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GEM PROPOSAL SUMMARY PAGE

(To be filled in by proposer)

Project Title:	G-040635 Trophic dynamics of intertidal soft-sediment communities: interaction between top-down and bottom-up processes (Renewal, Submitted under the BAA)
Project Period:	FY 04-FY 06
Proposer(s):	Dr. Mary Anne Bishop (Prince William Sound Science Center), Dr. Sean P. Powers (University of South Alabama)
Study Location:	Southeast Prince William Sound (Orca Inlet) and the Copper River Delta

Abstract: Vast expanses of intertidal sand/mudflats serve as a critical link in the food web of nearshore communities along the southcentral Alaska coastline. The rich abundance of benthic invertebrates residing within the sediments of intertidal flats and the large network of subtidal channels that bisect these flats provide a significant prey resource for numerous species of fish, crabs, birds, and marine mammals. One of the largest expanses of intertidal mud/sand flats occurs in the Copper River Delta and southeastern Prince William Sound (Orca Inlet). Here we propose a large-scale field study that examines the physical/chemical and biological factors that limit and/or regulate invertebrate community dynamics. The largely "bottom-up" approach we propose (physical/chemical parameters – phytoplantkon/epibenthic production – invertebrate production) is balanced by the largely "top-down" focus of a companion project funded by the Prince William Sound Oil Spill Recovery Institute that examines predator dynamics and assesses their role in invertebrate community dynamics. At the completion of this project (FY 06), the results of both projects will be synthesized and a subset of key physical/chemical parameters will be identified for long- term monitoring.

Funding:				
	EVOS Funding Requested:	FY 04	$ 149,500	
		FY 05	$ 164,000	
		FY 06	$ 151,400	TOTAL: $464,900
	Non-EVOS Funds to be Used:	FY 04	$ 99,900	
		FY 05	$ 99,900	
		FY 06	$ 99,900	TOTAL: $298,500

Date: June 14, 2003

I. NEED FOR THE PROJECT

A. Statement of Problem

Nearshore habitats (e.g., intertidal and subtidal mudflats, rocky outcroppings, cobble beaches, sea grass meadows and kelp beds) are an integral component of the Gulf of Alaska ecosystem serving as essential nursery and feeding grounds for numerous marine, avian and terrestrial species (Peterson 2001). These highly productive habitats are characterized by elevated densities of invertebrate prey that, in turn, provide a critical prey resource for fish, crabs, shorebirds, waterfowl and mammals (Peterson and Peterson 1979; Powers et al. 2002). Because many nearshore habitats are intertidal (e.g., rocky intertidal and tidal flats), these communities are available to consumers from a variety of adjacent habitats, i.e., marine, terrestrial, and aerial predators (Leigh et al. 1987). Consequently, nearshore habitats represent a critical component of both marine and terrestrial landscapes in coastal Alaska and a primary factor explaining the ecosystem's rich diversity and high productivity (Peterson 2001). Further, the utilization of nearshore habitats by highly migratory, avian fauna link changes in Alaskan nearshore habitats to regional and global systems.

Vast expanses of intertidal and shallow subtidal mudflats are a ubiquitous feature of the southcentral Alaskan coastline and in many areas represent the dominant nearshore marine habitat. One of the largest expanses of intertidal and shallow subtidal flats occurs at the terminus of the Copper River. Large expanses of mudflats also occur throughout Controller Bay, Cook Inlet, and in northern Bristol Bay with more modest expanses of intertidal mudflats scattered throughout small embayment along the Alaska coastline. Located at the eastern edge of Prince William Sound near the port of Cordova, the vast 500-km^2 mudflats of the Copper River Delta stretch almost continuously for 80 km from Egg Island to Castle Island, and from Kokinhenik Island to Softuk Bar. Extensive mudflats also occur in Orca Inlet, a large bay in southeast Prince William Sound influenced by the Copper River. The vast network of intertidal mudflats and shallow sloughs that meander through the flats of the Copper River Delta and Orca Inlet serve as a critical connection between the Gulf of Alaska and the vast expanse of freshwater wetlands, rivers, lakes and glaciers.

The tidal flats of the Copper River Delta provide foraging habitat for a variety of migratory (shorebirds and salmonid fish) and resident demersal species (e.g., dungeness crabs, Pacific halibut, lingcod). Over 4 million shorebirds, the largest spring concentration of shorebirds in the Western Hemisphere (Isleib 1979, Bishop et al. 2000) visit the Copper River flats annually between late April and mid-May on their way to breeding grounds in western Alaska. The Delta also supports a substantial commercial and subsistence fishery that is an integral element of the local economy: some 549 gillnet fishers commercially harvest 3 species of salmon in the estuarine portion of Copper River Delta. Equally important, subsistence fishing provides an important food source for residents of Cordova and the upper Copper River watershed. In 1990 nearly 6,000 households participated in the Copper River subsistence and personal use fishery. Sockeye salmon (*Oncorhyncus nerka*) is the most important species fished by Copper River commercial and subsistence users, followed by chinook *(O. tshawytscha*) and coho salmon (*O. kisutch)* salmon. In addition, recreational anglers targeting mainly coho and chinook are the primary support for local hotels, lodges and restaurants. The economic and cultural role of salmon harvest is similar in many coastal cities along the Alaska coastline (*e.g.,* Homer, Kodiak, and Dillingham). The tidal flats serve as both an entry and exit corridor for these salmon. The fish migrate through the delta first as smolts (i.e., late-stage juveniles) leaving freshwater habitats and then again as adults attempting to return to the same freshwater habitats to spawn (Christensen et al., 2000). The duration of stay on the delta is unknown for adult and juvenile salmonids. Given that harpacticoid copepods and amphipods make up a significant portion of smolt diets (Willette, 2002), the tidal flats of the Copper River Delta could serve as a potentially important feeding ground for these fish.

The unique interface of land, sea and air characteristic of intertidal habitats serves to promote high biological productivity within the intertidal and adjacent subtidal habitats. The land provides a substratum for the occupation of intertidal organisms, the seawater facilitates import and export of nutrients and larvae, and the air provides a medium for passage of solar energy and a source of physical stress (Peterson 2001). In addition to high levels of internal energy production (e.g., benthic microalgae and macroalgae, Pinckney and Zingmark 1993), many intertidal areas receive substantial energy subsidies because they serve as the interface between the oceanic photic zone and coastal river runoff (Raffaelli and Hawkins 1996). Whereas tidal energy and wind subsidize the intertidal zone with planktonic foods produced in the photic zone, freshwater runoff injects inorganic nutrients from terrestrial communities (Nixon et al. 1986, Peterson 2001). This mix of nutrients coupled with high solar energy levels results in high primary production that is readily transferred to higher trophic levels through a sizeable benthic invertebrate prey base.

Many of the factors that contribute to the high biological productivity also result in heightened sensitivity of intertidal systems to natural and anthropogenic change. Short and long-term changes in sea level resulting from annual or decadal changes in atmospheric pressure and global warming result in changes in tidal inundation, which can result in changes in the location of the land-sea interface. Changes in habitat boundaries may also result from subsidence and/or elevation of flat areas resulting from tectonic activity (e.g. the 1964 Good Friday Earthquake, Plafker 1990). Spatial and temporal variation in coastal circulation patterns or upwelling/down-welling intensity can result in shifts in temperature regime or delivery of oceanic nutrients and significantly modify species distributions, primary production and trophic transfer (Andersen and Piatt 1999, Zheng and Kruse 2000, Clark and Hare 2002). Patterns of freshwater inputs, which affect both nutrient levels and ambient salinities, can vary in response to climatic oscillation that in turn effect precipitation levels and transgression or regression of glaciers. A variety of direct and indirect effects on marine community structure may result from the propagation of these changes up or down coastal food chains.

