PROPOSAL SIGNATURE FORM

THIS FORM MUST BE SIGNED BY THE PROPOSED PRINCIPAL INVESTIGATOR AND SUBMITTED ALONG WITH THE PROPOSAL. If the proposal has more than one investigator, this form must be signed by at least one of the investigators, and that investigator will ensure that Trustee Council requirements are followed. Proposals will not be reviewed until this signed form is received by the Trustee Council Office.

By submission of this proposal, I agree to abide by the Trustee Council's data policy (Trustee Council Data Policy*, adopted March 17, 2008) and reporting requirements (Procedures for the Preparation and Distribution of Reports**, adopted June 27, 2007).

PROJECT TITLE: **PWS herring survey: Plankton and oceanographic observations, submitted under the BAA**

Printed Name of PI **Robert W. Campbell**

Email: **rcampbell@pwssc.org**

Mailing Address **Box 705**

City, State, Zip **Cordova, AK, 99574**

Phone: **(907)424-5800 x241**

Signature of PI: ______________ Date: **14 April 2009**

Printed Name of PI ______________

Email: ______________

Mailing Address ______________

____

Phone: ______________

Signature of PI: ______________ Date: ______________

Printed Name of PI ______________

Email: ______________

Mailing Address ______________

City, State, Zip ______________

Phone: ______________

Signature of PI: ______________ Date: ______________

* www.evostc.state.ak.us/Policies/data.cfm
** www.evostc.state.ak.us/Policies/reporting.cfm

FY10 INVITATION
PROPOSAL SUMMARY PAGE

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA

Project Period: October 1, 2009 to September 30, 2013

Primary Investigator(s): Robert W. Campbell, Prince William Sound Science Center

Study Location: Prince William Sound

Abstract:

Herring stocks collapsed in the years following the Exxon Valdez Oil Spill. The cause of the collapse remains highly controversial, and several empirical and theoretical studies have implicated different factors, including the spill, disease outbreaks, fishing activity, and ecosystem productivity. Herring stocks have not rebounded since the collapse in the early 90's and show no signs of recovery; similarly controversial, varied, and not necessarily mutually exclusive.

The work described in this proposal is part of several collaborative proposals to survey herring in PWS, and seeks to monitor the environmental and food climate experienced by herring in order to address the hypothesis that carrying capacity can be limiting the recovery of herring. Observations of environmental conditions and plankton abundance over time will be integrated with observations of herring distributions and energetics, in order to assess how the food climate in Prince William Sound may structure herring populations in space and time.

Estimated Budget:
EVOS Funding Requested *(must include 9% GA)*

FY10	FY11	FY12	FY13	Total
$201500	$197300	$200100	$64400	$598800

Non-EVOS Funds to be used:

FY10	FY11	FY12	FY13	Total
$23000	$23000	$23000		70000

PROJECT PLAN

I. NEED FOR THE PROJECT
A. Statement of Problem

Pacific Herring (*Clupea pallasi*) occupy a crucial role in the coastal ecosystems of the Gulf of Alaska. They are generally the most common forage fish, and are responsible for the transfer of a large amount of energy from lower trophic levels (plankton and small nekton) to higher ones, including several commercially important species of fish. Besides the ecosystem services they provide, herring are important to the economy of coastal communities, and have historically sustained a number of dedicated fisheries including reduction, bait, and roe fisheries.

The Pacific Herring population in Prince William Sound (PWS) crashed in the years following the Exxon Valdez Oil Spill (EVOS). Prior to the spill the spawning stock biomass was in excess of 100000 metric tons (Deriso et al. 2008; Hulson et al. 2008; Thorne and Thomas 2008), and it had declined to below the minimum fishery threshold of 22000 tons by 1993. The fishery was again opened from 1996 to 1999, with very low catches relative to historical ones, and it has remained closed since 2000. The cause of the crash is a matter of considerable controversy, and several hypotheses have been put forward, including direct mortality from the spill (Carls et al. 2002; Thorne and Thomas 2008), density dependant mortality as a result of high biomass (Pearson et al. 1999), low food availability (Pearson et al. 1999; Carls et al. 2002), predation or overwinter mortality (Pearson et al. 1999), and disease outbreaks (Marty et al. 1998).

Herring stocks in Prince William Sound have remained at a low, but stable population abundance since 2000; the 2008 spawning stock biomass was estimated to be 10000 tons, and the forecast for 2009 is 17902 tons. Herring stocks are known to fluctuate widely (Blaxter and Hunter 1982), but it is fairly unusual for them to remain at low abundance for long periods of time (e.g. see the spawning stock biomass time series in Hay et al. 2001). The causes for the lack of recovery by the herring population are as debatable as the causes of their initial decline, and include disease, predation, physical and biological oceanographic conditions, and competition (EVOSTC 2008).

The problem that we wish to address, then, is that herring stocks have not rebounded. There are several reasons why there has not been a recovery; most of those reasons are not mutually exclusive, it is likely that several are acting in combination to keep herring at low levels. Herring are currently listed as a resource that is not recovering by the EVOS Trustee Council, and most every piscivorous fish, bird and mammal found in PWS consumes herring at some point in its life cycle, including several species that were impacted by the spill. That includes the only other species listed as not recovering (Pigeon Guillemots), and several species listed as recovering, plus several species whose recovery status is unknown.

The EVOS Trustee Council has supported the development of an Integrated Herring Restoration Plan which has been in progress since 2006. The current draft plan (EVOSTC 2008) outlines a number of restoration objectives, including determining the reasons behind the lack of recovery, determining the feasibility of intervening, monitoring of the status of the population and the environment, and improving the accuracy of predictions; there are also a number of specific goals by which the herring population in PWS will be determined to be restored. In addition to restoration options, the plan includes a core program, which is designed to provide the basic information required about the PWS herring population, in order to assess if it has recovered, as well as to evaluate any restoration option that might be selected. One component of that core program is the need to understand what the oceanographic and food climate is for herring in PWS.

Prior work has suggested that environmental changes were partially responsible for the collapse of the population: there is evidence that food quantity or quality declined (Pearson et al. 1999; Carls et al. 2002; Deriso et al. 2008) and that ocean temperatures were suboptimal (Pearson et al. 1999; Deriso et al. 2008). The evidence for those environmental effects is however somewhat circumstantial, it is based on changes in the weight at age of herring (Pearson et al. 1999) or correlation with climate indices (Deriso et al. 2008). The work proposed here is designed to collect that basic information about the state of the physical, chemical, and biological climate in PWS, and, within the framework of several other proposed studies, will provide direct evidence about the influence of the physical environment and lower trophic level productivity on herring production.

B. Relevance to 1994 Restoration Plan Goals and Scientific Priorities

Pacific herring was classified as “not recovered” in the 1994 restoration plan, and presently remains in “not recovering” status. Since both carrying capacity and oceanographic conditions (see references above) have been implicated in the initial crash of the population and its continuing lack of recovery, the work proposed here is relevant to the priorities of the restoration plan.

This work falls under the **monitoring and research** provision of the restoration plan, in that it proposes to monitor the status of the physical environment and lower trophic levels in PWS. It applies an **ecosystem approach**, documenting changes in primary and secondary producers (which may be integrated with other studies examining higher trophic levels). In the event that **natural recovery** occurs, the data collected as part of this project will permit understanding of role of bottom-up factors in recovery. In the event that **restoration activities** are chosen as an option (following the feasibility studies requested in the FY10 RFP), the data collected will be valuable in choosing the site and timing for those efforts.

This work will also include significant **community involvement**. All charters will be with local vessels and the results will be disseminated by community presentations, the print and broadcast media, and an annual visit to the Chugach Corporation Spirit Camp at Nuchek.

