materialize. The fall 1993 acoustic survey, conducted by the Prince William Sound Science Center with support from the Alaska Department of Fish and Game and the Cordova District Fishermen United, documented a population level of only 20,000 metric tons (DeCino et al. 1995). Subsequently, acoustic surveys of the adult herring were conducted during fall in 1994 and 1995, and during early spring since 1995.

The distributional characteristics of the herring in Prince William Sound from November to April are highly amenable to acoustic surveys. School groups are highly aggregated in a few select locations, reducing the area that needs to be surveyed (Thorne and Thomas 2000). Marine mammals, especially Steller sea lions are closely associated with the herring school groups and can be readily detected from aerial surveys, which provides a very rapid method of locating concentrations and even further delineates the area to be surveyed. The early spring surveys provide an estimate that is especially timely for an opening of a commercial fishery on herring roe.

This report details the results of an acoustic survey on the PWS adult herring population that was conducted in spring 2000. The acoustic survey also incorporated infrared scanning technology to observe levels of marine mammal and seabird predation on the herring population. The combined acoustic and infrared technologies allowed documentation of herring and predator behaviors not previously reported.

## METHODS

Acoustic surveys have been conducted on herring populations for several decades (MacLennan and Simmonds 1992; Thorne 1977a,b; Thorne et al. 1983; Thorne and Thomas 1990; Thorne 1998). Methods for pre-spawning herring were developed during the late 1970's (Trumble et al. 1983). The most effective survey techniques are based on three-stage sampling: (1) location of the school or schools is detected by reconnaissance surveys, (2) intense small-scale surveys are conducted over the limited area encompassing the concentration, and (3) net sampling is conducted on the concentration for biological information, including species and size composition (McClatchy and Thorne 2000).

For Prince William Sound, the over-wintering concentrations of herring are located by a combination of aerial surveys and sonar surveys. The aerial surveys look for bird and marine mammal activity that is often associated with feeding on herring schools. Sonar

surveys allow very rapid coverage of these and other likely areas looking for herring schools. Once an area of herring abundance is located, a sonar survey delineates the boundaries of the concentration. Then a series of closely-spaced transects are run with the acoustic assessment system. Sonar monitoring continues at this stage to ensure that the survey covers the extent of the herring concentration. Biological information is obtained using a commercial herring purse seine.

The acoustic system used for the spring 2000 survey was identical to the system used the previous year (Kirsch and Thomas 1999). It consisted of a BioSonics 120 kHz Digital Transducer (DT) scientific echosounder with a dual-beam transducer mounted on a 1.2 m towed vehicle. BioSonics Visacq (DT) software provided real-time digital signal acquisition, and a Magellan DLX-10 GPS receiver provided precise transect locations. A –80 dB flat threshold was used for the data collection. The ping rate was one/sec, and the pulse length was 0.5 msec. The acoustic system was field calibrated with a standard target (tungsten carbide) prior to the survey to verify system performance parameters (Foote et al. 1987). The parameters were unchanged from the previous year.

The acoustic data were analyzed using BioSonics Analyzer Program, version 3.1.1. The target strength value for the analysis (-32.2 dB/kg) was based on the mean length of herring captured in purse seine samples taken at various locations (Thorne 1983a; Thomas et al. in prep.). Density estimates (biomass per unit surface area) were made for each transect. The mean density for each survey was calculated from the estimates along each transect, weighted by transect length (Seber 1973, p 6.). The surface areas covered by each survey were measured by plotting the transect endpoints from the GPS data, and abundance estimates were derived by multiplying the mean density per unit surface area by the total surface area of the survey. Confidence intervals for the biomass estimates were calculated from the variation among estimates from replicate surveys (Seber 1973; Cochran 1977; Scheaffer, Mendenhall and Ott 1986).

The acoustic surveys were conducted March 28-31 aboard the F/V *Miss Kayley*. Based on the aerial surveys and historic data, sonar surveys were conducted in Zaikof Bay, Rocky Bay, Port Chalmers, Stockdale Harbor, and throughout Port Fidalgo, Port Gravina and Sheep Bay. Appreciable concentrations (over 500 tons) were found only in Rocky Bay, Stockdale Harbor and St. Mathews Bay (Figure 1). Surveys on these concentrations were conducted primarily at night when the schools were slightly more dispersed and typically more off-bottom.

The F/V *Miss Kayley* was equipped with a Texas Instruments Model M100 "Night Sight" infrared scanner. The system includes an infrared camera with a 27° by 18° field of view. Large numbers of birds and marine mammals were observed with this system during the initial night surveys of the school in Rocky Bay. Subsequently, we fixed the scanner in the forward position and enumerated the numbers of birds and marine mammals and their association with the school during three of the surveys.

# RESULTS

Eight surveys were conducted on the population in Rocky Bay, which was the largest observed, two surveys in Stockdale Harbor and three in St. Mathews (Table 1, Appendix 1). The mean abundance in Rocky Bay was estimated at 3,955 metric tons, with a 95% confidence interval 2,757 to 5,153 metric tons.

The surveys in Stockdale Harbor began with a reconnaissance survey of the Stockdale Harbor-Port Chalmers area, but only one concentration was observed in Stockdale Harbor. The two surveys focused on that single concentration. The mean estimate was 1,526 metric tons, with a 95% confidence interval of 941 to 2111 metric tons.

The three surveys in St. Mathews resulted in an estimate of 1,799 metric tons, with a 95% confidence interval of 1,430 to 2168. Combining the three areas resulted in a total survey biomass of 7,281 metric tons, with a 95% confidence interval of 5,898 to 8,664.

Counts off the infrared scanner were made during runs 3, 3b and 4 in Rocky Bay. The abundance of birds was related to the densities of herring and increased considerably at a herring density of about 10 kg/m$^2$ (Figure 2). Such thresholds are commonly observed in seabird/forage fish relationships (John Piatt, pers. comm.) The marine mammals, primarily Steller sea lions, were often aggregated along the boundaries of the school (Figure 3). The Steller sea lions were often oriented in a row of 20+ individuals and appeared to be herding the herring school (Figure 4). Humpback whales were also observed over the school at night (Figure 4). A small pod of killer whales was seen near the school during the day.

The infrared scanner also detected individual herring flipping at the surface. These observations were correlated with indications on the acoustic echograms of herring near surface (Figure 5). These observations confirm earlier speculation (Thorne and Thomas 1990) that herring needed to surface on a nightly basis in order to refill their swimbladders.

# DISCUSSION

## Factors Affecting Accuracy

It is well documented that acoustic surveys can provide an accurate estimate of the population under survey (Thorne 1983b, MacLennan and Simmonds 1992). There are three primary components of uncertainty. One source is the precision of the survey, and the magnitude of that uncertainty is incorporated in the confidence intervals. The other two sources are biases. One is error associated with the acoustic scaling factor, which is dependent upon the accuracy of the target strength estimate, and the second source is the survey coverage.

The precision of the estimate depends on the variability of the distribution and on the survey intensity. The school in St. Mathews was surveyed only during one night. It was a single, well-defined mid-water school. Consequently the estimate was relatively

precise, with the confidence interval representing only plus or minus 20% of the mean estimate. The school in Rocky Bay was larger and more complex. It was also surveyed over several dates, and included some daytime surveys. Nevertheless, the precision was reasonable, with a 95% confidence interval corresponding to plus or minus 30% of the mean. The school in Stockdale Harbor was also a single, well-defined school with replicate surveys under similar conditions. The slightly larger 95% confidence interval of plus/minus 38% reflects the minimal number of replicates. The 95% confidence interval around the total population estimate, plus/minus 19%, is very typical of acoustic surveys (Thorne 1983b).

Target strength values for Pacific herring are very well documented (Trumble et al. 1983; Thorne 1983a; DeCino et al. 1993). The target strength equation was originally derived from comparison between acoustics and independent measures of herring abundance (Thorne 1977a). Recent studies have shown the equation to be reasonable for the depth ranges occupied by PWS herring, but there are indications that target strengths of herring during the spring period may be slightly higher than fall period because of lower lipid content (Thomas et al. in prep.). In that case, spring results would be overestimated and fall results proportionally underestimated. The magnitude of this potential bias needs further investigation.

The second source of bias, survey coverage, is always toward underestimation because of the possibility that some fish are distributed too near the surface or the bottom to be detected, or are in locations that are not surveyed (Thorne 1998). As noted above, the acoustic echograms indicated a minor abundance of herring near surface during these surveys (Figure 5). Herring could be seen at the surface with the infrared scanner when these echogram indications were present. However, most of the time the schools were sufficiently deep for accurate measurement with the down-looking acoustic system. Only during one day survey in Rocky Bay (#6) was there an indication that some fish might be too near shore to be surveyed.

Undoubtedly there are several small concentrations of herring that were not detected. However, it is unlikely that the sum of these small exclusions would appreciably affect the overall biomass estimates. It is also unlikely that any large adult concentrations were missed given the intensity and extent of the aerial and sonar surveys, and the subsequent lack of evidence of any major spawning activity in areas that were not surveyed.

On several occasions the historical acoustic survey results have been in substantial disagreement with the results from the traditional models based on age structure and egg deposition. For example, those traditional models predicted a return of 134,000 metric tons in spring 1993, 27,000 metric tons in spring 1995, and 40,000 metric tons in spring 1998 (Thomas and Thorne 2000). In contrast, the acoustic estimates were 20,000, 12,000 and 18,000 metric tons respectively. The acoustic estimates are in far better accord with the magnitude of subsequent changes in the population levels (Thomas and Thorne 2000). As detailed below, well-documented major changes in the population in response to relatively minor fishing mortalities are inexplicable when considered in terms of the abundance levels predicted from the traditional models.

## Historical Trends

Historical records suggest that the PWS herring population may have been over 100,000 metric tons in the early 1990's. Catch removal in 1992 was about 40,000 metric tons, and 134,000 metric tons was predicted from traditional models and egg deposition to return for spring 1993. The initial acoustic survey in fall 1993, conducted in response to the evident lack of such abundance, estimated 20,000 metric tons (DeCino et al. 1995). A subsequent acoustic survey following a fall bait fishery in 1994, documented further reduction of the population to 13,000 metric tons (Figure 6). Following a moratorium on fishing after fall 1994, the population increased to 37,000 metric tons by spring 1997 (Kirsch and Thomas 1997). The fishery was reopened in spring 1997. A subsequent acoustic survey in spring 1998 indicated a collapse to 17,000 metric tons (Kirsch and Thomas 1998). However, the traditional methods predicted a return of 40,000 metric tons in spring 1998, and a fishery was opened. The acoustic survey in spring 1999 confirmed the collapse of the population (Kirsch and Thomas 1999). Although the commercial fishery was cancelled in 1999, additional extensive test netting may have compounded the disease problem as the spring 2000 acoustic survey reported here documents a further collapse of the population to a historic low of about 7,000 metric tons (Figure 6).

The two collapses occurred four and eight years subsequent to the EXXON VALDEZ oil spill and co-occurred with outbreaks of viral hemorrhagic septicemia virus (VHS/Marty and Meyers 1999). Considerable circumstantial evidence links the declines to damage from the oil spill. However, a plausible mechanism for oil exposure and damage to herring had not been formulated until recently (Thomas and Thorne 2000). Thorne and Thomas (1990) had speculated on the need for herring to surface in order to replace air in their swimbladder. The infrared observations during this study document that behavior. Nottestad (1999) has verified that Atlantic herring, *Clupea harengus*, also expel gas during vertical ascents. It is now clear that herring, and possibly other physostomatous fishes, make excursions every night to the surface to refill their swimbladders. Subsequent to the oil spill, herring have shown a low immunity to disease. Juvenile herring have been shown to be infected with VHS by the time they are 3-4 months old, and mechanical damage appears to be a mechanism that causes outbreaks. Since the two outbreaks followed large commercial fishing efforts, it is plausible that the handling by the fishery caused the mechanical damage that resulted in VHS outbreaks and high mortality. Marty and Meyers (1999) reported no impact of the 1997 viral outbreak on the stock. However, their conclusion was based on the traditional model prediction of 40,000 mt, which, as noted above, is more than twice that of the acoustic survey estimate. It is unlikely that the disease itself directly causes mortality. However, it is well documented that disease greatly increases vulnerability to predation.

## Impacts of Predation

The infrared system was amazingly effective. Despite total darkness, sea lions and whales could be detected at ranges of about 100 m, and even individual fish could be seen flipping at the surface. It is also clear from these observations that the herring are

exposed to unexpectedly high levels of over-winter predation. Although the association of marine mammals with the herring concentrations is well documented, the actual foraging activity was not previously observed because it is limited to nighttime hours. The association has been most notable around spawning itself, which is described as "a massive ecological event attended by large aggregations of gulls, shorebirds, humpback whales and Steller sea lions" (Norcross et al., 2000). While the spawning event is probably especially attractive to birds feeding on eggs, the humpback whales and Steller sea lions are feeding on adult herring. Previous acoustic surveys have shown that these herring concentrations persist from mid-October to mid-April. Consequently, the impact of the predation on the herring and the importance of herring as prey may be far greater than previously recognized. Further, the vulnerability to predation is undoubtedly aggravated by low immunity to disease, which may be linked to oil exposure.

There have been two occasions where acoustic surveys were conducted before and after a winter period: fall 94 to spring 95 and fall 95 to spring 96. Both indicate an over-winter population decline of about one thousand metric tons (Figure 6). However, if there is a difference between fall and spring target strengths, as indicated by recent studies (Thomas et al. in prep), the population decline could be considerably larger. An annual removal of even one thousand metric tons on the current population level could seriously jeopardize recovery. Marine mammals are long-lived, so changes in foraging pressure are likely to lag behind changes in the herring population, especially given the high vulnerability of large school concentrations. There is some indication from historic aerial survey data that the number of humpback whales associated with the herring have declined recently. However, the Steller sea lions, a threatened species, may have less mobility and fewer options.

## PWS Herring and the EXXON VALDEZ oil spill

The EXXON VALDEZ oil spill occurred just before herring spawning in March 1989, and spatially overlapped some herring pre-spawning and spawning locations. However, several researchers contended that the damage to the herring stock was minimal. For example, Beinert and Pearson (1995) concluded, "schools of herring present in Prince William Sound at the time of the EXXON VALDEZ spill were at minimum risk to exposure to toxic levels of petroleum hydrocarbons". They based their conclusions on an important axiom in the ecological risk assessment process that a definition of risk can only occur if "a stressor co-occurs or comes into contact with an ecological component long enough and in sufficient concentration or intensity to result in a measurable adverse effect". It is clear that their assessment was based on the assumption that any exposure would be subsurface. The discovery that herring make nightly excursions to the surface to replenish their swimbladders totally changes the parameters on which those conclusions were established. The fact that water-column concentrations were below toxic levels is not longer relevant. Direct contact between herring and the surface toxicants must now be viewed as highly likely. Bienert and Pearson admitted that "available data were too general to pinpoint the precise location of the schools relative to the oil slick, making it difficult to estimate exposure potential" and, "the possibility of sublethal exposures to oil cannot be... assessed".

A second paper (Pearson et al. 1995) attributes the subsequent collapse of the PWS herring population in 1993 to density dependent factors: "failure of the 1993 fishery has the characteristics of a response to the record high biomasses and recruitment of the 1988 year class, not those of an effect from the EVOS". However, attribution of the poor 1993 condition to classic density dependence ignores several facts. First of all, high population levels were well established for many years prior to the oil spill (Brady et al. 1990), and the population level at the time of the alleged density-dependent poor condition (1993) was in fact on the order of 20% of what it had been the previous year. If density dependent factors were at work, the condition of the fish should have been better, not worse. Further, Funk (2000) shows that density dependence shows up rarely in the PWS stock, and then only weakly. Finally, in the absence of an observable die off, populations do not simply collapse. Reductions can occur only as a result of commercial fishery removals or predation.

Fishing exploitation since 1992 has been minimal. The post-1997 collapse is explainable only in terms of predation removals. This study elucidates one unexpectedly large source of predation mortality as well as a potential mechanism for sublethal impacts to the adult population from the oil spill, which may contribute to increased mortality through lowered immunity to disease.

## Needs for Future Research

There has been a substantial increase in knowledge about the early life history of herring in PWS as a result of post-EXXON VALDEZ research (Norcross and Brown 2000; Norcross et al. 2000). Unfortunately, relatively little attention has been focused on the adult population. Near-term recovery of the adult population seems highly unlikely considering the conditions observed during this study. One of the few options available to management is elimination of commercial fishing. However, even without removals from commercial fishing, the predation rates by marine mammals and birds may depress the population even further if the predation intensity noted in this study extends over any appreciable time period. Observations of marine mammal/seabird predation rates during the entire winter period are urgently needed. Over-winter mortality can be estimated from marine mammal/seabird census or directly from acoustic surveys of adult populations in fall and spring. Both approaches are recommended. The acoustic survey will likely achieve the highest accuracy, but the marine mammal/seabird census will document the primary mechanism.

A major outcome of this study should be a growing awareness that the PWS herring population is highly vulnerable to impacts of surface toxicants because of the nightly excursions of herring to the surface, the highly concentrated distribution of the adults over an extended period, and the highly concentrated distribution of spawn. Such awareness needs to be incorporated into oil spill response strategies. The possibility that other physostomatous fishes may also make surface excursions to replace air needs to be investigated.

Ultimately, any population recovery of the PWS herring will depend on recruitment success. The highest and most variable mortality occurs during early life history stages. It is important to understand the factors that govern mortality at this stage. However, the

degree of variability associated with early life history stages precludes accurate assessment of recruitment from measurement of these factors. Direct assessment of the outcome is a more reliable measure. Acoustic surveys of juvenile herring populations were conducted as part of the post-EXXON VALDEZ research. However, most of these surveys were conducted during summer months. Summer feeding distributions are much less amenable to acoustic estimation (Thorne and Thomas 2000). A comprehensive juvenile herring survey in PWS was conducted during fall only one year, 1995. The distribution of the juvenile herring during this survey was very amenable to accurate assessment (Thomas and Thorne 2000). Such fall juvenile herring surveys would provide the most effective forecast of recruitment. Further, in conjunction with on-going assessment of adult populations, assessment of juvenile populations would allow estimation of mortality levels between these two life history stages.

## CONCLUSIONS

The findings of this study have very important ramifications. First, the population level of the PWS herring is the lowest every recorded. Second, the predation intensity on the adult herring population by marine mammals is far greater than previously documented. Third, the vulnerability of the herring to an oil spill is far greater than previously recognized.

The low population estimate, about 7,000 metric tons, continues the second of two population collapses that have occurred since the EXXON VALDEZ oil spill in 1989. The infrared observations show intense predation by marine mammals and seabirds on the adult herring. A limited retrospective analysis of the fall/spring acoustic surveys suggests that the over-winter mortality could be considerably greater than previously estimated. The PWS herring population may be especially susceptible to predation mortality as a result of a lowered immunity to disease. Recovery of the herring population is jeopardized by this predation, especially if it operates over an extended over-winter period. Expanded over-winter monitoring of the adult herring population and associated marine mammal/seabird abundance is needed to document this impact. Acoustic assessment of juvenile abundance would provide a long-range indication of potential recovery of the PWS herring population.

The infrared observations also verify the nightly surface excursions of herring to the surface that was hypothesized by Thorne and Thomas (1990). This behavior provides a plausible mechanism to explain the circumstantial evidence of harm to this stock from the EXXON VALDEZ oil spill. The nightly surface excursions, a highly concentrated adult distribution over an extended period of time, and a highly concentrated spawn deposition all combine to produce an extreme vulnerability to oil spills.

It is incumbent upon OSRI, and other organizations with similar responsibilities, to factor this extreme vulnerability into prevention, response and recovery plans. The economic value of a healthy Prince William Sound herring population has been estimated at about two million dollars per year (Thomas and Thorne, 2000). The value to the ecology of the region is incalculable. Considering its importance, vulnerability and the possible culpability of the EXXON VALDEZ oil spill in its decline, it is regrettable that greater attention has not been paid to this critical population. Hopefully, it is not too late to rectify that omission.

## ACKNOWLEDGEMENTS

The Alaska Department of Fish and Game, especially Nancy Speer, Mark Willette and Steve Moffitt, contributed substantially to this effort. Special thanks are also due to Jack Babic, captain of the FV *Miss Kayley*.

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Table 1. Results of spring 2000 herring surveys

| Location | Run | Date | Density Tons/Sq.N.M | Area Sq. N.M. | Biomass Tons | Mean | 95%C.I. |
|---|---|---|---|---|---|---|---|
| Rocky Bay | 1 | 3/28 | 8103 | 0.26 | 2107 | | |
| | 2 | 3/28 | 18068 | 0.26 | 4698 | | |
| | 3 | 3/28 | 13079 | 0.20 | 2616 | | |
| | 3b | 3/28 | 35632 | 0.20 | 7126 | | |
| | 4 | 3/28 | 17128 | 0.21 | 3597 | | |
| | 5 | 3/30 | 8252 | 0.29 | 2393 | | |
| | 6 | 3/31 | 21410 | 0.18 | 3854 | | |
| | 7 | 3/31 | 29175 | 0.18 | 5251 | | |
| | mean, C.I. | | | | | 3955 | +/- 1198 |
| Stockdale | 1 | 3/29 | 11215 | 0.11 | 1234 | | |
| | 2 | | 18194 | 0.10 | 1819 | | |
| | mean, C.I. | | | | | 1526 | +/- 585 |
| St Mathews | 1 | 3/31 | 9064 | 0.20 | 1813 | | |
| | 2 | | 5891 | 0.25 | 1473 | | |
| | 3 | | 14077 | 0.15 | 2112 | | |
| | mean, C.I. | | | | | 1,799 | +/- 369 |
| Total Survey | | | | | | 7281 | +/- 1383 |

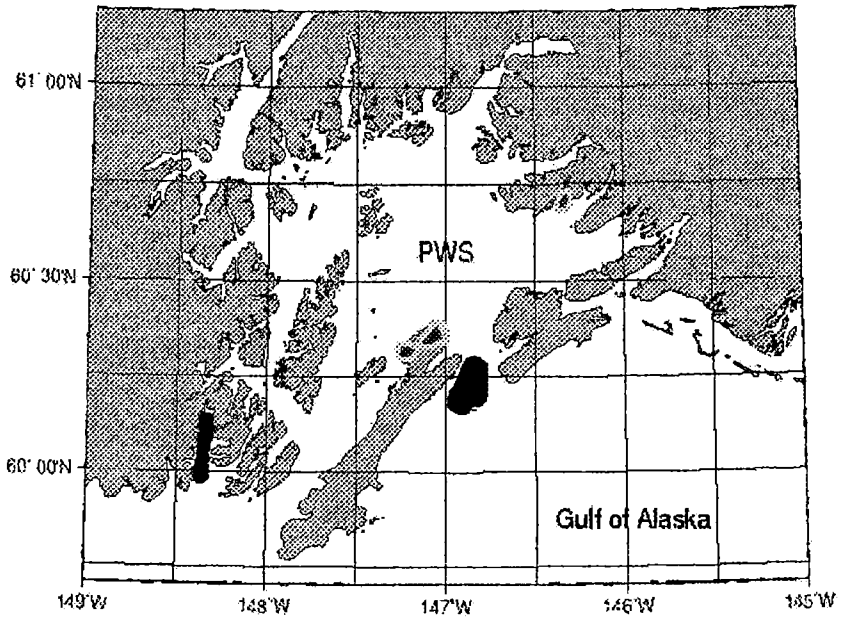


Figure 1. Map of Prince William Sound showing areas of over-wintering adult herring concentrations (red) along with seabird/Steller sea lions concentrations (yellow) and pollock (blue), from surveys in February/March 2000.

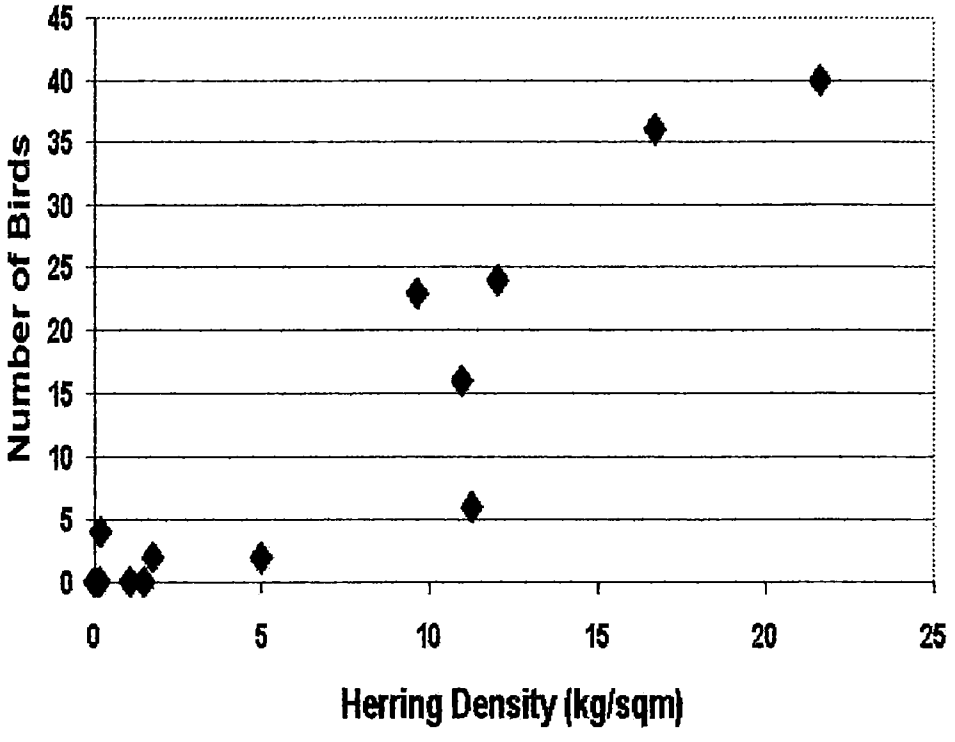


Figure 2. Relationship between number of birds observed along transects and herring density.

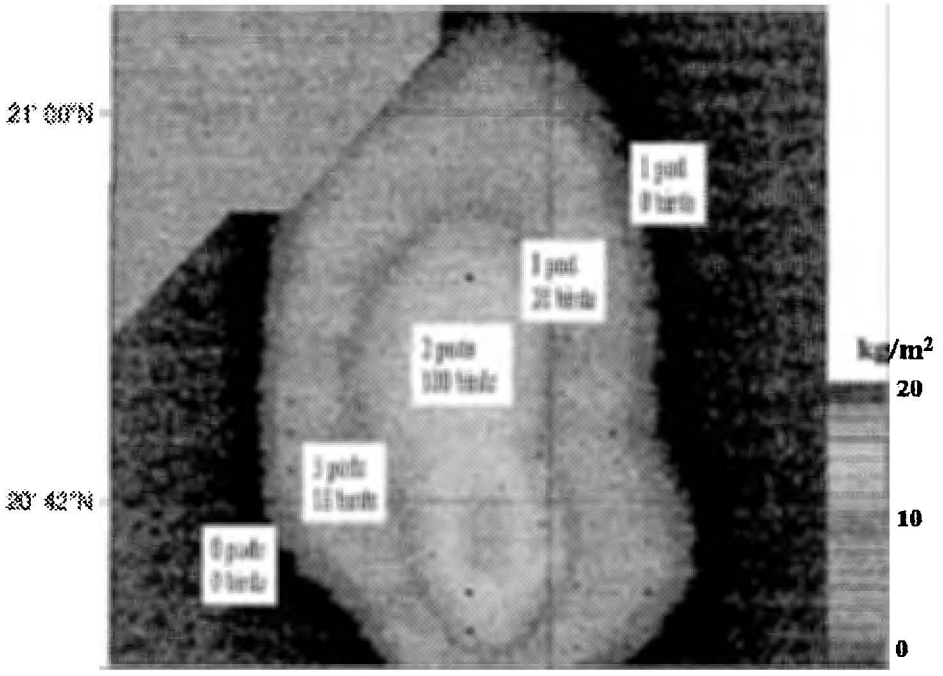


Figure 3. Typical plan view of Steller sea lion and sea bird distribution in relation to the herring school in Rocky Bay. Color scale for herring density is: red/brown-20 kg/m$^2$, yellow-15 kg/m$^2$, green-10 kg/m$^2$, light blue-5 kg/m$^2$.