Adding to the heightened sensitivity of intertidal habitats is the fact that these areas are often the repositories for contaminants released in coastal areas (Short and Heintz 1997, Short et al. 1999, Peterson 2001). As with changes caused by variation in natural forcings, a host of direct and indirect effects may result from acute and chronic exposure to contaminants that ultimately modify the complex ecological network of a coastal system (Peterson 2001). The detection of these effects is often difficult and requires long-term field research that incorporates a web of ecological interactions (Underwood and Peterson 1984, Gilbert 1987, Underwood 1991, 1992, Peterson et al. 2001). While the acute response of intertidal communities to large-scale releases of contaminants has received a considerable amount of study, chronic exposure often resulting in sublethal effects on organisms (e.g., changes in fitness or fecundity) has proven difficult to study as a result of the paucity of long-term data sets (National Research Council 1985, Peterson and Holland-Bartels 2002). Although difficult to detect, ecological assessments following the Exxon

Valdez oil spill demonstrate the high potential for many sublethal changes to prolong species and ecosystem recovery (Peterson 2001, Dean et al. 2002, Esler et al. 2002, Golet et al. 2002). Particularly for sedimentary habitats, which are characterized by a large biomass of deposit feeders, chronic exposure to contaminants deposited in the sediments can cause shifts in community composition and/or abundance patterns (Shaw et al. 2002, Blanchard et al. *in press*).

Whereas the Copper River Delta was once thought to be safe from potential pollution events such as oil spills because of the westward flow of the Alaska Coastal Current, recent data show that previous assumptions may be flawed, and that the Delta is, in fact, vulnerable to oiling. Preliminary results of a circulation study in the Gulf of Alaska indicate that sub-surface currents in the vicinity of the Copper River Delta Flats can flow eastward from the Gulf toward the Copper River Delta (Vaughan 1997), a pattern noted for some time by local fishermen (Allen et al. 1996). The most serious threats to the Copper River Delta and Flats include: a powered oil-tanker grounding at Hinchinbrook Entrance, a loss of tanker power in the Gulf of Alaska during inclement weather (C. Shaw, CDFU, pers. comm., 1998), and an inland spill of the Trans Alaska pipeline in the vicinity of the Tsina and Tiekel Rivers (Alaska Regional Response Team 1997, 1998). In addition, on the eastern side of the Delta near Katalla, future onshore oil and gas exploration and coal mining could trigger an increase in shipping activities and heighten the risk of an oil spill.

B. Relevance to GEM Program Goals and Scientific Priorities.

In establishing the GEM Program, the Trustee Council explicitly recognized that complete recovery from the oil spill may not occur for decades and that full restoration of injured resources will most likely be achieved through long-term observation and, as needed, restoration actions. The Council further recognized that conservation and improved management of injured resources and services will require substantial ongoing investment to improve understanding of the marine and coastal ecosystems that support the resources, as well as the people, of the spill region. In addition, prudent use of the natural resources of the spill area without compromising their health and recovery requires increased knowledge of critical ecological information about the northern Gulf of Alaska. This knowledge can only be provided through a long-term monitoring and research program that will span decades, if not centuries.

The Gulf Ecosystem Monitoring Program (GEM) hypothesizes that natural forces and human activities serve as distant and local factors, in causing short-term and long-lasting changes in the community structure of intertidal and subtidal habitats. The high sensitivity of intertidal sedimentary systems to natural and anthropogenic change coupled with a relatively simple invertebrate community, makes the of intertidal mudflats of the Copper River Delta and Orca Inlet (see Powers et al. 2002) a highly tractable system in which to test the central GEM hypothesis. The similarity of the Delta's food web with that of mid- and upper Cook Inlet habitats (see Powers et al. 2002, Lees et al. 2001) as well as subarctic estuaries throughout the Northern Hemisphere (e.g. Wadden and Baltic Sea, Beukema 1991, 2002) provides for more generic application of the findings. In addition, the pristine nature of the Copper River Delta allows the establishment of baseline conditions without complications of previous exposure to pollutants common in other systems. Finally, ongoing ecological studies of the Delta provide information key to formulating sampling designs and contributes to a data set in which to examine longer temporal change.

In 2000, the Prince William Sound Science Center (PWSSC) and the Institute of Marine Sciences-University of North Carolina at Chapel Hill (UNC) under the auspices of the Prince William Sound Oil Spill Recovery Institute (OSRI) began the first study of the Copper River Delta's intertidal communities. Now in its fourth season, the purpose of this study is to examine on large spatial and temporal scales the effects of abiotic (e.g. sediment grain size, tidal elevation, salinity) and biotic factors (primarily predation by shorebirds, crabs and flatfish) on the Delta's intertidal mudflats. Because of budget limitations, the OSRI study has primarily focused on top-down processes (predator – prey). However, a complete understanding of the intertidal community, in particular understanding how the community will respond to local and regional environmental change (i.e. temperature, circulation patterns, major environmental perturbations), is impossible without elucidating the extent to which bottom-up forcing (i.e. primary production) regulates production (biomass produced per unit time) of invertebrates residing within the sediments (Lenihan and Micheli 2001, Posey et al. 2002). Changes in the prey production resulting from modifications in bottom-up forcing can greatly impact predator usage of intertidal habitats and consequently production within the predator community, many of which are commercially and/or recreationally exploited. For the 2003 field season, we began a project designed to focus on both top-down and bottom-up processed by coupling the OSRI supported study of the Copper River Delta and Orca Inlet mudflats, with the initial year of a GEM-supported project that focuses on the "bottom-up" processes and the response of the community to local and regional forcings.

The coupled GEM/OSRI project (Figure 1) is designed to provide a comprehensive understanding of the intertidal coastal ecosystem that is critical to the socioeconomic fabric of Cordova and Prince William Sound and the necessary long-term data to test the central GEM hypothesis regarding nearshore habitats. Funds for 2004-2006 have been allocated for the top-down portion of the project by OSRI, this proposal request funds from EVOS for the bottom-up portion of the project for an identical period. Of the nearshore projects the Trustee Council approved as part of the GEM FY03 work plan, the Copper River Delta study is the only project whose principal focus is intertidal, soft-bottom habitat.

II. PROJECT DESIGN

Our overall hypothesis is that the distribution, abundance and production of benthic invertebrates residing in intertidal sediments are controlled by a combination of top-down and bottom-up processes. Further, we hypothesize that changes in natural forcings alter the relative importance of bottom-up and top-down factors. Specifically, we will test the following predictions as part of our overall hypothesis:

(1) The overall distribution of intertidal species inhabiting soft-sediments is largely determined by abiotic factors (e.g. temperature, tidal inundation, sediment grain size, salinity, etc.); and,
(2) within the habitat range of each species, abundance of benthic invertebrates is controlled primarily by demersal predators; or,
(3) abundance of benthic invertebrates is tightly linked with patterns of primary production.

Clearly there is substantial support for the first prediction as it represents a cornerstone of modern marine ecology (Connel 1972, Bertness et al. 2001). Quantifying such patterns can lead to improved predicative capabilities in delineating and mapping resources, which is particularly relevant to the creation of GIS-based habitat maps. Predictions 2 and 3 and more importantly their interaction is central to current debates in marine community ecology. We believe the relatively simple prey community (dominated largely by a few species of bivalves) results in a tractable system in which these predictions can be assessed.

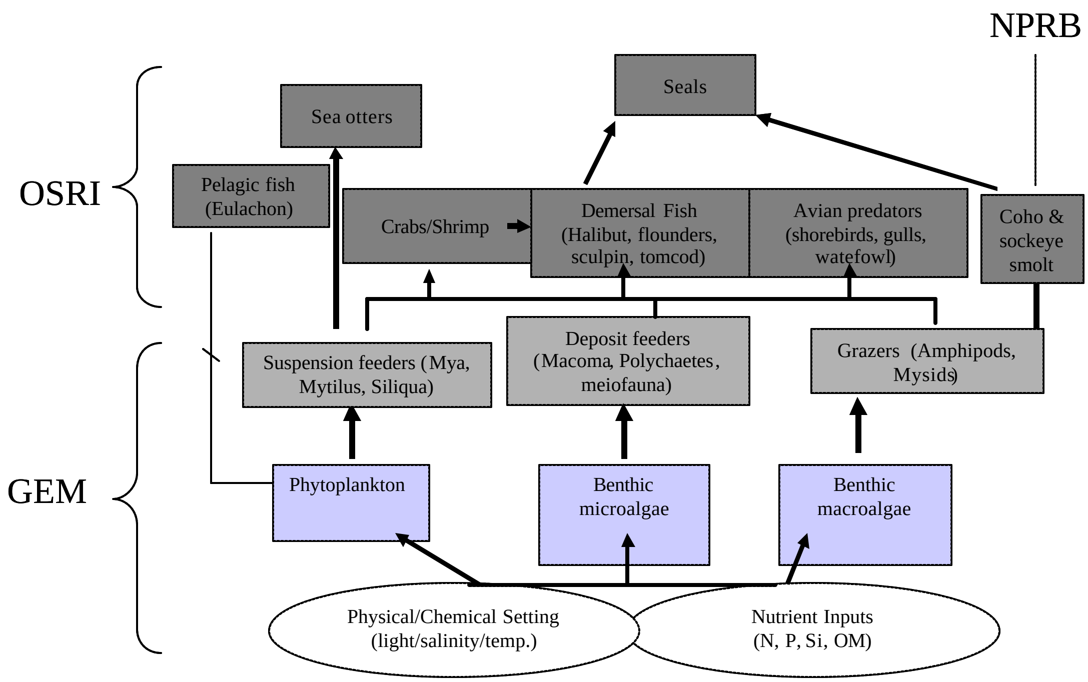

Figure 1. Outline of the major components of the Copper River Delta foodweb that are the focus of the proposed GEM/OSRI study. Funding agencies for each set of components are noted incapital letters.