II. PROJECT DESIGN

A. Objectives

1. Observe how ocean climate and the annual production cycle in PWS evolves in space and time.

The state of the oceanographic climate in PWS plays a large role in ecosystem productivity. The Alaska Coastal Current (ACC) sometimes flows directly into PWS (Niebauer et al. 1994) and increased flushing rates can lower productivity. Similarly, when the ACC is located seaward, productivity may be enhanced (this is known as the "river/lake" hypothesis: Cooney et al 2001a). Temperature regimes are important in determining the rates of vital processes and the timing of production events (e.g. Edwards and Richardson 2004), although the role of temperature in the PWS ecosystem is unclear (Eslinger et al. 2001). The annual amount of primary production that occurs is ultimately limited by the availability of nutrients, both by the onset and breakdown of stratification in spring and autumn, and by occasional wind-driven upwelling events (Behrenfeld and Falkowski 1997; Eslinger et al. 2001; Weingartner 2005). The timing and magnitude of the autumn bloom may be particularly important for determining the food environment experienced by herring prior to their overwintering period.

In short, the physical environment will set up the amount of biological productivity that can occur in PWS, which will ultimately determine how much energy and mass is transferred up the trophic web to herring.

2. Make quantitative estimates of the amount of plankton food available to juvenile and adult herring.

A broad understanding of the ecosystem status of PWS is important and worthwhile, and a more focused understanding of the implications to herring is also required. There is a potential energetic bottleneck for age-0 herring entering their first winter: plankton abundance is at its lowest during winter, and feeding activity by herring is reduced (Foy and Norcross 1999); there may be significant overwintering mortality due to starvation (Foy and Paul 1999). It is thus important to know the temporal and spatial variability of the prey fields encountered by juvenile herring.

Assessing a prey field is a difficult task because it is a moving target: prey concentrations change over time due to both growth and mortality. Tracking of growth and mortality are theoretically possible, but is notoriously difficult and costly (Huntley and Lopez 1992). Rather than tracking growth and mortality, one may also track prey fields over time: every sample taken at any point and space in time provides a snapshot of the prey available at that instant. However, the sampling design must trade off spatial and temporal resolution with feasibility and cost.

Plankton populations are generally cyclical, usually with a single, species-specific peak biomass. The timing of that biomass peak (i.e. the phenology of a given species' life history) is not static. For instance, the timing of the biomass peak of the large copepod *Neocalanus plumchrus* in the open North Pacific varies by several weeks (Mackas et al. 1998). The variability in the phenology of plankton species in PWS is not known. It is therefore important to obtain samples with a temporal resolution that is appropriate to observe changes in phenology: it is required to know something about the timing and magnitude of the peak biomass of species commonly consumed by herring in order to assess the availability of plankton food.

The results of plankton collections during the SEA program (which unfortunately only had a single year of good temporal coverage) may be summarized in a conceptual model of the more common biomass dominant plankton (Cooney et al. 2001b; figure 1). Several of the common species (*Pseudocalanus* and *Metridia* copepods, larvaceans, and euphausiids) have been identified as important prey items for herring, particularly juvenile herring (Foy and Norcross

1999). The timing and biomass of several other species identified as important prey items (meroplanktonic barnacle larvae, for instance) is unknown. The size of the peaks in figure 1 illustrates that observations should be made at least monthly to resolve the timing and magnitude of each of the peaks. Shifts in the timing and the magnitude of the peaks from year to year will determine the prey field experienced by herring during their entire life cycle.

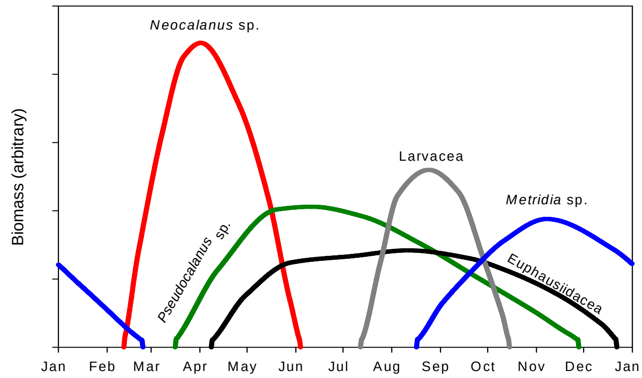

Figure 1: Conceptual model of the annual progression of different plankton during an annual cycle. Developed from Cooney et al., 2001b.

3. Integrate those oceanographic and plankton observations into the broader picture of herring recovery.

Following the development of an understanding of the temporal progression of the physical and food environment for herring in PWS, the data collected as part of this project will be integrated with that collected by other relevant projects. Observations of herring distribution (submitted proposals "*PWS herring survey: Community Involvement, Outreach, Logistics, and Synthesis*" submitted by W. Pegau; "*PWS herring survey: Assessment of Juvenile Herring Abundance and Habitat Utilization*", submitted by R. Thorne and "*PWS herring survey: Sound Wide Juvenile Herring, Predator, and Competitor Density via Aerial Surveys*", submitted by E. Brown), combined with observations of herring diets and energetics (submitted proposal "*PWS herring survey: Growth and energy allocation in overwintering herring*" submitted by R. Heintz; Foy and Norcross 1999) and herring forage (this proposal) will be combined to pinpoint which areas and times are most important for young herring, and where restoration efforts are best focused. This will inform the integrated final report that will be put together from all studies. The results of this study will also be used to make recommendations on the scale (both in space and time) of any continued monitoring efforts.

Additionally, the results of this work and its implications within the broader restoration plan will be used to direct outreach activities. The results will be shared with the local community through the broadcast and print media, and local education programs. As well as presentations to the community in Cordova, the monthly survey in June will include participation by the PI in an education program at the Chugach Corporation Spirit Camp at Nuchek.

B. Procedural and Scientific Methods

Sampling regime

In order to capture the spatial and temporal variability in plankton production and oceanographic features, it is proposed to do several rapid surveys throughout PWS over the course of the year. The use of a small, fast boat (a PWS bowpicker) will allow good temporal and spatial coverage,

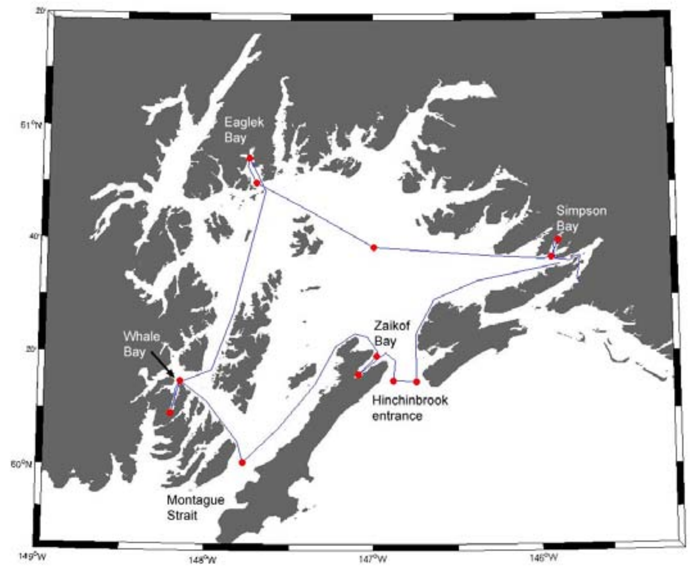

Figure 2: Proposed cruise track and stations.

at modest cost, and deploying from Cordova will allow flexibility to choose weather windows to be most efficient with ship days. Two-day trips done monthly will permit visiting all of the bays previously studied by the Sound Ecosystem Assessment (SEA) project, as required by the RFP, as well as representative sites in central PWS, Hinchinbrook Entrance, and Montague Strait (fig 2). Two locations in each bay, at the head and at the mouth will be sampled, to measure plankton in juvenile habitats (at the head of bays) and in more open water areas used by adults.
At each of the twelve sampling locations, a suite of biological and oceanographic measurements will be made. Salinity and temperature will be measured with a SeaBird Electronics conductivity-temperature-depth (CTD) meter (0.01 ^{o}C, 0.001 S m^{-1} and 0.005 psi resolution), chlorophyll-*a* fluorescence and turbidity will be measured with a WETlabs FLNTU fluorometer (0.01 µg l^{-1} chl-a and 0.01 NTU resolution), and nitrate concentrations will be measured with a Satlantic Submersible Ultraviolet Nutrient Analyzer (SUNA; 2 µM resolution). The instrument package will be suspended beneath a bongo-style (i.e. two net) zooplankton net (60 cm mouth diameter 253 µm mesh), so that measurements can be made and zooplankton collection can be done in a single cast. A flowmeter will be suspended inside the plankton net to estimate the volume of water sampled, and one of the net samples will be preserved in 4% formalin for later analysis of taxonomic composition. The second sample, when required, will provided to other projects for energetic and biochemical analysis (see section E below).