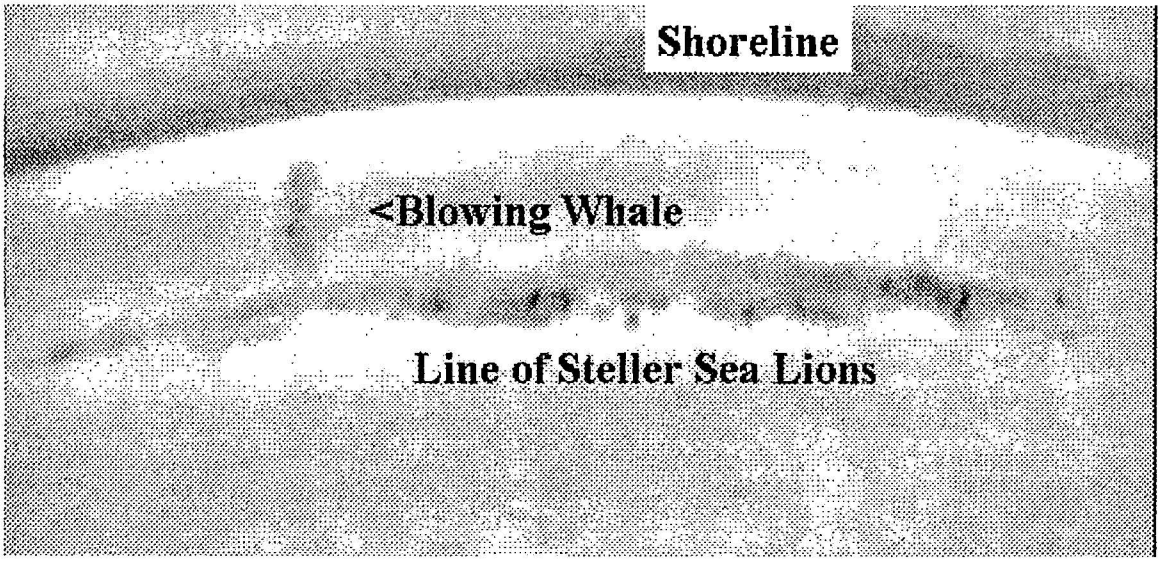


Figure 4: Nightime infrared video frame showing line of Steller sea lions and blowing humpback whale at the surface near the herring school group in Rocky Bay, PWS, March 2000.

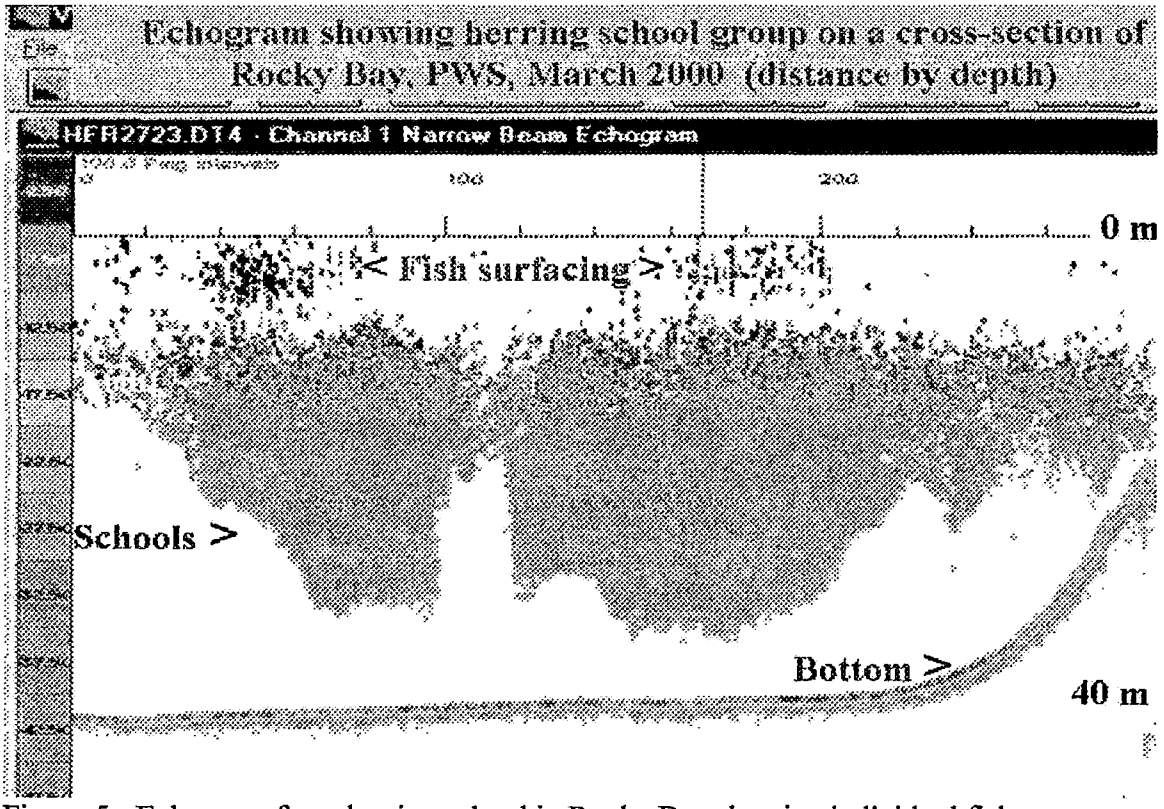


Figure 5. Echogram from herring school in Rocky Bay showing individual fish near surface above main school.

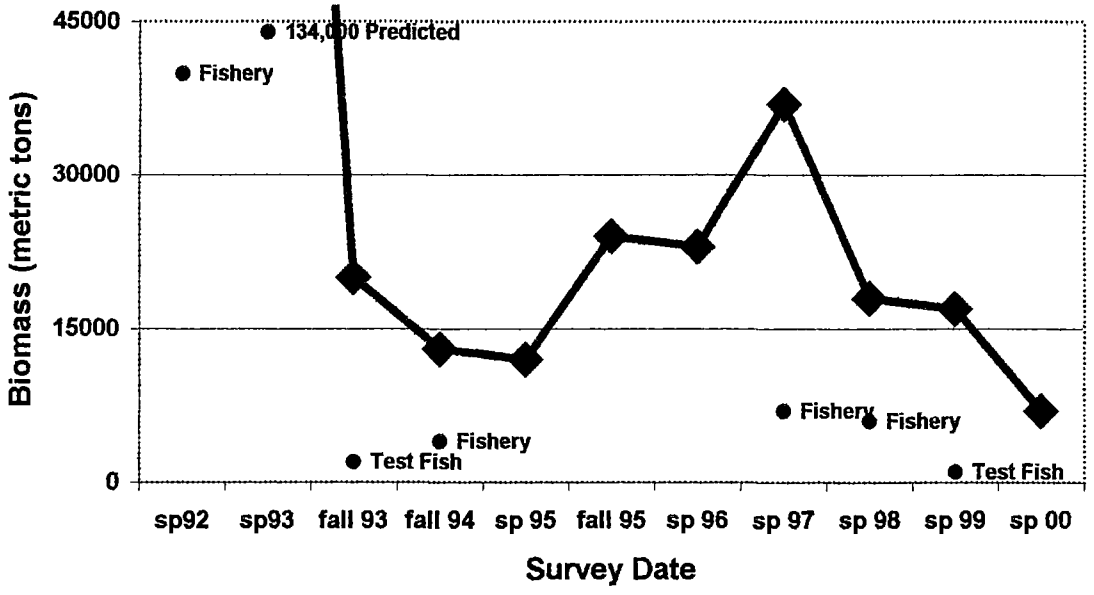


Figure 6. Biomass estimates of herring abundance in Prince William Sound, Alaska from acoustic surveys fall 1993 to spring 2000, and removals from fisheries and test fisheries.

**FY 01 EXXON VALDEZ TRU : COUNCIL PROJECT BUDGET**

October 1, 2000 - September 30, 2001

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 |
|---|---|---|
| Personnel | | $0.0 |
| Travel | | $0.0 |
| Contractual | | $80.4 |
| Commodities | | $0.0 |
| Equipment | | $0.0 |
| Subtotal | | $80.4 |
| General Administration | | $5.6 |
| Project Total | $0.0 | $86.0 |
| Full-time Equivalents (FTE) | | 8.5 |
| Other Resources | | $60.0 |

LONG RANGE FUNDING REQUIREMENTS

| Estimated FY 2003 | Estimated FY 2004 | Estimated FY 2005 |
|---|---|---|
| $85.0 | $0.0 | $0.0 |

Dollar amounts are shown in thousands of dollars.

Comments:

**FY 02**

Prepared:

Project Number: 02457-BAA
Project Title: Monitoring the recovery of the Pacific herring stock using Echointegration-Optical-Purse Seine Surveys , submitted under the BAA
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

**FY 01 EXXON VALDEZ TRU E COUNCIL PROJECT BUDGET**
October 1, 2000 - September 30, 2001

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 |
|---|---|---|
| Personnel | | $51.7 |
| Travel | | $2.1 |
| Contractual | | $8.6 |
| Commodities | | $0.7 |
| Equipment | | $0.0 |
| Subtotal | | $63.1 |
| Indirect | | $17.3 |
| Project Total | $0.0 | $80.4 |
| Full-time Equivalents (FTE) | | 8.5 |
| Other Resources | | $60.0 |

| LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|
| | Estimated FY 2003 | Estimated FY 2004 | Estimated FY 2005 | | |
| | $80.0 | | | | |

Dollar amounts are shown in thousands of dollars.

Comments:

*Salary rate for G.L. Thomas reflects research time at 20% reduction from administrative costs

**OSRI and ADF&F are contributing approximately $60,000 to this program

**FY 02**

Prepared:

Project Number:
Project Title: Monitoring the recovery of the Pacific herring stock using Echointegration-Optical-Purse Seine Surveys, submitted under the BAA
Name: Prince William Sound Science Center

FORM 4A
Non-Trustee
SUMMARY

**FY 01 EXXON VALDEZ TRU E COUNCIL PROJECT BUDGET**
October 1, 2000 - September 30, 2001

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | | Budgeted | Costs | Overtime | FY 2002 |
| R.E. Thorne | co-Principal Investigator | | 2.0 | 11.0 | | 22.0 |
| G.L. Thomas | co-Principal Investigator | | 0.5 | 11.4 | | 5.7 |
| Other | Technician | | 6.0 | 4.0 | | 24.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 8.5 | 26.4 | 0.0 | |
| | | | | | **Personnel Total** | $51.7 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| Description | | Price | Trips | Days | Per Diem | FY 2002 |
| EVOS and collaborative workshops | | 0.5 | 1 | 8.0 | 0.2 | 2.1 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | **Travel Total** | $2.1 |

**FY 02**

Prepared:

Project Number:
Project Title: Monitoring the recovery of the Pacific herring stock using Echointegration-Optical-Purse Seine Surveys, submitted under the BAA
Name: Prince William Sound Science Center

FORM 4B
Personnel
& Travel
DETAIL

**FY 01 EXXON VALDEZ TRU : COUNCIL PROJECT BUDGET**
October 1, 2000 - September 30, 2001

| **Contractual Costs:** | Proposed |
|---|---|
| Description | FY 2002 |
| tele, communications, fax, etc. | 0.5 |
| maintenance | 0.1 |
| Vessel Charters | 8.0 |
| **Contractual Total** | $8.6 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 2001 |
| supplies | 0.7 |
| **Commodities Total** | $0.7 |

**FY 02**

Prepared:

Project Number:
Project Title:Monitoring the recovery of the Pacific herring stock using Echointegration-Optical-Purse Seine Surveys, submitted under the BAA
Name: Prince William Sound Science Center

FORM 4B
Contractual & Commodities DETAIL

**FY 01 EXXON VALDEZ TRU : COUNCIL PROJECT BUDGET**

October 1, 2000 - September 30, 2001

| **New Equipment Purchases:** Description | Number of Units | Unit Price | Proposed FY 2002 |
|---|---|---|---|
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| 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 |
|---|---|
| 120 kHz BioSonicsDT4000 Digital Echosounder<br>Towfin and harnesses<br>Processing hardware and software | |

**FY 02**

Prepared:

Project Number:
Project Title: Monitoring the recovery of the Pacific herring stock using Echointegration-Optical-Purse Seine Surveys, submitted under the BAA
Name: Prince William Sound Science Center

FORM 4B
Equipment
DETAIL

# Effect of Disease on Pacific Herring Population Recovery in Prince William Sound



| | |
|---|---|
| Project Number: | 02462 |
| Restoration Category: | Research and Monitoring |
| Proposer: | University of California, Davis |
| Lead Trustee Agency: | ADFG |
| Cooperating Agencies: | None |
| Alaska SeaLife Center: | no |
| Duration: | 4th year, 4-year project (1-yr. extension proposed) |
| Cost FY02: | $26,800 (UCD) + $50,600 (ADFG) = $77,400 |
| Geographic Area: | Prince William Sound |
| Injured Resource/Service: | Pacific herring, commercial fishing, subsistence |

## ABSTRACT

The Pacific herring population of Prince William Sound has not recovered from severe population decline in 1993. The Alaska Department of Fish and Game now predicts that fisheries closed since 1999 will not open for several years. Long-term systematic disease monitoring and research since 1994 has shown a clear relationship between disease prevalence and population change, and this information significantly improves our ability to forecast population change. Because of the importance of Pacific herring in the Prince William Sound ecosystem, and the importance of this project to marine fisheries worldwide, a 4th year of disease study is proposed to ensure seamless flow of data from this Restoration project to the Gulf Ecosystem Monitoring program.

## INTRODUCTION

The population of Pacific herring (*Clupea pallasi*) in Prince William Sound (PWS), Alaska has not recovered since the estimated spawning biomass decreased precipitously from over 100,000 tons in 1992 to less than 20,000 tons in 1994 (Figure 1). Study of the population since 1993 revealed that viral hemorrhagic septicemia virus (VHSV), associated ulcers, and the fungus-like organism *Ichthyophonus hoferi* cause the major diseases in Pacific herring, and that VHSV and associated ulcers probably contributed most to population decline in 1993 (Meyers et al. 1994; Marty et al. 1998; Quinn In press). Prince William Sound Pacific herring fisheries were severely curtailed in 1993, and were never opened in 1994 or 1995. The population began to recover in 1996, and a small bait fishery was opened in November of 1996. All fisheries were opened in 1997, but an unexpected increase in prevalence of VHSV in spring samples (15% in 1997 vs. 0% in 1996) was associated with abnormal spawning activity. In 1998, continued high virus prevalence (15%) was associated with increased ulcer prevalence (0% in 1997, 3.2% in 1998; Figure 2).

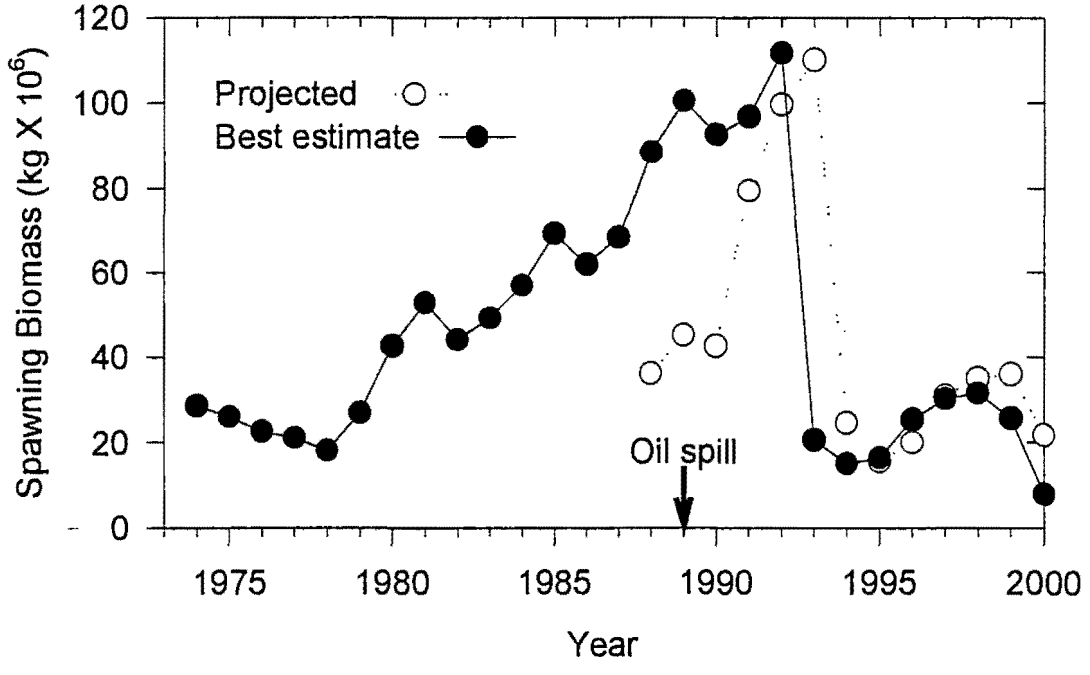


Figure 1. Spring prespawning biomass estimates of mature Pacific herring in Prince William Sound, Alaska. Unexploited spawning biomass is estimated using an age-structured assessment model (ADFG, unpublished data).

After the major crash of 1993, the Pacific herring population continued to decline in 1994 and project 94320-S was initiated under emergency conditions to determine causes of herring morbidity (sickness), with particular emphasis on the role of VHSV. Beginning in 1995, a 4-year multidisciplinary project was initiated to explore the role of VHSV, *Ichthyophonus hoferi*, and other parasites on population change (95320-S, 96162, 97162, and 98162). Study in 1995 and 1996 included examination of fish from a reference site, Sitka Sound, in which the herring fishery was strong and there was no history of a large oil spill. Although 1998 was the final field season

for project \\162, the high ulcer and virus prevalence in 1998 provided strong evidence that the population was at high risk of disease-related decline. Therefore, this project (\\462) was proposed and funded for 3 years to continue research on the effect of disease on Pacific herring population recovery.

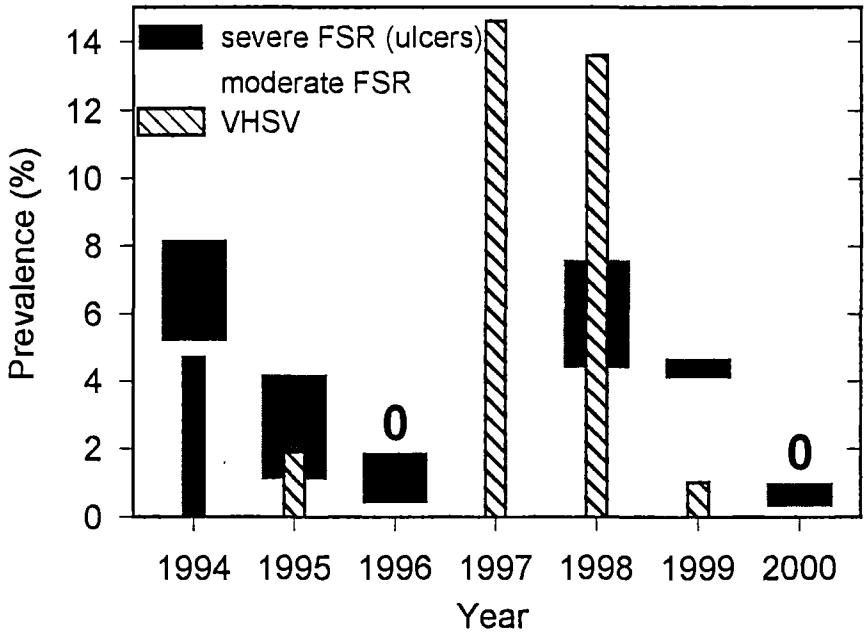


Figure 2. Spring prevalence of focal skin reddening (FSR) and viral hemorrhagic septicemia virus (VHSV) in adult Pacific herring sampled from Prince William Sound, Alaska.

The foresight of funding this study was immediately obvious in its first year, 1999. The Alaska Department of Fish and Game had predicted increasing biomass (Figure 1), and a fishery was scheduled for April 1999. But poor returns closed most of the fisheries, including the most valuable sac roe fisheries. Unlike in 1993—when the population crashed but Pacific herring damage assessment studies were not funded—in 1999 disease study was fully funded and we were able to document a fairly healthy population in 1999 (sample virus prevalence = 1%) and 2000 (sample virus prevalence = 0%). The continuous series of high quality disease information allowed us to determine that most of the population decline occurred in 1998, nearly a year before the decline was detected by biomass estimates. Note that the best biomass estimates are made on prespawning aggregations in early April, but spawning itself can result in high mortality of susceptible fish. Spawning-related mortality in 1998 was not detected until the next prespawning aggregation in 1999.

Results from long-term disease study supported by the Trustee Council have broad significance beyond the herring population of PWS. We are answering basic questions about how disease contributes to mortality of free-ranging, schooling, marine fish. To more fully answer these basic questions, the U.S. National Science Foundation (Biological Oceanography) funded a 3-year project to augment continued disease research in PWS. The NSF project is closely linked to this project (\\462). This proposal asks the Trustee Council to continue to fund fish necropsy, tissue

sampling, and virus analysis. NSF has committed to fund analysis of blood and tissues (histopathology) as well as a modeling component through Dr. Terrance Quinn of the University of Alaska, Fairbanks. Both organizations benefit from high quality, multiyear research, but at a fraction of the cost of supporting the entire project. The full NSF component of the project cannot continue unless the Trustee Council continues to fund sample collection. In funding the sampling and virus analysis components of the study, the Trustee Council will have access to the same types of data generated from 1994-2001, with the addition of a modeling component to determine the role of disease in stock assessment.

This project is already the most comprehensive study of disease in a wild fish population, but all 8 years of study have been conducted on a depressed population. We will almost certainly learn more about the interaction of disease and population change when population biomass eventually recovers. The next year is critical period for this project. Extending the project for the final year of restoration funding has two distinct advantages. First, the NSF component of the project is up for competitive renewal (submission deadline 8-15-01, with new project dates 2-1-02 through 1-31-07). A fourth year of funding by the Trustees will provide a strong boost to the NSF renewal proposal (as it did for the original 3-year NSF proposal). And second, because population biomass is at the lowest level ever recorded, continued disease study will help us understand if disease continues to inhibit recovery. Pacific herring are extremely important in the Prince William Sound ecosystem, and this project provides an understanding of disease and population change that is important for understanding marine fisheries worldwide. A 4$^{th}$ year of disease study is proposed to ensure seamless flow of data from this Restoration project to the Gulf Ecosystem Monitoring program.

This project has benefited from project \468 "Fundamental Estimations of Acoustic Target Strength" because acoustic estimates of population size are an important component of estimating population biomass. Better estimates of population biomass allow us to more accurately assess the relation of disease and population change.

## NEED FOR THE PROJECT

### A. Statement of Problem

Pacific herring are an injured biological resource in Prince William Sound (PWS) classified as "recovering." However, estimates of population biomass in 2000 were the lowest on record. The population was low enough in 2000 that ADFG closed all herring fisheries in 2001 without using their age structured assessment model to calculate prespawning biomass. From ADFG's announcement Wednesday, March 28, 2001, "the PWS herring spawning biomass could be expected to remain below threshold for several more years" (http://www.cf.adfg.state.ak.us/region2/finfish/herring/pws/pwsupd01.htm). Lack of recovery of the resource has resulted in lost services, particularly for commercial fisheries. Also, Pacific herring and herring spawn-on-kelp are harvested annually for subsistence purposes and form an important part of the local native culture of Chenega and Tatitlek. Delay in recovery of the herring population results in lost resources for subsistence use. Continued study is needed to examine how disease may be limiting recovery and to document when recovery has occurred.

### B. Rationale/Link to Restoration

This project should be done because it will provide information on what might be limiting population recovery and it will monitor when fish are healthy and recovery has begun. Also, ADFG now uses disease information as part of it mathematical model to estimate population biomass. If disease prevalence again increases, ADFG can use this information to delay opening of any commercial fisheries until the population has truly recovered. Continued sampling of fish twice a year is needed to determine the dynamics of disease in the population.

### C. Location

Study will be done in Prince William Sound, Alaska. Information will benefit fisheries managers as they consider alternatives for managing Pacific herring fisheries. As the resource is enhanced, users throughout PWS could potentially benefit. Because we have identified ulcer prevalence as a key indicator of population health, managers of other Pacific herring fisheries can use this information to monitor the health of their populations.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

Dr. Marty has a solid record of local contact and dissemination of information, and continued collaboration with local users is proposed for FFY02. For example, Dr. Marty led a herring dissection and necropsy demonstration for the Youth Area Watch in Cordova on April 19, 1999. Contact with fishers, processors, and ADFG managers occurs through participation in conference telephone calls, personal contact while in Anchorage and Cordova, and via e-mail.

To aid in dissemination of information, Dr. Marty is available by phone for interviews and will respond quickly to requests from the Restoration Office for general information and articles for newsletters. Dr. Marty is based in California, but Dr. Kathy Burek of Alaska Veterinary Pathology Services (one of only two board-certified veterinary pathologists residing in Alaska) has been contracted as a necropsy pathologist in 1995, and 1996, and 1999, and she has indicated her interest to serve as the second pathologist in April 2002. Alaska residents will be hired by ADFG for sampling logistics and recording data, and ADFG will charter vessels from local residents for collecting and processing fish.

## PROJECT DESIGN

### A. Objectives

The restoration objective states, "Pacific herring will have recovered when the next highly successful year class is recruited into the fishery and when other indicators of population health are sustained within normal bounds in PWS." The population cannot be classified as healthy until

individuals within that population are healthy. Field sampling to determine the ongoing disease status is a high priority of this project. Objectives include:

1. Determine the prevalence of major diseases in Pacific herring.

2. Determine the interaction of gender, age, and season on disease prevalence.

3. Determine if disease prevalence correlates with population trends.

## B. Methods

Pacific herring will be randomly sampled from PWS in November (at the end of the feeding season, n = 100) and in April (near the time of spawning, n = 300). Each fish will be examined for abnormalities (e.g., *Ichthyophonus hoferi*), and tissues from each fish will be assayed for VHSV.

This proposal has two specific hypotheses to test:

1. Prevalence of external lesions, VHSV, or *Ichthyophonus hoferi* is different from previous years.
2. Gross lesions, VHSV, or *Ichthyophonus hoferi* are related season, age, or gender.

To test the hypothesis that reproductive stage affects the development of disease, sampling is needed during the spawning season (spring) and during the period of gonadal development and peak condition (fall). Nearly 70% of the PWS Pacific herring biomass schools in the waters on the northern and western edge of Montague Island during November, and the fish remain in this area until after they spawn in April. Most fish will be sampled from this region. During the summer, fish disperse throughout the Sound. The other 30% of the PWS Pacific herring biomass overwinter and spawn in the Northeast region of PWS. Our primary goal is to get a representative sample of disease in PWS herring, and we reserve the option to sample fish in the Northeast region if warranted by changes in biomass trends. During the spawn-on-kelp investigations among fish from Northeast PWS in 1997 and 1998, trends in viral prevalence were similar to fish in the Montague area (Hershberger et al. 1999).

To provide a minimum number of fish from which at least the dominant year class can be analyzed in detail, we propose sampling 300 fish in April. Fish are easier to capture in the spring, and the age distribution in the spring is most consistent with data used in the historical age-structured assessment model. With a sample size of 300, diseases with a prevalence as low as 1% can be detected with 95% confidence, and a 6% difference in sample prevalence (e.g., 10 vs. 16%) can be detected with a statistical power of 0.80 (Becker and Grieb 1987). To test hypotheses of age differences, the dominant year class-often >40% of the sampled population-will be compared with combined groups of smaller year classes. To detect seasonal differences, and minimize costs, 100 fish will be sampled in the fall. A sample size of 100 is sufficient to have 95% confidence that disease with a prevalence of 3% will be detected in at least one fish sampled (Becker and Grieb 1987).