A. Objectives

To evaluate the central predictions of our hypothesis, four objectives have been formulated. Objectives 1 and 2 are the central focus of the *Exxon Valdez* Oil Spill Trustee Council GEM funding, whereas Objective 3 will be conducted using funds provided by the Prince William Sound Oil Spill Recovery Institute. Objective 4 will be accomplished using resources of both projects. The objectives are:

1. Characterize the spatial abundance of macrobenthic species inhabiting intertidal sediments within the Copper River Delta and Orca Inlet, Southeast Prince William Sound.
2. Determine and quantify those factors that best serve as predictors for primary production in the overlying water and within the sediments of tidal flat communities.
3. Characterize the spatial and temporal abundance of demersal and avian consumers and assess the role of epibenthic predation on recruitment of intertidal macroinvertebrates.
4. Develop a cost-effective strategy and sampling design for long-term monitoring of the intertidal sedimentary habitats.

B. Procedural and Scientific Methods

Objective 1. Distribution and abundance of intertidal invertebrates

To test our prediction that the overall distribution of intertidal species inhabiting soft-sediments is largely determined by abiotic factors (e.g. temperature, tidal inundation, sediment grain size, salinity), we will monitor benthic invertebrates in four study areas: near the outflows of the Copper River (Pete Dahl) and Eyak River (Eyak) and near Egg Island (Egg) and Hartney Bay (Hartney). In each area we will sample benthic invertebrates over a range of tidal elevations: high, mid and low tidal elevation. Within each tidal elevation nine replicate 15-cm diameter core samples (our prior studies have shown this a sample is sufficient because of low variability in species richness) will be taken to a depth of 10 cm to sample infaunal organisms (e.g. bivalves, polychaetes, and amphipods). The replicate cores for benthic invertebrates will be collected from random location along a 300-m swath (E-W) within each of tidal elevation. Our previous benthic sampling (Powers et al. 2002) has demonstrated surprisingly little variance within a tidal elevation. Replicates generally have 100% agreement in species composition and over 80% agreement in density. Sediment properties are also similar within tidal elevations. The primary sources of variation in infaunal abundances are tidal elevation followed by sampling area. Each sampling position will be recorded with a GPS. Sampling areas will be accessed via helicopter during low tide. The entire sampling will be repeated twice a year: early April (before shorebird migration, but after spring recruitment and winter mortality) and in late September (to determine the number of individuals surviving that year - predator activity drops off substantially before this period). Three of the study areas (Copper, Eyak, and Hartney Bay) have been sampled under a similar sampling scheme as part of the OSRI and then OSRI-GEM studies in 2000, 2001, 2002 and 2003.

Upon collection, each core sample is placed in a pre-labeled plastic bag, placed on ice and transported to PWSSC (generally 3 hour from collection of first sample). Core samples for macroinvertebrates are then rinsed onto a 0.5-mm sieve and the contents placed in a 10% Formalin/rose-Bengal solution. Rose-Bengal, which stains animals red, is added to facilitate sorting of the samples. After 48 hours, the formalin is rinsed from the sample and the remaining material stored in 70% Ethanol. After initial sorting of the samples (removing stained animals from the background detritus material), analysis of the cores entails identification and enumeration of <u>all</u> benthic invertebrates (the fauna is relatively simple with few species present and hence can be worked up in an efficient manner). Shell length is measured to the nearest 0.5 mm for all bivalves. A subset of clams from each area/tidal elevation combination will be aged (external annuli counted, see Powers et al. 2002). Growth rates calculated from age and size information may be particularly useful in examining temporal changes in natural or anthropogenic forcings. For all benthic invertebrates, length vs. dry weight relationships will be quantified. These data coupled to age structure of bivalves and density information will be used in calculating production (g/yr) of benthic invertebrate production.

Physical/chemical parameters known to influence benthic community structure will be measured throughout the study. Sediment temperature and pore-water salinity will be measured during all collection trips. Samples for sediment grain size, a primary determinant of benthic community structure (Hall 1994) and predator feeding (Quammen 1982), will be collected once each year during the April collection trip from each site where benthic invertebrate samples are collected (72 samples, 6 samples within each tidal elevation, 3 tidal elevation per area, and 4 areas). One 5-cm diameter core (inserted to a depth of 3 cm) for sediment grain size analysis will be collected from each plot, placed in plastic sack, labeled and placed on ice. Previous sediment grain size analysis has demonstrated little within year variation in sediment grain size. Similarly sediment grain size is similar within a tidal elevation (Powers et al. 2002). In the laboratory, a subsample of the sediment sample will be processed according to methods given in Carver (1970) for wet sieving of sand (particle size > 63 um) and decantation of silts and clays. Another subsample will be used for determination of total organic matter using the Ash-Free-Dry-Weight method.

Objective 2. Spatial and temporal patterns of primary production

A key prediction of our overall hypothesis is that spatial and temporal patterns of production of benthic invertebrates are tightly linked with patterns of primary production. Spatial patterns in primary production may be significantly influenced by spatial patterns of nutrient inputs. For example our preliminary nutrient surveys in 2002 and 2003 indicate that high salinity waters represent the primary source of nutrients (a potential generic pattern for subarctic estuaries in Alaska). We hypothesize that primary production and consequently higher benthic secondary production increases with proximity to the Gulf Alaska and Prince William Sound. Because water clarity increases along this same gradient, nutrient concentrations, light penetration (PAR), and primary producers must be quantified to identify the principal causal factor for this relationship. Primary producers that serve as potential energy sources for benthic invertebrates include larger epibenthic algae (e.g. *Enteromorpha* sp.), smaller epibenthic microalgae that reside on top or within the top 2 cm of the sediment, and suspended phytoplankton in the water column. Benthic microalgae may be the most important of these food sources for infaunal benthic invertebrates (Cahoon 1999, Posey et al. 2002). Measurements of all three groups are included in this component of the project. In addition, water column samples for nutrients (nitrate, ammonia, phosphate, silicate, total inorganic and organic carbon) and chlorophyll *a* will be collected and analyzed to discern patterns of primary production and nutrient supply.

During each of 8 sampling trips (March, April, May, June, July, August, September and October) in 2004, 2005 and 2006, 500-ml water samples will be collected for nutrient and chlorophyll *a* measurements from 11 stations dispersed throughout the marine/estuarine portion of the study area and 6 stations located at principal freshwater sources (Fig 1). For the 11 marine/estuarine stations, samples will be collected from a chartered fishing vessel, whereas road access exists for the 6 freshwater stations. At each station, replicate (n =3) water samples will be collected from 0.5 m below the surface and, where appropriate, near bottom waters (depth difference > 3m; water shallower then this depth are generally well mixed). Once collected, water samples will be placed on ice until filtration is possible (~ 4 hours). Then 100 to 150 ml of water will be filtered through WhatmanTM GF/C filters. The filter will then be wrapped in aluminum foil and frozen for chlorophyll *a* analysis and a 60 ml sample of the filtered liquid will be frozen for inorganic nutrient analysis. Chlorophyll *a* concentrations will be determined using a Turner Designs Model 10 Fluorometer following the acidification method of Lorenzen (detailed in Strickland and Parsons 1972). Nutrient analyses will be carried out using standard wet chemical techniques (Alpkem Manual 1988) adapted for use on an Alpkem RFA/2 Nutrient Autoanalyzer. All chlorophyll *a* and nutrient samples will be analyzed at the University of South Alabama's Dauphin Island Sea Lab (Powers's home institution)

Sediment samples (upper 2 cm) for chlorophyll *a* will be collected using a 1 cm diameter core 3 times (April, June-July and September) from intertidal plots. The April and September trips will correspond to the benthic invertebrate collections. On each date replicate sediment samples (n=9) will be collected from each tidal elevation strata in each of the four areas (identical sampling scheme as the benthic invertebrate sampling). Once returned to the lab, chlorophyll pigments will be extracted from the sediment with acetone and concentration determined by fluorometry. During these same sampling trips, ¼ m^2 quadrats will be harvested for all large epibenthic algae in an identical sampling scheme as described for sediment chlorophyll *a* analyses. Once returned to the lab, algae will be separated by species and dried at a constant temperature for 24 hours. Both wet and dry weight will then be recorded.