Many zooplankton undergo daily vertical migrations to the surface at night where feeding takes place (juvenile herring also undertake a similar migration). Therefore, sampling will be done during darkness where possible, although the long day-length during summer, and short cruise times will necessitate some sampling during the day.

The proposed sampling regime is trade off between spatial and temporal completeness, the requirements of the RFP, and the costs of vessel charter. Wherever possible, automated measurements have been included to reduce analytical costs. Nutrient analysis has been confined solely to nitrate, because it has been shown to be limiting in a nearby coastal environment (Childers et al. 2005; phosphate and silicate are drawn down but not depleted) and it can be measured quickly and accurately with the SUNA instrument. Automated methods are not appropriate for zooplankton, because the taxonomic information is valuable within the context of herring feeding (herring are selective feeders: Foy and Norcross 1999). The choice of a fairly small number of stations (12) trades off spatial completeness with the time and cost required to process zooplankton samples and the need for good temporal coverage. A timeline of the activities done during each cruise is given in appendix A.

Methods

All of the instruments will be calibrated annually, and a small number of water samples will be taken with Niskin bottles to validate the observations (2 bays and 1 open water station). Water will be filtered through a Whatman GF/F filter (nominal pore size 0.7µm), which will be retained for the extraction of chlorophyll-*a* (Parsons et al. 1984), and the filtrate will be retained for colorimetric analysis of nitrate (Jones 1984). Following each cruise, quality assurance checks will be made on all the data collected, and the CTD data will be processed with standard methods; the data and associated metadata will be databased for later analysis and distribution. Zooplankton samples will be subsampled with a Folsom plankton splitter (McEwan et al. 1954), and identified to species and stage under a stereomicroscope.

C. Data Analysis and Statistical Methods

The field program will result in time series observations of temperature, salinity, chlorophyll fluorescence, turbidity, and nitrate concentration, all as a function of depth, at two locations in each of the study bays, as well as four sites representative of open water habitat and water entering and leaving PWS. Those data will be used to create temporal sections, using standard methods (e.g. Sandwell 1987; Chatfield 1995), which will then be used to describe the changes in oceanographic conditions over time within each of the bays, as well as PWS in general. Comparisons will also be made to previous observations (e.g. Meunch and Schmidt 1975; Gay and Vaughan 2001). Autocorrelation statistics such as the Mantel test (Smouse et al 1986) will be used to infer decorrelation scales between bays and the open PWS, both spatially between sites and temporally within sites.

The zooplankton collections will also provide a time series of plankton concentrations in each of the bays, in the central sound, and in the entrances and exits, although it will be depth-integrated instead of depth-specific. Differences in the concentrations of each species among the bays and open water sites will be examined with multivariate statistical methods, including hierarchical clustering and nonmetric dimensional scaling (Manly 1994). The association between plankton species and environmental parameters will also be examined with ordination techniques, including Principle Components Analysis and Redundancy Analysis (Legendre and Gallagher 2001; Clarke et al 2008).

The data will also be used to refine the conceptual model presented above (fig. 1), and the results of three different years of data collection will permit inferences about how the oceanographic climate influences the biological productivity in the nearshore and offshore waters of PWS. That data will be integrated with the data streams from several other projects in the final synthesis stage. Data on plankton taxonomy and abundance, combined with measurements of gut contents (submitted proposal "PWS herring survey: Growth and energy allocation in overwintering herring"), and knowledge of the energetics of overwintering herring (EVOSTC project 090806: "Are Herring (*Clupea Pallasi*) Energetics in PWS a Limiting Factor in Successful Recruitment of Juveniles and Reproduction Investment of Adults?") will permit testing of hypotheses about the potential for food limitation of juvenile herring in PWS.

D. Description of Study Area

Prince William Sound is a large and complicated estuarine-fjord system with numerous sub-basins around its margins. It is separated from the Gulf of Alaska (GoA) by several large islands, and surrounded on its three landward sides by the Chugach mountains. The surface waters of PWS receive considerable freshwater inputs, from streams, rivers, and icefields, as well as considerable sediment loading. Circulation in central PWS is generally anticyclonic, and driven by local winds (Vaughan et al. 2001), although there may be occasional reversals (Niebauer et al. 1994). The depth of the main basin is approximately 350 m (although there are some basins in the western part that are 700 m deep), while the depth of the sill at Hinchinbrook Entrance is approximately 200 m deep; deepwater renewal occurs mostly during the winter, though may occur episodically at other times (Niebauer et al. 1994).

Figure 3: MODIS image of southcentral Alaska taken August 22, 2003. Sediment loading from freshwater input is visible as a band along the coast. Image courtesy of MODIS Land Response Team (http://rapidfire.sci.gsfc.nasa.gov/)

An estuarine front occurs during summer and autumn near the mouth of Valdez Arm (Muench and Schmidt 1975; Vaughan et al. 2001; Okkonen et al. 2005). Okkonen et al. (2005) observed a front at Hinchinbrook entrance; satellite images (fig. 3) and personal observations from small aircraft show that there are sometimes different water masses on the western and eastern side of the entrance. The eastern side is usually turbid and makes up coastally trapped fresh water, including the outflow of the Copper River. The western side can be made up of outflowing PWS water; reflux events (where water crosses the entrance without necessarily entering PWS) also occur (Claude Belanger, pers. comm.; fig. 3). Observations upstream of the Hinchinbrook Entrance area suggest a convergent front on the offshore side of the ACC, with onshore drift in the surface Ekman layer (Royer et al. 1979) and observations downstream of PWS show offshore drift of the fresher water inshore of the front (Johnson et al. 1989).

The biological setting in the PWS area is set up by the physical environment. During the winter, nutrient availability is high, as deep, nutrient-rich water is mixed to the surface. Deep water renewal events occur in PWS but are not well described, renewal is likely set up during the summer and autumn by the on-shelf movement of deep water (Weingartner 2005). Phytoplankton production during the winter is light-limited, with a vernal bloom following the onset of stratification in the spring. Stratification is driven by the balance between the stabilizing inputs of freshwater and heat and the destabilizing influence of wind and tidal mixing. PWS is destabilized by negative heat flux and tidal mixing in the winter, and stabilized by freshwater and heat inputs in the summer (Eslinger et al. 2001; Henson 2007). In general, the spring bloom starts PWS in late March (Weingartner 2005) and is temporally broad, occurring into July

(Henson 2007). PWS also experiences an autumn bloom, as stability breaks down and nutrients are moved to the surface (Eslinger et al. 2001).

The specific dynamics of nutrient cycling in PWS are not well described. On the adjacent shelf, nitrate is depleted following the spring bloom, particularly in inshore areas (Childers et al. 2005); phosphate and silicate are also drawn down, but not depleted. Deep water in the GoA is among the most nutrient rich waters in the ocean (Reid 1965), and its movement onshore and mixing upward in the water column fuels extremely high amounts of primary production (Behrenfeld and Falkowski 1997), among the highest in the world. That production in turn fuels a diverse ecosystem, and ultimately makes its way into numerous top level predators, including birds, fish (many of which sustain large fisheries) and mammals.