Proposed study is designed to minimize bias associated with gear type, capture, and holding

(Holst 1996). All fish will be sampled using commercial purse seines. In the event that large numbers of fish begin to spawn in areas too shallow for commercial seines, fish will be captured using cast nets. All necropsies will be completed < 5 hours after the seine is pursed around the fish.

To best characterize the condition of herring in Prince William Sound, herring will be subjected to complete necropsy using the following sampling schedule (as field conditions allow) during the final two years of proposed study:

| Dates | Reproductive Stage | Number of Fish |
|---|---|---|
| **FY02:** Oct./Nov., 2001 (4 nights) | peak condition/ gonadal development | 100 |
| mid-April, 2002 (7 days) | spawning/post-spawning | 300 |
| | Total Fish, FY02: | 400 |

Fish for necropsy will be anesthetized in tricaine methane sulfonate (Finquel®) and visually screened for external lesions (Marty et al. 1998), which are ranked as none (0), mild (1), moderate (2), or severe (3). Prevalence of *Ichthyophonus* will be estimated by gross examination of internal organs, especially the heart. With funding from NSF, histopathological analysis will be done on 10 organs to determine *Ichthyophonus* prevalence.

Measurements on each fish include body weight, standard length, age (from scales), liver weight, and gonad weight. Otoliths are archived for later use if information on annual growth rates is desired. This study is designed to diagnose gross lesions (e.g., ulcers) and the two major disease agents: VHSV and *Ichthyophonus hoferi*. Results will be compared with previous years of study. Several samples will be collected, but only selected samples will be analyzed:

a. Virus isolation - To assay fish for virus, anterior kidney, spleen, and any severe skin lesions will be put into individually labeled plastic bags and stored on ice (for each fish, one bag will hold kidney and spleen, and a separate bag will be used for skin lesions). Every 48 to 72 hours, samples will be shipped by air to the ADFG fish pathology laboratory in Juneau (under the direction of Dr. Ted Meyers) for analysis. Isolation using EPC cell lines will be as previously described (Meyers et al. 1994). The application of polymerase chain reaction (PCR) techniques for primary diagnosis of VHSV has been explored (R.M. Kocan and J.R. Winton, personal communication); to date, PCR has not proved more useful than virus isolation.

b. Bacteriology – during the past 8 years, bacteriology was done on the kidney of each fish with severe gross lesions, but pathogenic bacteria have never cultured. Therefore, tissue around ulcers will be preserved for histopathology or virology, but the kidney will not be cultured for bacteria (superficial bacteria can be diagnosed on histopathology).

Other samples will be collected and analysis will be done using funding from NSF:

a. Histopathology (fix in 10% neutral buffered formalin) - gill, spleen, liver, gonad, heart, stomach, intestinal tract, exocrine pancreas, trunk kidney, skeletal muscle, skin, brain, and other gross lesions. Also, a touch prep of kidney from each fish is made on a glass slide.

b. Hematology - blood will be drawn from the caudal vein into a Lithium-heparinized syringe and stored on ice. Packed cell volume (PCV) is determined on site. A blood smear is made on a glass slide, dried, and archived. Plasma is separated by centrifugation (3,000 *g* for 7 min) and frozen within 3 h of collection.

c. Immunology - a blood smear for leukocyte differential counts will be collected.

In previous study, spring samples from PWS had several other parasites, but these did not seem to be significant on the population level. Gross lesions and other observations will be scored as in previous years. All lesions are described in a "comments" section on a data sheet, but only the most common gross findings are scored for statistical analysis: caudal fin fraying, caudal fin reddening, fin base reddening, focal skin reddening, diffuse skin reddening, iris reddening, branchial copepods, number of 0.5-mm-diameter white foci on gills, number of peritoneal Anisakidae, and gonadal fullness. Parasites requiring histopathology for diagnosis will be scored using NSF funds.

The ADFG fisheries laboratory in Cordova, Alaska, will handle logistics for sampling fish for necropsy, collecting age and length data, preparing formalin and containers for tissue fixation, providing a data recorder for one pathologist on site, and ship all samples. Results from virus isolation will be reported as a VHSV titer.

Quality control and quality assurance is part of all examinations. For necropsy examination, the senior pathologist (Dr. Marty) is on site at all times; when questionable or difficult lesions are encountered, the second pathologist can consult with Dr. Marty. In the event that Dr. Marty is unavailable for necropsy, five other pathologists have experience on the herring necropsy team, and services of these pathologists would be secured.

Statistical analysis in this study will focus on determining changes in disease prevalence over time. The association of selected categorical variables (e.g., VHSV status versus external lesion scores) will be evaluated using chi-square methods for categorical data analysis; comparisons will be considered valid only if individual expected cell frequencies are >1 and no more than 20% of the cells have expected cell frequency <5. Odds ratios will be calculated only for standard (2x2) two-way contingency tables. Significance of changes in disease prevalence will be tested using chi-square or Fisher's Exact test. For all analyses, comparisons will be considered significant when $P<0.05$ and highly significant when $P<0.01$.

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

This proposal includes significant contributions from ADFG as the lead agency. The project is being run through ADFG because Dr. Marty has worked closely with ADFG on several Trustee Council-funded projects during the past decade. ADFG has unique local knowledge on Pacific herring in PWS, including the necessary experience and expertise to secure all necessary charters

and ship hazardous materials from Cordova to Davis. Close collaboration with ADFG allows for seamless transfer of disease information to fishery managers, and rapid transfer of disease information to commercial and subsistence fishers. No other agencies are requesting funds for this section of the project, and no other agencies or universities will be contracted for this work. Dr. Marty has provided information to Dr. Brenda Norcross on ways in which disease information can be used as part of overall Pacific herring studies in PWS during the next century. Results of this effort will not be realized until the Gulf Ecosystem Monitoring plan in initiated.

## SCHEDULE

### A. Measurable Project Tasks for FY02

| DATES (results due on final date) | ACTIVITY |
|---|---|
| **Fall Samples:** | |
| Oct. 1 - Nov. 30, 2001: | Collect samples; Person in charge: Gary D. Marty, UC Davis |
| Nov. 1 - Dec. 31, 2001: | Scale analysis (age); Person in charge: Steve Moffitt, ADFG, Cordova, AK |
| Nov. 1, 2001 – Feb. 28, 2002: | Virology and bacteriology; Person in charge: Ted Meyers, ADFG, Juneau, AK |
| March 1- Aug. 1, 2002: | Statistical analysis; Person in charge: Gary D. Marty |
| January 14-23, 2002 (4 days): | Attend annual restoration workshop (Gary D. Marty) |
| **Spring Samples** | |
| April 1 - April 30, 2002: | Collect samples; Person in charge: Gary D. Marty |
| April - July 31, 2002: | Scale analysis (age); Person in charge: Steve Moffitt, ADFG, Cordova, AK |
| April - Sept. 30, 2002: | Virology and bacteriology; Person in charge: Ted Meyers, ADFG, Juneau, AK |
| Oct. 2002 - Feb. 1, 2003: | Statistical analysis; Person in charge: Gary D. Marty |
| Jan. 11, 2003 –April 15, 2003: | Final report writing; Person in charge: Gary D. Marty |
| open: | Opportunities for public comment |

### B. Project Milestones and Endpoints

Review of Objectives:

1. Determine the prevalence of major diseases in Pacific herring.
2. Determine the interaction of gender, age, and season on disease prevalence.
3. Determine the effect of disease on population trends.

Objectives will be met when the multi-year study is completed and the final synthesis report is submitted April 15, 2003.

### D. Completion Date

Basic project objectives will be met at the end of the fourth year of proposed study. Note, however, that each additional year of disease study in Prince William Sound provides more information on the recovery of the Pacific herring population. High prevalence of virus and ulcers among recruiting populations of both the 1994 and 1995 year-classes in 1998 severely limited the capacity of these year classes to contribute to population recovery. Recruitment of the 1996 and 1997 year classes was minimal. Preliminary evidence indicates that the 1998 year-class is no more than average. Even if the 1999 year class is as large as the last major year class (1988), recovery cannot be fully documented until that year class is 5 years old: in 2004 (two years after the current project ends). Therefore, termination of study in 2002 is not likely to be sufficient to document population recovery. Comments from reviewers of my NSF proposal were favorable, but most reviewers agreed that following the population through a full cycle—probably 16 to 20 years—would be needed to understand how disease and population size are linked. Currently proposed study through 2002 will provide us with 9 years of disease information, and this is already the most comprehensive study ever conducted on disease in a wild fish population. However, 9 years of study will provide information on only about ½ of a population cycle. Extending this project another 5-10 years through the Gulf Ecosystem Monitoring and cost sharing with NSF will greatly enhance our understanding of how and when the Pacific herring population recovers. Such an extension is not being proposed now, but the possibility of a long-term extension will be considered, as more details of the Gulf Ecosystem Monitoring plan become known.

## PUBLICATIONS AND REPORTS

Several publications are anticipated in FY02 that will combine earlier work (\\162) with this project:

Marty, G. D., C. J. Kennedy, C. R. Davis, and N. H. Willits. In preparation. Effect of age, gender, size, season, and lesions on plasma of free-ranging Pacific herring. I. Total protein, albumin, IgM, cholesterol, and PCV. Diseases of Aquatic Organisms

Marty, G. D., C. J. Kennedy, and N. H. Willits. In preparation. Effect of age, gender, size, season, and lesions on plasma of free-ranging Pacific herring. II. Glucose, bilirubin, ALP, ALT, AST, and CPK. Diseases of Aquatic Organisms

Marty, G. D., C. J. Kennedy, and N. H. Willits. In preparation. Effect of age, gender, size, season, and lesions on plasma of free-ranging Pacific herring. III. Osmolarity, sodium, potassium, chloride, phosphate, calcium, and lactate. Diseases of Aquatic Organisms

These manuscripts will be submitted later in FY01 or early in FY02. Funds needed for these publications have already been appropriated through \\162 and NSF.

**PROFESSIONAL CONFERENCES** – No funds are requested. Funds to attend a professional conference each year are provided by the NSF component of the project.

**NORMAL AGENCY MANAGEMENT** - Not applicable.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Continuation of proposed disease research in PWS is critical for obtaining other funding. In late 1998, the National Science Foundation's Division of Biological Oceanography funded an unsolicited proposal to continue complete analysis of the samples collected as part of project \\462. The three-year $286.4K NSF project has no funds for sample collection, and depends entirely on Trustee Council funds for sample collection. The NSF project includes collaboration with ADFG (through Steve Moffitt) and the University of Alaska, Fairbanks (Dr. Terrance J. Quinn). Using Dr. Quinn's expertise, the NSF project includes a modeling component to mathematically determine the relation of disease and changes in population biomass (Quinn et al In press). Trustee Council-funded studies of herring disease since 1994 were highlighted in the NSF proposal as a significant source of matching funds (about $2.2 million over the life of the project). NSF normally does not fund unsolicited proposals for more than $150K per year. Because the Trustee Council funded the first three years of this project (99462 - 01462), NSF saved about $230K on its project. At the same time, the Trustee Council benefits from $286.4K worth of analysis funded entirely by NSF. In August 2001, Dr. Marty plans to submit a competitive renewal proposal to NSF to continue funding disease analysis and modeling for another 5 years (2002-2006). The extension to a fourth year of funding included as part of this proposal will provide funds for sample collection during the first year of the 5-year NSF extension. NSF strongly encourages matching funds, and commitment to a fourth year of funding will go far towards convincing NSF to fund additional Pacific herring disease study.

This project is designed to provide the same types of data that were generated during detailed disease study since 1994 (94320S, 95320S, 96162, 97162, 98162, 99462, 00462, and 01462). Each year of research produces some new findings, but with each year the significance of the project becomes greater than its individual parts. The addition of one more year of data to our knowledge about the most important diseases will only add to the significance of this work.

**EXPLANATION OF CHANGES IN CONTINUING PROJECTS** – This proposal requests extension of this project from 3 years to 4 years. An extra year of study is needed because Pacific herring fisheries were again closed in 2001, and there are no prospects for population recovery in the foreseeable future. Also, an extra year of funding is needed as part of cost sharing to increase the chances that NSF will extend Pacific herring disease research in PWS another 5 years (2002-2006). Methods and budget have no other substantial changes.

**PROPOSED PRINCIPAL INVESTIGATOR**

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## PRINCIPAL INVESTIGATOR

**Gary D. Marty, DVM, Ph.D.**, and Diplomate, American College of Veterinary Pathologists, will be responsible for design of pathology studies, on-site necropsy evaluation, and final report writing. Dr. Marty has the required fisheries background (BS and MS in fisheries biology) to integrate the many parts of this study, and he has performed these duties on similar projects since 1994.

## OTHER KEY PERSONNEL:

**Steve Moffitt, BS**, is in charge of chartering a commercial seiner for capturing fish and a laboratory vessel for fish necropsy. Mr. Moffitt is also in charge labeling sample vials, mixing 10% neutral buffered formalin, and for shipping hazardous materials (e.g., formalin) to UC Davis.

**Theodore R. Meyers, Ph.D.**, is certified as a Fish Pathologist by the Fish Health Section of the American Fisheries Society. Dr. Meyers has been Principal Pathologist for the AK Dept. of Fish and Game since 1985. Dr. Meyers and the laboratories he supervises have been involved in the detection and diagnosis of VHSV in Alaskan fisheries since 1990, detecting the virus in cod and herring from PWS and in herring from other parts of Alaska. Dr. Meyers will oversee the diagnostic virology and bacteriology parts of this project.

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Rahimian, H., and J. Thulin. 1996. Epizootiology of *Ichthyophonus hoferi* in herring populations off the Swedish west coast. Dis. Aquat. Org. 27:187-195.

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**2002 EXXON VALDEZ TR E COUNCIL PROJECT BUDGET**

October 1, 200. September 30, 2002

| Budget Category: | Authorized FFY 2001 | Proposed FFY 2002 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|
| Personnel | 12.9 | $12.9 | | | | | | |
| Travel | 0 | $0.0 | | | | | | |
| Contractual | 58.1 | $50.1 | | | | | | |
| Commodities | 9 | $9.0 | | | | | | |
| Equipment | 0 | $0.0 | | | | | | |
| Subtotal | 80 | $72.0 | | | | | | |
| General Administration | 6 | $5.4 | | | | | | |
| Project Total | 86 | $77.4 | | | | | | |
| Full-time Equivalents (FTE) | 0.4 | 0.4 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

Comments:

This project proposal includes two components:

1. University of California, Davis: Fish necrospsy
   a. Funds for writing the final report in FY03 were included in the FY01 budget.

2. Alaska Department of Fish and Game: Logistical and analytical support .

**2002**

Project Number: 02462
Project Title: **Effect of Disease on Pacific Herring Population Recovery in Prince William Sound**
Agency: AK Dept. of Fish & Game

FORM 3A
AGENCY
PROJECT
DETAIL

Prepared:
GDMarty 4-6-01



4/13/01

**2002 EXXON VALDEZ TRL : COUNCIL PROJECT BUDGET**

October 1, 2001 - September 30, 2002

| Personnel Costs: | | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|---|
| PM | Name | Position Description | Step | Budgeted | Costs | Overtime | FFY 2002 |
| | Vacant | Fishery Biologist II | 16D | 1.5 | 5,817 | | 8.7 |
| | Vacant | Fish & Wildlife Technician II | 9A | 0.5 | 3,229 | 2,614 | 4.2 |
| | | Subtotal | | 2.0 | 9,046 | 2,614 | |
| Those costs associated with program management should be indicated by placement of an *. | | | | | | **Personnel Total** | $12.9 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| PM | | Price | Trips | Days | Per Diem | FFY 2002 |
| | Description | | | | | |
| Those costs associated with program management should be indicated by placement of an *. | | | | | **Travel Total** | $0.0 |

**2002**

Project Number: 02462
Project Title: **Effect of Disease on Pacific Herring Population Recovery in Prince William Sound**
Agency: AK Dept. of Fish & Game

FORM 3B
Personnel
& Travel
DETAIL

| Contractual Costs: | | Proposed FFY 2002 |
|---|---|---|
| Description | | |
| PWS Fall Sampling | Vessel Charter (lodging boat/sampling platform 5d @ 800/d) | 4.0 |
| | Vessel Charter (seiner to locate fish, 5d @ 1100/d) | 5.5 |
| | Shipping | 0.2 |
| PWS Spring Sampling | Vessel Charter (lodging boat/sampling platform, 7d @ 800/d) | 5.6 |
| | Vessel Charter (seiner to locate fish, 7d @ 1100/d) | 7.7 |
| | Shipping | 0.3 |
| When a non-trustee organization is used, the form 4A is required. | **Contractual Total** | $23.3 |

| Commodities Costs: | Proposed FFY 2002 |
|---|---|
| Description | |
| Misc. sampling supplies (tubes, jars, preservative, coolers, totes etc.) (approximately $500/sample event - 2 events) | 1.0 |
| Pathology Laboratory - Virology Supplies (400 samples @ $20/sample) | 8.0 |
| **Commodities Total** | $9.0 |

**2002**

Project Number: 02462
Project Title: **Effect of Disease on Pacific Herring Population Recovery in Prince William Sound**
Agency: AK Dept. of Fish & Game

FORM 3B
Contractual & Commodities DETAIL

| New Equipment Purchases: Description | Number of Units | Unit Price | Proposed FFY 2002 |
|---|---|---|---|
| | | | |
| Those purchases assoc. with replacement equipment should be indicated an "R." | | **New Equipment Total** | $0.0 |

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

**2002**

Project Number: 02462
Project Title: Effect of Disease on Pacific Herring Population Recovery in Prince William Sound
Agency: AK Dept. of Fish & Game

FORM 3B
Equipment
DETAIL

2002 EXXON VALDEZ TR :E COUNCIL PROJECT BUDGET

October 1, 20.. September 30, 2002

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|
| Personnel | $18.6 | $12.3 | | | | | | |
| Travel | $4.9 | $5.4 | | | | | | |
| Contractual | $2.5 | $2.5 | | | | | | |
| Commodities | $2.3 | $2.3 | | | | | | |
| Equipment | $0.0 | $0.0 | | | | | | |
| Subtotal | $28.3 | $22.5 | | | | | | |
| Indirect | $5.3 | $4.3 | | | | | | |
| Project Total | $33.6 | $26.8 | | | | | | |
| Full-time Equivalents (FTE) | 0.3 | 0.2 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

Comments: Indirect Costs include the standard overhead rates and applications for the Institute of Toxicology and Environmental Health (ITEH) at the University of California, Davis (18.9%).

Other funds - A 3-year $286.4K grant was funded by the National Science Foundation (NSF project # 9871982), 2-1-99 through 1-31-02, with Dr. Gary D. Marty as principal investigator. The NSF grant includes complete blood analysis, histopathology, and population modeling not included in this proposal. This proposal (02462) can stand on its own, but competive renewal of the NSF grant would be greatly enhanced if the NSF project had access to samples collected as part of this project. The Trustee Council benefits by getting complete analysis of all samples collected, including population modeling, at no additional cost.

Proposal includes funds (here, direct costs) for sample collection (1.0 month time for G. Marty, $400 of the supply budget), report writing (0.3 month), community involvement (0.2 month time for G. Marty, $50 for long distance phone calls), and the annual workshop (travel and per diem). The proposal does **not** include funds for NEPA compliance, publications, or professional conferences (the NSF grant provides funds for publication and for Dr. Marty to attend one professional meeting per year).

**FY02**

Project Number: 02462
Project Title: Effect of Disease on Pacific Herring Population Recovery in Prince William Sound
Name: University of California, Davis
Agency: ADFG

FORM 4A
Non-Trustee
SUMMARY

Prepared:
GDMarty 3-30-00



4/13/01

## 2002 EXXON VALDEZ TR E COUNCIL PROJECT BUDGET

October 1, 200. September 30, 2002

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| | Name | Position Description | Budgeted | Costs | Overtime | FY 2002 |
| | Marty, G. | Assistant Researcher V | 1.5 | 7.0 | 0.0 | 10.5 |
| | Teh, C. | Laboratory Assistant III | 0.5 | 3.5 | 0.0 | 1.8 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | Subtotal | 2.0 | 10.5 | 0.0 | |
| | | | | | Personnel Total | $12.3 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| | Description | Price | Trips | Days | Per Diem | FY 2002 |
| | RT airfare to Cordova for sample collection (1 fall, 3 spring)* | 0.7 | 4 | 16 | 0.1 | 4.4 |
| | airfare to Anchorage for annual restoration workshop | 0.6 | 1 | 4 | 0.1 | 1.0 |
| | | | | | | 0.0 |
| | *There are actually 32 days per diem rather than 16 on these trips, | | | | | 0.0 |
| | but the field rate is $45/day which these formulas will not | | | | | 0.0 |
| | accommodate. Thus the number of days were halved and the | | | | | 0.0 |
| | rate doubled. | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | Travel Total | $5.4 |

**FY02**

Prepared:
GDMarty 6-26-00



Project Number: 02462
Project Title: Effect of Disease on Pacific Herring Population Recovery in Prince William Sound
Name: University of California, Davis
Agency: ADFG

FORM 4B
Personnel
& Travel
DETAIL

4/13/01

| Contractual Costs: | Proposed FY 2002 |
|---|---|
| Description | |
| 150 fish necropsies @ $16.50/fish (professional services of consulting pathologist) | 2.5 |
| **Contractual Total** | $2.5 |

| Commodities Costs: | Proposed FY 2002 |
|---|---|
| Description | |
| Materials and supplies (for sampling supplies, report writing, long distance phone, film, computer disks) | 1.7 |
| statistical analysis | 0.4 |
| ITEH supplies | 0.2 |
| **Commodities Total** | $2.3 |

**FY02**

Project Number: 02462
Project Title: Effect of Disease on Pacific Herring Population Recovery in Prince William Sound
Name: University of California, Davis
Agency: ADFG

FORM 4B
Contractual & Commodities DETAIL
4/13/01

Prepared:
GDMarty 6-26-00

**2002 EXXON VALDEZ TR :E COUNCIL PROJECT BUDGET**

October 1, 20C . September 30, 2002

| New Equipment Purchases: | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | FY 2002 |
| 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 an "R." | | New Equipment Total | $0.0 |

| Existing Equipment Usage: | Number |
|---|---|
| Description | of Units |
| IEC clinical centrifuge equipped with rotors for on-site plasma separation and packed cell vol. determination | 1 |
| Revco -80° freezer for archiving plasma | 1 |
| YSI Model 55 hand-held dissolved oxygen meter for checking fish holding conditions before necropsy | 1 |
| For report writing and correspondence: | |
| Pentium III 866 DELL-PC desktop computer with 256 Mb RAM, Ethernet card, and internal 56,600 baud modem | 1 |
| HP4L LaserJet printer | 1 |
| Codonics NP-1600 Color Photographic Network Printer, for publication grade printing of digital images | 1 |
| | 1 |

**FY02**

Project Number: 02462
Project Title: Effect of Disease on Pacific Herring Population Recovery in Prince William Sound
Name: University of California, Davis
Agency: ADFG

FORM 4B
Equipment
DETAIL

Prepared:
GDMarty 4-6-01



4/13/01

**GEM Data System Specification**

Submitted under the BAA

| | |
|---|---|
| Project Number: | 02475-BAA |
| Restoration Category: | |
| Proposer: | Stephen Marley, Ph.D. |
| Lead Trustee Agency: | |
| Cooperating Agencies: | |
| Alaska SeaLife Center: | no |
| Duration: | 1st Year, 1 Year Project |
| Cost FY 02: | $234,500 |
| Cost FY 03: | $0 |
| Geographic Area: | N/A |
| Injured Resource: | N/A |



**ABSTRACT**

The purpose of this proposal is to produce the Operations Concept and System Requirements Specification for the data system for the Exxon Valdez Oil Spill (EVOS) Trustee Council Gulf Ecosystem Monitoring (GEM) initiative. This study will capitalize on the work already performed, and through a detailed requirements definition approach, we will be able to develop the detailed description necessary to release a formal Request for Proposal (RFP) for the permanent system.

## INTRODUCTION

This proposal moves forward from the work started in 1999 to evaluate the Data System for The EVOS Long Term Monitoring Program, by defining the technical requirements of the proposed data system. In February 2001, the NRC released its interim report on the GEM program. In that report, the success of GEM was highlighted as being ***"critically dependant on a Data Management System"***. The report emphasized the key roles played by both scientists and the Data Manager. In addition, strong emphasis was placed on the role of a data archive for interdisciplinary data exchange, public outreach and long term data integrity.

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 user community will depend on the effectiveness of the data system that will manage that archive and provide access to the data. We are proposing to perform the needs analysis to define the data system to a level of detail that will enable EVOS Trustee Council to move ahead with an open RFP. This will be achieved through the characterization of the users of the system and the physical data products and product metadata being held within the system.

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. An effective data delivery system increases the value of the data by increasing the long-term utility of the data by the widest number of stakeholders and applications.

Building on the work performed under EVOS funding over the last 18 months, and leveraging our extensive experience with NASA EOSDIS data system development (http://ecsinfo.gsfc.nasa.gov/welcome2.html), we are proposing to utilize a Unified Modeling Language (UML) approach to systems design. UML is a development of the Object Management Group (OMG), an industry consortium focused "creating a component-based software marketplace by hastening the introduction of standardized object software". Object Oriented Analysis and Design (OOA/OOD) has emerged in recent years as the design methodology most suited to the information age. It is heavily focused on understanding the workflow of the system through a detailed analysis of the manner in which the various users of a system need to interact with the software, the data, and each other. For details of the UML approach and its relevance to software engineering, see http://cgi.omg.org/news/pr97/umlprimer.html.

## 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 and diverse 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, or at least provide access to 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 is expected to continue. Making final reports available, along with the data, is

often the best data documentation possible. The ability to provide a coherent link from funding through research to publications and citation is an invaluable aid to both the research itself, and also to evaluate benefit. In addition, both GIS and text data can be extremely useful in locating relevant research data. Data are often requested using specific geographic features. Datasets can be linked to electronic reports, and full text searches can be used in conjunction with gazetteers to locate other 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*

**System Specification**

Effective planning for the data system should begin with clarifying goals of the system and reviewing the prior work done in this area. 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 background for this work has been established through a series of four notes already delivered under the existing contract:

- Job description for the Data Manager,
- Focus Group Feedback,
- Classification of web based data systems,
- Preliminary recommendations,

Together with an additional two notes to be delivered before July, 2001:

- Data Characterization and Archive & Access Requirements
- Data Policy

We will specify the data system requirements and candidate design needed to support the long-term monitoring and research program. We develop the Key User Scenarios and the ramifications of some of the choices that will be made in the detailed design phase of the program. We will then develop a Conceptual Architecture that will identify the main components of the data systems. This architecture and the user scenarios will then be folded into the Operations Concept which will specify the data and information flows through the system. This will include the identification of external interfaces, the specification of Operational Scenarios, and the development of a Functional Architecture that supports those scenarios. Lastly, we shall develop a System Requirements Specification that together with the Operations Concept will form the technical backbone of an RFP for the procurement of a data system. Such a specification is a key prerequisite for releasing a public RFP.

### *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 Maryland offices of ECOlogic Systems Corp. and at EVOS meetings or ad hoc meetings in Anchorage.

## COMMUNITY INVOLVEMENT AND TRADITIONAL KNOWLEDGE

It is expected that the local community will be an important user of the GEM data system, and so they will be explicitly included in the design of the data system. Their input shall be included through two principle activities:

- ***Local Community Data Access*** – will focus on how the local community access the information (educational, research results, etc.) within GEM, and will form part of the System Definition Study; and
- ***Local Community Data Entry*** – will focus on how to bring local community observations (fishing fleet data; K-12input) into the information space of GEM.