Because spatial and temporal patterns in physical/chemical factors can influence primary production and invertebrate species distribution, we will characterize the temporal and spatial patterns in key parameters from 2004-2006. A series of discrete depth profiles of salinity, temperature, photosynthetically active radiation (PAR), fluorescence (a proxy for chlorophyll *a*) and current velocity will be made at each of the 11 nutrient/chl *a* stations on the 8 sampling dates identified above. Vertical profiles will be performed using a Yellow Springs Instrument (YSI) 6000 multi-parameter recorder fitted with a Sontek acoustic Doppler velocity meter (ADV). The instrument will be provided by the Prince William Sound Science Center. These discrete profiles will be augmented with measurements from unattended monitoring instruments (measuring conductivity, temperature and depth) during winter at Egg Island Channel and during summer at Strawberry Channel and near Eyak outflow. Prince William Sound Science Center will install and collect this data using separate funds. In addition, temperature data will be collected using unattended Hobotemp that record through out the year at representative intertidal locations. With the possible exception of the Hobotemp loggers, accuracy and precision of these instruments are in accordance with the GEM recommendations (as are all physical/biological measurements mentioned in this section).

Finally, in the second field season (2005) of the project, we will conduct experiments that examine the relative influence of top-down and bottom-up factors on benthic invertebrate abundance. The basic designs of these experiments follow that of Posey *et al.* 2002 in which nutrient levels and predator access are manipulated in a factorial design. The central hypotheses of these experiments are that (1) resource availability (e.g. nutrients) controls benthic primary production which in turn cascades upward to higher infaunal abundance in the absence of predators and (2) in the presence of predators the abundance of infauna is decreased and consequently benthic microalgae is freed from grazing pressure. These hypotheses are similar to those proposed by others (Cahoon 1999, Micheli 1999, Heck et al. 2000, Posey et al. 2002); however, few experimental tests of these hypotheses have been made for soft-bottom communities (see Posey *et al.* 2002 for discussion). Further, with the exception of work by Beukema and colleagues (Beukema 1991, Beukema and Cadee 1997), these hypotheses have yet to be fully explored for subarctic estuarine systems, which are of particular interest for GEM. The design of our experiment has a total of 6 treatments: 2 levels of nutrients (ambient and enriched) and 3 levels of predator control (open plots, full cages, and partial cages). Full cages, which will exclude all predators, will be 1m x 1m x 12.5 cm tall. Six-mm aquaculture mesh will be placed on all four sides and the top of the cage. The mesh, a clear, monofilament line matrix, should allow sufficient light into the area. Partial cage, which will control for cage artifacts by mimicking changes in hydrodynamic regime and shading within the cage, but allowing predator access, will have the same overall dimensions as full cages but have two sides and half the top open. Small tent spikes will mark the corners of the $1m^2$ open plots. Nutrient enrichment will be

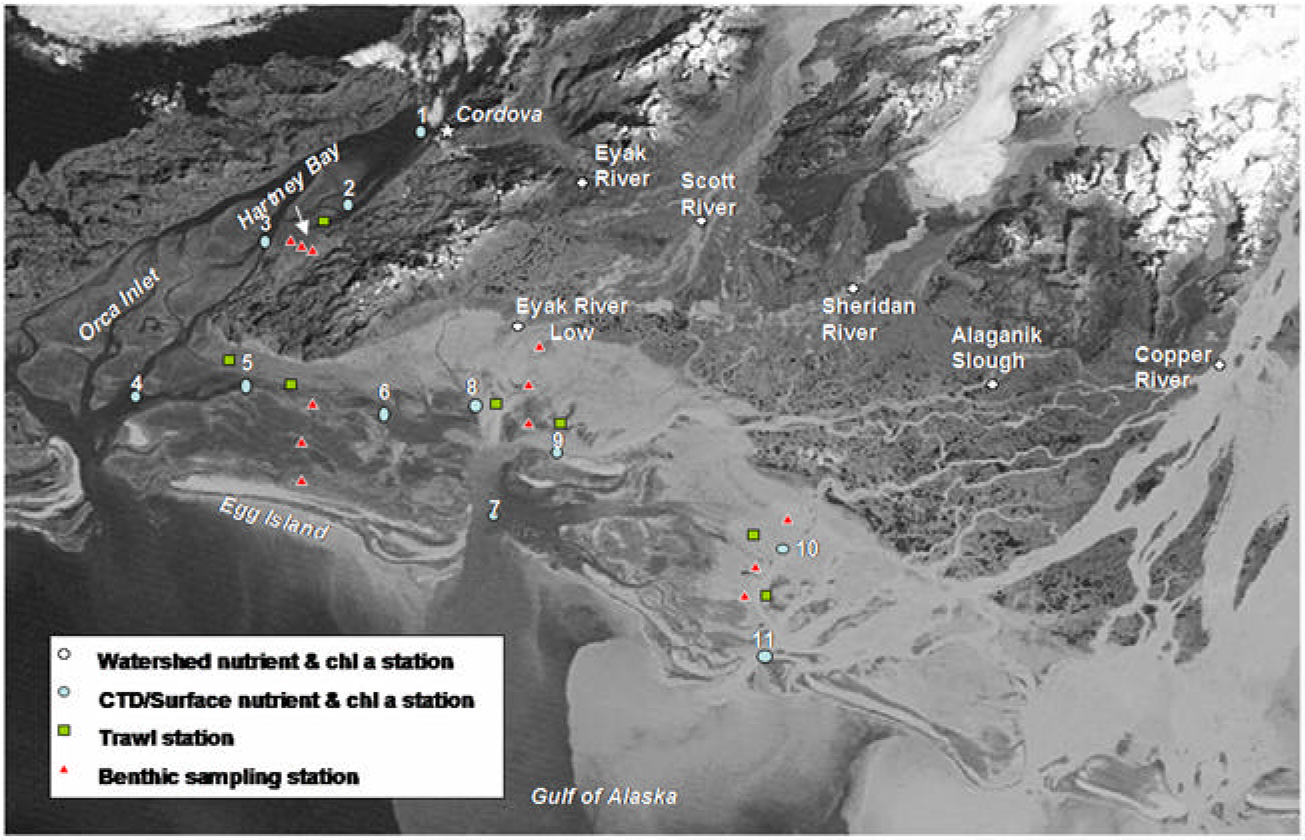

Figure 2. Aerial image of the western Copper River Delta showing the spatial extent of the Copper River outflow (cloudy, gray water vs. deep black water) and the network of mudflats throughout the brackish water portions of the Delta and Orca Inlet. Sampling station for CTD, nutrient and chlorophyll water column measurements (numbered from 1 to 11), benthic invertebrates (triangle at different tidal elevations), demersal fish trawls (filled squares) and freshwater nutrient sampling stations (crosses). Sampling according to the above design occurred in 2003 with a large subset of the stations sampled from 2000-2002.

achieved by placing four 56-gram fertilizer spikes with a N:P ratio of 16:10 contained with an inert gypsum matrix (Posey et al. 1999, 2002) in a diamond pattern within the 1m^2 area. The spikes provide gradual nutrient release over a 4 – 6 week period. Four cages for each of the six treatments will be placed at mid-tidal elevation and the experiment will be allowed to run for six weeks. This duration is chosen as a compromise to reduce cage artifacts but allowing enough time for detection of density dependent responses and benthic microalgae response (Posey et al. 2002). The experiment will be replicated in two areas (Hartney Bay and Pete Dahl). These areas are chosen to represent the two extremes in physical/chemical setting of the tidal flats. The entire experiments (4 replicates x 6 treatments x 2 areas) will be performed twice: late-April to the end of May (a period that coincides with shorebird migration and immediately after spring recruitment) and August-September (a period of high demersal fish abundance). Our previous experiences with cages in the system have demonstrated little hydrodynamic artifact and little fouling of the mesh over a 6-week period. Benthic invertebrate cores will be collected from the area before experiments begin to establish baseline data. At the end of six weeks samples for benthic invertebrates (2 per cage), pore water nutrients (2 per cage), and benthic microalgae (2 cores for sediment chl *a*) will be collected from each cage. Samples will be analyzed as previously described. Benthic invertebrate samples will be processed to the species level for all taxa collected by the core.