E. Coordination and Collaboration with Other Efforts

The activities outlined within this project and the data produced ties in with several other proposals that have been submitted. This project would provide samples for biochemical analysis of herring prey to the project "*PWS herring survey: Growth and energy allocation in overwintering herring*", submitted by R. Heintz; samples for energetic analysis in the project "*PWS herring survey: Pacific Herring Energetic Recruitment Factors*", submitted by T. Kline; and shares several boat-days per year to provide ground truth data for the project "*PWS herring survey: Sound Wide Juvenile Herring, Predator, and Competitor Density via Aerial Surveys*", submitted by E. Brown. Plankton samples are also planned to be collected for this project during cruises made during the project "*PWS herring survey: Assessment of Juvenile Herring Abundance and Habitat Utilization*", submitted by R. Thorne.

The results from this project, following summary and synthesis, will then be integrated into the results from all the other projects, included in the integrated final report outlined in the project "*PWS herring survey: Community Involvement, Outreach, Logistics, and Synthesis*" submitted by W. Pegau. This will entail active collaboration with those researchers involved with surveys of herring locations (W. Pegau, R. Thorne, R. Heintz, and E. Brown) prior to the synthesis activities. The PI will also participate in the outreach activities outlined in that project, including community seminars, stories in print and on the radio, and an annual visit to participate in education and outreach activities at the Chugach Corporation Spirit Camp at Nuchek.

III. SCHEDULE

A. Project Milestones

Objective 1. Observe how ocean climate and the annual production cycle in PWS evolves in space and time.
To be met by April 2012

Objective 2. Make quantitative estimates of the amount of plankton food available to juvenile and adult herring.
To be met by April 2012

Objective 3. Integrate those oceanographic and plankton observations into the broader picture of herring recovery.
Outreach activities will be ongoing in all project years, data synthesis will be ongoing as well, with final synthesis goals met by April 2012.

B. Measurable Project Tasks

FY10 1st Quarter (October 1, 09 to December 31, 09)

November	2 day survey of PWS; sample analysis ongoing.
December	2 day survey of PWS; sample analysis ongoing.

FY10 2nd Quarter (January 1, 10 to March 31, 10)

January	Annual Marine Science Symposium
	2 day survey of PWS; sample analysis ongoing.
February	2 day survey of PWS; sample analysis ongoing.
March	Plankton and oceanographic sampling done during post-winter juvenile herring survey of 5 bays including 4 SEA bays, by R. Thorne.

FY10 3rd Quarter (April 1, 10 to June 30, 10)

April	2 day survey of PWS; sample analysis ongoing.
May	2 day survey of PWS; sample analysis ongoing.
	Principle Investigator update and outreach meeting
June	2 day survey of PWS; sample analysis ongoing.
	Participate in Spirit Camp program

FY10 4th Quarter (July 1, 10 to September 30, 10)

July	2 day survey of PWS; sample analysis ongoing.
August	2 day survey of PWS; sample analysis ongoing.
	Submit Annual Report
September	2 day survey of PWS; sample analysis ongoing.

FY11 1st Quarter (October 1, 10 to December 31, 10)

October	2 day survey of PWS; sample analysis ongoing.
November	2 day survey of PWS; sample analysis ongoing.
	Begin synthesis of plankton productivity and oceanography 2009-2010
December	2 day survey of PWS; sample analysis ongoing.

FY11 2nd Quarter (January 1, 11 to March 31, 11)

January	Annual Marine Science Symposium
	2 day survey of PWS; sample analysis ongoing.
February	2 day survey of PWS; sample analysis ongoing.
March	Plankton and oceanographic sampling done during post-winter juvenile herring survey of 5 bays including 4 SEA bays, by R. Thorne.

FY11 3rd Quarter (April 1, 11 to June 30, 11)

April	2 day survey of PWS; sample analysis ongoing.
May	2 day survey of PWS; sample analysis ongoing. Principle Investigator update and outreach meeting
June	2 day survey of PWS; sample analysis ongoing. Participate in Spirit Camp program

FY11 4th Quarter (July 1, 11 to September 30, 11)

July	2 day survey of PWS; sample analysis ongoing.
August	2 day survey of PWS; sample analysis ongoing. Submit Annual Report
September	2 day survey of PWS; sample analysis ongoing.

FY12 1st Quarter (October 1, 11 to December 31, 11)

October	2 day survey of PWS; sample analysis ongoing.
November	2 day survey of PWS; sample analysis ongoing. Begin synthesis of plankton productivity and oceanography 2009-2011
December	2 day survey of PWS; sample analysis ongoing.

FY012 2nd Quarter (January 1, 12 to March 31, 12)

January	Annual Marine Science Symposium 2 day survey of PWS; sample analysis ongoing.
February	2 day survey of PWS; sample analysis ongoing.
March	Plankton and oceanographic sampling done during post-winter juvenile herring survey of 5 bays including 4 SEA bays, by R. Thorne.

FY12 3rd Quarter (April 1, 12 to June 30, 12)

April	2 day survey of PWS; sample analysis ongoing.
May	2 day survey of PWS; sample analysis ongoing. Principle Investigator update and outreach meeting
June	2 day survey of PWS; sample analysis ongoing. Participate in Spirit Camp program

FY12 4th Quarter (July 1, 12 to September 30, 12)

July	2 day survey of PWS; sample analysis ongoing.
August	2 day survey of PWS; sample analysis ongoing. Submit Annual Report
September	2 day survey of PWS; sample analysis ongoing.

FY13 1st Quarter (October 1, 11 to December 31, 11)

October	2 day survey of PWS; sample analysis ongoing. First synthesis meeting of PIs

FY013 2nd Quarter (January 1, 12 to March 31, 12)

January	Alaska Marine Science Symposium
	Second synthesis meeting of PIs
March	Final synthesis meeting of PIs

FY13 3rd Quarter (April 1, 12 to June 30, 12)

April	Submit Draft Final Report
June	Respond to peer reviews

FY13 4th Quarter (July 1 to September 30, 12)

July	Secure final approval, acceptance of final report
September	Publication of final report complete, delivered to ARLIS

Curriculum vitae: Robert William Campbell

Prince William Sound Science Center
P.O. Box 705, Cordova, AK, 99574
rcampbell@pwssc.org
(907)424-5800 x241

EDUCATION

Doctor of Philosophy, University of Victoria, School of Earth and Ocean Sciences (1999-2003)
Thesis: "Overwintering ecology of Neocalanus plumchrus"
Master of Science, Biology, Dalhousie University (1996-1998)
Thesis: "Reproduction of Calanus finmarchicus in the western North Atlantic: fecundity and hatching success"
Bachelor of Science (Hons), Biology, University of Toronto (1991-1996)
Thesis: "Simulation and bioenergetic modeling of Walleye (Stizostedion v. vitreum) populations"

APPOINTMENTS

2007 – present Oceanographer, Prince William Sound Science Center
2004-2006 Post-doctoral researcher, University of Hamburg, Germany

PROFESSIONAL SOCIETY MEMBERSHIP/PROFESSIONAL SERVICE

Member, American Society of Limnology and Oceanography (1998-present)
 2007-present: Member-at-large, Education and Human Resource Image Library Subcommittee
Member, International Council for the Exploration of the Sea (Working Group Zooplankton Ecology, 2004-present)
Reviewer, National Science Foundation, Exxon Valdez Trustee Council, Canadian Journal of Fisheries and Aquatic Sciences, Deep-Sea Research, ICES Journal of Marine Science, Journal of Marine Systems, Journal of Plankton Research, Marine Ecology Progress Series, Progress in Oceanography.