## PROJECT DESIGN

### *A. Objectives*

The principle objective of this work is to develop system definition specification for the GEM Data System that is consistent with the GEM mission for a long term archive system, and which satisfies the access and usage needs of all the user communities who interact with it. The documentation that results from this study will be of sufficient quality to form the technical basis of a commercial RFP for the GEM Data System (GDS). Documentation resulting from this study will include, but may not be limited to:

- ***GEM Data Systems Operations Concept*** – The primary purpose of this document is to provide a technical of description the planned functionality and operations of the GEM Data System. The document describes the functionality based upon User Community input and derived requirements from EVOS Chief Scientist and Data Manager. The document will include a description of all functions associated with the GDS and related interfaces to external entities that directly provide information to, or receive information from the GDS. Internal process flows, both normal and contingent, are described.

- ***GEM Data System Requirements Specification*** – This document will establish the requirements baseline for the GDS. It will include a conceptual and functional architecture, interface, functional, performance and design requirements.
- ***GEM Data System External Interface Requirements Specifications*** – This series of documents (1 per external interface) defines the data exchanges between GDS and external entities. It will identify data flows, performance constraints, and implementation responsibility.

### *B. Methods*

**System Specification**

We will follow the formal software systems design methodology known as Unified Modeling Language (UML). The Unified Modeling Language™ (UML) was developed jointly by Grady Booch, Ivar Jacobson, and Jim Rumbaugh at Rational Software Corporation, with contributions from other leading methodologists, software vendors, and many users. Based on extensive use of the Booch, OMT, and Jacobson methods, the UML is the evolution of these and other approaches to business process, object, and component modeling. The full UML cycle can be used to develop a design a system to the point where it can be handed off to be coded. We propose to primarily follow only the first few steps of this methodology; specifically, Use Case Analysis.

Use Case Analysis identifies the users of the system and the process work flows through which they interact with the system. The output of Use Case Analysis is a set of functions and interfaces that the end system needs to support. The Use Case Analysis shall be conducted by:

- **Identifying the key users and key scenarios**. This will be achieved through detailed interaction with the EVOS Chief Scientist & Data Manager.
- **Conducting interviews with representatives of the key users**. EVOS Chief Scientist & Data Manager will need to establish a group of active participants from the user community that represent all the key users. We can then work with them to gain detail to the scenarios. A working session and the presentation of interim results of this activity will be made at the Annual Restoration Workshop.
- **Developing the Operations Concept Document**. This shall be the formal output from the scenario development. This document shall be released for review to the community.
- **Developing the Requirements Specification Document**. Based on community feedback to the ConOps, we will update that document and then develop a formal requirements baseline that will expand upon the concepts developed in the ConOps to include performance, design, interface, and functional requirements for the end system.

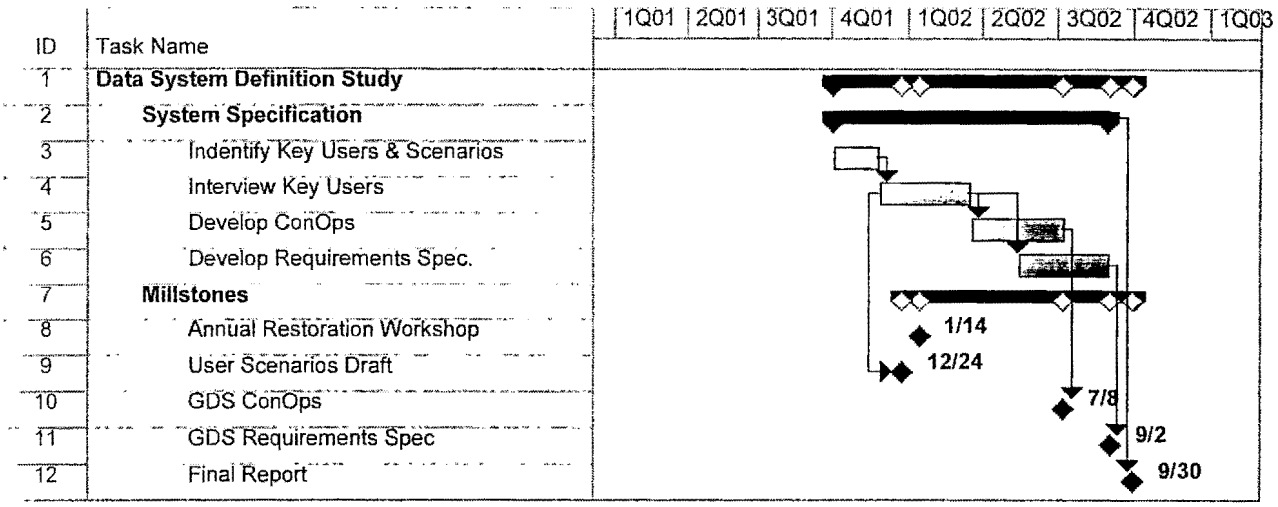
### *C. Cooperating Agencies and Groups*

The project will be lead by Stephen Marley from ECOlogic Systems Corporation. Charles Falkenberg from ECOlogic will also play a key role. It is important that this effort is independent of the influence of any one user group, and so no other agency or group will be explicitly involved. However, active participation by representatives of the User Community is vital to the eventual success, and so it is anticipated that an Advisory Group constituted and lead by the

EVOS Chief Scientist & Data Manager will act as the principle source of input, as well as the preliminary review body of all technical output.

## SCHEDULE

### *A. Measurable tasks for FY02 (Oct 1, 2001 – Sept 30, 2002)*




### *B. Project milestones*

| Item | Description | Date |
|---|---|---|
| Draft User Scenarios | First cut at the key user scenarios of the system | 12/24/01 |
| Operations Concept | Detailed description of system characterization | 7/8/02 |
| Requirements Specification | Detailed system level requirements | 9/2/02 |

### *C. Completion Date*

The program is slated for completion on 9/30/02.

## PUBLICATIONS AND REPORTS

Principle deliveries will be:

- Operations Concept, and
- Requirements Specification

In addition, we will produce all the material necessary for participation in the Annual Restoration Workshop, and provide the same for publication on the web.

A final report will be issued at the end of the project .

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project will define the implementation requirements of the GEM data management plan, and as such needs to be fully coordinated with historical, existing, and future restoration efforts. This coordination will be facilitated through the offices of the Chief Scientist and the Data Manger.

## PROPOSED PRINCIPAL INVESTIGATOR

Stephen Marley PhD
ECOlogic System Corporation
4409 Forbes Boulevard,
Lanham, MD 20706
Tel: 240-737-4007
Fax:240-737-4050
Email: smarley@ecologic.net

## PRINCIPAL INVESTIGATOR

Steve Marley graduated from University of Leeds, United Kingdom in 1988 having completed his dissertation in Infrared Astrophysics. He has spent 13 years in the field of science data information systems. Initially at through developing Earth Observation data processing and ground segment management systems for both the British National Space Center (BNSC) where he developed the Synthetic Aperture Radar processing system for the UK data center for ERS-1, and later with the ESA team in Frascati, Italy where he supported ERS microwave instrument validation, and developed ground segment applications. Since late 1994 he has worked within the framework of NASA's Mission To Planet Earth program. For most of this time he was one of the senior systems architects of the EOSDIS Core System (ECS) ground segment developed to support NASA's flagship Earth observation platforms (Terra, Aqua, Landsat 7 ...).

## OTHER KEY PERSONNEL

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.

FY 02 *EXXON VALDEZ* TRI E COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Personnel | | $226.5 | | | | | | |
| Travel | | $8.0 | | | | | | |
| Contractual | | $0.0 | | | | | | |
| Commodities | | $0.0 | | | | | | |
| Equipment | | $0.0 | | | | | | |
| Subtotal | $0.0 | $234.5 | Estimated FY 2003 | | | | | |
| Indirect | | | | | | | | |
| Project Total | $0.0 | $234.5 | | | | | | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 0.9 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

Comments:

**FY02**

Project Number: 02475-BAA
Project Title:GEM Data Systems Specification
Name: Stephen Marley

FORM 4A
Non-Trustee
SUMMARY

Prepared: Apr-01

FY 02 *EXXON VALDEZ* TRI E COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| | Name | Position Description | Budgeted | Costs | Overtime | FY 2002 |
| | Stephen Marley | Principle Investigator | 3.6 | 22.8 | | 82.1 |
| | Charles Falkenberg | Science Advisor | 3.0 | 19.0 | | 57.0 |
| | Don Brown | Senior Engineer | 4.6 | 19.0 | | 87.4 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | Subtotal | 11.2 | 60.8 | 0.0 | |
| | | | | | **Personnel Total** | $226.5 |

| Travel Costs: | | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|---|
| | Description | | Price | Trips | Days | Per Diem | FY 2002 |
| | EVOS Annual Meeting | Air fare & Hotel | 1.0 | 2 | 10 | 0.2 | 4.0 |
| | Key User Interviews | Air fare & Hotel | 1.0 | 2 | 10 | 0.2 | 4.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | | | 0.0 |
| | | | | | **Travel Total** | | $8.0 |

**FY02**

Project Number:
Project Title:GEM Data Systems Specification
Name: Stephen Marley

FORM 4B
Personnel
& Travel
DETAIL

Prepared: Apr-01

FY 02 *EXXON VALDEZ* TRI E COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

| **Contractual Costs:** | Proposed FY 2002 |
|---|---|
| Description | |
| | |
| **Contractual Total** | $0.0 |

| **Commodities Costs:** | Proposed FY 2002 |
|---|---|
| Description | |
| | |
| **Commodities Total** | $0.0 |

**FY02**

Prepared: Apr-01

Project Number:
Project Title:
Name:

FORM 4B
Contractual & Commodities DETAIL

FY 02 *EXXON VALDEZ* TR :E COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

| **New Equipment Purchases:** Description | Number of Units | Unit Price | Proposed FY 2002 |
|---|---|---|---|
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

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

**FY02**

Project Number:
Project Title:
Name:

FORM 4B
Equipment
DETAIL

Prepared: Apr-01

# Effects of Oiled Incubation Substrate on Pink Salmon Reproduction



| | |
|---|---|
| Project Number: | 02476 |
| Restoration Category: | Research |
| Proposer: | Ron Heintz<br>NMFS, Auke Bay Laboratory<br>ABL Program Manager, Dr. Stan Rice |
| Lead Trustee Agency: | NOAA |
| Cooperating Agencies: | none |
| Alaska SeaLife Center: | No |
| Duration: | Fifth of six years. |
| Cost FY02: | $39.8 |
| Cost FY03: | $36.0 |
| Geographic Area: | Little Port Walter, Baranof Island, Southeast Alaska |
| Injured Resource: | Pink salmon |

## ABSTRACT

Populations are maintained through successful reproduction; this study is designed to determine if exposure to oil impairs pink salmon reproduction. Examination of the ability of the parental generation (P1) to produce offspring (F1) is underway as described for Project 01476. The P1 generation was exposed when they incubated in 1998; the F1 incubated in clean water beginning in FY01. After the F1 emerges in spring 2001 the fish will be marked and released. At the end of FYO2, the released fish will be recovered when they return as mature adults. At that time we will measure the ability of the F1 to produce viable offspring (F2). A diminished ability to produce the F2 generation represents a genetic effect transmitted to unexposed generations. Such an effect was demonstrated with for similarly treated pink salmon in 1997, but corroborating data do not exist. This project is designed to provide the needed corroboration thereby demonstrating a grave and unanticipated effect of oil pollution.

## INTRODUCTION

This project measures the delayed effects of oil exposure on pink salmon reproduction. Evidence has been accumulating that delayed effects of oil exposure extend to unexposed generations. This possibility was first revealed in 1991, when elevated egg mortalities were observed in the freshwater zone of oiled streams. The direct effects of oil exposure were not possible in this zone because of its location relative to the intertidal. However, adults returning to the oiled streams in 1991 may have been exposed when they incubated (Bue et al. 1996). This observation stimulated a series of field and laboratory studies. In 1998, Bue et al. reported adult fish returning to oil contaminated streams had reduced gamete viability. In that experiment, gametes were collected from adults returning to oil contaminated and uncontaminated streams and incubated in a hatchery before they could be they could be exposed to oil. Despite the identical incubating environments for the eggs, the gametes derived from oil contaminated streams consistently produced fewer viable embryos than gametes derived from uncontaminated streams. As in 1991, this difference was thought to result from the exposures the adults endured when they incubated as eggs, in the oiled streams. However, the exposure histories of the pink salmon used for the study could only be inferred. In addition, the underlying cause for the reduction in gamete viability was not identified.

The field evidence of reproductive impairment has some corroborating experimental evidence. Controlled laboratory exposure tests designed to measure direct and delayed effects of embryonic exposure have identified delayed effects on growth at the part per billion level of PAH exposure. These tests have provided secondary results also suggesting a reproductive effect, but the results were equivocal for the most part. Hence, the present study has been designed to specifically measure reproductive effects from adults with known exposure histories. However, a recent analysis of egg mortalities in earlier experiments by Smoker et al. (2000) indicates that exposure to crude oil can cause heritable damage to female pink salmon, and is consistent with other research on the mutagenicity of crude oil (Roy et al. 1999) and existence of heritable effects of benzo[a]pyrene after exposure during embryonic development (White et al. 1999).

Reproductive impairment described by Bue et al. may result from phenotypic effects on the parents, or genetic effects passed to the offspring. Both result in delayed impacts on the successive generations, and have significant but different implications for the recovery of the damaged populations. A phenotypic effect resulting in the failure to produce high quality gametes would be limited to those individuals that experienced sufficient exposure to oil. Consequently, the effect would diminish along with the exposure levels in the contaminated streams. However, genetic damage passed to offspring could potentially persist for a large number of generations; existing even after oil could no longer be found in contaminated streams. Phenotypic effects on the adults, or genetic effects are not mutually exclusive, and may occur at the same time.

This project is designed to measure the effect of parental exposure on reproductive ability by measuring the viability of gametes taken from exposed and unexposed salmon. Exposures began with eggs collected from wild fish in 1998. Fish that survived incubation were marked in

released in the spring of 1999 and the surviving adults returned in the fall of 2000. Evaluation of the viability of the offspring of the exposed fish is underway. The surviving offspring will be marked and released in the spring of 2001. When they mature the viability of their offspring will be measured, effectively repeating the work reported by Smoker et al. (2000). Incubation of the final generation in the fall of 2002 will require about 90 days to identify effects on that generation. Neither these fish nor their parents will have been exposed to oil, thus effects related to the exposure history will represent effects with a genetic basis. Effects identified in the fish incubated in fall 2000 represent effects that could result from a combination of phenotypic and genotypic effects. Both types of effects are suggested by existing data (Bue et al. 1988, Smoker et al. 2000, White et al. 1999). The final product of this project includes a life-history model with the phenotypic and genotypic impacts of exposure quantified for each life stage. This model represents an important advance in our understanding of the impacts of environmental contaminants on populations.

## NEED FOR THE PROJECT

### A. Statement of the Problem

Field and laboratory work conducted after the EVOS by Restoration Study 191 demonstrated that pink salmon populations in contaminated streams had reduced fitness when they were exposed to low concentrations of polynuclear aromatic hydrocarbons (PAH). The data clearly demonstrate that reductions in average fitness are the result of decreased survivorship in the exposed populations. This study is designed to verify that fitness is further reduced by the failure to produce viable offspring. This will lead to refinement of our current estimates of the reduction in average fitness. Identification of reduced fertility in the contaminated streams field will greatly strengthen the Trustee conclusions regarding EVOS impacts on pink salmon, and demonstrate the relevance of our model to real-world conditions.

Smoker et al.'s (2000) demonstration of a genetic effect suggests that the fitness model we have proposed to construct should include both genetic and phenotypic components to the total reduction in impairment. Fitness reductions resulting from phenotypic impacts will persist only as long as the exposures take place. However, fitness reductions resulting from genotypic impacts may persist for long after the exposures have ended. Elaboration of the fitness model to account for genotypic effects can potentially provide the Trustees with a time line for recovery.

We propose replicating the genetic analysis to verify the claims of Smoker et al. (2000) and to provide more information for elaborating the fitness model. Confirmation of the genetic effect is required because such claims are likely to be met with skepticism. The work reported by Smoker et al. (2000) was not corroborated by our evaluations performed the same year. The differences in results are likely due to the high mortality rates we observed in our own studies. Thus, replication of the genotypic effects will provide a firm basis for refuting the criticism we expect from the oil industry. Replicating the genotypic effects also provides opportunity to design experiments that will permit us to evaluate the contribution of dominance effects to the genetic component of variance. Such an evaluation provides a basis for estimating the number of

generations required for the genetic load to dissipate.

### B. Rationale/Link to Restoration

Identification of a genetic effect of embryonic exposure to crude oil provides EVOS Trustees with important evidence of a grave and unanticipated effect of the EVOS. This information is important to managers working to restore salmon populations in PWS. The recovery status of pink salmon in PWS remains controversial, and establishing an identifiable endpoint for recovery remains problematic. Pink salmon escapements to oiled streams were high even in the years when embryo mortality rates were elevated. Recently, embryo mortality has not differed from reference streams, but evidence for oil in stream waters can be found (Rice personal communication). Measurement of the potential genetic load acquired by incubating in oil contaminated streams coupled with the estimated persistence of such a load can provide valuable insight into the recovery status of these populations.

Pink salmon are an ideal species for identifying prolonged population effects resulting from embryonic oil exposure which makes them a premier sentinel species for detecting EVOS impacts. Consequently, a large amount of effort and money was expended towards understanding how oil affected pink salmon populations. This work has led to important advances in our understanding of the scope and mechanisms of oil toxicity and has led to developing a model describing the average reduction in reproductive fitness of exposed populations. The importance of this work transcends the immediate needs of the Trustees to evaluate recovery and can be generalized for all natal fish habitats. Thus, this work represents an important legacy of the EVOS.

### C. Location

This project is underway at Little Port Walter (LPW), a research hatchery operated by NMFS in southeastern Alaska. This location is appropriate because it has been the site of these studies since their inception. The facility 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

This project began in southeastern Alaska, and maturing fish will return to their natal stream on Baranof Island. We will continue to provide information to interested public (primarily fishermen) who visit the station by displaying at the facility the posters developed for the Restoration Workshop for 97191B and 97076 as interpretative tools. In addition, we have presented our data to the RCAC in the winter of 2000.

## PROJECT DESIGN

### A. Objectives

The objectives of this study are to:

1. Determine the average viability of gametes taken from adult fish exposed to uncontaminated and contaminated water during incubation.

2. Determine how incubating in oiled contaminated water influences individual variation in gamete viability.

3. Determine if reductions in gamete viability can be inherited in unexposed generations.

4. Develop a fitness model that includes all observed phenotypic and genotypic impacts of oil exposure.

We are currently testing the hypothesis that incubating in gravel contaminated with oil leads to reduced gamete viability. Evaluation of objectives 1 and 2 is underway. Objective 3 is also underway, the F1 generation is currently emerging from incubators, and they will be marked and released this spring. Objective 4 will be completed in the close-out year for this project, once all the impacts have been evaluated. To our knowledge this type of analysis does not exist for any vertebrate and these effects occur at concentrations that are commonly seen in urban locations.

### B. Methods

*Overview of completed work*

The exposure mechanism and fish culture procedures followed those described in previous proposals for Restoration Study 191B. Gametes were taken from an intertidally spawning pink salmon stock, transferred to our hatchery at Little Port Walter where they were incubated beginning in FY98. The eggs were exposed to effluent from either oil-coated or untreated gravel. In FY99, approximately 60,000 surviving fry from each exposure group were marked and released. Marked fish were held for a short period to recover from the marking procedure and then released. Exposures began in September of 1998; between 30 and 100 mature fish representing each treatment returned in September 2000.

All pink salmon returning to the Sashin Creek weir during the 2000 escapement period were inspected for marks. The exposure history was identified by external marks and those with similar histories were held in holding pens for spawning. On a given spawning date, fish were removed from each pen and spawned,, we have released fish from

multiple treatments, which

Gamete viability was determined for the oil treatment and the control groups by two different methods. The first method replicated the procedure used by Bue et al. (1998) and precisely estimated the average survival of offspring derived from parents exposed to oil or clean gravel during incubation . While this method precisely measures the mean gamete viability in an exposure group, the primary source of variation will be measurement error and no information will be available on individual variation. Therefore, a second method was used to estimate how much of the variability in offspring survival was due to individual variation. The mating designs employed in FY01 to evaluate the combined phenotypic and genotypic impacts on survival of the F1 will also be employed in FY02 to evaluate the genetic impacts on the survival of the F2 generation. These are described below.

*Estimation of average offspring survival*

Average offspring survival will be estimated by measuring the survival in pools of gametes comprising all the possible pairwise crosses. On each day of spawning, 2 embryo pools will be formed per treatment. Upon formation of an embryo pool, 6 subsamples, each of approximately 150 embryos, will be randomly selected and incubated in an individual cell within a Heath tray. On a given day, pools will be formed by randomly assigning half the males and females from a treatment group to one of two subgroups. Each female in a subgroup will contribute approximately 900 eggs to a common pool, the pool will be mixed and the mixture divided into a number of aliquots equal to the number of males in the subgroup. Each male in the subgroup will fertilize one aliquot, and the fertilized eggs will be recombined in a common container, mixed and divided into six aliquots that will be incubated in randomly assigned locations. Thus, the average survival of a treatment group on a given day will be the mean of the average survivals in each of the two subgroups. Estimates will be made on as many days as practical.

The estimates of mean survival of the treatment groups will be compared with *t* tests after assuming that variability between groups of like-treated incubators is negligible. A *t* test between, for example, treatment 1 and 2, when there are *d* spawning days, *q* treatments, *p* subgroups per treatment, and *r* cells per subgroup will have the following form:

$$t_{((p-1)*q*d)df} = \frac{\frac{1}{d}[\overline{sv_{11}} + \ldots \overline{sv_{1d}} - \overline{sv_{21}} \ldots - \overline{sv_{2d}}]}{\sqrt{\frac{1}{d^2} * \frac{s_e^2}{p*r} * 2 * d}}$$

where,

$\overline{sv_{ij}}$ = Survival rate for treatment *i* on day *j*

$s^2_c$ = Combined Between-Pools Mean Square obtained by ANOVA.

Comparisons will be made between each of the doses and the control with an overall $\alpha$ = 0.05. Effects identified under this approach will necessarily have to arise from genetic effects because neither the parental nor the offspring generations will have been exposed to oil.

*Identification individual variation*

The spawning design will replicate that reported by Smoker et al. (2000). The fish will be used to produce as many 2 x 3 mating sets as possible on a given day. Mating sets consist of crosses between individuals from lines with similar exposure histories, and represent indivdual pairings of 2 females with 3 males. Therefore, each set will produce 6 families. Each family will be divided in 2 parts, each of which will be randomly placed in an incubator compartment.

Additive genetic, maternal, non-additive genetic, and phenotypic variances will be estimated and heritabilities, and ratios of maternal and nonadditive genetic variances to phenotypic variances will be calculated using an animal model solved by applying a derivative free technique for estimating variance components employing restricted maximum likelihood (Graser et al., 1987). The derivative-free restricted maximum likelihood (DFREML) analysis procedure of Meyer (1988) will be utilized. The technique has been utilized to analyze data from breeding experiments of fish (Crandell and Gall, 1993). Heritability estimates may be used to predict expected genetic change due to natural selection for a range of selection intensities (Van Vleck, 1987).

*Estimation of fitness reduction*

Average fitness for pink salmon that incubate in oiled gravel will be estimated from the fitness function

$$W_i = S_i F_i$$

where $W_i$ is the average fitness of the population incubated at the $i^{th}$ exposure level, with survivorship $S_i$ from the time of exposure to maturity, and fecundity equal to $F_i$. Survivorship will be estimated as the product of survival during incubation and marine survival. Both of these values have been reported in previous reports where embryos were exposed to conditions similar to those used here. Estimates of fecundity will be calculated as the proportion of eggs that survive through eyeing. Thus, W will be expressed as the probability of producing a viable offspring. Assuming a genetic effect is corroborated then the fitness model then the difference in survival between exposed and unexposed lines can be used to parameterize the model proposed by Cronin and Bickham (1998).

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

Fish spawning and handling of gametes in FY 00 will be directed by a contracted expert in the field of fish reproduction. The statistical analysis of the results for experiment 1 have been designed by the Alaska Department of Fish and Game (ADF&G). The University of Alaska has assisted in the design of part B.

## SCHEDULE

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

Tasks for FY02

Sep. 2002: Recover mature F1, begin incubation of F2

TASKS for FY03

Oct. 2002: Evaluate F2 survival to eyeing.
Jan. 2003: Begin analysis of results and development of life history model.
Sep 2003: Final Report due

### B. Project Milestones

Completed in FY98, FY99, FY00 :

Sept. 1998: Set-up exposure apparatus, collect gametes, begin exposures of P1

May 1999: Mark and release P1 generation

Sept. 2000: Examine oil effect on viability of F1 generation by recovering and spawning marked P1adults when they return to weir.

Sept. 2001: Complete analysis of gamete viability and fitness model.

Underway in FY01:

May 2001: Mark and release F1 fry from oiled and control lines.

FY02 Milestones:

Sep. 2002: Recover adult F1 generation and begin incubating F2 generation
Dec. 2002 Complete evaluation of incubation of F2 generation.
Sep . 2003 Submit final report.

### C. Completion Date

Final Report will be submitted on September 15, 2003.

## PUBLICATIONS AND REPORTS

FY00: Annual report describing the doses, exposure apparatus and effects on early incubation.

FY 01: Annual Report describing survival to maturity, mating procedures and fertilization rates.

FY 02: Annual report describing survival of F1 during incubation, release numbers of F1.

FY 03: Final report

Other potential reports:

Heintz, R. 2002. Effect of incubating in oil on pink salmon reproductive capacity. Journal Unknown.

Heintz, R. 2002. Incubating in oiled gravel damages the entire life-history of pink salmon. Journal Unknown.

Heintz, R. 2003. Embryonic exposure to oil causes genetic damage in pink salmon. Journal unknown.

## PROFESSIONAL CONFERENCES

Travel to 2002 EVOS Oil Spill Symposium.

## NORMAL AGENCY MANAGEMENT

This project will complete the work begun under Restoration 191B which has been performed cooperatively between the Trustees and NMFS from the outset. However, NMFS proposes providing most labor requirements for this project and seeks funding for primarily contractual labor and commodities. There is no charge for project support costs which include management of the LPW facility and project budget, or production of. There was no charge for setting up the experiment in FY98 and early FY99, NMFS covered costs associated with setting up the exposure apparatus, spawning pink salmon, and maintaining the incubation for 9 months and analyzing the hydrocarbon data.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This project will be coordinated with continuation of NOAA research and monitoring efforts regarding pink salmon embryo survival under 01454, and integrates with a new study proposed to evaluate the effects of egg dig timing on mortality estimates. This study also coordinates the results of Restoration 191B and 076 by completing a life-history model for oil effects on pink

salmon. Investigators and agencies will coordinate by sharing data. NOAA/NMFS will coordinate with the Trustees by providing labor requirements and laboratory overhead.

## EXPLANATION OF CHANGES IN CONTINUING PROJECTS

No changes to the existing study have been described.

## PROPOSED PRINCIPAL INVESTIGATOR


| | |
|---|---|
| Name | Ron Heintz |
| Affiliation | NMFS |
| Address | Auke Bay Laboratory<br>11305 Glacier Hwy.<br>Juneau, AK 99801 |
| Phone | 907-789-6058 |
| Fax | 907-789-6094 |
| E-mail | ron.heintz@noaa.gov |


## PRINCIPAL INVESTIGATOR

Ron Heintz has been involved in examining the effects of *Exxon Valdez* oil on pink salmon since 1992. He has developed the methods proposed for this project, published 4 peer-reviewed papers and has another in press on this topic. In addition, he has presented results of these studies at 15 professional meetings.

## OTHER KEY PERSONNEL

Dr. S. D. Rice provides consultation.

## LITERATURE CITED


Bue, B. G., S. Sharr, S. D. Moffitt, and A. Craig. 1996. Injury to salmon eggs and preemergent fry due to the T/V *Exxon Valdez* oil spill. *In* S.D. Rice, R.B. Spies, D.A. Wolfe, and B. A. Wright (Eds.). *Exxon Valdez* Oil Spill Symposium Proceedings. American Fisheries Society Symposium Number 18.