Objective 3. Predator community.

From March to October 2004 - 2006, trawl surveys will be conducted every 4 weeks (n = 8 survey trips) at 7 trawling in and around our 4 study sites on the western Copper River Delta and Orca Inlet (Hartney Bay, Egg Island, Eyak, and Pete Dahl). Using a commercial gillnet boat as the platform, a 5m otter trawl will be deployed for 10 minutes. At each site, two sets of 3 replicate trawls will be conducted near the high/mid tide plots and the low tide plots. Our previous work has demonstrated that even with an n of 3 species richness and density show little variance among replicates. Surveys will be conducted $\pm$2h around low tide, when fish and crab are concentrated in the navigable channels.

All fish and crabs caught in trawls will be identified and measured for SL (standard length) and TL (total length) and weighed. A subset of each species will be collected and preserved in 10% buffered formalin for gut contents. An additional subset will be collected and frozen for aging (i.e. otolith analyses). Once back in the laboratory, stomachs will be removed and weighed. Stomach contents will be separated by prey type, and identified to the lowest practical taxon. A modified index of importance (MI) will be determined for each prey type.

Depending on the salmon species and race, early sea life of a juvenile salmon may include a prolonged residence time in estuarine waters. For 2004 and 2005 field seasons, additional sampling on the Delta targeting juvenile coho and sockeye salmon will be performed under a North Pacific Research Board sponsored project (Powers, Bishop and Reeves, PI's).

Objective 4. Development of long-term sampling monitoring strategy.

Because of the high potential for spatial and temporal variability in biological and physical parameters, re-evaluation of the level of replication and the spatial and temporal sampling plan will be performed after the first few collection trips and at the end of year 1. For the nutrient/ chl *a*/physical/chemical sampling, the primary purpose of the ongoing and proposed sampling is to identify large-scale variation in nutrient inputs and physical/chemical parameters (oceanic vs. riverine) and to identify seasonal signatures in nutrient inputs that may correlate to primary production. We strongly believe that the current sampling approach will be successful in documenting these patterns. Additional resolution, which may be achieved with our current sampling plan would be of significant value in evaluating spatial patterns on smaller scales (e.g. among tidal elevation strata), but are not as critical. For the benthic invertebrate and demersal fish sampling our goal is to develop the necessary understanding to separate within and among site variability from annual patterns - the latter element critical in developing a long-term sampling strategy to address the overall GEM hypothesis. At the end of the 3 year study, we will evaluate the possibility of minimizing the spatial and temporal extent of sampling, thereby reducing cost, while maintaining our ability to detect inter-annual change in nutrient inputs, physical/chemical parameters, species composition, benthic invertebrate production, and predator abundance. This process will also rely on data collected in the previous OSRI and OSRI/GEM projects in 2000, 2001, 2002, and 2003.

C. Data Analysis and Statistical Methods.

A combination of multivariate and univariate analyses will be utilized to examine distributions of major taxa and determine to what degree physical/chemical and biological parameters explain invertebrate abundance patterns. Analysis of variance ANOVA will be performed to test our *apriori* hypotheses that benthic microalgae (measured by chl *a*), benthic invertebrate abundance (total abundance as well as abundances of specific taxa) vary in response to sampling area (Hartney Bay, Egg Island, Eyak, Pete Dahl) and tidal elevation (high, mid, low). The factors in the ANOVA will be sampling date, sampling area, and tidal elevation. While some effect of date may be evident (as a result of predation or recruitment), we expect no interaction with date (i.e. seasonal effects should not interact with the overall pattern of higher benthic microalgae and benthic invertebrate abundance with area or within tidal elevation. Our *apriori* prediction is that both benthic microalgae and benthic inveterate abundance will be highest at areas that experience greater nutrient input and light penetration (i.e. Hartney Bay > Egg > Eyak > Pete Dahl). Data from the nutrient and physical/chemical surveys will be used to support the ranking of these sites. Within each area abundances should be highest at mid-tidal elevation reflecting the pattern of greatest benthic microalgae production at these elevations (see Beukema 1988, Beukema and Cadee 1997, Beukema et al. 2002 for support of this prediction). To test the rank order of these predictions, post hoc contrasts will be performed using Student-Newman-Keuls (SNK) tests. Homogeneity of variances will be verified using a Cochran's test. Square root or log transformations will be used if Cochran's tests reveal heterogeneous variances. Because our statistical analysis includes multiple ANOVA's as well as post-hoc tests on the same data sets, *p* value for determining significance levels will be adjusted accordingly (see Rice et al. 1989).

Analysis of *Macoma* in the above mentioned ANOVA may also be performed on separate size classes of *Macoma*. The dependent variable for *Macoma* abundance may be separated out into small, medium, or large size classes. Analysis will then proceed as described above, but using the abundance of small, medium, and large *Macoma* as separate dependent variables (size class definition will be based on size-distribution data collected in year 1). Birds or other consumers may preferentially select one size class to feed upon; previous studies have failed to address this possibility in their analyses. For example, small clams may be the most susceptible to predation creating a size-induced refuge from predation for larger *Macoma.* Finally growth curves will be generated for each area/plot. The slopes of these curves can then be tested against each other to determine which area/tidal elevation combination result in faster growth.

Principal Components Analysis (PCA) and cluster analysis will be used to explore patterns in the overall data sets (Gauch 1981). PCA analysis will be used to address large-scale patterns and determine which sets of the many variables measured best explain the greatest percentage of the variance in the community. Cluster analysis will be used to discern overall similarities in the various response variables (invertebrate abundance, primary production patterns, physical/ chemical parameters) between areas and tidal elevation. These analyses will be particularly useful in examining redundancy in station responses, which can be used to address objective 4 (cost-effective long-term monitoring). Both multivariate approaches can be used to formulate specific hypotheses that can then be tested using analysis of variance (ANOVA) and also discern covariates that may be appropriate to incorporate in ANCOVA. Correlation, simple and multiple regressions between various parameters (nutrient concentrations, primary production levels, benthic abundances, predator abundances) will be used to evaluate specific relationships identified by the PCA and cluster analyses.

A three factor-ANOVA (area, nutrient level, predator access) will be used to analyze the nutrient enrichment experiment. Dependent variables will include benthic microalgae biomass, benthic invertebrate abundance (which may then be further separated by functional groups or specific taxa). Two separate analyses will be performed for the separate periods (April-May, Aug-Sept). Results of the two runs will be compared qualitatively. Post hoc contrasts will be performed using Student-Newman-Keuls (SNK) tests. Homogeneity of variances will be verified using a Cochran's test. Square root or log transformations will be used if Cochran's tests reveal heterogeneous variances.

D. Description of Study Area.

This study will take place on the Copper River Delta and in Orca Inlet (Figure 2), located in southcentral Alaska near the southeastern corner of Prince William Sound. Three of the benthic invertebrate study areas have already been established as part of the OSRI and OSRI-GEM studies. These include intertidal mudflats: a) near the Copper River along Pete Dahl Channel, b) near the outflow of Eyak River, and c) Hartney Bay, Orca Inlet. In addition, one new sampling area will be established on intertidal mudflats near Egg Island.