CURRENT ACTIVITIES RELEVANT TO THE PROPOSED PROJECT

1. Murdoch Foundation grant to purchase, outfit and deploy a Hydro-Bios (Kiel) Multiple Plankton Sampler (“Multi-net”). This project is complete: the net has been deployed several times in 2007 and 2008.
2. EVOSTC funded project (“Herring forage contingency”) to measure plankton and herring distributions in Prince William Sound. Responsible for sample collection, data analysis, and synthesis.
3. NOAA funded project (Alaska Ocean Observing System) to deploy satellite-telemetered nearshore moorings measuring temperature, salinity, fluorescence and turbidity. A pilot mooring was deployed in 2008, two more were deployed in early 2009.
4. OSRI funded project to develop and plan a technical and socioeconomic synthesis of research conducted in Prince William Sound.
5. NPRB project #806, collaborator, for collection of *Euphasia pacifica* for laboratory incubations.

6. ONR funded project "Long term *in situ* chemical sensors for monitoring nutrients", responsible for test deployments of two *in situ* nutrient analyzers and collection and analysis of validation samples.

5 RELEVANT PUBLICATIONS

1. Campbell, R.W and J.F. Dower. 2008. Life history and depth distribution of *Neocalanus plumchrus* in the Strait of Georgia. J. Plankton Res. 30:7-20.
2. Kattner, G., Hagen, W., Lee, R.F., Campbell, R.W., Deibel, D., Falk-Petersen, S., Graeve, M., Hansen, B.W., Hirche, H.J., Jonasdottir, S.H., Madsen, M.L., Mayzaud, P., Müller-Navarra, D., Nichols, P., Paffenhöffer, G.A., Pond, D., Saito, H., Stübing, D., and P. Virtue. 2007. Perspectives on zooplankton lipids. Can. J. Fish. Aquat. Sci. 64:1628-1639.
3. Campbell, R.W., Boutillier, P. and J.F. Dower. 2004. Ecophysiology of overwintering in the copepod *Neocalanus plumchrus*: Changes in lipid and protein contents over a seasonal cycle. Mar. Ecol. Prog. Ser. 280:211-226.
4. Campbell, R.W. and J.F. Dower. 2003. The role of lipids in the regulation of buoyancy by zooplankton. Mar. Ecol. Prog. Ser. 263:93-99.
5. Irigoien, X., Harris, R.P., Verheye, H.M., Joly, P., Runge, J.A., Starr, M. Pond, D., Campbell, R.W., Shreeve, R., Ward, P., Smith, A.N., Dam, H.G., Napp, J., Peterson, W., Tirelli, V., Koski, M., Smith, T., Harbour, D., Strom, S. and R. Davidson. 2002. Copepod Hatching Success Rate in Marine Ecosystems With with High Diatom Concentrations - the Paradox of Diatom-Copepod Interactions Revisited. Nature. 419:387-389.

RECENT COLLABORATORS

E. Acheampong (University of Hamburg); P. Boutillier (Department of Fisheries and Oceans); R.T. Cooney, (UAF emeritus); J. Crusius (USGS); D. Deibel (Memorial University of Newfoundland); A.B. Diekmann (University of Hamburg); J.F. Dower (University of Victoria); S. Falk-Petersen (Norwegian Polar Institute); L. Feinburg (Oregon State University); M. Graeve (Alfred Wegener Institute for Polar and Marine Research); G. Gust (Technical University of Hamburg); W. Hagen (University of Bremen); B.W. Hansen (University of Roskilde); P. Hershberger (USGS); H-J. Hirche (Alfred Wegener Institute for Polar and Marine Research); S.H. Jónasdóttir (Danish Institute for Fisheries Research); G. Kattner (Alfred Wegener Institute for Polar and Marine Research); W. Lee (Skidaway Institute of Oceanography); M.L. Madsen (University of Roskilde); P. Mayzaud (Laboratoire d'Océanographie de Villefranche); K.O. Möller (University of Hamburg); D. Müller-Navara (University of Hamburg); D. Nichols (Commonwealth Scientific and Industrial Research Organization); M.H. Nielsen (Technical University of Denmark); S. Pegau (OSRI); G.A. Paffenhöffer (Skidaway Institute of Oceanography); W.T. Peterson (NOAA); M. Peck (University of Hamburg); D. Pond (British Antarctic Survey); H. Saito (Nation Research Institute of Fisheries Science); A. Schroth (USGS); C.J. Stevens (National Institute of Water and Atmospheric Research, NZ); M.A. St. John (University of Hamburg); D. Stübing (University of Bremen); A. Temming (University of Hamburg); P. Virtue (University of Tasmania).

Budget Justification

Personnel: ($65.6K in FY10, $67.6K in FY11, $69.6K in FY12 and $42.4K in FY13)

Principal investigator Robert Campbell will dedicate 6 months of time and 31 sea days during years 1 through 3. During the final synthesis year, 4 months is requested for synthesis activities, and 1.5 months is requested for the production of a peer-reviewed scientific publication. Technical assistance is requested for the analysis of plankton, nutrient and chlorophyll samples (Ms. Jennifer Todd, an employee of PWSSC) for three months per year in years 1 through 3. A 3% cost-of-living increase is included in each year of the project.

Travel: ($1K in FY10, $1K in FY11, $1K in FY12 and $1K in FY13)

Travel is requested to attend the Alaska Marine Science Symposium in Anchorage in each of the four project years. The stay in Anchorage will be extended during the final year to attend the second integration meeting for PIs in FY 13. No travel is requested for the other integration meetings, they are planned to be held in Cordova.

Contractual: ($70.3K in FY10, $69.3K in FY11, $69.3K in FY12 and $2.2K in FY13)

All of the instruments (CTD, fluorometer, SUNA) require annual service and calibration, $1000 per instrument is requested in the first three years. Charter of a small fast boat (a PWS bowpicker) is budgeted at $2100 per day including fuel, for approximately monthly surveys (24 days per year). Six days per year (an additional two days to be added to the sorties in June, July and August) are requested do ground-truthing for the aerial surveys proposed by E. Brown ("PWS herring survey: Sound Wide Juvenile Herring, Predator, and Competitor Density via Aerial Surveys"). A single day is also requested in each year to stop over at Port Etches in July in order to participate in the Spirit Camp program activities. A $1000 allowance for shipping of equipment and sampling supplies is requested in year 1. A small amount for network and telephone use ($150 per month) and printing ($50 per month) is requested in each year. In the final year $1000 is requested for page charges for the production of a peer-reviewed publication. The page charge will be used to purchase open access rights to the publication.

Commodities ($4.5K in FY10, $3.5K in FY11 and $3.5K in FY12)

$2500 is requested in the first three years for the purchasing of reagents and supplies for measurements of nutrients and chlorophyll-*a* and associated calibration standards. Sample containers are budgeted in the first year at $1000. Miscellaneous sampling equipment (ropes, shackles, sheaves, tools, etc.) is budgeted at $1000 per year in each of the first three years.

Equipment: ($3K in FY10)

Funds for the purchase of a new plankton net and plankton splitter and sample containers is requested in year 1 ($2500 and $500 respectively).

Indirect Costs: ($40.4K in FY10, $39.6K in FY11, $40.2K in FY12 and $12.9K in FY13)

Prince William Sound Science Center has a pending federally approved indirect rate of 28.01% on modified total direct costs (excluding equipment, subawards in excess of $25,000, and tuition).

Other Support/In kind Contributions for the Prince William Sound Science Center

Equipment:
The Science Center will contribute all field sampling gear excepting the plankton net, including a CTD, chlorophyll fluorometer, transmissometer, Submersible Ultraviolet Nitrate Analyser, ropes, cables and sampling bottles. The field equipment has a replacement value of on order of $50000. The Science Center will also contribute a Varian Cary 50 spectrophotometer for the analysis of chlorophyll and nutrients and assorted laboratory glassware, with an approximate replacement value of $20000. For cost sharing purposes the annual contribution is estimated as 1/3 of the replacement value.

Data Management and Quality Assurance/Quality Control ("QA/QC") Statement.