Bue, B. G., S. Sharr and J. E. Seeb. 1998. Evidence of damage to pink salmon populations inhabiting Prince William Sound, Alaska, two generations after the *Exxon Valdez* oil spill. Trans. Am. Fish. Soc.

Crandell, P.A. and G.A.E. Gall, 1993. The genetics of body weight and its effect on early maturity based on individually tagged rainbow trout (Oncorhynchus mykiss). Aquaculture, 117:77-93.

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Heintz, R. , S. D. Rice and J. W. Short. 1995. Injury to pink salmon eggs and preemergent fry incubated in oiled gravel (Laboratory Study). Restoration Project 94191-2 Annual Report. *Exxon Valdez* Trustee Council, Anchorage, AK.

Maltby, L., D. M. Forrow, A. B. A. Boxall, P. Calow and C. I. Betton. 1995. The effects of motorway runoff on freshwater ecosystems: 1. Field Study. Env. Tox and Chem. 14:6 1079-1092.

Marty, G. D., J. W. Short, D. M. Dambach, N. H. Willits, R. A. Heintz, S. D. Rice, J.J. Stegeman and D. E. Hinton. 1997. Ascites, premature emergence, increased gonadal cell apoptosis, and cytochrome P4501A induction in pink salmon larvae continuously exposed to oil-contaminated gravel during development. Can. J. Zool. 75:989-1007.

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Roy N. K. , J. Stabile, J. E. Seeb, C. Habicht and I. Wirgin. 1999. High frequency of K-ras mutations in pink salmon embryos experimentally exposed to Exxon Valdez oil. Environ Toxicol Chem 18(7):1521-1528

Smoker, W. W., P. A. Crandell, P. Malecha and I. Wang. 2000. Genetic analysis of development mortality in oiled and unoiled lines of pink salmon. Juneau Center, School of Fisheries and Oceans. University of Alaska, Fairbanks Alaska. SFOS-JCSFOS 2000-03.

Van Vleck, L.D., 1987. Genetics for the Animal Sciences, W.H. Freeman and Co., New York

Wertheimer, A. C., S. D. Rice, A. G. Celewycz, J. F. Thedinga, R. A.Heintz, R. F. Bradshaw, and J. Maselko. 1996. Effects of oiled incubation substrate on straying and survival of wild pink salmon. Restoration Project 95076 Annual Report. *Exxon Valdez* Trustee Council, Anchorage, AK.

White P.A., S. Robitaille and J. B. Rasmussen . 1999. Heritable reproductive effects of benzo[a]pyrene on the fathead minnow (*Pimephales promelas*). Environ Toxicol Chem 18(8):1843-1847

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

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 |
|---|---|---|
| Personnel | | $16.0 |
| Travel | | $7.0 |
| Contractual | | $11.6 |
| Commodities | | $2.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $36.6 |
| General Administration | | $3.2 |
| Project Total | $0.0 | $39.8 |
| Full-time Equivalents (FTE) | | 0.2 |
| Other Resources | | $29.3 |

LONG RANGE FUNDING REQUIREMENTS

| Estimated FY 2003 | | | | | |
|---|---|---|---|---|---|
| $36.0 | | | | | |

Dollar amounts are shown in thousands of dollars.

Comments:
Labor costs reflect costs associated with data collection only, costs associated with writing reports and management are contributed by NOAA
Principle Investigator R. Heintz, 2.0 mo = $16.2
Fishery Research Biologist R. Bradshaw 1.0 mo = $6.6
Additional Operating Costs of Little Port Walter Field Station = $8.0

Total NOAA Contribution for Part A = $30.8

**FY02**

Prepared: 4/10/01

Project Number: 02476
Project Title: Oil Effects on Pink Salmon Reproduction
Agency: National Oceanic and Atmospheric Administration

FORM 3A
TRUSTEE
AGENCY
SUMMARY

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

| **Personnel Costs:** | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FY 2002 |
| R. Heintz | Fishery Research Biologist | GS 12 | 1.0 | 8.1 | | 8.1 |
| R Bradshaw | Fishery Research Biologist | GS 11 | 1.2 | 6.6 | | 7.9 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 2.2 | 14.7 | 0.0 | |
| | | | | | **Personnel Total** | $16.0 |

| **Travel Costs:** | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 2002 |
| | | | | | 0.0 |
| Beaver Charters to LPW to spawn adults | 1.0 | 4 | | | 4.0 |
| | | | | | 0.0 |
| Anchorage, EVOS Symposium, (Heintz) | 0.4 | 1 | 4 | 0.2 | 1.2 |
| Miscellaneous (Car rental, telephone chgs, POV mileage, etc) | | | | | 0.0 |
| | | | | | 0.0 |
| SETAC Meeting | 1.0 | 1 | 4 | 0.2 | 1.8 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $7.0 |

**FY02**

Prepared: 4/10/01

Project Number: 02476
Project Title: Oil Effects on Pink Salmon Reproduction
Agency: National Oceanic and Atmospheric Administration

FORM 3B
Personnel
& Travel
DETAIL

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

| **Contractual Costs:** | | | Proposed FY 2002 |
|---|---|---|---|
| Description | | | |
| Contract Labor to Recover, Hold and Spawn Adult Pink Salmon | | | |
| 480 hours *16.00 per hour | | | 7.6 |
| 240 hours * 17 per hour | | | 4.0 |
| When a non-trustee organization is used, the form 4A is required. | | **Contractual Total** | $11.6 |
| **Commodities Costs:** | | | Proposed FY 2002 |
| Description | | | |
| groceries | | 1.5 | 1.0 |
| miscellaneous supplies | | 1.0 | 1.0 |
| | | **Commodities Total** | $2.0 |

**FY02**

Prepared: 4/10/01

Project Number: 02476
Project Title: Oil Effects on Pink Salmon Reproduction
Agency: National Oceanic and Atmospheric Administration

FORM 3B
Contractual & Commodities DETAIL

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

| **New Equipment Purchases:** Description | Number of Units | Unit Price | Proposed FY 2002 |
|---|---|---|---|
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

| **Existing Equipment Usage:** Description | Number of Units | Inventory Agency |
|---|---|---|
| Wet Lab space at Little Port Walter | | |
| Incubation units at Little Port Walter | | |
| Scales for measuring fish | | |
| Computers for recording data | | |
| Weir for collecting adultts | | |
| Holding facilities for adult fish | | |
| Station boats and fuel | | |

**FY02**

Prepared: 4/10/01

Project Number: 02476
Project Title: Oil Effects on Pink Salmon Reproduction
Agency: National Oceanic and Atmospheric Administration

FORM 3B
Equipment
DETAIL

# Effects of food stress on survival and reproductive performance of seabirds

| | |
|---|---|
| Project Number: | 02479 |
| Restoration Category: | Research |
| Proposed By: | USGS, University of Washington |
| Lead Trustee Agency: | DOI |
| Cooperating Agencies: | University of Washington |
| Duration: | final year, 4-year project |
| Cost FY 02: | $75,000 |
| Geographic area: | Cook Inlet, Gulf of Alaska |
| Injured resource: | Common Murre, Black-Legged Kittiwake |



## ABSTRACT

Traditional field methods of assessing effects of fluctuations in food supply on the survival and reproductive performance of seabirds may give equivocal results. In this project we applied an additional tool: The measure of stress hormones in free-ranging seabirds. Food stress can be quantified by measuring base levels of stress hormones such as corticosterone in the blood of seabirds, or the rise in blood levels of corticosterone in response to a standardized stressor: capture, handling and restraint. We applied these techniques to seabirds breeding in Lower Cook Inlet and also used captive birds for controlled experiments. This study provided a unique opportunity for a concurrent field and captive study of the behavioral and physiological consequences of stress in seabirds. Moreover, this study provides the basis for management of seabird populations in the areas affected by the *Exxon Valdez* oil spill, which will have broader applications for seabird monitoring programs. This year represents production of a synthesis of the project.

## INTRODUCTION

During the last decade, reduced productivity, increased mortality and subsequent population declines occurred among some seabirds and marine mammal species in the Gulf of Alaska. It has been suggested that declines in food availability resulted in food-related stress (Merrick *et al.* 1987, Piatt & Anderson 1996). Oil pollution from the Exxon Valdez oil spill may have exacerbated these stress-related effects. In this context, nutritional stress can be defined as changes in the physiological conditions of individuals that experience a long-term shortage of

food or rely on low quality and/or contaminated food resources that impair their ability to reproduce successfully. Alternatively, less severe food shortages may allow reproduction to proceed, but additional stress such as from anthropogenic sources may precipitate reproductive failure. It is frequently difficult, or impossible, to detect these possible types of perturbations by using traditional field methods (Piatt & Anderson 1996).

An approach using well-characterized responses of hormones to stress can provide a sensitive indicator of chronic stress in the environment, or the potential impact of future stressors (Wingfield et al. 1997). Food-related stress is associated with elevated levels of corticosteroids (also known as "stress hormones") in the peripheral system of affected animals (Axelrod & Reisine 1984; Wingfield, 1994). In seabirds, corticosterone levels were elevated in free-living Magellanic penguins exposed to oil pollution (Fowler et al. 1995), and in Black-legged Kittiwakes breeding under poor foraging conditions (Kitaysky et al., 1999*a*). Chronically elevated corticosteroid levels are known to result in regression of the reproductive system, suppression of memory and immune systems, lead to muscle wasting and cause neuronal cell death (e.g. Sapolsky 1987; Wingfield 1994). Exposure to oil pollution and decreased food availability can have similar debilitative effects on foraging and reproductive behaviors in seabirds. The effects of the stress can be detected and monitored through measurements of baseline plasma levels of corticosterone in the peripheral system of potentially affected seabirds. The pattern and extent of a corticosterone increase following application of a standardized stressor such as capture, handling and restraint then indicate potential for stress effects. Furthermore, experimental manipulations with corticosterone levels in captive seabirds provide a way to examine the mechanisms by which increased mortality and decreased reproduction are expressed.

In this study we have examined the possible consequences of food-related stress by measuring circulating levels of plasma corticosterone as an indicator of current and potential stress. We also proposed to investigate the effects of stress on survival and reproduction of several species of seabirds that breed in the Gulf of Alaska and have been affected by the *Exxon Valdez* oil spill. The results of our preliminary results show clearly that the hormone aspects of the study are effective and are powerful indicators of current stress state and equally important, point to populations that are vulnerable to future stress.

## NEED FOR THE PROJECT

### A. Statement of the Problem

Immediate and potential long-term effects of food-related stress on foraging and reproductive behavior in seabirds are not completely known. Recent declines of seabird populations in the Gulf of Alaska may be a result of a decrease in reproductive success due to an elevated mortality of food-stressed chicks after fledging, and/or the increased mortality of parents that rear their

young under poor feeding conditions. Traditional field methods of assessing potential pollution-related stress on the survival and reproductive performance of seabirds may give equivocal results. Lack of knowledge of the long-term effects of pollution-related stress on physiology and behavior prevents us from developing a successful rehabilitation program for seabird populations in the areas affected by the *Exxon Valdez* oil spill. The basic problem is that we do not know the mechanisms of how and at what stage of a bird's life the effects of stress might most strongly affect survival and reproductive performance. Furthermore, we know even less about the recovery of populations from stressful episodes in their life cycles. The latter is critical if we are to implement future programs to successfully manage seabird populations.

### B. Rationale

Long-term effects of pollution and stress on seabird reproductive biology are poorly known mostly because, to date, there have been no possibilities for a concurrent study of stress, survival and the monitoring of foraging conditions in seabirds. A critical concurrent assessment of variation in survival of seabirds in Lower Cook Inlet will be provided by on-going project that is designed specifically for these purposes (Restoration Project #01338). An ideal natural experiment to study effects of food stress can be conducted in Cook Inlet because seabirds at one study colony (Chisik Island) are chronically deprived of food, while seabirds at another study colony (Gull Island) have a surplus of food. From these studies, we will develop a protocol to monitor populations of seabirds at other colonies for possible effects of both natural and human-induced environmental perturbations.

### B. Location

The project will use laboratory-based location for analyses of samples collected during summer of 2001 and office-based location for writing.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

None in this phase of the project, which will draw only upon existing data.

## PROJECT DESIGN

We propose to investigate whether profiles of corticosterone in free-living seabirds reflect stress status and vulnerability to environmental stress, and how increased corticosterone levels affect reproduction and survival of individual seabirds. To address these questions we will investigate hypotheses and predictions on the relationships among stress physiology, behavior and reproduction in seabirds that breed in the areas affected by the *Exxon Valdez* oil spill. The first set of hypotheses states that the observed population declines are due to a decrease in post-breeding survival or reduced reproductive performances of adult seabirds that reproduce in the

areas affected by the *Exxon Valdez* oil spill. In particular, parent seabirds that rear their chicks in the area affected by pollution complete the reproductive season in poorer physiological conditions and suffer greater post-breeding mortality compared with birds that rear young under favorable environmental conditions. These hypotheses predict that: (a) pollution-related stress results in chronically elevated concentrations of corticosterone in the peripheral system of parent seabirds; (b) prolonged increases in concentration of corticosterone cause reproductive failure and an increase in the post-breeding mortality. The second set of hypotheses states that the observed population declines are due to a decrease in post-fledging survival of juvenile seabirds in the areas affected by the *Exxon Valdez* oil spill. In particular, seabirds chicks that were reared in the area affected by pollution complete the reproductive season in poorer physiological conditions and suffer greater post-fledging mortality compared with young reared under favorable environmental conditions. These hypotheses predict that the recovery of seabirds from pollution or food-related stress depends on: (a) age- and species-specific responses to stress in general; (b) the degree to which individuals are stressed and how debilitated they may become by exposure to chronically high corticosterone levels; and (c) foraging conditions after exposure to stress.

Thus, our main objective is to explore the relationships among endocrinological parameters, foraging conditions and survival of seabirds that breed in the areas affected by the *Exxon Valdez* oil spill

## A. Objectives

1. Produce a synthesis that summarizes the results of the four-year project and publish major findings in refereed scientific journals.
2. Develop a protocol to monitor populations of seabirds for possible effects of both natural and human-induced environmental perturbations.

## C. Methods

All activities will involve analyses of data and samples and writing up of the materials. Details of the original sub-projects are available in the previous FY98-01 Detailed project descriptions.

## SYNTHESIS OUTLINE

### 1. General concept. Endocrine responses to varying foraging conditions: stress or anti-stress hormones?

Authors: Wingfield JC, Kitaysky AS. In preparation for publication in *American Zoologist*.
In addition to seasonal changes in physiology and behavior that occur in predictable annual cycles, there are facultative responses to unpredictable events such as food shortages. These rapid behavioral and physiological changes represent the emergency life-history strategy and

serve to enhance life-time fitness of individuals. Glucocorticoids (corticosterone is a primary glucocorticoid hormone in birds) interacting with other hormones in the hypothalamo-pituitary-adrenal cascade, initiate and orchestrate the emergency life history strategy within minutes to hours. Components of the emergency life history strategy include: re-direction of behavior from a normal life history stage to increased foraging, elevated gluconeogenesis and recovery once the food shortage passes. These physiological and behavioral changes allow an individual to avoid potential deleterious effects of stress that may result from chronically elevated levels of circulating glucocorticoids over days and weeks. In other words, acute rises in glucocorticoids following food shortages allow individuals to avoid chronic stress and serve primarily as anti-stress hormones. Although it is clear that elevated secretion of corticosterone allows an individual to survive "stressful" events, there is a severe cost of prolonged high blood corticosterone levels. There is massive evidence that chronic elevation of corticosterone over weeks or longer has dramatic and debilitating effects including: inhibition of the reproductive system, suppression of the immune system, promotion of severe protein loss, neuronal cell death, and suppression of growth. Therefore it is possible that the stress response only increases fitness during relatively short-term responses (hours to days) to food shortages, and is detrimental to the animal during protracted challenges to homeostasis (days to weeks).

The frequency and magnitude of food shortages vary along environmental gradients. Behavioral responsiveness (or latency of response) of animals to environmental changes might reflect this variability. For instance, behavioral and physiological responses of seabirds to variability in food resources reflects their phylogenetic and ecological characteristics as well as that of their prey (Kitaysky 1999; Kitaysky and Golubova 2000; Kitaysky et al. 2000). In seabirds relying on continuously available food resources, even a short-term decrease in food availability might trigger an emergency life history strategy. So, the more predictable the environment (less stochastic), the quicker physiological and behavioral response to food shortage would be, whereas in less predictable environments (more stochastic) those responses are expected be delayed.

In contrast to variability of environmental change and diversity of life history traits that allow animals to cope with them, the emergency life history strategy is a remarkably consistent trait among all vertebrates, and is aimed to maximize life-time fitness. However, animals are faced with contrasting trade-offs in different stages of reproductive cycle. For example, outside of the reproductive season, survival seems paramount, whereas when breeding, the number of viable offspring produced during current versus future reproductive attempts must be maximized. Thus, the strategy that animals are pursuing when responding to food shortages should reflect which specific component of lifetime fitness is currently being maximized.

## 2. Specific tasks to be addressed in the synthesis

### I. The relationships among corticosterone levels, reproductive stage and varying foraging conditions in adult seabirds.

To assess whether Black-legged kittiwakes and Common murres from the different populations are chronically stressed or not, we will examine the relationships among baseline and acute stress

induced levels of corticosterone, reproductive stages (pre-incubation, incubation and chick-rearing), and food abundance. Some of the obtained results have been already published (Kitaysky et al. 1999a, Kitaysky et al in press). Also, we are planning to prepare two major papers on this subject by incorporating the data collected during reproductive seasons of 1998-2001 for publication in ecological journals (authors: Kitaysky, Piatt, Wingfield).

**II. The relationships among food provisioning, nutritional state and corticosterone secretion in juvenile seabirds.**

To address the issue of the physiological response of juvenile seabirds to variability in food provisioning, we will analyze the results of captive experiments and compare them to data collected in the wild. Some of the obtained results have been published (Kitaysky et al. 1999b, Kitaysky et al. in press), and we are planning to prepare two more manuscripts for publication in physiological journals (authors: Kitaysky, Wingfield, Piatt).

**III. The long-term effects of early nutritional stress on cognition and sexual maturation of young seabirds.**

We will prepare the results of long-term captive experiments as two manuscripts for publication in behavioral journals (authors: Kitaysky, Kitaiskaia, Piatt and Wingfield).

**IV. The relationship between corticosterone secretion, reproductive performance and post-breeding survival of seabirds.**

To make a conclusive statement about the relationships between stress and survival in parent Black-legged Kittiwakes and Common Murres in Lower Cook Inlet, we will coordinate this component of the study with the results of EVOS-funded project (Restoration Project #01338) that is specifically designed to address the issue of survival of adult murres and kittiwakes in relation to foraging condition. We are planning to prepare two manuscripts for publication in ecological journals (authors: Kitaysky, Piatt, Shultz).

### 3. Field endocrinology protocol for monitoring seabird populations.

The major findings of this project are worth formalizing in a protocol for monitoring seabird populations. We will prepare a manuscript summarizing major results and methods for publication at the Journal of Wildlife Management.

### D. Contracts and Other Agency Assistance

The laboratory analyses will be carried out by Dr. Alexander Kitaysky, a research associate in the Zoology Department at University of Washington, Seattle, with the aid of one full-time assistant. Dr. John Piatt of the US Geological Survey will provide logistical support and participate in writing. Radio-immuno assay analyses of blood samples collected during summer 2001 will be conducted in Dr. Wingfield's laboratory at UW. Dr. Wingfield will provide the supervision of laboratory analyses, provide logistical support and participate in writing.

## SCHEDULE

### A. Measurable Project Tasks for FY 01

2002

| | |
|---|---|
| September - February: | laboratory analyses and finalizing the results |
| May-August: | Synthesis manuscripts due |
| September: | Final report due |

### B. Project Milestones and Endpoints

| | |
|---|---|
| 2002 | Final analyses completed. |
| 2003 | Synthesis of the results published |

### C. Completion Date

September 30, 2003

## PUBLICATIONS AND REPORTS

See section above for publications. A progress report will be produced by April 15, 2003.

## NORMAL AGENCY MANAGEMENT

None of the proposed research described here would normally be conducted by the USGS.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

This study addresses a number of questions related to conservation and management of Alaskan seabirds. The proposed research will be coordinated with on-going projects being supported by the Exxon Valdez Oil Spill Trustee Council and US Geological Survey.

## EXPLANATION OF CHANGES IN CONTINUING PROJECTS

The design of the proposed work has not changed, and the budget is the same as that originally proposed and accepted by the EVOSTC in FY98.

## PRINCIPAL INVESTIGATORS

Principal Investigator and Project Leader - Dr. Alexander S. Kitaysky, Research Associate with the University of Washington, Seattle. Obtained a Ph.D. in Ecology and Evolutionary Biology from University of California in 1996 (dissertation on behavioral, physiological and reproductive responses of seabirds to environmental variability). Since 1986, studied seabird behavior and physiology at colonies in Okhotsk Sea and on the Aleutian Islands, and foraging behavior of seabirds at sea in Bering Sea, Aleutian Islands and in Gulf of Alaska.

Dr. John F. Piatt (Research Biologist GS-14, Alaska Biological Science Center, USGS, Anchorage, AK) obtained a Ph.D. in Marine Biology from Memorial University of Newfoundland in 1987. His dissertation involved seabird-forage fish interactions. Since 1987, he has studied seabirds both at colonies and at sea in the Gulf of Alaska, Aleutian Islands, and Bering and Chukchi seas. His is an author on over 75 peer-reviewed scientific publications about seabirds, fish, marine mammals, and effects of oil pollution on marine birds.

## OTHER KEY PERSONNEL

Professor John Wingfield (University of Washington, Seattle). Financial and logistic support for laboratory analyses in his lab at UW. He is an author on over 250 scientific publications. Prof. Wingfield is Chair of the Zoology Department at UW and an internationally recognized leader in the field of avian endocrinology.

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**2002 EXXON VALDEZ TRU E COUNCIL PROJECT BUDGET**

October 1, 2001 - September 30, 2002

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|
| Personnel | | $0.0 | | | | | | |
| Travel | | $0.0 | | | | | | |
| Contractual | | $70.1 | | | | | | |
| Commodities | | $0.0 | | | | | | |
| Equipment | | $0.0 | | | | | | |
| Subtotal | $0.0 | $70.1 | | | | | | |
| General Administration | | $4.9 | | | | | | |
| Project Total | $0.0 | $75.0 | | | | | | |
| Full-time Equivalents (FTE) | | 0.0 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

Comments:

Close out year, costs for Research Work order with University of Washington only.

**FY02**

Prepared:

Project Number: 02479
Project Title: Effects of food stress on survival and reproductive performance of seabirds
Agency: USGS

FORM 3A
TRUSTEE
AGENCY
SUMMARY

**2002 EXXON VALDEZ TRU E COUNCIL PROJECT BUDGET**

October 1, 2001 - September 30, 2002

| **Personnel Costs:** | | GS/Range/ Step | Months Budgeted | Monthly Costs | Overtime | Proposed FY 2000 |
|---|---|---|---|---|---|---|
| Name | Position Description | | | | | |
| NONE | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 0.0 | 0.0 | 0.0 | |
| | | | | | **Personnel Total** | $0.0 |

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

**FY02**

Prepared:

Project Number: 02479
Project Title: Effects of food stress on survival and reproductive performance of seabirds
Agency: USGS

FORM 3B
Personnel
& Travel
DETAIL

**2002 EXXON VALDEZ TRI E COUNCIL PROJECT BUDGET**

October 1, 2001 - September 30, 2002

| **Contractual Costs:** | Proposed FY 2000 |
|---|---|
| Description | |
| 4A Linkage | 0.0 |
| Research Work Order with University of Washington to support Alexander Kitaysky for 12 months to write final report and publications | 70.1 |
| When a non-trustee organization is used, the form 4A is required. **Contractual Total** | $70.1 |

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

**FY02**

Prepared:

Project Number: 02479
Project Title: Effects of food stress on survival and reproductive performance of seabirds
Agency: USGS

FORM 3B
Contractual & Commodities DETAIL

**2002 EXXON VALDEZ TRU E COUNCIL PROJECT BUDGET**

October 1, 2001 - September 30, 2002

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

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

**FY02**

Prepared:

Project Number: 02479
Project Title: Effects of food stress on survival and reproductive performance of seabirds
Agency: USGS

FORM 3B
Equipment
DETAIL

**Links Between Persistent Oil in Mussel Beds and Predators.**
**(Submitted Under BAA)**



Project Number: 02~~xxx~~ 486 -BAA

Restoration Category: Research

Proposers: Dr. Stan Rice- NOAA Auke Bay Laboratory, ABL Program Manager
Dr. Thomas A. Dean- Coastal Resources Associates, Inc., President
Dr. Stephen Jewett- UAF/SFOS, Research Professor

Lead Trustee Agency: NOAA

Cooperating Agencies: none

Alaska SeaLife Center: No

Duration: 1 year project

Cost FY 02: $170.8

Cost FY 03: $130

Geographic Area: Prince William Sound

Injured Resource/Service: Intertidal communities, sea otters, harlequin ducks

## ABSTRACT

Links between oil-contaminated mussel beds and impacts on infauna and vertebrate predators have been inferred, but have not been definitively demonstrated. Significant oil concentrations in some mussel beds have persisted to present, much longer than originally expected, and may explain contemporary observations of vertebrate predator exposure to oil. The possibility that oiled beds are long-term sources of vertebrate contamination was unanticipated, and has implications for future monitoring and response decisions in the event of future spills. In a more holistic approach than in the past, several research groups will examine evidence for links between persistence of *Exxon Valdez* oil in mussel beds, infauna, and in nearshore vertebrate predators.

## INTRODUCTION

High concentrations of *Exxon Valdez* oil have persisted in some oiled mussel beds within the spill region for 10 years (Babcock *et al.* 1998, Carls *et al.* 2001). Recent evaluations suggest that average oil concentrations in sediment have declined over the past several years (from 1994 through 1999). However, total polynuclear aromatic hydrocarbon (TPAH) concentrations ≥ 31 $\mu g\ g^{-1}$ dry sediment still persisted in about 1/3 of oiled mussel beds surveyed in 1999, and projections suggest contamination will persist in some beds for several decades. This persistence was not anticipated when decisions were made in 1989-90 NOT to clean mussel beds, and in fact raises the question of whether a few very persistent mussel beds should now be cleaned.

The relevance of persistent oil in mussel beds is that contaminated beds may be the contemporary source of vertebrate exposure to oil. There is evidence of oil exposure and continued injury to sea otters and harlequin ducks that feed on mussels and associated fauna (Bodkin *et al.* 1999, Esler *et al.* 2000, Trust *et al.* 2000), and more recently to masked greenling (Jewett *et al.* In Review). These, as well as one other species that feed on mussels, Barrow's goldeneye, were exposed to oil as indicated by elevated levels of cytochrome P450-1A (Ballachey *et al.* 1999). Feeding on mussels or other contaminated prey in oiled mussel beds is a likely route of exposure in nearshore vertebrate predators, and exposure to oil is a likely cause for lack of total recovery for these species (Ballachey *et al.* 1999, Bodkin *et al.* 1999, Esler *et al.* 2000, Trust *et al.* 2000). However, there is no direct evidence to link exposure of vertebrates to feeding in oiled mussel beds. These are different mobile species to work with.

The concentrations of oil in some oiled mussel beds in 1999 were also high enough to be of concern to associated infauna. While there is little evidence of impacts of oil on population density or physiology of mussels (Thomas *et al.* 1999) other species in the mussel community are much more sensitive to oil (e.g., Dauvin *et al.* 1982, 1998, Jewett *et al.* 1999). Benthic communities from sites with concentrations of TPAH in excess of 34 $\mu g\ g^{-1}$ are generally impacted by exposure to oil (Long and Morgan 1990, Long 1992). In 1999, 8 of 26 oiled mussel beds had TPAH concentrations in sediments that were in excess of 34 $\mu g\ g^{-1}$ (Carls *et al.* 2001). Also, subtidal benthic communities at sites that were oiled after the *Exxon Valdez* oil spill were adversely impacted by the spill (Jewett *et al.* 1999) yet TPAH concentrations were much lower than observed in oiled mussel beds in 1999 (Jewett *et al.* In Review). These data suggest that infauna associated with oiled mussel beds may be impacted by continued exposure to oil. However, there has been no direct investigation of the impacts of oil in oiled mussel beds on associated infauna, either in population diversity, or hydrocarbon loads. These data are needed to evaluate interaction and risk with vertebrate predators.