Site Name	Approx Locations
Copper	60 21'N 145 29'W
Eyak	60 25'N 145 38'W
Egg Island	60 23'N 145 50'W
Hartney Bay, Orca Inlet	60 30'N 145 52'W

E. Coordination and Collaboration with Other Efforts.

The proposed study would extend the ongoing OSRI-GEM and the past OSRI study (2000-2003). The proposed GEM study would utilize the same study areas, and would sample the same plots. The GEM portion would allow for continuous long-term monitoring of species diversity, abundance, and recruitment of the benthic invertebrate communities. All data from both projects will be archived by the project staff in accordance with GEM standardized procedures. The proposed OSRI-GEM study will also complement and benefit from the North Pacific Board supported project "Estuaries as essential fish habitat for salmonids: Assessing residence time and habitat use of coho and sockeye salmon in Alaska estuaries", which will be conducted on the Copper River Delta. The field results from the GEM study will be integrated into the upcoming OSRI funded biological model of Prince William Sound and the Copper River Delta ecosystem.

This project will also be able to access meteorological and oceanographic data. In August 2002 the first meteorological station was placed on the Copper River Delta at Grass Island (western Copper River Delta) under the auspices of the Oil Spill Recovery Institute. And, the PWSSC maintains oceanographic moorings at Hinchinbrook Island and Egg Island Channel (2004 installation) that will provide data applicable to this project.

In addition, the similarities between mid- and upper Cook Inlet and the Copper River Delta and southeast Prince William Sound mudflats provide an unusual opportunity to make comparisons. Vast expanses of intertidal mudflats dominate both the Copper River Delta and mid-and upper Cook Inlet. Both are large and important geographic areas included in the GEM study area. Previous studies include those conducted by Lees *et al.* (1980, 2001) of upper and mid-Cook Inlet. More recently, Kachemak Bay Research Reserve has become a member of NOAA's System-Wide Monitoring Program (SWMP), a program that monitors many parameters similar to our study including nutrients, conductivity and salinity. One of the PI's of this proposed project (Powers) has and will assist in the future NOAA investigators in their study of the Kachemak Bay. In addition, we are aware of at least 2 studies by Dr. Brenda Konar (Univ. Alaska Fairbanks) Kachemak Bay that will generate data that could be compared with the Copper River Delta. Our close association with these previous and ongoing studies will foster extensive inter-site comparisons.

III. SCHEDULE

A. Project Milestones

Objective 1. Characterize the spatial abundance of macrobenthic species inhabiting intertidal sediments within the Copper River Delta and Orca Inlet, Southeast Prince William Sound. To be met by completion date of 2006 grant.

Objective 2. Determine and quantify those factors that best serve as predictors for primary production in the overlying water and within the sediments of tidal flat communities. To be met by completion date of 2006 grant.

Objective 3. Characterize the spatial and temporal abundance of demersal and avian consumers and assess the role of epibenthic predation on recruitment of intertidal macroinvertebrates. To be met by December 2006.

Objective 4. Assess the generality of our findings through coordination and comparisons with Cook Inlet studies. To be met by April 2006.

B. Measurable Project Tasks

- FY 04, 1st quarter (October 1, 2003-December 31, 2003)
  Oct — Project funding approved by Trustee Council
  Nov — Submit manuscript
- FY 04, 2nd quarter (January 1, 2004-March 31, 2004)
  Jan — Annual EVOS Workshop
  Mar 20-30 — Field work (primary productivity sampling (pps), ctds, fish surveys)
- FY 04, 3rd quarter (April 1, 2004-June 30, 2004)
  Apr 15-Jun 30 — Field Work (benthic & sediment cores, pps, ctds, fish surveys)
- FY 04, 4th quarter (July 1, 2004-September 30, 2004)
  Jul 1-Sep 30 — Field Work (benthic & sediment cores, pps, ctds, fish surveys)
  Sep 1 — Submit annual report to EVOS
- FY 05, 1st quarter (October 1, 2004-December 31, 2004)
  Oct — Field work (pps, ctds, fish surveys)

Dec 31 Finish lab analyses

- FY 05, 2nd quarter (January 1, 2005-March 31, 2005)
  Jan Annual EVOS Workshop
  Mar 20-30 Field work (pps, ctds, fish surveys)
- FY 05, 3rd quarter (April 1, 2005-June 30, 2005)
  Apr 15-Jun 30 Field Work (benthic & sediment cores, pps, ctds, fish surveys, experiments)
- FY 05, 4th quarter (July 1, 2005-September 30, 2005)
  Jul 1-Sep 30 Field Work (benthic & sediment cores, pps, ctds, fish surveys, experiments)
  Sep 1 Submit annual report to EVOS and submit manuscript
- FY 06, 1st quarter (October 1, 2005-December 31, 2005)
  Oct Field work (pps, ctds, fish surveys)
  Dec 31 Finish lab analyses
- FY 06, 2nd quarter (January 1, 2006-March 31, 2006)
  Jan Annual EVOS Workshop
  Jan –Mar Prepare 2 manuscripts
  Mar 20-30 Field work (pps, ctds, fish surveys)
- FY 06, 3rd quarter (April 1, 2006-June 30, 2006)
  April 15 Submit final report to EVOS (2 draft manuscripts for publication)
  Apr 15-Jun 30 Field Work (benthic & sediment cores, pps, ctds, fish surveys,)
- FY 06, 4th quarter (July 1, 2005-September 30, 2005)
  Jul 1-Sep 30 Field Work (benthic & sediment cores, pps, ctds, fish surveys)

IV. RESPONSIVENESS TO KEY TRUSTEE COUNCIL STRATEGIES

A. Community Involvement and Traditional Ecological Knowledge (TEK).

Because of the extensive knowledge of local fishers and the historic knowledge of native Alaskans, an interactive exchange with local fishermen will be of great benefit to the project. Direct input to the project will be solicited from the local fishing community via the EVOS-sponsored Prince William Sound Fisheries Research Application and Planning group (PWSFRAP). Results of the project will also be fully available to the local fishing community through presentations at PWSFRAP workshops and public seminars given through the Prince William Sound Science Center. Articles will also be written for the local newspaper, *The Cordova Times*, and for *The Breakwater*, the newsletter of the Prince William Sound Science Center informing the public of the study. The *Cordova Times* is publicly available. The Prince William Science Center also maintains a regional science education and outreach program. Our project will also use the education/outreach program to communicate the need and benefits of conservation of marine resources to the public and visiting student groups. As part of its outreach program, the Prince William Sound Science Center maintains an extensive web site. This GEM project would be featured on the web, and would have links to the EVOS web site as well as links to any other collaborating projects.

B. Resource Management Applications.

Three species of salmon: sockeye, chinook, and salmon are commercially fished on the Copper River Delta by a gillnet fleet numbering 549 permitees. Dungeness Crabs and razor clams (*Siliqua patula*) were commercially fished, but these fisheries have been closed for > 10 years due to depleted stocks. The tidal flats of the Copper River Delta serve may serve as essential habitat for a variety of fish, crab and waterfowl species. Many of these species are in desperate need of management plans that incorporate ecosystem level approaches. The results of our study would be of significant value within this context. Data from the GEM project will be coupled to the OSRI "top down" study to construct a quantitative food web model of the system (i.e. Ecopath, Ecosim). This model can then be used as a predictive tool to examine how disruptions in various components affect higher trophic levels (i.e. shorebirds, crabs, etc.). And the standard fisheries data collected from the companion OSRI companion study can be used to assist in current fisheries management.

In the event of an oil spill or some other catastrophe (e.g., an earthquake), this data would be critical in assessing change caused by the event. Nearshore ecosystems such as tidal flats are often the repository for oil spills. Once thought to be safe from potential oil spills, the Copper River Delta has been largely ignored as an area of potential risk. Current data shows that previous assumptions may be flawed and that the Delta has potential for oiling. The predictive capabilities developed by this project have a multitude of uses, many of which are of immediate need for GEM. Predictive relationships between sediment grain size and tidal inundation can be coupled with aerial photography of habitats to map prey resources and potentially the distribution of predators.

V. PUBLICATIONS AND REPORTS

In addition to quarterly and annual reports, we foresee at least 4 peer-reviewed publications produced from this study. These are:

- The relationship between migrant shorebirds and invertebrate densities on intertidal areas of the Copper River Delta. Journal Field Ornithology. November 2003.
- Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes *Marine Ecology Progress Series.* Submit: September 2005.
- The importance of experimental approaches for elucidating the relative importance of "top-down" versus "bottom-up" regulation of marine benthic communities. *Journal of Experimental Marine Biology and Ecology.* March 2006
- The ecology of the Copper River Delta. *Ecological Monographs*, June 2006

VI. PROFESSIONAL CONFERENCES

Powers will give presentations at the:

- Estuarine Research Federation Meeting, November 2003 Seattle, Washington & 2005 (location TBD)
- Benthic Ecology Meeting, March 2004 Mobile, Alabama & 2005 (location TBD)
- Congress of World Fisheries, Vancouver, British Columbia (May 2004)

Bishop will give presentations at the

- Society for Conservation Biology, Columbia Univ., New York City, June 2004
- American Ornithologists' Union, Aug. 2005 (Location TBD)

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Education

Ph.D. Wildlife Ecology, Department of Wildlife & Range Sciences, University of Florida, Gainesville, 1988.