1. Study design, sample types and locale

The sampling design of this study is a tradeoff between spatial and temporal completeness, and sampling costs. By using a relatively inexpensive and fast boat, the four SEA bays specified in the FY10 RFP may be visited at temporally appropriate scales (order of monthly) to see the succession of the most common planktonic taxa. In each bay, a sample will be taken in the nearshore area at the head of the bay where age-0 juveniles tend to reside, and at an open water station, where later stage juveniles and adults are more likely to occur. Reference stations will also be visited at the primary entrance (Hinchinbrook entrance) and exit (Montague Strait) of PWS, as well as a single station in central PWS. At each sampling instance, depth-specific measurements will be made of temperature, conductivity, chlorophyll fluorescence, turbidity, and nitrate concentration. Water samples will be taken occasionally to measure particulate chlorophyll fluorescence and nitrate concentration, to validate the depth-specific observations. Zooplankton will be collected with a 60 cm mouth diameter, 253 μm mesh plankton net.

2. Data and collection characteristics

Inasmuch as is possible, the collection method will be standardized such that samples are all collected in the same manner. The instrument package will be suspended beneath the plankton net, so that all sampling may be accomplished in a single cast, and the plankton net will be towed at a constant velocity (1 m s^{-1}). A flowmeter will be suspended in the mouth of the plankton net so that sampled volume may be estimated.

Conductivity, temperature and depth will be measured with a SeaBird Electronics model SBE19 CTD (0.01 ^{o}C, 0.001 S m^{-1} and 0.005 psi resolution); chlorophyll-*a* fluorescence and turbidity will be measured with a WETlabs FLNTU fluorometer (0.01 μg l^{-1} chl-*a* and 0.01 NTU resolution); and nitrate concentrations will be measured with a Satlantic Submersible Ultraviolet Nutrient Analyzer (SUNA; 2 μM resolution). The FLNTU and SUNA will be interfaced through the CTD. The CTD samples at 2 Hz, so the depth resolution of all of the samples will be on order of 0.5 m. All of the data is stored in memory in the CTD and will be uploaded as soon as possible following the cast so that the data may be visually checked to see that it is within appropriate limits.

Water samples will be collected with a series of standard 5 L Niskin bottles. At shallow stations (< 50 m depth) the bottles will be spaced to cover the entire water column. At deep stations (> 50 m depth) samples will be collected at the surface, 5 m, 10 m 25 m and 50 m.

Each sampling instance in each sortie will be assigned a unique event number, and that number and other metadata (position, time, date, depth, wire angle) will be recorded on standard paper log sheets that will be later transferred to an electronic format. Following each cruise, quality assurance checks will be done in software and questionable data flagged. CTD data will be processed with standard software and the data and associated metadata will be retained in electronic format for later analysis and distribution.

Upon return to the laboratory, zooplankton taxa from the net samples will be enumerated under a binocular microscope. In the case of very abundant taxa, the sample will be successively split with a Folsom splitter until a fraction is arrived at that contains an appropriate number of individuals. In general, at least 200 individuals are required for an accurate count (McEwen et al. 1954; Cassie 1968).

3. Criteria and procedures for determining data quality

The CTD, fluorometer, and SUNA will be returned to the manufacturer annually for maintenance and calibration at their facilities. *In situ* data will be compared to the validation samples to ensure accuracy. Chlorophyll-*a* and nitrate will be measured colorimetrically using standard methods and a Varian Cary-50 spectrophotometer. In the case of nitrate measurements, a potassium nitrate calibration curve will be generated every time samples are analyzed. An annual calibration curve will be done for chlorophyll-*a*, because standard solutions are expensive and unstable.

4. Conversion algorithms

Conversion of pressure, temperature and conductivity frequency measurements made by the CTD are done with standard software available from the manufacturer (ftp://ftp.halcyon.com/pub/seabird/OUT/). Salinity is calculated from conductivity, using the equation given by Fofonoff and Millard (1983). Seawater density is calculated with the UNESCO equation of state (Fofonoff and Millard 1983). *In situ* chlorophyll fluorescence and turbidity are measured as voltages and are calculated with a linear relationship:

Chl-*a* / turbidity = Scale factor x (voltage – dark voltage).

Where the scale factor and dark voltage are determined empirically during calibration.

The SUNA determines nitrate concentration using the UV absorption spectrum method of Johnson and Coletti (2002); the algorithms are implemented in software provided by the manufacturer (www.satlantic.com).

5. Sample handling

Water samples will be gently passed with a 60 ml syringe through a Millipore Swinnex™ filter holder, containing a Whatman GF/F filter (nominal pore size 0.7µm), which will be frozen in tin foil for the extraction of chlorophyll-*a* ($\mu g\ l^{-1}$; Parsons et al. 1984). The filtrate will be collected in a 30 ml polyethylene bottle and will be frozen and retained for colorimetric analysis of nitrate (µM; Jones, 1984). The syringe bodies, filter holders and bottles will be acid-cleaned in 10% HCl prior to use. Zooplankton samples will be preserved in 4% formalin in polycarbonate bottles. It is not anticipated that the samples will leave the possession of PWSSC staff during the study, but the samples will be retained following analysis and will be made available to any other researchers who wish to use them. All sample containers will be labeled on the side of the container (i.e. not on the lid) with an indelible marker, and the label will include the sortie designator, event number, position, date, depth and sample type.

Literature cited:

Behrenfeld, M.J. and P.G. Falkowski. 1997. Photosynthetic rates derived from satellite-based chlorophyll concentration. Limnology and Oceanography **42:**1-20.

Blaxter, J.H.S., and J.R. Hunter 1982. The biology of the clupeoid fishes. Advances in Marine Biology **20:**1–223.

Carls, M. G., Marty, G. D., and Hose, J. E. 2002. Synthesis of the toxicological impacts of the Exxon Valdez oil spill on Pacific herring (Clupea pallasi) in Prince William Sound, Alaska, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences, **59:**153–172.

Cassie, R.M. 1968. Sample design. pp. 105-122 *in*: Zooplankton Sampling. The UNESCO Press, Paris.

Chatfield, C. 1989. The analysis of time series (4^{th} ed.).Chapman & Hall, London. 241pp.

Childers, A.R. Whitledge, T.E. and D.A. Stockwell. 2005. Seasonal and interannual variability in the distribution of nutrients and chlorophyll *a* across the Gulf of Alaska shelf: 1998-2000. Deep Sea Research II **52:** 193-216.

Clarke, K.R., Somerfield, P.J. and R.N. Gorely. 2008. Testing of null hypotheses in exploratory community analysese: similarity profiles and biota-environment linkage. Journal of Experimental Marine Biology and Ecology. **366:**56-69.

Cooney, R.T., Allen, J.R., Bishop, M.A., Eslinger, D.L., Kline, T., Norcross, B.L., Mcroy, C.P., Milton, J., Olsen, J., Patrick, V., Paul, A.J., Salmon, D., Scheel, D., Thomas, G.L., Vaughan, S.L. and T.M. Willette. 2001a. Ecosystem controls of juvenile pink salmon (*Onchorynchus gorbuscha*) and Pacific herring (*Clupea pallasi*) populations in Prince William Sound, Alaska. Fisheries Oceanography. **10(Suppl. 1):**1-13.

Cooney, R.T., Coyle, K.O., Stockmar, E. and C. Stark. 2001b. Seasonality in surface-layer net zooplankton communities in Prince William Sound, Alaska. Fisheries Oceanography. **10(Suppl. 1):**97-109.

Deriso, R.B., Maunder, M.N. and W.H. Pearson. 2008. Incorporating covariates into fisheries stock assessment models with application to Pacific Herring. Ecological Applications. **18:**1270-1286.

Edwards, M. and A.J. Richardson. 2004. Impact of climate change on marine pelagic phenology and trophic mismatch. Nature. **430:**881-884.

Eslinger, D.L., Cooney, R.T., Mcroy, C.P., Ward, A., Kline, T.C., Simpson, E.P., Wang, J. and J.R. Allen. 2001. Plankton dynamics: observed and modeled responses to physical conditions in Prince William Sound, Alaska. Fisheries Oceanography. **10(Suppl. 1):**81-96.