Oiled beds will be chosen from previously studied beds where contamination levels are projected to persist for long periods of time, and within areas where vertebrate predators are expected. Hydrocarbon concentrations in sediment and mussel tissue will be determined at each site. The prey base (species diversity) will be examined, along with hydrocarbon loads in the more common species. Links to vertebrate predators will be examine in two ways: (1) vertebrate predator activity will be recorded in the winter and spring using a remote video system, and (2)

mixed function oxidase enzyme activity [cytochrome P450-1A as ethoxyresorufin *O*-deethylase (EROD)] will be measured in masked greenling caught at each site and (3) fluorescent aromatic compounds (FACs) will be measured in selected masked greenling from each site. Based on recent results, this species now appears to be the most likely to demonstrate a link of vertebrate predators to oiled mussel beds.

Masked greenling still show evidence of exposure, as shown in Figure 1 where elevated EROD activity was measured in both oiled and un-oiled areas of Prince William Sound. This species may not be an ideal species, as it's range is not restricted to mussel beds, but probably has less range than higher profile species such as sea otters and sea ducks. Attempts will be made to link prey species in the diet of masked greenling with infauna prey species collected in the oiled mussel beds. Further, the hydrocarbon exposure measurements (EROD, and biliary FACs) will be repeated, but with the balanced 5-oiled and 5-unoiled to determine if there are differences between oiled areas and non-oiled areas.

Linking vertebrate predators to contemporary oil is a difficult task, which becomes more difficult with each passing year. Some oil persists, in a toxic form, but do vertebrate predators feed in these areas? If so, when? If so, how much? Is that exposure enough? Most of these questions will remain unanswered. This project will likely be the last attempt to link known oiled areas with prey and with vertebrate predator exposure. In some respects, it is a fishing trip of sorts, but the linkage issue is a nagging issue that deserves direct attention, rather than a secondary level of attention. The last effort of this project will by a synthesis of the linkage issue, which will combine the information from this study with the results from the comprehensive general survey for remaining oil in PWS, a separate project proposed for summer 2002.

## NEED FOR THE PROJECT

### A. Statement of Problem

Several nearshore vertebrate predators and some intertidal communities have failed to show clear signs of full recovery 10 years after the *Exxon Valdez* Oil Spill. The continued injury to several nearshore vertebrate predator species is likely due to continued exposure to *Exxon Valdez* oil. High concentrations *Exxon Valdez* oil persisted in several mussel beds within heavily oiled portions of Prince William Sound as of summer 1999. Several of the injured nearshore vertebrate species (e.g., sea otters and harlequin ducks) and other species for which there is evidence of continued exposure to oil (e.g., Barrow's goldeneyes and masked greenlings) feed on mussels and/or associated fauna (McConnaughey 1978; Blackburn *et al.* 1983; Rosenthal 1983; Jewett *et al.* In Review). In June 1999, the stomach contents of 23 adult masked greenling collected adjacent to oiled mussel beds were examined. Dominant prey, in decreasing frequency of occurrence, were crabs (*Pagurus, Telmessus, Cancer*), benthic amphipods, and shrimps (*Pandalus*) (Jewett, unpubl.). Some of these prey are also consumed by sea otters and harlequin ducks. Thus, oil in mussels, other associated prey species, or in associated sediments are likely sources of contamination of nearshore vertebrates. For some of these beds, oil is projected to

persist for several decades, and hence be a potential source and threat for predators to cope with. Links between oiled mussel beds and predators were never anticipated, and have not been studied directly. Persistence of oil in beds has been studied (last sampled in 1999), and vertebrate species recovery has been monitored, but the link between mussel beds and vertebrate predators is inferential rather than direct. Future decisions to clean some Prince William Sound mussel beds, or to clean beds after potential future spills need further study to support these decisions.

### B. Rationale/Link to Restoration

Continued injury of nearshore vertebrate predator species appears to be caused by exposure to oil, and persistent oil in mussel beds is a likely source of contamination. If the hypothesis that mussel beds serve as sources of oil for nearshore vertebrate predators, further cleanup of oiled beds may be warranted as a means of accelerating recovery of the nearshore ecosystem. Future cleanup of oiled mussel beds, or beds after potential future spills can only be justified if natural restoration is inadequate or too slow, and there is a linkage between these beds and other fauna, including predators.

### C. Location

The proposed study will be conducted in Prince William Sound.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The proposed study will extend Trustee-sponsored research conducted during the damage assessment and restoration phases of the *Exxon Valdez* Oil Spill. Past work has been presented at various public meetings sponsored by the council. Manuscripts produced will likely be the basis of future presentations at Trustee sponsored restoration workshops.

## PROJECT DESIGN

### A. Objectives

For each of 5 oiled and 5 reference mussel beds:

1. Determine hydrocarbon loads:
   a) Sediment and mussel tissue from mussel beds.
   b) Hydrocarbon concentrations in representative infauna prey.

2. Determine impacts on fauna:
   a) Infauna species diversity will be determined in the same 10 mussel beds.
   b) Macrofauna abundance and community structure

c) Determine growth/size structure of mussels between oiled and unoiled beds.

3. Evaluate potential links to vertebrate contamination:
   a) Measure hydrocarbon exposure in masked greenling by measuring cytochrome P450-1A (EROD) and biliary FACs from the same 10 mussel bed areas.

4. Re-evaluate the contribution potential of oiled mussel beds as links to nearshore vertebrate predators.

## B. Methods

Design Overview

A balanced design approach will be utilized; 5 oiled and 5 unoiled mussel beds will be examined. Concentrations of total polynuclear aromatic hydrocarbons (TPAH) (in both sediments and mussel tissue) will be determined and correlated with a series of impact measurements ranging from prey contamination, to infauna species diversity, to vertebrate exposure measurements. Infauna associated with mussel beds will be characterized in five oiled mussel beds and five unoiled reference sites within Prince William Sound. These sites will be chosen based on 1999 sediment and mussel hydrocarbon results from the mussel bed restoration project (Figure 2). Hydrocarbon analysis in sediment will typically be completed by ultraviolet fluorescence, and GC/.MS analysis of sediment will be restricted to verification of sources of hydrocarbons at each site. Oiled sites will be chosen from those where 1) sediments and mussel tissue have previously been sampled, 2) sediment TPAH concentrations were above 30 $\mu g\ g^{-1}$ in 1999 (Harris, unpublished data), 3) contamination levels are projected to persist for long (decadal) periods, and 4) vertebrate predator utilization is expected, particularly masked greenling. Reference sites will include one that was sampled in 1999 (Barnes Cove) and 4 additional sites to be selected based on a preliminary survey. Reference sites will be located along unoiled shorelines within the Knight Island/Naked Island region. Sites will be selected that match the oiled mussel beds with respect to physical characteristics other than oil, including slope, exposure, aspect, and substrate type.

The mussel beds at each site will be mapped as described by Babcock *et al.* (1998). In general, selected beds will be about 5 x 5 m (25 $m^2$) or more in size. Previous sampling at several representative beds indicated that hydrocarbon concentration in sediment can vary up to two orders of magnitude within a few meters, with some correlation with elevation ($r^2 = 0.65$) (Babcock *et al.* 1998). Accordingly, sample collection will be stratified by elevation, but randomized within elevation.

1. Hydrocarbon loads in sediment, mussel tissue, and crabs

   (1a) Sampling of hydrocarbons will be designed to inspect both intra- and inter-bed variation, and allow correlation of sediment, mussels and infauna at specific spots within each bed. Previous research demonstrated some correlation between elevation and oil

concentration in sediment ($r^2 = 0.65$, Babcock *et al.* 1998), thus sampling will be stratified by elevation. Transects will be placed at two vertical elevations spaced in parallel 2 m apart, and 3 spots selected at random along each transect will be sampled from each transect. The samples will be collected and analyzed as described in Babcock *et al.* (1998). A 0.25 x 0.25 m quadrate will be centered on each collection spot. At least 10 g of mussels will be frozen for hydrocarbon analysis. All predatory snails (primarily *Nucella lammelosa* and *Nucella lima*) will be counted within the quadrates. Sediment under the mussel layer will be collected for hydrocarbon analysis, grain size and total organic carbon content.

(1b) Representative samples of amphipods and crabs (primarily *Telmessus cheiragonus*) will be collected from each site for determination of TPAH concentrations within their tissues. The animals will be collected by hand or from sediments shoveled from each site and sieved. All animals will be collected from an area between the mussel bed and MLLW. A sufficient number of animals will be collected to obtain a 10 g sample of each species.

2. Oil impacts on fauna.

(2a) Benthic invertebrates will be collected from a 10-cm diameter by 10-cm deep core sample at each randomly chosen spot described above. The cores will be preserved in formalin and returned to the laboratory for sorting and analysis. Samples will be sieved through a 1-mm mesh, and the animals identified and counted. Organisms will be identified to at least the family level, and analyzed to species for more commonly encountered species.

(2b) Larger invertebrate predator species will be counted at each site. A 50-m long stretch of shoreline will be delineated at each site with the mussel bed in the center. Counts will be made during a falling tide to minimize the chance of not counting animals that retreat to the subtidal zone during periods of low tides. The area censused will be measured at each site so that the number of animals per unit area (density) can be determined.

(2c) Mussels (0-5 mm grouped for recruitment and >5 mm) from the hydrocarbon sampling quadrates (see 1a. methods) will be counted to estimate mussel density and measured to estimate size distributions in each bed at each site.

3. Evaluate potential links to vertebrate contamination

(3a) Masked greenling will be captured by hook and line, baited pots, or seine net at high tide in the vicinity of each selected mussel bed (8 per site) and analyzed for 1) tissue hydrocarbons [by gas chromatograph/mass spectroscopy GC/MS], 2) cytochrome P450-1A (EROD) activity in liver, 3) hydrocarbon metabolites in bile (FACs). Livers and bile will be collected and frozen for analyses. Stomachs will be removed and preserved for prey analysis. Remaining tissues will be frozen for potential GC/MS analysis. These measures of hydrocarbon concentration or exposure will be compared to mean hydrocarbon concentrations in sediment, mussels, and infauna by site to determine possible correlations.

Data analysis

We will test the null hypothesis of no significant difference between oiled and reference sites using analysis of variance (ANOVA). Metrics to be tested in this manner will include: 1) hydrocarbon concentrations in sediments, 2) TPAH concentrations in mussels, masked greenling, amphipods, and other selected fauna, 3) the density of dominant taxa within core samples, 4) the density of dominant sea stars and other invertebrate predators, and 5) EROD activity in livers and FACs in bile from masked greenling. The analysis of dominant benthic invertebrates may use sediment grain size as a covariate if appropriate.

We will also examine possible correlations between all measured variables. For correlations of mussel TPAH, sediment hydrocarbon concentrations, and density of dominant benthic invertebrates within cores we will conduct separate analyses using both cores and sites as sampling units. Correlation between FAC and EROD assays will be done using individual fish as the sampling unit. For all other metrics, site means will be used as sampling units.

A time series of mussel and sediment hydrocarbon concentrations will be plotted for each site for which there are historical data (all five oiled sites and one reference site). In addition, concentrations averaged across beds will be determined to describe regional trends and the average 'half-life' of oil in these mussel beds.

Personnel and project management

The project will be conducted by a team of scientists who have been directly involved in the studies of the nearshore system in Prince William Sound since 1989. The work will be coordinated by Dr. Stanley Rice of the NOAA Auke Bay Laboratory. Dr. Thomas Dean, President of CRA will serve as project leader for fish and invertebrate studies. Pat Harris and Mandy Lindeberg will direct studies of contamination in mussels and sediments. Dr. Stephen Jewett will direct the laboratory workup of benthic invertebrates in core samples and the processing of fish tissues. Jeff Short will oversee hydrocarbon analyses, Mark Carls will assist with sampling design, analyses and writing. Cytochrome P450-1A expression (EROD) in fish tissues will be conducted at Woods Hole Oceanographic Institution. Analysis of biliary FACs will be conducted through NOAA.

Responsibilities for each of the contractors is as follows:

NOAA Auke Bay Laboratory (PI J. Rice, P.Harris, M. Lindeberg)
- Manage and Direct the Project
- Assist in manuscript preparation
- Provide for all logistical support for field sampling efforts
- Conduct all hydrocarbon and biliary FACs analyses

Coastal Resources Associates, Inc. (PI Dean)
- Manage field sampling
- Assist in sampling and data analysis

Assist in manuscript preparation

University of Alaska, Fairbanks (PI Jewett)
Assist in sampling
Do laboratory analysis of benthic samples
Prepare, catalogue, ship, and enter fish tissue data
Assist in manuscript preparation

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

This proposal is being submitted by NOAA. However, a portion of the funding will probably be directed to under BAA by Coastal Resources Associates, Inc. and to the University of Alaska.

## SCHEDULE

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

| | |
|---|---|
| January 2002: | Annual Workshop, finalize sampling design |
| July 2002: | Complete sample collection |
| October 2002: | Progress report |
| March 2003: | Complete chemical, infauna, and masked greenling analyses |
| June 2003: | Complete statistics |
| August 2003: | Complete report |

### B. Project Milestones and Endpoints

All field work will be completed by July 2002, and all field data will be entered and databases established by September 30, 2002. Laboratory analysis of benthic infauna, hydrocarbon and CYP1A data will be completed by March 1, 2003. A draft final report will be submitted by July 1, 2003. Results of this study will be presented at the annual EVOS workshop in Jan 2004 and that manuscripts will be finalized in FY2004.

### C. Completion Date

Except for peer-reviewed publication and presentation at the annual EVOS workshop, the project will be complete by September 2003.

## PUBLICATIONS AND REPORTS

A progress report will be submitted to the Trustee Council in October 2002 summarizing field sampling efforts of the previous summer.

Three manuscripts will be prepared and will serve as the final report for the project. Anticipated titles, authorship, and journals for submission are as follows:

Oiled mussel beds: a source of continued contamination of nearshore vertebrates 13 years after the *Exxon Valdez* Oil Spill. S Rice, T Dean, S Jewett, M Carls, P Harris, M Lindeberg, (anticipated submission to Marine Ecology Progress Series or Marine Pollution Bulletin).

Altered communities in oiled mussel beds 13 years after the *Exxon Valdez* oil spill. T Dean, S Jewett, P Harris and M Lindeberg (anticipated submission to Marine Ecology Progress Series or Marine Pollution Bulletin).

Linking oiled mussel beds as a persistent source of contamination to predators and their prey 13 years after the *Exxon Valdez* oil spill - S Rice, T Dean, S Jewett, M Carls, P Harris, M Lindeberg, J Stegeman. (anticipated submission to Marine Ecology Progress Series or Marine Pollution Bulletin as a synthesis).

## PROFESSIONAL CONFERENCES

No funding is being requested for attendance at professional conferences in FY02.

## NORMAL AGENCY MANAGEMENT

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

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

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The scientists involved in the preparation of manuscripts have worked collaboratively in previous Trustee funded investigations of injury and recovery in coastal habitats.

## EXPLANATION OF CHANGES IN CONTINUING PROJECTS

None

## PROPOSED PRINCIPAL INVESTIGATORS

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## BIOGRAPHICAL SKETCHES FOR PRINCIPAL INVESTIGATORS

**Dr. Stanley Rice,** GM-14 physiologist, has been Habitat Program Manager of NOAA/NMFS/Auke Bay Laboratory since 1986. Dr. Rice has conducted and managed *Exxon Valdez* damage assessment and restoration sudies since 1989 including cooperative projects with other agencies, and providing critical reviews and input in agency decisions. He has over 20 years experience researching oil effects encompassing a wide variety of organisms and conditions.

**Dr. Thomas A. Dean** is President of the ecological consulting firm Coastal Resources Associates, Inc. (CRA) in Vista, CA. Dr. Dean has over 20 years of experience in the study of nearshore ecosystems, and has authored over 30 publications, including several dealing with impacts of the *Exxon Valdez* oil spill on nearshore plants and animals. He has extensive experience in long-term monitoring studies, and has played a major role in both intertidal and subtidal EVOS investigations since 1989.

**Dr. Stephen C. Jewett** has been a researcher at the School of Fisheries and Ocean Science, University of Alaska Fairbanks, since 1975. He currently serves as Research Professor. During this time he has been involved in numerous benthic and intertidal investigations throughout Alaska that emphasize assessment and/or monitoring. He has authored more than 30 publications in scientific journals and books. He has been the coordinator of the federal/state EVOS shallow subtidal investigations in Prince William Sound (1989-1999). He most recently conducted an EVOS investigation on the lingering effects of the spill to nearshore fishes (Project 00379; Jewett *et al.* In Review).

**Patricia M. Harris** has been involved in *Exxon Valdez* oil spill research since March 1989; as a co-principal investigator for NRDA project Subtidal 3, Mussel bed monitoring and restoration,

and Pristane monitoring in mussels, she has been responsible for study design, field logistics, sample collection and assisted in data analysis and proposal and report preparation.

**Mandy R. Lindeberg** has been involved in *Exxon Valdez* oil spill research for the last 10 years. Her research includes intensive studies on intertidal invertebrates and seaweeds, mussel populations, and currently she is a co-principal investigator of spot shrimp populations in Prince William Sound. Her responsibilities include quality control of field and laboratory sample processing, data analysis, graphics, and proposal and report preparation.

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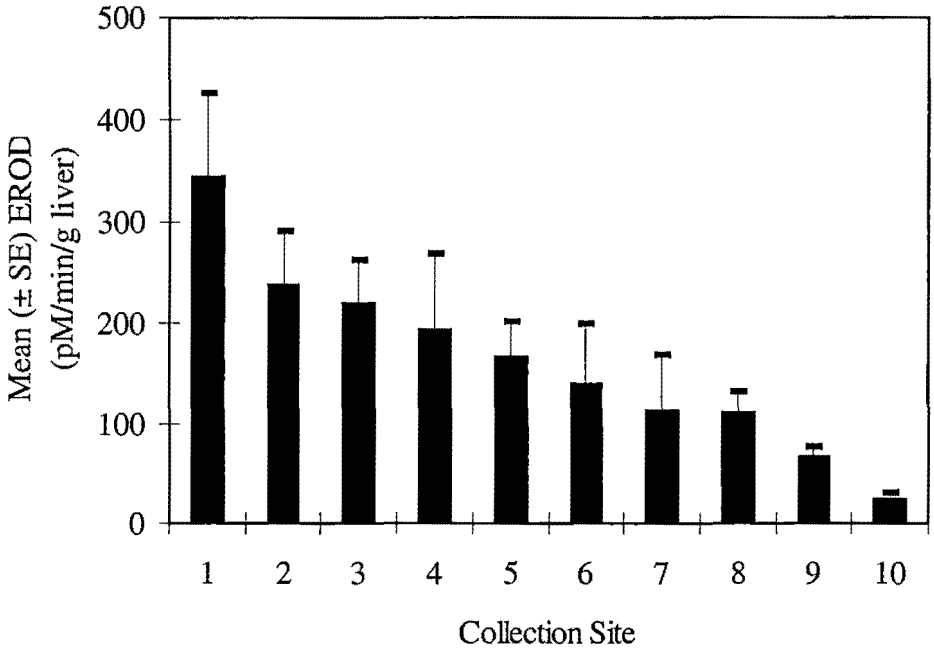


Figure1. Inter-site differences in mean EROD values in masked greenling, Prince William Sound 1999. P-values are presented and values significantly different are in bold.

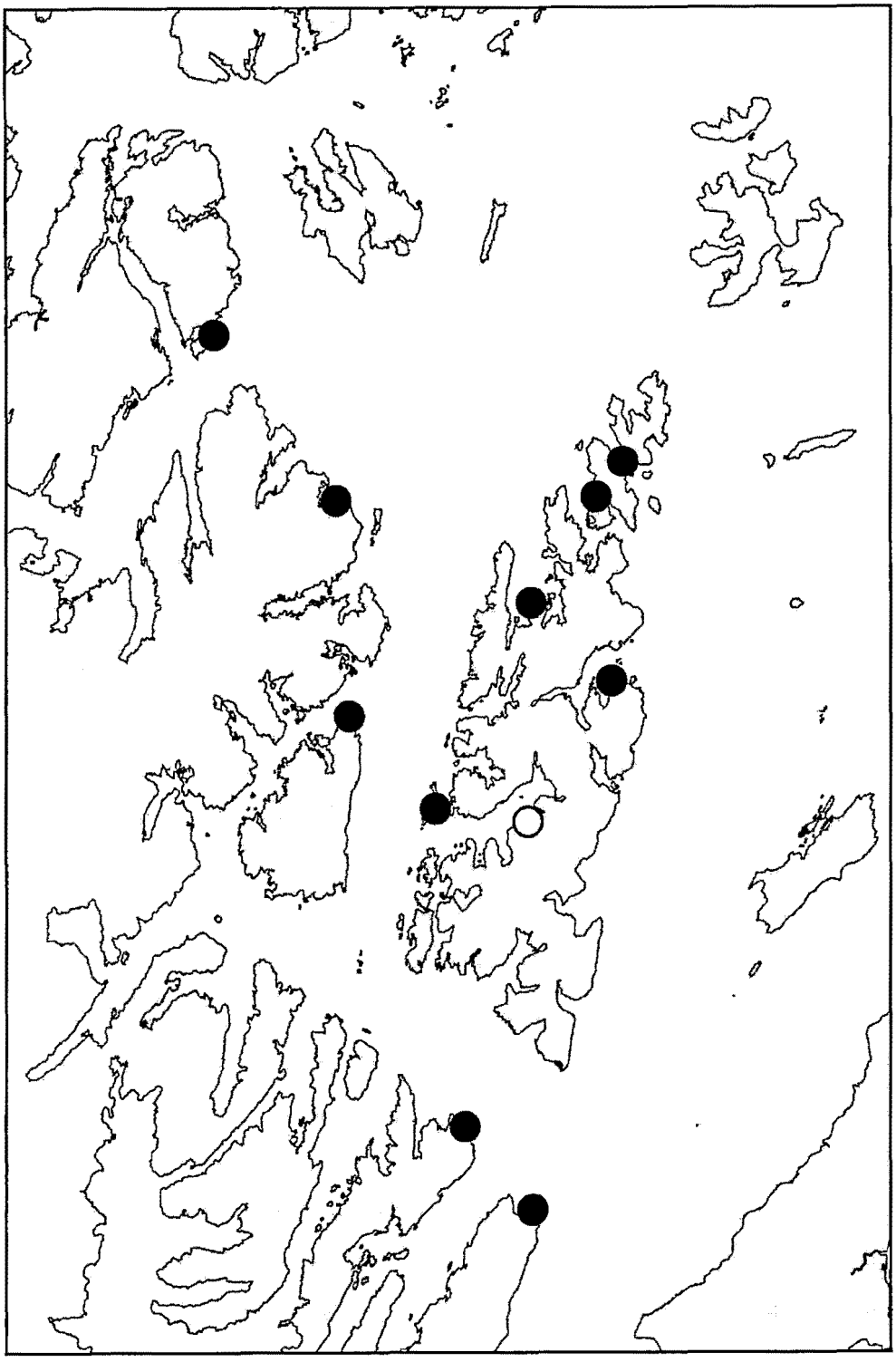

Figure 2. Oiled mussel beds in PWS to be used as candidates for sampling.

**BUDGET SUMMARIES** By task and affiliation (without GA)

| Task | NOAA | | CRA | | UAF | |
|---|---|---|---|---|---|---|
| | FY02 | FY03 | FY02 | FY03 | FY02 | FY03 |
| 1a | $29.0 | $28.7 | $1.0 | - | - | - |
| 1b | - | $15.6 | $4.0 | - | - | - |
| | | | | | | |
| 2a | - | - | - | - | $16.4 | - |
| 2b | - | - | $5.3 | $3.7 | - | - |
| 2c | $6.0 | $5.1 | - | - | - | - |
| | | | | | | |
| 3a | - | $4.7 | - | - | $25.8 | $9.8 |
| | | | | | | |
| 4 | $6.4 | $16.3 | $13.8 | $17.8 | $0.6 | $10.4 |
| Vessel | $22.5 | | | | | |
| Total | $63.9 | $70.4 | $24.1 | $21.5 | $42.8 | $20.2 |

**2001 EXXON VALDEZ TRUS COUNCIL PROJECT BUDGET**

October 1, 200- -eptember 30, 2001

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 |
|---|---|---|
| Personnel | | $29.5 |
| Travel | | $6.0 |
| Contractual | | $120.4 |
| Commodities | | $2.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $157.9 |
| General Administration | | $12.9 |
| Project Total | $0.0 | $170.8 |
| Full-time Equivalents (FTE) | | 0.3 |
| Other Resources | | |

| LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|
| | | | Estimated FY 2003 | | |
| | | | $130.0 | | |

Dollar amounts are shown in thousands of dollars.