M.S. Wildlife & Fisheries Sciences, Department of Wildlife and Fisheries Sciences, Texas A & M University, College Station, 1984.

B.B.A. School of Business, University of Wisconsin-Madison, 1974.

Professional Experience

6/99-present Research Ecologist, Prince William Sound Science Center, Cordova, Alaska.

11/88-present Research Associate & Principal Investigator for Tibet Black-necked Crane Study, Intl. Crane Foundation, Baraboo, Wisconsin (location: Tibet, PR China).

3/97-5/99& 4/90-4/94 Research Wildlife Biologist, Pacific Northwest Research Station, U.S. Forest Service, Cordova, Alaska

4/94-3/97 Research Wildlife Biologist, Dept. Fisheries and Center Streamside Studies, Univ. Washington assigned to Copper River Delta Institute, US Forest Service

5/92-4/93 Acting Manager, Copper River Delta Institute, Pacific Northwest Research Station, U.S. Forest Service, Cordova, Alaska.

7/89-4/90 Wildlife Biologist, Forestry and Range Sciences Laboratory, Pacific Northwest Research Station, U.S. Forest Service, LaGrande, Oregon.

9/88-6/89 Biological Technician, Malacology Lab, Florida Museum of Natural History, Gainesville, Florida.

8/83-8/88 Project Biologist, Department of Wildlife and Range Sciences, University of Florida, Gainesville.

Awards

U.S. Forest Service National *Taking Wing* Awards:
- 2001 Capacity Building Category
- 1999 Public Awareness & Community Involvement Category
- 1997 Research Investigations Category
- 1993 Research Investigations Category

Tibet Autonomous Region, PR China:
- 1994 *Development of Science and Technology in Tibet* Award (2nd Place)

Wildlife Conservation Society: 1993 Research Fellow

The Wildlife Society
- 1992 Monograph Publication Award for "A conservation strategy for the Northern Spotted Owl," Interagency Scientific Committee (Team Member).
- 1991 Group Achievement Award for Participation as Team Member in Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl

Team Memberships

U.S. Shorebird Conservation Plan, Research and Monitoring Working Group (since 1998)
Scientific Advisory Board, Western Hemisphere Shorebird Reserve Network (since 1998)
Crane Specialist Group, IUCN Species Survival Commission (since 1995)
Platte River Whooping Crane Maintenance Trust, Science Review Panel (since 1999)
Copper River Watershed Project, Board of Directors (since 1998)

Five Most Relevant Publications

Powers, S.P., **M.A. Bishop**, and J.H. Grabowski. in review. *Biotic and abiotic limitations of an invasive bivalve, Mya arenaria: growth and distribution on the Copper River Delta Alaska.* Canadian Journal Fisheries & Aquatic Sciences.

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Other Publications

Bishop, M.A., N. Warnock, and J. Takekawa. In review. *Differential spring migration of male and female Western Sandpipers at interior and coastal stopover sites.* Ardea.

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Warnock, N. and **M.A. Bishop**. 1998. *Spring stopover ecology of migrant Western Sandpipers.* Condor 100(3): 456-467.

Publications in Preparation

Bishop, M.A. and S.P. Powers. in prep. *The relationship between migrant shorebirds and invertebrate densities on intertidal areas of the Copper River Delta.* Journal Field Ornithology.

Professional Collaboration (in addition to Powers & Peterson)

Clesceri, Erica J., University of North Carolina, Chapel Hill, NC
Grabowski, John, University of Maine.
Li, Fengshan. International Crane Foundation, Baraboo, Wisconsin.
Reeves, Gordon. Pacific Northwest Research Station, US Forest Service & Oregon State Univ.
Takekawa, John T., US Geological Survey- Biological Research Division, San Francisco CA
Tsamchu, Drolma. Tibet Plateau Institute of Biology, Lhasa, Tibet, PR China
Warnock, Nils. Pt. Reyes Bird Observatory, Pt. Reyes, CA
Yangzom, Drolma. Dept. of Forestry, Tibet Autonomous Region, Lhasa, Tibet, PR China

Sean P. Powers, Ph.D.
Assistant Professor of Marine Sciences, University of South Alabama
& Senior Marine Scientist, Dauphin Island Sea Lab
Dauphin Island Sea Lab
101 Bienville Blvd.
Dauphin Island, AL 36528
(251) 861-7591 (voice); 861 -7540 (fax)
spowers@disl.org

Education

1997 **Doctor of Philosophy**, Department of Biology, Texas A&M University, College StationAreas of Specialization: Ecology &Evolution, Zoology, Biostatistics

1992 **Master of Science** in Biological Sciences, University of New Orleans

1990 **Bachelor of Science with Honors** in Biology and Chemistry, Loyola University

Professional Experience

2003- Assistant Professor, Department of Marine Sciences, University of South Alabama.

2003- Senior Marine Scientist I, Dauphin Island Sea Lab.

2002- Associate Research Scientist, Prince William Sound Science Center, Cordova, Alaska.

2002-2003 Research Assistant Professor, Institute of Marine Sciences, University of North Carolina at Chapel Hill.

1999-2001 Post-doctoral Research Associate, Institute of Marine Science, University of North Carolina-Chapel Hill.

1998. Oceanographer (Assistant Program Manager), Division of Ocean Sciences, National Science Foundation.

1997-1998 NOAA Seagrant Dean John A. Knauss Marine Policy Fellow, Division of Ocean Sciences, National Science Foundation.

1995-1997 Graduate Teaching Assistant, Texas A&M University, Department of Marine Biology.

Five Most Relevant Publications

Powers, S.P., and M. Sperduto. 2003. Scaling restoration actions to achieve quantitative enhancement of loon, seaduck, and seabird populations. *Marine Ecology Progress Series,* In press.

Powers, S. P., M. A. Bishop, J.H. Grabowski and C.H. Peterson. 2002. Intertidal benthic resources of the Copper River Delta, Alaska. *Journal of Sea Research* 47: 13-23.

Borsuk, M. E., **S. P. Powers** and C. H. Peterson. 2002. A survival model of the effects of bottom-water hypoxia on the population density of an estuarine clam (*Macoma balthica*). *Canadian Journal of Fisheries and Aquatic Sciences,* 59: 1266-1274.

Powers, S. P. and J. N. Kittinger. 2002. Hydrodynamic mediation of predator-prey interactions: differential patterns of prey susceptibility and predator success explained by variation in water flow. *Journal of Experimental Marine Biology and Ecology*. 273: 171-187.

Powers, S. P. and C. H. Peterson. 2000. Conditional density dependence: The flow trigger to expression of density-dependent emigration in bay scallops. *Limnology and Oceanography,* Vol. 45 (3): 727-732.

Five Other Publications

Powers, S. P., J. Grabowski, C.H. Peterson, and W.J. Lindberg. 2003. Estimation of expectation and uncertainty of augmented fish production per unit area of artificial reef. *Marine Ecology Progress Series,* In press.

Peterson, C. H. and **S. P. Powers.** 2003. Quantitative enhancement of fish production by oyster reef habitat: restoration valuation. *Marine Ecology Progress Series,* In press.

Buzzelli, C. P., R. A. Luettich, Jr., **S. P. Powers**, C.H. Peterson, J. E. McNinch, J. Pinckney and H. W. Paerl. 2002. Estimating the spatial extent of bottom-water hypoxia and habitat degradation in a shallow estuary. *Marine Ecology Progress Series* 230: 103-112

Powers, S. P., D. E. Harper, Jr. and N. N. Rabalais. 2001. Effect of large-scale hypoxia/anoxia on supply-settlement relationships of benthic invertebrate larvae. Pages 185 - 210, In: N.N. Rabalais and R.E. Turner (eds.), *Coastal Hypoxia: Consequences for Living Resources and Ecosystems.* Coastal and Estuarine Studies 58, American Geophysical Union, Washington, D.C.