Exxon Valdez Oil Spill Trustee Council. 2008. Prince William Sound integrated herring restoration program. Draft report dated Dec. 31, 2008.

Fofonoff, P. and Millard, R.C. Jr. 1983. Algorithms for computation of fundamental properties of seawater. UNESCO Technical Paper in the Marine Sciences. **44.** 53 pp.

Foy, R.J. and B.L. Norcross. 1999. Spatial and temporal differences in the diet of juvenile Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska. Canadian Journal of Zoology. **77:**697-706.

Foy, R.J. and A.J. Paul. 1999. Winter feeding and changes in somatic energy content for age-0 Pacific herring in Prince William Sound, Alaska. Transactions of the American Fisheries Society. **128:**1193-1200.

Gay., S.M. and S.L. Vaughan. 2001. Seasonal hydrography and tidal currents of bays and fjords in Prince William Sound, Alaska. Fisheries Oceanography. **10(Suppl. 1):**159-193.

Hay, D.E., R. Toreson, R. Stephenson, M. Thompson, R. Claytor, F. Funk, E. Ivshina, J. Jakobsson, T. Kobayashi, I.H. McQuinn, G. Melvin, J. Molloy, N. Naumenko, K.T. Oda, R. Parmanne, M. Power, V. Radchenko, J. Schweigert, J. Simmonds, B. Sjöstrand, D.K. Stevenson, R. Tanasichuk, Q. Tang, D.L. Watters and J. Wheeler. 2001. Taking stock: an inventory and review of world herring stocks in 2000. pp. 381-454 *in*: F. Funk, J. Blackburn and D. Hay (eds). Herring: expectations for a new millennium. University of Alaska Sea Grant. Fairbanks, Alaska 800 p.

Henson, S.A. 2007. Water column stability and spring bloom dynamics in the Gulf of Alaska. Journal of Marine Research. **65:**715-736.

Hulson, J.F., Miller, S.E., Quinn, T.J., Marty, G. D., Moffitt, S. D. and F. Funk. 2008. Data conflicts in fishery models: incorporating hydroacoustic data into the Prince William Sound Pacific herring assessment model. ICES Journal of Marine Science. **65:**25 - 43.

Huntley, M.E. and M.D.G. Lopez. 1992.Temperature dependent production of marine copepods: a global synthesis. The American Naturalist. **140:**201-242.

Johnson, K.S. and L.J. Coletti. 2002. In situ ultraviolet spectrophotometry for high resolution and long-term monitoring of nitrate, bromide and bisulfide in the ocean. Deep Sea Research. **49:**1291-1305.

Johnson, W.R., Royer, T.C. and J.L. Luick. 1988. On the Seasonal Variability of the Alaska Coastal Current. Journal of Geophysical Research. **93**:12423-12437.

Jones, M.N. 1984. Nitrate reduction by shaking with cadmium. Water Research. **18:**643-646.

Legendre, P. and E.D. Gallagher. 2001. Ecologically meaningful transformations for ordination of species data. Oecologia. **129:**271-280.

Mackas, D.L., R. Goldblatt, and A.G. Lewis. 1998. Interdecadal variation in developmental timing of *Neocalanus plumchrus* populations at ocean station P in the subarctic north Pacific. Canadian Journal of Fisheries and Aquatic Sciences. **55:**1878-1893.

Manley, B.F.J. 1994. Multivariate Statistical Methods (2nd ed.). Chapman & Hall, London. 215 pp.

Marty, G.D., Freiberg, E.F., Meyers, T.R., Wilcock, J., Farver, T.B., and D.E. Hinton. 1998. Viral hemorrahagic septicemia virus, *Ichthyophonus hoferi*, and other causes of morbidity in Pacific herring *Clupea pallasi* spawning in Prince William Sound, Alaska, USA. Diseases of Aquatic Organisms **32:**15–40.

McEwen, G.F., Johnson M.W. and T.R. Folsom. 1954. A statistical analysis of the performance of the Folsom plankton sample splitter, based upon test observations. Archiv fur Meteorologie, Geophysik und Bioklimatologie A **6:**502-527.

Meunch, R.D. and C.M. Schmidt. 1975. Variations in the hydrographic structure of Prince William Sound. IMS/Sea Grant Report R75-1. University of Alaska Institute of Marine Science, Fairbanks.

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

Okkonen, S.R., Cutchin, D.L., and T.C. Royer. 2005. Seasonal variability of near-surface hydrography and frontal features in the northern Gulf of Alaska and Prince William Sound. Geophys. Res. Lett. **32**, L11611, doi:10.1029-2005GL023195.

Parsons, T.R., Y.Maita and C.M. Lalli. 1984. A manual of biological and chemical methods for seawater analysis. Pergamon Press, Oxford. 173 pp.

Pearson, W.H., Elston, R.A., Bienert, R.W., Drum, A.S., and L.D. Antrim 1999. Why did the Prince William Sound, Alaska, Pacific herring (*Clupea pallasi*) fisheries collapse in 1993 and 1994? Review of hypotheses. Canadian Journal of Fisheries and Aquatic Sciences. **56:** 711–737.

Reid, J.L. 1965. Intermediate waters of the Pacific Ocean. John Hopkins Press, Baltimore. 85 pp.

Royer, T.C., Hansen, D.V. and D.J Pashinski. 1979. Coastal flow in the northern Gulf of Alaska as observed by dynamic topography and satellite-tracked drouged drift buoys. Journal of Physical Oceanography. **9:**785-801.

Sandwell, D.T. 1987. Biharmonic Spline Interpolation of GEOS-3 and SEASAT Altimeter Data. Geophysical Research Letters **2:**139-142.

Smouse, P.E., J.C. Long, and R.R. Sokal. 1986. Multiple regression and correlation extensions of the Mantel test of matrix correspondence. Systemic Zoology. **35:** 627-632.

Thorne, R. E., and Thomas, G. L. 2008. Herring and the "Exxon Valdez" oil spill: an investigation into historical data conflicts. ICES Journal of Marine Science. **65:**44–50.

Vaughan, S.L., Mooers, C.N.K. and S.M. Gay III. 2001. Physical variability in Prince William Sound during the SEA study (1994-1998). Fisheries Oceanography **10(Suppl. 1):**58-50.

Weingartner, T. 2005. Physical and geological oceanography: coastal boundaries and coastal and ocean circulation. pp. 35-48 *in:* Mundy, P.R. (Ed.) The Gulf of Alaska: biology and oceanography. Alaska Sea Grant, Fairbanks. 214 pp.

Appendix 1: Cruise logistics

The following is a calculation of the time required for travelling between stations and station operations. The cruising speed (20 kts) is a conservative estimate of the cruising speed of a PWS bowpicker. SB = Simpson Bay; EB = Eaglek Bay; WB = Whale Bay; ZB = Zaikof Bay; MS = Montague Strait; HE = Hinchinbrook entrance.