Comments:

Affiliation Costs (w/oGA):
- NOAA: $63.9
- CRA: $40.4
- UAF: $53.5

NOAA Contributions:
J. Rice (0.5 mos =$6.1); J. Short (0.5mos =$5.0); M. Carls (0.5mos =$4.1)

Other:

**FY02**

Prepared: 4/13/01

Project Number: 02~~XXX~~486
Project Title: **Links between Persistent Oil in Mussel Beds and Predators**
Agency: NOAA

FORM 3A
TRUSTEE
AGENCY
SUMMARY

**2001 EXXON VALDEZ TRU** **COUNCIL PROJECT BUDGET**

October 1, 200- September 30, 2001

| **Personnel Costs:** | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FY 2001 |
| | | | | | | 0.0 |
| Jeep Rice | Toxicologist | GS-14 | 0.5 | 13.1 | | 6.6 |
| Mark Carls | Fisheries Research Biologist | GS-12 | 0.5 | 8.6 | | 4.3 |
| Pat Harris | Zoologist | GS-11 | 1.0 | 6.6 | | 6.6 |
| Mandy Lindeberg | Fisheries Research Biologist | GS -11 | 2.0 | 6.0 | | 12.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 4.0 | 34.3 | 0.0 | |
| | | | | | **Personnel Total** | $29.5 |

| **Travel Costs:** | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 2001 |
| | | | | | 0.0 |
| RT Juneau/ Cordova | 0.4 | 3 | 6 | 0.2 | 2.4 |
| RT Anchorage to PWS | 0.8 | 2 | 4 | 0.2 | 2.4 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| RT Juneau/ Anchorage Trustee Workshop | 0.4 | 2 | 2 | 0.2 | 1.2 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $6.0 |

**FY02**

Prepared: 4/13/01

Project Number: 02xxx
Project Title: Links between Persistent Oil in Mussel Beds and Predators
Agency: NOAA

FORM 3B
Personnel
& Travel
DETAIL

**2001 EXXON VALDEZ TRUS COUNCIL PROJECT BUDGET**

October 1, 200- -eptember 30, 2001

| **Contractual Costs:** | | | Proposed |
|---|---|---|---|
| Description | | | FY 2001 |
| 4A Linkage CRA | | | 40.4 |
| 4A Linkage UAF | | | 53.5 |
| Vessel Charter: | $1500/day | 15 days | 22.5 |
| Temporary Labor (NOAA) | | | 4.0 |
| When a non-trustee organization is used, the form 4A is required. | | **Contractual Total** | $120.4 |

| **Commodities Costs:** | Proposed |
|---|---|
| Description | FY 2001 |
| Chem Lab supplies for analyses (solvents, glassware, gasses) | 2.0 |
| **Commodities Total** | $2.0 |

**FY02**

Prepared: 4/13/01

Project Number: 02xxx
Project Title: Links between Persistent Oil in Mussel Beds and Predators
Agency: NOAA

FORM 3B
Contractual & Commodities DETAIL

**2001 EXXON VALDEZ TRUS COUNCIL PROJECT BUDGET**

October 1, 200_ _eptember 30, 2001

| **New Equipment Purchases:** Description | Number of Units | Unit Price | Proposed FY 2001 |
|---|---|---|---|
| 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 | Inventory Agency |
|---|---|---|
| computer, printer | 4 | NOAA |
| GC/MS | 1 | NOAA |
| HPLC | 1 | NOAA |
| GPS | 1 | NOAA |
| UVF radio | 1 | NOAA |
| camera | 1 | NOAA |
| freezer | 1 | NOAA |
| skiff/outboard | 1 | NOAA |

**FY02**

Prepared: 4/13/01

Project Number: 02xxx
Project Title: Links between Persistent Oil in Mussel Beds and Predators
Agency: NOAA

FORM 3B
Equipment
DETAIL

**2001 EXXON VALDEZ TRUS COUNCIL PROJECT BUDGET**

October 1, 200- -eptember 30, 2001

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| Personnel | | $19.7 | | | | | | |
| Travel | | $3.8 | | | | | | |
| Contractual | | $0.0 | | | | | | |
| Commodities | | $0.6 | | | | | | |
| Equipment | | $0.0 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
| Subtotal | $0.0 | $24.1 | | | | Estimated FY 2003 | | |
| Indirect | | $16.3 | | | | | | |
| Project Total | $0.0 | $40.4 | | | | $38.7 | | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 0.3 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

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)

**FY02**

Prepared: 4/13/01

Project Number: 02xxx
Project Title: Links between Persistent Oil in Mussel Beds and Predators
Name: Coastal Resources Associates, Inc., submitted under BAA

FORM 4A
Non-Trustee
SUMMARY

**2001 EXXON VALDEZ TRUS COUNCIL PROJECT BUDGET**

October 1, 200. eptember 30, 2001

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| | Name | Position Description | Budgeted | Costs | Overtime | FY 2001 |
| | T.A. Dean | Senior Scientist, P.I. | 2.0 | 8.0 | 0.0 | 16.0 |
| | D. Jung | Field Operations Manager | 1.0 | 3.7 | 0.0 | 3.7 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | Subtotal | 3.0 | 11.7 | 0.0 | |
| | | | | | **Personnel Total** | $19.7 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| | Description | Price | Trips | Days | Per Diem | FY 2001 |
| | | | | | | 0.0 |
| | RT San Diego-Anchorage Trustee Workshop | 1.0 | 1 | 2 | 0.15 | 1.3 |
| | | | | | | 0.0 |
| | RT San Diego-PWS field work | 1.1 | 2 | 2 | 0.15 | 2.5 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | **Travel Total** | $3.8 |

**FY02**

Prepared: 4/13/01

Project Number: 02xxx
Project Title: Links between Persistent Oil in Mussel Beds and Predators
Name: Coastal Resources Associates, Inc., submitted under BAA

FORM 4B
Personnel
& Travel
DETAIL

**2001 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET**
October 1, 2000 - September 30, 2001

| **Contractual Costs:** | Proposed FY 2001 |
|---|---|
| Description | |
| | |
| **Contractual Total** | $0.0 |

| **Commodities Costs:** | Proposed FY 2001 |
|---|---|
| Description | |
| Misc. field supplies | 0.4 |
| Shipping costs | 0.2 |
| **Commodities Total** | $0.6 |

**FY02**

Prepared: 4/13/01

Project Number: 02xxx
Project Title: Links between Persistent Oil in Mussel Beds and Predators
Name: Coastal Resources Associates, Inc., submitted under BAA

FORM 4B
Contractual & Commodities DETAIL

**2001 EXXON VALDEZ TRU: COUNCIL PROJECT BUDGET**

October 1, 200. eptember 30, 2001

| **New Equipment Purchases:** | Number | Unit | Proposed |
|---|---|---|---|
| Description | of Units | Price | FY 2001 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

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

**FY02**

Prepared: 4/13/01

Project Number: 02xxx
Project Title: Links between Persistent Oil in Mussel Beds and Predators
Name: Coastal Resources Associates, Inc., submitted under BAA

FORM 4B
Equipment
DETAIL

**2001 EXXON VALDEZ TRUS COUNCIL PROJECT BUDGET**

October 1, 200- -eptember 30, 2001

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 |
|---|---|---|
| | | |
| Personnel | | $29.8 |
| Travel | | $1.8 |
| Contractual | | $10.4 |
| Commodities | | $0.8 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $42.8 |
| Indirect | | $10.70 |
| Project Total | $0.0 | $53.5 |
| | | |
| Full-time Equivalents (FTE) | | 0.3 |
| | Dollar amounts are shown in thousands of dollars. | |
| Other Resources | | |

| LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|
| | | | Estimated FY 2003 | | |
| | | | $25.3 | | |
| | | | | | |
| | | | | | |

Comments:

Indirect costs calculated as follows: Total Cost + GA
(GA = 25%)

**FY02**

Prepared: 4/13/01

Project Number: 02xxx
Project Title: Links between Persistent Oil in Mussel Beds and Predators
Name: UAFsubmitted under BAA

FORM 4A
Non-Trustee
SUMMARY

**2001 EXXON VALDEZ TRU[illegible] COUNCIL PROJECT BUDGET**

October 1, 200[illegible] September 30, 2001

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| | Name | Position Description | Budgeted | Costs | Overtime | FY 2001 |
| | S. Jewett | Research Associate/Professor | 2.0 | 9.8 | 0.0 | 19.6 |
| | M. Hoberg | Technician | 2.0 | 5.1 | 0.0 | 10.2 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | Subtotal | 4.0 | 14.9 | 0.0 | |
| | | | | | **Personnel Total** | $29.8 |

| Travel Costs: | | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|---|
| | Description | Price | Trips | Days | Per Diem | FY 2001 |
| | | | | | | 0.0 |
| | RT Fairbanks- PWS | 0.5 | 2 | 2 | 0.12 | 1.2 |
| | | | | | | 0.0 |
| | RT Fairbanks-Anchorage Workshop | 0.4 | 1 | 2 | 0.12 | 0.6 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | **Travel Total** | $1.8 |

**FY02**

Prepared: 4/13/01

Project Number: 02xxx
Project Title: Links between Persistent Oil in Mussel Beds and Predators
Name: UAF submitted under BAA

FORM 4B
Personnel
& Travel
DETAIL

**2001 EXXON VALDEZ TRUS COUNCIL PROJECT BUDGET**

October 1, 200- - September 30, 2001

| **Contractual Costs:** | Proposed FY 2001 |
|---|---|
| Description | |
| P450 , EROD analysis (80 samples @ $130ea) | 10.4 |
| **Contractual Total** | $10.4 |

| **Commodities Costs:** | Proposed FY 2001 |
|---|---|
| Description | |
| Misc. field supplies | 0.5 |
| Shipping costs | 0.3 |
| **Commodities Total** | $0.8 |

**FY02**

Prepared: 4/13/01

Project Number: 02xxx
Project Title: Links between Persistent Oil in Mussel Beds and Predators
Name: UAF submitted under BAA

FORM 4B
Contractual & Commodities DETAIL

**2001 EXXON VALDEZ TRUS COUNCIL PROJECT BUDGET**

October 1, 200- -eptember 30, 2001

| **New Equipment Purchases:** Description | Number of Units | Unit Price | Proposed FY 2001 |
|---|---|---|---|
| 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 | |
|---|---|---|
| | | |

**FY02**

Prepared: 4/13/01

Project Number: 02xxx
Project Title: Links between Persistent Oil in Mussel Beds and Predators
Name: UAF submitted under BAA

FORM 4B
Equipment
DETAIL

## Project Title: Were pink salmon embryo studies in PWS biased?



| | |
|---|---|
| Project Number: | 02492 |
| Restoration Category: | Research |
| Proposer: | John Thedinga, Mark Carls, Ron Heintz,<br>NMFS, Auke Bay Laboratory<br>ABL Program Manager: Dr. Stanley Rice |
| Lead Trustee Agency: | NOAA |
| Alaska Sea Life Center: | No |
| Cooperating Agencies: | |
| Duration: | 1 year (close out) |
| Cost FY02: | $24.0 |
| Geographic Area: | Auke Bay Laboratory |
| Injured Resource/Service: | Pink salmon |

### ABSTRACT

Effects of the *Exxon Valdez* oil spill on wild pink salmon embryo survival in Prince William Sound are disputed among government- and industry-sponsored researchers. Exxon contends the government's conclusions that reduced embryo viability in oiled streams was caused by persistent oil contamination were biased because sampling times were earlier in oiled streams than in reference streams. We conducted experimental studies to determine the ability to discriminate eggs killed by sampling (shock mortality) and previously dead eggs in order to help ascertain if estimates of pink salmon embryo survival in Prince William Sound were accurate or biased. Preliminary results of our studies indicate that shock resistance of eggs increased in a sigmoidal fashion from the end of September to mid November and that the timing of egg examination after being pumped from a stream is critical in differentiating shocked eggs from previously dead eggs. By removing eggs pumped from stream gravel soon after sampling, shocked eggs were easily discernable and could easily be separated from previously dead eggs. This method can alleviate discrimination of egg condition problems posed by differing egg maturity within and between streams and over time. These results suggest that further examination of procedures used for egg sampling in PWS following the oil spill would not help clarify the controversy over potential biased estimates of egg survival.

## INTRODUCTION

The Trustee Council view of damage to pink salmon in Prince William Sound (PWS) is different than that of Exxon (Rice et al. 1999; Brannon and Maki 1996; Brannon et al. 1999). One controversial issue has been embryo mortality in oiled vs. non-oiled streams. Bue (1998) found that oiled streams had significantly higher pink salmon embryo mortality than non-oiled streams and Heintz et al. (1999a) confirmed that incubation in oiled substrate can cause damage to embryos. Brannon (1996), however claimed that increased mortality in oiled streams was an artifact of sample design due to shocking and bias from sampling timing. Collins et al. (2000) showed that hydraulic sampling of embryos can cause mortality that can bias mortality estimates upward if not accounted for.

After 11 years, the questions remain- -was there bias in the sampling because of run timing differences between oiled and non-oiled streams? Were egg counters able to separate new mortalities caused by shocking during the sampling, and did they account for the sampling mortalities? Is it possible to account for the mortalities? These questions are basic to the assessment of damage to pink salmon from the spill, and to restoration strategies that should result. This project examined this continuing controversy with an experimental study.

The experimental study focused on the ability to separate live eggs and dead eggs from newly shocked eggs. This was be done first in a controlled laboratory situation (hatchery) with a series on known life stages. A field test was also conducted to test the relationship between run timing and susceptibility of eggs to pumping damage. For the field test, we used the spawning channel at Lovers Cove Creek near Little Port Walter (LPW). A proportion of the eggs in these experiments were repeatedly viewed by several observers to test discrimination of recent and past mortality as a function of time.

In order to determine what level of misinterpretation of egg condition (live or dead) would bias the results of the embryo mortality study, we modeled the 1989-1993 PWS embryo data. Based on Bue's (1996) data, we modeled the number of eggs counted in the oiled and control streams in PWS to account for the misidentification of eggs shocked and killed by the egg pumping procedure. We used a GLM two factor model based on the height above intertidal where the eggs were collected and compared the oiled vs. non-oiled streams. The difference in egg mortality between the oiled and non-oiled streams became non significant ($P = 0.05$) when 9.5% of eggs in all of the oiled streams were incorrectly counted as dead, but were actually killed by egg pumping and should have been counted as live. Whereas in the non-oiled streams, 11.3% of dead eggs would have to be incorrectly counted as live before mortality between oiled and non-oiled streams was no longer significantly different.

Spawning for pink salmon began in August and September; Auke Bay Laboratory provided in kind funds to facilitate initiation of this project in late FY02 so that it could be fully functional for FY01.

Our FY01 proposal called for conducting experimental studies for identifying shocked eggs and the effect of time on egg shock resistance. These studies were successfully carried out in fall 2000. For FY02, we originally suggested conducting an analysis of the 1990-1991 preserved eggs from PWS and evaluating ADFG's egg sampling procedures to help determine if the egg mortality studies done following the oil spill were biased. A preliminary analysis of the preserved eggs showed that the developmental stage of the eggs could not be determined because of deterioration of the eggs. Preliminary results of our experimental studies showed that the timing of egg examination after being pumped from a stream is critical in differentiating shocked eggs from previously dead eggs, and that the amount of experience a person has in classifying eggs significantly affects the accuracy of separating live, dead, and shocked eggs. Results from an ADFG study indicate that when egg mortality data from 1991 was controlled for run timing and sensitivity to mechanical shock, oiled streams still had higher egg mortality than non-oiled streams (Craig et al. 1999). Based on these preliminary results we feel that further investigation is unnecessary and would not help clarify the controversy over potential bias in the egg mortality studies. Therefore, we feel that only a final report that synthesizes the two experimental studies and relates our findings to the egg mortality studies in PWS following the oil spill is necessary in FY02.

## NEED FOR PROJECT

### A. Statement of problem

There is an ongoing dispute between government and industry researchers concerning the impact of the Exxon Valdez oil spill on pink salmon in PWS. Government researchers concluded that pink salmon embryo survival was lower in oiled streams than in non-oiled streams from 1989-1993. Industry researchers allege that government sampling in oiled streams was earlier than in reference streams relative to run timing, thus biasing estimates of egg survival, because early egg stages are more susceptible to mechanical damage caused by hydraulic pump sampling than later stages. Industry researchers further contend that government observers failed to discriminate between previously dead eggs and those killed by sampling, thereby compounding the problem. The controversy continues after 11 years; this study was conducted in to attempt to clarify the controversy if possible. The controversy continues to cloud estimates of damage, restoration strategies, the impact of long term damage, and the definition of full recovery for this species.

### B. Rationale/Link to Restoration

Pink salmon are listed as a recovering species, but before they can be added to the list of recovered species we need to know if persistent oil caused increased mortality of pink salmon embryos in PWS streams. Controversy over how sampling techniques and run timing affected the results of past embryo mortality studies needs to be resolved in order to determine the extent of possible damage from EVOS. Recent studies have shown that oil still exists near natal habitats and that pink salmon embryos are significantly more sensitive to oil exposure than

previously believed (Heintz, et al. 1999a, b). If embryos are continuing to be exposed to oil in streams then the extent of damage needs to be understood. Understanding the damage that oil can cause to pink salmon embryos is also important in realizing potential risks associated with future oil spills.

### C. Location

The field portion of the project took place at Lovers Cove Creek near the Little Port Walter field station (LPW) in Southeast Alaska and at Auke Creek Hatchery in Juneau. Lovers Cove Creek provided a uniform spawning channel and an intertidal spawning population of pink salmon that allowed repeated sampling. This location was appropriate because the streams physical characteristics are conducive to this type of project and it close to LPW which provides the necessary logistical and infrastructure support.

## COMMUNITY INVOLVEMENT AND TRADITIONAL 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.

## PROJECT DESIGN

### A. Objectives

The objective is to finish two manuscripts based on the two experimental studies conducted in FY01 and to complete a final report that synthesizes both experiments and relates those results with the egg mortality studies in PWS following the oil spill. Further investigation is unwarranted based on our experimental results and the inability to determine the developmental stage of preserved eggs that were sampled by ADFG in 1990-1991 from oiled and non-oiled streams.

### B. Methods

Complete two manuscripts and a final report

### C. Cooperating agencies, contracts and other agency assistance

NMFS pumped eggs in the field and tested egg shock mortality recognition in the hatchery. In order to sample eggs from the year 2000 pink salmon run, this project started in FY02. NMFS facilitated the start of the experimental portion of this project by making preparations in summer

2000 for sampling in September 2000.

## SCHEDULE

### A. Measurable tasks for FY02 (October 1, 2001 - September 30, 2003)

Complete final report

### B. Project Milestones and Endpoints

Winter 2002: Initiate preparation of final synthesis report

Spring 2002: Complete final synthesis report

### C. Completion Date

Two manuscripts on egg shocking will be submitted in 2002.

A final report will be submitted April 15, 2002.

## PUBLICATIONS AND REPORTS

Final report

peer-reviewed manuscripts: Thedinga, J. T. et al. Detection of pink salmon eggs killed by hydraulic sampling. Journal unknown.

Carls, M. G. et al. Ability of observers to discriminate shock mortality in pink salmon eggs as a function of time after shock. Journal unknown.

## PROFESSIONAL CONFERENCES

Travel to 2002 oil spill symposium is included.

## NORMAL AGENCY MANAGEMENT

This project seeks to address the hypothesis that the effects of oil in streams on pink salmon embryo mortality was confounded by time of sampling through a cooperative relation ship

between NMFS and the Trustees. NMFS would not be conducting this project if the oil spill had not occurred. NMFS proposes to make a significant contribution to the operation of this project, making it a cooperative venture with the Trustee Council.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The design of this project has been coordinated with work performed in the past by ADFG. NMFS will coordinate with the Trustees by providing labor requirements and laboratory overhead.

## PROPOSED PRINCIPAL INVESTIGATOR


| | |
|---|---|
| Name | John Thedinga |
| Affiliation | NMFS |
| Address | Auke Bay Laboratory |
| | 11305 Glacier Hwy |
| | Juneau, AK 99801 |
| Phone | 907-789-6025 |
| Fax | 907-789-6094 |
| E-mail | john.thedinga@noaa.gov |


## PRINCIPAL INVESTIGATOR

GS-12 Fisheries Research Biologist - John F. Thedinga. BS Fisheries and Wildlife Management, University of North Dakota (1975); MS Fisheries Science, University of Alaska (1986). He has been employed by the National Marine Fisheries Service, Auke Bay Laboratory since 1978 specializing in research on the effects of logging on salmon and freshwater habitat. He has been principle investigator and co-investigator on several projects. Recently he was co-investigator of Trustee project 98076 and principal investigator of Trustee project 00163A. He has published over 20 scientific papers.

## CO INVESTIGATORS

GS-12 Fisheries Research Biologist - Mark G. Carls 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.

GS-12 Fisheries Research Biologist - Ron A. Heintz Education: BS Ecology, University of Illinois (1979); MS Fisheries Science, University of Alaska (1986). Ron has been involved in examining the effects of Exxon Valdez oil on pink salmon since 1992. He has published 4 peer-reviewed papers and has another in press on this topic. To date his work has identified the sensitivity of pink salmon embryos to low concentrations of oil, demonstrated the existence of delayed effect on marine survival and the persistence of oil in stream deltas in Prince William Sound. He is currently working on two other EVOS projects related to this same topic.

## OTHER KEY PERSONNEL

GS-9 Fisheries Research Biologist - Jacek M. Maselko will assist in analyzing data.

## LITERATURE CITED

Brannon, E. L. and A. W. Maki. 1996. The Exxon Valdez oil spill: Analysis of impacts on the Prince William Sound pink salmon. Reviews in Fisheries Science 4(4): 289-337.

Brannon, E. L., L. Moulton, K. Parker, M. Cronin, and K. Collins. 1999. Resolution of oil spill affects on incubation pink salmon Prince William Sound. Center for salmonid and freshwater species at risk, University of Idaho, Moscow, ID. Research Bulletin 99-1.

Bue, B. G., Sharr, S. D. Moffitt, and A. Craig. 1996. Injury to salmon eggs and preemergent fry due to the T/V Exxon Valdez oil spill. In S D. Rice, R. B. Spies, D. A. Wolfe, and B. A. Wright (eds.). Exxon Valdez Oil Spill Symposium Proceedings. American Fisheries Society Symposium Number 18.

Bue, B. G., S. Sharr, and J. E. Seeb. 1998. Evidence of damage to pink salmon populations inhabiting Prince William Sound, Alaska, two generations after the Exxon Valdez oil spill. Trans. Am. Fish. Soc. 127:35-43.

Craig, A. K., M. Willette, D. G. Evans, and B. G. Bue. 1999. Injury to pink salmon embryos in Prince William Sound - field monitoring. Exxon Valdez Trustee Council Restoration Project 98191A-1 Final Report.

Heintz, R. A., S. D. Rice, A. C. Wertheimer, R. Bradshaw, F. P. Thrower, J. E. Joyce, and J. W. Short. 1999a. Delayed effects on growth and marine survival of pink salmon after exposure to crude oil during embryonic development. P. 5.1-5.19 in A. C. Wertheimer,

A. C., R. A. Heintz, J. F. Thedinga, J. M. Maselko, A. G. Celewycz, R. Bradshaw, and S. D. Rice. Effects of oiled incubation substrate on straying and survival of wild pink salmon. Exxon Valdez Trustee Council Restoration Project 98076 Final Report.

Heintz, R. A., J. W. Short, and S. D. Rice. 1999b. Sensitivity of fish embryos to weathered crude oil: part II. Increased mortality of pink salmon (Oncorhynchus gorbuscha) embryos incubating downstream from weathered Exxon Valdez crude oil. Environ. Toxicol. Chem. 18(3):494-503.

Rice, S. D., R. E. Thomas, R. A. Heintz, A. Moles, M. Carls, M. Murphy, J. W. Short, A. Wertheimer. 1999. Synthesis of long term impacts to Pink Salmon following the Exxon Valdez oil spill: persistence, toxicity, sensitivity, and controversy. Final Report: project 99329, Exxon Valdez Trustee Council.

**FY 02 *EXXON VALDEZ* TRU COUNCIL PROJECT BUDGET**

October 1, 200 - September 30, 2002

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 |
|---|---|---|
| Personnel | $22.5 | $20.0 |
| Travel | $8.1 | $1.0 |
| Contractual | $16.8 | $0.0 |
| Commodities | $9.0 | $0.0 |
| Equipment | $2.0 | $0.0 |
| Subtotal | $58.4 | $21.0 |
| General Administration | $3.7 | $3.0 |
| Project Total | $62.1 | $24.0 |
| Full-time Equivalents (FTE) | | 0.2 |
| Other Resources | | |

LONG RANGE FUNDING REQUIREMENTS

| Estimated FY 2003 | | | | | |
|---|---|---|---|---|---|
| $0.0 | | | | | |

Dollar amounts are shown in thousands of dollars.

Comments:

This project addresses the controversy between government and industry -sponsored researchers over the effect of oil on pink salmon embryo mortality in Prince William Sound streams.

NOAA Contribution: Principal Investigator - John Thedinga 1 mo. @ $8K
Co-PI - Mark Carls 1 mo. @ $8.2K

**FY02**

Prepared: 4/12/01

Project Number: Number: 02492
Project Title: Were Embryo Studies Biased
Agency: National Oceanic & Atmospheric Administration

FORM 3A
TRUSTEE
AGENCY
SUMMARY

**FY 02 *EXXON VALDEZ* TRU COUNCIL PROJECT BUDGET**

October 1, 200 - September 30, 2002

| **Personnel Costs:** | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FY 2002 |
| John Thedinga | PI | GS12/4 | 1.5 | 8.0 | | 12.0 |
| Mark Carls | Co-PI | GS12/5 | 1.0 | 8.0 | | 8.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 2.5 | 16.0 | 0.0 | |
| | | | | | **Personnel Total** | $20.0 |

| **Travel Costs:** | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 2002 |
| Juneau to Anchorage (Restoration Workshop/Thedinga) | 0.4 | 1 | 3 | 0.2 | 1.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | **Travel Total** | $1.0 |

**FY02**

Prepared: 4/12/01

Project Number: Number: 02-492
Project Title: Were Embryo Studies Biased
Agency: National Oceanic & Atmospheric Administration

FORM 3B
Personnel
& Travel
DETAIL

**FY 02 *EXXON VALDEZ* TRU : COUNCIL PROJECT BUDGET**

October 1, 200 - September 30, 2002

| **Contractual Costs:** | Proposed FY 2002 |
|---|---|
| Description | |
| | |
| When a non-trustee organization is used, the form 4A is required. **Contractual Total** | $0.0 |
| **Commodities Costs:** | Proposed FY 2002 |
| Description | |
| | |
| **Commodities Total** | $0.0 |

**FY02**

Prepared: 4/12/01

Project Number: Number: 02-492
Project Title: Were Embryo Studies Biased
Agency: National Oceanic & Atmospheric Administration

FORM 3B
Contractual & Commodities DETAIL

**FY 02 *EXXON VALDEZ* TRU COUNCIL PROJECT BUDGET**

October 1, 2001 - September 30, 2002

| **New Equipment Purchases:** Description | Number of Units | Unit Price | Proposed FY 2002 |
|---|---|---|---|
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

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

**FY02**

Prepared: 4/12/01

Project Number: Were Embryo Studies Biased
Project Title: Were Embryo Studies Biased
Agency: National Oceanic & Atmospheric Administration

FORM 3B
Equipment
DETAIL

**Orca Inlet Restoration**

| | |
|---|---|
| Project Number: | 02503 |
| Restoration Category: | Enhance/Replace Subsistence Resources |
| Proposer: | Native Village of Eyak |
| Lead Trustee Agency: | Native Village of Eyak, a Federally Recognized Tribal Government. |
| Cooperating Agencies: | DOI, ADFG, NMFS, EPA & CRRC. |
| Duration: | 1st year of a five year project. |
| Cost FY 02: | $100,000 |
| Cost FY 03: | $150,000 |
| Cost FY 04: | $150,000 |
| Cost FY 05: | $150,000 |
| Cost FY 06: | $150,000 |
| Geographic area: | Orca Inlet, Prince William Sound. |
| Injured Resource/Service | Subsistence |



**Abstract:**

Orca Inlet has become barren over the years. While it used to supply many of the Subsistence resources to the residents of Eyak/Cordova, in recent years it has supplied very little. A combination of the 1964 earthquake raising the area resulted in a die off of clams and crab. The expanding of the sea otters accelerated this. The shallowing of the inlet combined with the increase of fish waste dumped has resulted in a dead bay. We need to come up with a plan to restore Orca Inlet to what it was when we were children.

# The Native Village of Eyak

**P.O. Box 1388**
**Cordova, Alaska 99574-1388**
**PH (907) 424-7738 * FAX (907) 424-7739**


April 13, 2001

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

Dear Molly

Enclosed is a restoration proposal to restore Orca Inlet. This project will restore Orca Inlet to the way it was when many of us were children. Orca Inlet is being smothered by the discharge of fish waste from the processors. Due to the increase in the salmon runs and the polleck and cod fisheries, the amount of fish waste is far greater then it was in the past. Much of our Subsistence used to come from Orca Inlet. If we can restore the damage done to the inlet over the years, then we again use it for a large part of our subsistence needs.

We are requesting technical assistance from EVOS for this proposal.

Sincerely yours

Bob Henrichs
President
Native Village of Eyak
Traditional Council

**Nuchek Subsistence Camp proposal**

| | |
|---|---|
| Project Number: | 02507 |
| Restoration Category: | Enhance/Replace Subsistence Resources |
| Proposer: | Native Village of Eyak |
| Lead Trustee Agency: | Native Village of Eyak, a Federally Recognized Tribal Government. |
| Cooperating Agencies: | DOI, ADFG, NMFS & CRRC. |
| Duration: | One year. |
| Cost FY 02: | $125,000 |
| Geographic area: | Nuchek, Hinchenbrook Island, and Prince William Sound. |
| Injured Resource/Service | Subsistence |



**Abstract:**

As result of the Exxon Valdez Oil Spill the availability of subsistence foods has changed. The residents of the Oil Spill Region are spending more time gathering Traditional Subsistence foods. A Subsistence Camp at Nuchek would allow the Youth and Elders to address these changes. Many of the people in the Region trace the ancestry back to Nuchek. As Chugach Alaska Corporation has built a facility at Nuchek and holds annual Spirit Camps, this would be an appropriate location for this Subsistence Camp.

# The Native Village of Eyak

02507

P.O. Box 1388
Cordova, Alaska 99574-1388
PH (907) 424-7738 * FAX (907) 424-7739


April 13, 2001

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

Dear Molly

Enclosed is a restoration proposal for a Youth/Elders Subsistence Camp at Nuchek. As result of the Exxon Valdez Oil Spill, the harvest of subsistence foods is changing in the Oil Spill region. This proposal would allow the Youth and Elders of the Region to address these changes.

We are requesting technical assistance from EVOS for this proposal.

Sincerely yours

Bob Henrichs
President
Native Village of Eyak
Traditional Council

# Coupling of Oceanic and Nearshore: The Search for Indicator Species

RECEIVED
APR 13 2000
EXXON VALDEZ OIL SPILL
TRUSTEE COUNCIL

Project Number: 02532

Restoration Category: Research/Monitoring

Proposer: Dr. Gail Irvine
USGS-BRD
Alaska Biological Science Center
1011 E. Tudor Rd.
Anchorage, AK 99503

Lead Trustee Agency: DOI--USGS
Cooperating Agencies:

Alaska SeaLife Center: No

Duration: 1 year

Cost FY 02: $121.3

Geographic Area: Gulf of Alaska

Injured Resource/Service: Intertidal and subtidal communities, clams, subsistence, commercial fishing, sport fishing

## ABSTRACT

The primary purposes of this proposal are to: 1) identify nearshore species whose abundances are coupled with low-frequency dynamic processes (e.g., regime shifts) occurring in the oceanic realm, and that could serve as sentinels of change for the Gulf Ecosystem Monitoring program, 2) examine other types of trends occurring for nearshore species with historical records (e.g., longer-term declines, increases, etc.), and 3) propose mechanisms that could be responsible for cyclical or directional changes in species abundances, thereby identifying processes that could also be monitored.

## INTRODUCTION

A significant portion of the Gulf Ecosystem Monitoring (GEM) plan addresses the relationships between patterns of long-term, low-frequency change in oceanographic parameters and the abundances of species. Certainly one of the lessons from the *Exxon Valdez* oil spill was that it is difficult to decipher the effects of a perturbation against other shifting patterns in abundances of species. Additionally, it is difficult to manage oceanic, nearshore, and coastal ecosystems when we do not understand how marine climate influences changes in community structure. With potentially significant alterations in climate possible due to global warming, it is imperative that we elucidate the relationships between ocean climate and species abundances and distributions, and that we identify key species and processes that may be indicators of changing conditions. A first step in evaluating long-term patterns is examination of historical records (near-term history) and retrospective analyses that may illustrate how ocean productivity and species shifts may have changed in the recent past and over millenia.

Evidence supporting the link between changing ocean conditions (e.g., regime shifts, changes in productivity) and species abundances comes primarily from offshore oceanic species, though some of those, like salmon, spend only part of their lives in the oceanic realm. The coupling of nearshore species with longer-term changes in ocean conditions is more poorly known (but see Anderson and Piatt, 1999). Nearshore invertebrate species with planktonic larvae may be linked through the exposure of larvae to offshore conditions and the transport of larvae. Effects on larvae may translate into effects on settlement and recruitment into the adult population. Additionally, nearshore species may be affected by changing ocean conditions through effects on their food, competitors, predators, or habitat.

Although the patterns of species abundances through time, especially as related to regime shifts (e.g, Pacific Decadal Oscillation [PDO], North Pacific Oscillation, 18.6 lunar nodal cycles, etc.; see GEM plan; Francis et al., 1998; Hare and Mantua, 2000) and other types of ocean conditions (e.g. El Niño Southern Oscillation or ENSO), are becoming clearer (e.g., Hare and Mantua, 2000), there is little understanding of the mechanisms that underly the patterns (Anderson and Piatt, 1999; Francis et al., 1998). Analysis of patterns of species abundances through time, especially as related to known patterns of alterations in oceanic state, may provide clues as to which mechanisms are likely to be important. Additionally, analysis of life history patterns may also provide clues to the relative importance of different mechanisms or processes.

As stated above, cyclic patterns in species abundances that may be brought about by cyclic, low-frequency changes in ocean conditions driven by atmospheric alterations, must be understood against the broader spectrum of truly long-term (century to millenial) changes and more directional climate change (global warming). Comparisons of records from different scales of time allow development of such a perspective.

In this project, we propose to create an historical perspective against which to examine the evidence for coupling of nearshore species and communities to oceanic conditions.

The goals are to understand long-term patterns in productivity, relative species abundances, and the influence of broad-scale ocean conditions on nearshore communities.

## NEED FOR THE PROJECT

### A. Statement of Problem

In order to effectively manage coastal ecosystems, it is necessary that we acquire an increased understanding of the processes that shape the distributions, abundances and interactions of species through time. There is an emerging awareness of the extensive influence of changing ocean conditions on the abundances of oceanic species and their linked interactions. However, much less is known about the influence of offshore and nearshore oceanic parameters on nearshore species and communities. Within this pattern of low-frequency cyclic change, longer-term changes are occurring that reflect climate changes. When large-scale perturbations, such as the *Exxon Valdez* oil spill occur, we need to know what the general state of nearshore communities is in order to be able to evaluate the extent of the perturbation, and to be able to plan restoration options. We are proposing to identify sentinel nearshore species that reflect changing ocean conditions, investigate the mechanisms underlying the patterns, and develop a long-term view of changing ocean productivity and nearshore species abundances. Within the context of the GEM plan, the information developed will help detect change, understand the processes, and help predict trends in species abundances.

### B. Rationale/Link to Restoration

As stated above, in order to understand both the effects of the *Exxon Valdez* oil spill and other perturbations, we need to have an increased understanding of how species are changing through time. This project focuses on the nearshore environment, an area that was heavily injured by the *Exxon Valdez* oil spill. Data on a number of nearshore (both intertidal and subtidal) species will be considered. Some of the species for whom historical data are likely to be most abundant include species that are harvested commercially, recreationally (sport fishing), or by subsistence users. Developing an understanding of the influence of changing ocean conditions on some of these species will enable better management of these species and communities, and fuller understanding of the effects of the *Exxon Valdez* oil spill.

### C. Location

Nearshore environments along the Gulf of Alaska.

## COMMUNITY INVOLVEMENT AND TRADITIONAL KNOWLEDGE

This project will involve tapping into both traditional and historical knowledge of changing patterns of abundances of nearshore species (e.g., clams, shrimp). In particular, communities such as Cordova, Kodiak and Tatitlek will be queried for information in the early stages of the project.

## PROJECT DESIGN

### A. Objectives

Phase I: Evaluation of Species and Patterns for Evidence of Coupling and Long-term Change

1. Evaluate available historical data on species abundances and population structure of nearshore species (primarily invertebrates), in conjunction with known patterns in oceanic parameters, with the goal of identifying nearshore species that are apparently coupled with cyclic oceanic conditions or longer-term changes, and that could act as sentinels of such change.

2. Evaluate correlations among species abundance patterns, life history traits, and oceanic parameters to suggest potential mechanisms that could be responsible for linking nearshore species abundances with oceanic conditions.

### B. Methods

This project focuses on identifying nearshore species and processes that are coupled to cyclic or changing ocean conditions. The primary approach is the gathering, evaluation, and synthesis of existing information on species abundances through time. Both historical data and select historical samples will be examined. In addition, available information on life histories and factors that may foster coupling will be collected and evaluated in order to propose mechanisms whereby species may be coupled. The available evidence supporting the different mechanisms will also be synthesized. In the future, combining evaluation of existing information and modeling will increase the likelihood of identifying mechanisms that may lead to or foster coupling of species abundances and changes in ocean conditions.

The following hypotheses are addressed by this project:

H1: Nearshore invertebrate species can be "coupled" to oceanic conditions by productivity (timing, composition, intensity of blooms), temperature, advection/transport, effects on their planktonic larvae, competitors, and/or predators.

H2: Nearshore invertebrate species with coupling to broad-scale oceanic conditions through their planktonic larval stages could show:

a. Consistent correlations of abundances (of larvae or adults), settlement/recruitment, and/or post-settlement mortality with certain ocean conditions.

    1. Varying patterns of success based on the patterning of primary production (for example, within Prince William Sound):

        a. When phytoplankton blooms are short in duration, but of high intensity, carbon is transferred primarily to the benthos, resulting in high growth rates of the invertebrates, but more limited success of larval forms (only those tightly coupled to the bloom are successful).

        b. When phytoplankton blooms set up more gradually, with resetting by wind events, resulting in a bloom of lesser magnitude but longer duration, larval success is increased for species with longer development times and/or periodic production of larvae.

b. Similar patterns of recruitment across the Gulf of Alaska for an individual species, i.e., coupled species are consistently negatively or positively correlated with certain ocean conditions.

The methods used to test each of these hypotheses are given below, as well as information on some of the available data sets.

**HO1: Nearshore invertebrate species can be "coupled" to cyclic or changing oceanic conditions by productivity (timing, composition, intensity of blooms), temperature, advection/transport, effects on their planktonic larvae, competitors, and/or predators.**

The focus will be on evaluating the available evidence for indications of coupling of nearshore species and oceanic conditions. Historical data will be analyzed for cyclical patterns and long-term trends. The hypothesized mechanisms will then be collated, and the evidence for/against each mechanism will be evaluated. Additionally, new mechanisms will be proposed based on the patterns and correlative data. Evidence of coupling may be derived from correlations of abundance, growth, or recruitment with 1) known patterns of low-frequency, cyclic oceanographic changes, 2) longer-term directional trends, and 3) responses to oceanographic conditions. Suggestion of coupling also may be found through evaluation of life history patterns and the cues related to reproduction and settlement.

There is growing evidence for correlations of biotic abundances or responses with cyclical atmospheric and ocean conditions (e.g., GEM plan; Francis et al., 1998; Hollowed et al., 1998; Hollowed and Wooster, 1992; Anderson and Piatt, 1999; Hare and

Mantua, 2000). In fact, Hare and Mantua (2000) review 100 time series (31 climatic and 69 biological) to ascertain whether there is a consistent signal of another regime shift since the widely accepted one that occurred in the winter of 1976-1977. They found evidence of a 1989 shift in some components of the North Pacific ecosystem, but the changes were not as pervasive as the 1977 changes and apparently did not signal a simple return to pre-1977 conditions. Notably, biological time series showed more consistent patterns than did the physical time series, suggesting that biota integrate the stochasticity of the physical parameters. One of the first steps in this project will be delineation of the various periodicities of different types of ocean conditions (e.g., Pacific Decadal Oscillation [PDO], 18.6-year lunar nodal cycle; El Niño Southern Oscillation [ENSO]; etc.). One of the complications in expecting consistent repeating cycles is that at least two cycles having differing periodicities can overlap, resulting in increased amplitude of the signal or a dampening of effect (Minobe, 1999). Various researchers have proposed climate shifts in the Northeast Pacific in the early 1920s and mid 1940s (e.g., Kondo, 1988; Manuta et al, 1997; Zhang et al., 1997; Minobe, 1997; Ingraham et al., 1999), based on analyses of temperature, tree ring, and salmon catch data. One of the most striking aspects of Hare and Mantua's (2000) analysis is the delineation of two major patterns in the time series, based on principal components analysis. Given the comprehensive nature of the time series they examined, these are likely to be the most commonly observed recent patterns. It has been acknowledged by a variety of authors (e.g., Anderson and Piatt, 1999; Francis et al., 1998; GEM; Hare and Mantua, 2000) that although cyclical patterns are more commonly being recognized, the mechanisms giving rise to the patterns are vague or poorly known. A mechanistic interpretation of abundances of different crab species relative to ocean conditions has suggested how different species-specific mechanisms could be operating (Zeng and Kruse, 2000).

Some key sources of historical data for nearshore species include: a) small mesh trawl surveys from the Kodiak/ Alaska Peninsula area (Anderson and Piatt, 1999); b) benthic clam sampling from the Nearshore Vertebrate Predator Project (NVP), which includes data gathered over several years, as well as samples from a dramatically different, much denser multi-species clam assemblage of unknown age, c) harvest data for razor clams at sites along the Alaska Peninsula, Cook Inlet (east and west sides), and Cordova, and d) ecological studies conducted at various geographic and temporal scales (e.g., NOAA OCSEAP studies, post-earthquake studies in PWS [NRC, 1971]; Port Valdez pre-pipeline studies; fisheries assessment studies, etc.). A review of the biogeography and ecology of intertidal and shallow subtidal communities in the Gulf of Alaska is provided by O'Clair and Zimmerman (1986). We will investigate with ADFG and NOAA/NMFS personnel other sources of data for nearshore benthic or pelagic species. Consideration will be given to species from multiple taxa, however, we acknowledge that time series data is much more likely to be found for species that are harvested commercially or recreationally.

A few additional details concerning the data mentioned above are warranted. From the Anderson and Piatt (1999) analyses, it is apparent that there are a variety of nearshore species that are coupled with ocean conditions (e.g., shrimp, starfish, jellyfish, octopus, various fishes). Investigating the known life history parameters of these species should

help formulate hypotheses regarding the mechanisms producing these patterns. These data, as well as literature surveys, will provide information that would be suitable for modeling under GEM.

Analysis of the PWS subtidal benthic clam assemblages sampled by Van Blaricom and Fukuyama during the NVP project indicated a sharp dichotomy between surface/shallow subsurface clam assemblages, and a deeper, much denser clam assemblage. It is possible that the deeper clam assemblage represented clams that died as a result of the 1964 earthquake, or represent another time period. We propose to date these clams (using a radiometric analysis; Nevissi et al., 1995) in order to evaluate their temporal and ecological significance. Once they are dated, further detailed analysis of the shells (growth rates, isotopic analyses) may be desirable.

We also propose to analyze the age/size structure for a collection of dead clam shells collected by Glenn Van Blaricom in areas that had been uplifted by the 1964 earthquake. Approximately 200 0.25$m^2$ quadrats were sampled. Data were gathered between 1978 and 1984 at Gibbon Anchorage on Green Island; some data were also collected near Cordova during the same time period. Although this is not pre-otter (Lensink, 1962), it is probably before the peak abundance of otters, which may have occurred in the middle or late 1970s (Estes et al., 1981; A. Johnson, pers comm; as cited by VanBlaricom, 1988). These clams will provide a pre-spill reference for aspects of clam population structure. Although patchy in their distribution, these clams, when encountered, had densities well in excess of 10 clams/$m^2$, compared to the NVP subtidal densities from 1995 of approximately 2.7-3.2/$m^2$. Almost every quadrat contained members of the genera *Saxidomus*, *Protothaca*, and *Macoma*. Occasional individuals of *Mya, Tresus,* and *Hiatella* occurred. The 1995 suction-dredge samples also included some of these same genera (*Saxidomus, Protothaca, Macoma,* and *Mya*), but in much reduced abundances.

Razor clams (*Siliqua patula*) historically have been dense at four major sites in Alaska: Swikshak (Alaska Peninsula), Polly Creek (west side of Cook Inlet), the east side of Cook Inlet, and Cordova. Harvest data and population estimates (Szarzi, 1991) for eastside of Cook Inlet will be compared to harvest and biological data for the other areas to see if these long-lived (up to 18 years in Alaska) bivalves show evidence of coupling to ocean conditions. Historical and traditional information will also be gathered on patterns of abundance. Kaiser (1977) performed an assessment of razor clam distribution and a population assessment at 12 beaches along Kodiak Island and the Alaska Peninsula. Recent investigations of bear-clam dynamics along the Katmai National Park and Preserve coast have suggested a significant decline in the abundance of razor clams since Kaiser's 1976 study (T. Smith, pers comm.). It may be possible to separate human-harvest effects from other natural dynamics since the razor clam concentrations have varying levels of accessibility and different harvest histories.

**H2: Nearshore invertebrate species with coupling to broad-scale oceanic conditions through their planktonic larval stages should show:**

a. **Consistent correlations of abundances (of larvae or adults), settlement/recruitment, and/or post-settlement mortality with certain ocean conditions.**

b. **Varying patterns of success based on the patterning of primary production (e.g., within Prince William Sound):**

    1. **When phytoplankton blooms are short in duration, but of high intensity, carbon is transferred primarily to the benthos, resulting in high growth rates of the invertebrates, but more limited success of larval forms (only those tightly coupled to the bloom are successful).**

    2. **When phytoplankton blooms set up more gradually, with resetting by wind events, resulting in a bloom of lesser magnitude but longer duration, larval success is increased for species with longer development times and/or periodic production of larvae.**

c. **Similar patterns of recruitment across the Gulf of Alaska for an individual species, i.e., coupled species are consistently negatively or positively correlated with certain ocean conditions.**

Under H2.a.1.a., carbon gets transferred to the benthos because the bloom is established quickly and intensely, may get shut off by nutrient limitation (although grazing may also be a factor), and much of the planktonic biomass cannot be efficiently used. Therefore, considerable production gets shunted to the benthic environments (T. Cooney, pers. comm.). There is some evidence that the spawning of some invertebrate species has been triggered or correlated with dense algal suspensions, although temperature has also been implicated as a spawning trigger (Strathmann, 1987). In order for the triggering of spawning by phytoplankton blooms to be effective for reproductive success, larval development times have to be short enough for the larvae to be able to take advantage of the bloom. Thorson (1946) gives examples of several species that produce free-swimming veligers within a few hours to several days following fertilization of the gametes. Thus, it is quite likely that some species, including clams, might show a tight coupling of spawning and rapidly increasing larval abundances with an intense phytoplankton bloom. Further selection for tight coupling to intense phytoplankton blooms might derive from the potential "rain" of unconsumed carbon to the substrate, which could enrich the environment for newly settling larvae. Food-limitation has been suggested as a potentially limiting factor for new recruits or juveniles in soft-bottom habitats (see review by Olafsson et al., 1994).

The relative success of species with different patterns of larval development and timing with respect to the patterning of the phytoplankton bloom, will be examined for a variety of invertebrates (e.g., clams, mussels, echinoderms, shrimp, crabs).

The relationship between growth rates of benthic invertebrates and the patterning of the phytoplankton bloom (predicted effect: greater growth in years with an intense phytoplankton bloom), can be examined retrospectively by comparing periods of greater growth as recorded in the shells of bivalves and tests of echinoids, with historical knowledge of patterns of phytoplankton productivity, and information gathered by SEA.

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

A variety of important cooperators will be involved in this project. Drs. Paul Anderson (NMFS), Dr. Gordon Kruse, Nicky Szarsi (ADFG) and other agency staff will be involved in assessing the sources of biological information and interpretation of patterns and mechanisms. We will be collaborating closely with Dr. Glenn Van Blaricom (University of Washington) in aging and assessments of older clam assemblages in Prince William Sound. Contracts are expected with the University of Washington, an Institute in Germany for radiometric dating of clams, and WEST, Inc. for statistical analyses.

## SCHEDULE

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

| | |
|---|---|
| Oct. 1– March 31: | Setting up contracts |
| Oct – Dec.: | Collecting historical data, initiating discussion for local knowledge |
| November – Sept 30: | Evaluate historical data and samples |
| January 14-23 (2 days): | Attend Annual Restoration Workshop |
| April 15, 2003 | Draft Final Report |

### B. Project Milestones and Endpoints

Year 02: Evaluation Phase
- Collection of historical data; analyses of time series data
- Aging of historic clam samples from PWS
- Collection of life history data
- Synthesis of various data streams

Year 03: Draft Final Report

### C. Completion Date

A Draft Final Report will be produced April 15, 2003.

## PUBLICATIONS AND REPORTS

Reports and manuscript(s) will be generated in FY03.

## PROFESSIONAL CONFERENCES

Presentation of project results at the PICES 2002 meeting is planned.

## NORMAL AGENCY MANAGEMENT

The work involved in this project is not part of normal agency management, however, the results are expected to be useful for management purposes of a variety of agencies.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

The type of work outlined in this proposal needs to be integrated within the larger context of what is happening in the near-coastal and offshore ocean; thus the intent is to collaborate and integrate to the maximum extent possible. The proposal has detailed collaboration with other agency, science center and university staff. Additionally, we will be interacting with local communities in order to gather information on the historical presence and abundance of nearshore species of importance to them. We will make every effort to coordinate and integrate our efforts with those of other restoration projects.

## EXPLANATION OF CHANGES IN CONTINUING PROJECTS

N/A

## PROPOSED PRINCIPAL INVESTIGATOR

Dr. Gail V. Irvine
USGS-BRD
Alaska Biological Science Center
1011 E. Tudor Rd.
Anchorage, AK 99503
Phone: 907-786-3653
Fax: 907-786-3636
E-mail: gail_Irvine@usgs.gov

## PRINCIPAL INVESTIGATOR

Dr. Irvine is a Marine Ecologist with the Alaska Biological Science Center. She has extensive experience in coastal ecosystems in Alaska, the Pacific Northwest and the tropics. Her primary research interests have been in plant-herbivore interactions,

succession, life history dynamics, oil effects, and the design of long-term monitoring programs and associated research. She has been a Principal Investigator on several EVOS-funded studies involving oiled mussel beds and the residual oiling of coastlines. Recently she was invited to author a chapter on "Persistence of Spilled Oil on Shores and its Effects on Biota" for The Seas at the Millenium, a three-volume assessment of the state of the world's oceans being published by Elsevier. Over the last 4 years, she has also been involved in the designing protocols for broad-scale, inferential monitoring of intertidal assemblages in Glacier Bay National Park and Preserve, then adapting the design for the small coastline of Sitka National Historical Park.

**OTHER KEY PERSONNEL**

Dr. Glenn VanBlaricom
Washington Cooperative Fish and Wildlife Research Unit
USGS-BRD
School of Fisheries
Box 355020
University of Washington
Seattle, WA 98195
Phone: 206-543-6475
Fax: 206-685-7471
Email: glennvb@fish.washington.edu

**LITERATURE CITED**

Anderson, P. J. and J. F. Piatt. 1999. Community reorganization in the Gulf of Alaska following ocean climate regime shift. Mar. Ecol. Prog. Ser. 189:117-123.

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## 2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 |
|---|---|---|
| Personnel | | $62.6 |
| Travel | | $6.3 |
| Contractual | | $40.2 |
| Commodities | | $0.0 |
| Equipment | | $0.0 |
| Subtotal | $0.0 | $109.1 |
| General Administration | | $12.2 |
| Project Total | $0.0 | $121.3 |
| Full-time Equivalents (FTE) | | 1.0 |
| Other Resources | | |

LONG RANGE FUNDING REQUIREMENTS

| Estimated FY 2003 | | |
|---|---|---|
| $0.0 | | |

Dollar amounts are shown in thousands of dollars.

Comments:

**FY02**

Prepared: 4/13/01

Project Number: 02532
Project Title: Coupling of Oceanic and Nearshore: The Search for Indicator Species
Agency: DOI-USGS

FORM 3A
TRUSTEE
AGENCY
SUMMARY

## 2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

| Personnel Costs: | | GS/Range/ | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | Step | Budgeted | Costs | Overtime | FY 2002 |
| Gail Irvine | Marine Ecologist | GS/12/8 | 2.0 | 8.3 | | 16.6 |
| Vacant | Biologist | GS9/1 | 10.0 | 4.6 | | 46.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 12.0 | 12.9 | 0.0 | |
| | | | | | Personnel Total | $62.6 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 2002 |
| RT Anchorage/ Kodiak | 0.4 | 1 | 3 | 0.2 | 1.0 |
| RT Anchorage/Homer | 0.2 | 1 | 2 | 0.2 | 0.6 |
| RT Anchorage/Cordova | 0.6 | 1 | 3 | 0.2 | 1.2 |
| RT Anchorage/PWS | 0.6 | 1 | 2 | 0.2 | 1.0 |
| RT scientific meeting: PICES Annual Meeting | 1.3 | 1 | 6 | 0.2 | 2.5 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | Travel Total | $6.3 |

**FY02**

Prepared: 4/13/01

Project Number:
Project Title: Coupling of Oceanic and Nearshore: The Search for Indicator Species
Agency: DOI-USGS

FORM 3B
Personnel & Travel DETAIL

## 2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

| Contractual Costs: | Proposed FY 2002 |
|---|---|
| Description | |
| 4A Linkage: Statistical Analysis (WEST) | 12.2 |
| Radionuclide analysis (dating) of subtidal clams- 33 samples @estimated $400/sample | 13.2 |
| University of Washington: analysis of historic PWS clam assemblages | 14.8 |
| When a non-trustee organization is used, the form 4A is required. **Contractual Total** | $40.2 |

| Commodities Costs: | Proposed FY 2002 |
|---|---|
| Description | |
| **Commodities Total** | $0.0 |

**FY02**

Prepared: 4/13/01

Project Number:
Project Title: Coupling of Oceanic and Nearshore: The Search for Indicator Species
Agency: DOI-USGS

FORM 3B
Contractual & Commodities
DETAIL

## 2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2001 - September 30, 2002

| New Equipment Purchases: Description | Number of Units | Unit Price | Proposed FY 2002 |
|---|---|---|---|
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

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

**FY02**

Prepared: 4/13/01

Project Number:
Project Title: Coupling of Oceanic and Nearshore: The Search for Indicator Species
Agency: DOI-USGS

FORM 3B
Equipment
DETAIL

## 2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

| Budget Category: | Authorized FY 2001 | Proposed FY 2002 | LONG RANGE FUNDING REQUIREMENTS | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Estimated FY 2003 | | | |
| Personnel | | $6.1 | | | | | | |
| Travel | | $0.0 | | | | | | |
| Contractual | | $0.0 | | | | | | |
| Commodities | | $0.0 | | | | | | |
| Equipment | | $0.0 | | | | | | |
| Subtotal | $0.0 | $6.1 | | | | | | |
| Indirect | | $6.1 | | | | | | |
| Project Total | $0.0 | $12.2 | | | | | | |
| | | | | | | | | |
| Full-time Equivalents (FTE) | | 0.1 | | | | | | |
| | Dollar amounts are shown in thousands of dollars. | | | | | | | |
| Other Resources | | | | | | | | |

Comments:

**FY02**

Prepared: 4/13/01

Project Number:
Project Title: Coupling of Oceanic and Nearshore: The Search for Indicator Species
Name: Western Ecosystems Technologies, Inc., contract to USGS

FORM 4A
Non-Trustee
SUMMARY

## 2002 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET

October 1, 2001 - September 30, 2002

| Personnel Costs: | | | Months | Monthly | | Proposed |
|---|---|---|---|---|---|---|
| Name | Position Description | | Budgeted | Costs | Overtime | FY 2002 |
| L. McDonald | Senior Scientist | | 0.2 | 8.1 | | 1.6 |
| M. Bourassa | Biometrician I | | 1.0 | 4.5 | | 4.5 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | | | | | | 0.0 |
| | Subtotal | | 1.2 | 12.6 | 0.0 | |
| | | | | | Personnel Total | $6.1 |

| Travel Costs: | Ticket | Round | Total | Daily | Proposed |
|---|---|---|---|---|---|
| Description | Price | Trips | Days | Per Diem | FY 2002 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | | 0.0 |
| | | | | Travel Total | $0.0 |

**FY02**

Prepared: 4/13/01

Project Number:
Project Title: Coupling of Oceanic and Nearshore: The Search for Indicator Species
Name: Western Ecosystems Technologies, Inc., contract to USGS

FORM 4B
Personnel & Travel DETAIL

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

| Contractual Costs: | Proposed FY 2002 |
|---|---|
| Description | |
| | |
| **Contractual Total** | $0.0 |

| Commodities Costs: | Proposed FY 2002 |
|---|---|
| Description | |
| | |
| **Commodities Total** | $0.0 |

**FY02**

Prepared: 4/13/01

Project Number:
Project Title: Coupling of Oceanic and Nearshore: The Search for Indicator Species
Name: Western Ecosystems Technologies, Inc., contract to USGS

FORM 4B
Contractual & Commodities
DETAIL

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

| New Equipment Purchases: Description | Number of Units | Unit Price | Proposed FY 2002 |
|---|---|---|---|
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| | | | 0.0 |
| Those purchases associated with replacement equipment should be indicated by placement of an R. | | **New Equipment Total** | $0.0 |

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

**FY02**

Prepared: 4/13/01

Project Number:
Project Title: Coupling of Oceanic and Nearshore: The Search for Indicator Species
Name: Western Ecosystems Technologies, Inc., contract to USGS

FORM 4B
Equipment
DETAIL