Activity	Distance (nm)	Speed (kts)	Time (h)	Elapsed Time (h)
Transit Cordova to SB	13	20	0.65	0.65
SB head station			0.5	1.15
Transit SB head to SB mouth	3.5	20	0.175	1.325
SB mouth station			0.5	1.825
Transit SB mouth to central PWS	31.5	20	1.575	3.4
Central PWS station			0.5	3.9
Transit central PWS to EB	28.5	20	1.425	5.325
EB head station			0.5	5.825
Transit EB head to EB mouth	6	20	0.3	6.125
EB mouth station			0.5	6.625
Transit EB mouth to WB	46	20	2.3	8.925
WB head station			0.5	9.425
Transit WB head to WB mouth	6	20	0.3	9.725
WB mouth station			0.5	10.225
Transit WB to MS	19	20	0.95	11.175
MS station			0.5	11.675
Transit MS to ZB	41.5	20	2.075	13.75
ZB head station			0.5	14.25
Transit ZB head to ZB mouth	6	20	0.3	14.55
ZB mouth station			0.5	15.05
Transit ZB to HE West	9.5	20	0.475	15.525
HE West station			0.5	16.025
Transit HE West to HE east	4	20	0.2	16.225
HE East station			0.5	16.725
Transit HE East to Cordova	50	20	2.5	19.225

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 10- FY 12

Budget Category:	Proposed FY 10	Proposed FY 11	Proposed FY 12	Proposed FY 13	TOTAL PROPOSED
Personnel	$65.6	$67.6	$69.6	$42.4	$245.2
Travel	$1.0	$1.0	$1.0	$1.6	$4.6
Contractual	$70.3	$69.3	$69.3	$2.2	$211.1
Commodities	$4.5	$3.5	$3.5	$0.0	$11.5
Equipment	$3.0	$0.0	$0.0	$0.0	$3.0
Indirect *(will vary by proposer)*	$ 40.4	$ 39.6	$ 40.2	$ 12.9	$133.1
SUBTOTAL	$184.8	$181.0	$183.6	$59.1	$608.4
General Administration (9% of subtotal)	$16.6	$16.3	$16.5	$5.3	$49.4
PROJECT TOTAL	$201.5	$197.3	$200.1	$64.4	$598.8
Other Resources (Cost Share Funds)	$23.3	$23.3	$23.3	$0.0	$70.0

COMMENTS: The Science Center will contribute all field sampling gear excepting the plankton net, including a CTD, chlorophyll fluorometer, transmissometer, Submersible Ultraviolet Nitrate Analyser, ropes, cables and sampling bottles. The field equipment has a replacement value of on order of $50000. The Science Center will also contribute a Varian Cary 50 spectrophotometer for the analysis of chlorophyll and nutrients and assorted laboratory glassware, with an approximate replacement value of $20000. For the purposes of cost share calcuations, the annual cost is estimated at 1/3 of the replacement cost.

FY10 - 13

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4A
NON-TRUSTEE
AGENCY SUMMARY

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

Personnel Costs: Name	Project Title	GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Personnel Sum
Robert Campbell	Principle Investigator		6.0	7.1		42.6
Robert Campbell (at sea rate)	Principle Investigator		1.0	7.7		7.7
Jennifer Todd	Technician		3.0	5.1		15.3
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		10.0	19.9	0.0	
					Personnel Total	$65.6

Travel Costs: Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Travel Sum
Alaska Marine Science Symposium	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

FY10

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B PERSONNEL & TRAVEL DETAIL

EXXON VALDEZ **OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

Contractual Costs: Description	Contract Sum
Instrument calibration	3.0
Vessel Charter	65.1
Shipping	1.0
Network and telephone	0.9
Printing	0.3
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$70.3

Commodities Costs: Description	Commodities Sum
Reagents and lab supplies	2.5
Sample containers	1.0
Sampling hardware	1.0
Commodities Total	$4.5

FY10

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B CONTRACTUAL & COMMODITIES DETAIL

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 10- FY 12

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
Plankton net	1.0	2.5	2.5
Plankton splitter	1.0	0.5	0.5
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
		New Equipment Total	$3.0

Existing Equipment Usage: Descriptior	Number of Units	Inventory Agency
CTD	1	PWSSC
Fluorometer/turbidometer	1	PWSSC
Submersible Ultraviolet Nitrate Analyser	1	PWSSC
Varian Cary 50 spectrophotometer	1	PWSSC

FY10

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B EQUIPMENT DETAIL

EXXON VALDEZ **OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

Personnel Costs: Name	Project Title	GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Personnel Sum
Robert Campbell	Principle Investigator		6.0	7.3		43.8
Robert Campbell (at sea rate)	Principle Investigator		1.0	7.9		7.9
Jennifer Todd	Technician		3.0	5.3		15.9
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		10.0	20.5	0.0	
					Personnel Total	$67.6

Travel Costs: Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Travel Sum
Alaska Marine Science Symposium	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

FY11

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B PERSONNEL & TRAVEL DETAIL

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 10- FY 12

Contractual Costs: Description	Contract Sum
Instrument calibration	3.0
Vessel Charter	65.1
Network and telephone	0.9
Printing	0.3
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$69.3

Commodities Costs: Description	Commodities Sum
Reagents and lab supplies	2.5
Sampling hardware	1.0
Commodities Total	$3.5

FY11

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B CONTRACTUAL & COMMODITIES DETAIL

EXXON VALDEZ **OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
			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
		New Equipment Total	$0.0

Existing Equipment Usage: Descriptior	Number of Units	Inventory Agency
CTD	1	PWSSC
Fluorometer/turbidometer	1	PWSSC
Submersible Ultraviolet Nitrate Analyser	1	PWSSC
Varian Cary 50 spectrophotometer	1	PWSSC

FY11

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B EQUIPMENT DETAIL

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

Personnel Costs: Name	Project Title	GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Personnel Sum
Robert Campbell	Principle Investigator		6.0	7.5		45.0
Robert Campbell (at sea rate)	Principle Investigator		1.0	8.1		8.1
Jennifer Todd	Technician		3.0	5.5		16.5
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		10.0	21.1	0.0	
					Personnel Total	$69.6

Travel Costs: Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Travel Sum
Alaska Marine Science Symposium	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

FY12

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B PERSONNEL & TRAVEL DETAIL

EXXON VALDEZ **OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

Contractual Costs: Description	Contract Sum
Instrument calibration	3.0
Vessel Charter	65.1
Network and telephone	0.9
Printing	0.3
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$69.3

Commodities Costs: Description	Commodities Sum
Reagents and lab supplies	2.5
Sampling hardware	1.0
Commodities Total	$3.5

FY12

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B CONTRACTUAL & COMMODITIES DETAIL

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
			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
		New Equipment Total	$0.0

Existing Equipment Usage: Descriptior	Number of Units	Inventory Agency
CTD	1	PWSSC
Fluorometer/turbidometer	1	PWSSC
Submersible Ultraviolet Nitrate Analyser	1	PWSSC
Varian Cary 50 spectrophotometer	1	PWSSC

FY12

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B EQUIPMENT DETAIL

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 10- FY 12

Personnel Costs: Name	Project Title	GS/Range/ Step	Months Budgeted	Monthly Costs	Overtime	Personnel Sum
Robert Campbell	Principle Investigator		5.5	7.7		42.4
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		5.5	7.7	0.0	
					Personnel Total	$42.4

Travel Costs: Description	Ticket Price	Round Trips	Total Days	Daily Per Diem	Travel Sum
Alaska Marine Science Symposium / Synthesis meeting	0.4	1	6	0.2	1.6
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$1.6

FY13

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B PERSONNEL & TRAVEL DETAIL

EXXON VALDEZ **OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

Contractual Costs: Description	Contract Sum
Network and telephone	0.9
Printing	0.3
Publication costs	1.0
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$2.2

Commodities Costs: Description	Commodities Sum
Commodities Total	$0.0

FY13

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B CONTRACTUAL & COMMODITIES DETAIL

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 10- FY 12

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
			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
		New Equipment Total	$0.0

Existing Equipment Usage: Descriptior	Number of Units	Inventory Agency

FY13

Project Title: PWS herring survey: Plankton and oceanographic observations, submitted under the BAA
Lead PI: Robert W. Campbell

FORM 4B EQUIPMENT DETAIL

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

EXXON VALDEZ **OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 10- FY 12

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 10- FY 12

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 10- FY 12

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12

EXXON VALDEZ **OIL SPILL TRUSTEE COUNCIL**

DETAILED BUDGET FORM FY 10- FY 12

EXXON VALDEZ **OIL SPILL TRUSTEE COUNCIL**

DETAILED BUDGET FORM FY 10- FY 12

EXXON VALDEZ OIL SPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 10- FY 12

EXXON VALDEZ **OIL SPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 10- FY 12