C. H. Peterson, F. J. Fodrie, H.C. Summerson and **S. P. Powers**. 2001. Site-specific and density-dependent extinction of prey by schooling rays: generation of a population sink in top-quality habitat for bay scallops. *Oecologia* 129: 349-356.

Graduate & Post Doc Advisors: M.A. Poirrier (U. New Orleans), P. O. Yund (U. Maine), D. E. Harper, Jr. (Texas A&M), and C.H. Peterson (U. North Carolina).

Collaborators: M. Benfield (LSU), M. A. Bishop (PWSSC), M. Borsuk (Switzerland), J. Cebrian (Dauphin Island Sea Lab), R. Christian (East Carolina U.), J.H. Grabowski (U. Maine), D.E. Harper (Texas A&M), K. Heck (Dauphin Island Sea Lab), N. N. Rabalais (LUMCON), C. H. Peterson (UNC), Gordie Reeves (USFS)

Charles H. Peterson
Alumni Distinguished Professor
Institute of Marine Sciences
University of North Carolina at Chapel Hill
3431 Arendell Street
Morehead City, NC 28557
(252) 726-6841
cpeters@email.unc.edu

Education

AB - 1968, Princeton, Phi Beta Kappa, Cum Laude (Biology).
MS - 1970, PhD 1972, Univ. Calif. (Santa Barbara): NSF and Woodrow Wilson Predoctoral Fellowships; Major: Population Biology. Minors: Oceanography, Biometry, Paeleoecology.
Postdoc - 1972, Univ. of Calif. (Santa Barbara): Ford Foundation Postdoctoral Fellowship.
Advisors: R. H. MacArthur (undergrad.); J. H. Connell (grad.); W. W. Murdoch (postdoc.).

Professional Experience

Positions: Univ. Maryland Baltimore Co., Asst. Prof. 1972-76; Univ. North Carolina, Assoc. Prof. 1976-1982, Prof. 1983-, Alumni Distinguished Prof. 1997-. [Depts.: Marine Sciences, Biology, Ecology]

Awards: NSF Special Creativity Award: 1990-93; PEW Charitable Trust Scholar in Conservation and the Environment: 1994-98.

Scientific Steering and Advisory Committees: UNC Marine Council 1985-91; LMER 1986; NSF ACOS 1987-90; NC Governor's Task Force on Aquaculture 1988; ESA's Sustainable Biosphere Initiative (SBI) Committee 1989-91; CIFO (Duke-UNC-NOAA Coop. Inst. Fish. Oceanogr.) 1989-; GLOBEC (chair) 1989-92; CoOP 1990-91; Canadian OPEN 1990-94; Univ. Calif. Coastal Toxicology Program 1991-; Australian Research Council Ecology Retrospective Review Panel 1992; Scientific Advisory Board to Exxon Valdez Oil Spill Trustee Council 1993-; ESA's Ecosystem Management Committee 1993-94; Lindbergh Fund Review Panel 1994-98; NSF National Center for Ecological Analysis and Synthesis (NCEAS) 1995-99 (chair 1997-99); Packard Foundation Marine Conservation Advisor 1997; NSF Futures Committee for Biol. Oce. 1998; EDF Environmental Science Advisory Committee 1999-.

Study Panels: National Academy NRC Options for Preserving the Cape Hatteras Lighthouse 1987-88; National Academy NRC Sea Turtle Conservation 1988-89; U.S. DOI North Carolina Environmental Sciences Review for OCS Oil and Gas Exploitation 1990-91; National Academy NRC Bering Sea Ecosystem 1993-95.

Five Most Relevant Publications (5 of 110):

Peterson, C.H., and L. Holland-Bartels. 2002. Chronic impacts of oil pollution in the sea: risks to vertebrate predators. Mar. Ecol. Prog. Ser. 241: 235-236.

Peterson, C.H. 2001. A synthesis of direct and indirect or chronic delayed effects of the Exxon Valdez oil spill. Adv. Mar. Biol. 39: 1-103.

Peterson, C.H., L.L. McDonald, R.H. Green, and W.P. Erickson. 2001. Sampling design begets conclusions: the statistical basis for detection of injury to and recovery of shoreline communities after the Exxon Valdez oil spill. Mar. Ecol. Prog. Ser.**210**: 267-295.

Peterson, C.H. 1991. Intertidal zonation of marine invertebrates in sand and mud. Am. Scientist 79: 236-249.

Underwood, A. J., and **C. H. Peterson.** 1988. Towards an ecological framework for investigating pollution. Mar. Ecol. Prog. Ser. **46**: 227-234.

Five Other Significant Publications

Peterson, C.H., J. Jackson, M. Kirby, H. Lenihan, B. Bourque, R. Bradbury, R. Cooke, and S. Kidwell. 2002. Response to factors in the decline of coastal ecosystems. Science 293: 1590-1591.

Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlandson, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, **C.H. Peterson**, R.S. Steneck, M.J. Tegner, and R.R. Warner. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293: 629-638.

Botsford, L. W., J. C. Castilla, and **C. H. Peterson.** 1997. The management of fisheries and marine ecosystems. Science **277**: 509-515.

Peterson, C. H. and R. Black. 1998. Density-dependent mortality caused by physical stress interacting with biotic history. Am. Nat. 131:257-270.

Peterson, C. H. 1979. Predation, competitive exclusion, and diversity in the soft-sediment benthic communities of estuaries and lagoons, in R. J. Livingston (ed.), Ecological Processes in Coastal and Marine Systems. Plenum Press, NY, pp. 233-264.

Collaborators:

Last 4 years: W. Berger, M. Bishop, R. Black, B. Bourque, R. Bradbury, J.E. Byers, J.C. Castilla, D.B. Colby, W.P. Erickson, J.A. Estes, C.R. Fisher, R.H. Green, M.E. Hay, M. Hooper, J. Huber, T.P. Hughes, E.A. Irlandi, J.B.C. Jackson, S. Kidwell, M. Kirby, L.L. McDonald, L. Mullineaux, J. Pandolfi, S.W. Schaeffer, R.S. Steneck, M. Tegner, G.W. Thayer, R.R.Warner, F.E. Wells.
Past MS and PhD students: S.V. Andre (Univ. Maryland), H.C. Summerson (Univ. of North Carolina), J.H. Hunt (Florida Dept. Natural Resources), T.B. Brown (Lawrenceville School), B.F. Beal (Univ of Maine at Machias), W.G. Ambrose, Jr. (Bates), S. Shipman (Georgia Dept. Natural Resources), J. Homziak (Univ Vermont), P.B. Duncan (U.S. EPA), M. Quammen with George Hunt of UC Irvine (deceased), M.C. Watzin (Univ. Vermont), S.R. Fegley (Maine Maritime Academy), M. Holmlund (Pharmacia), J. Rivera (Puerto Rico Dept Natural Resources), J. Lin (Florida Institute of Technology), E.A.. Irlandi (Florida Institute of Technology), R.C. Prescott (Portland Watershed Protectorate), F. Wilson (Environmental Attorney), F. Micheli (Stanford Univ.), H.S. Lenihan (NOAA).

CURRENT AND PENDING SUPPORT FORM

The following information must be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Sean P. Powers
University of South Alabama

Other agencies to which this proposal has been/will be submitted:
None

Support: x Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Ecology of the Copper River Delta

Source of Support: Prince William Sound Oil Spill Recovery Institute

Total Award Amount: $160,000 ($40K/yr) Total Award Period Covered: 4/1/03 to 3/31/07

Location of Project: Copper River Delta, Alaska

Months of Your Time Committed to the Project: FY04 FY 05 FY 06 Sumr: 1.0/yr

Support: x Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Estuaries as essential fish habitat for salmonids: Assessing residence time and habitat use of coho and sockeye salmon in Alaska estuaries

Source of Support: North Pacific Research Board

Total Award Amount: $150,000 Total Award Period Covered: 8/1/03-7/31/05

Location of Project: Copper River Delta, Alaska

Months of Your Time Committed to the Project: FY04 FY 05 FY 06 Sumr: 1.0/yr

Support: x Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Trophic dynamics of intertidal soft-sediment communities: interaction between top-down and bottom-up processes.

Source of Support: EVOS-GEM

Total Award Amount: $30,000 Total Award Period Covered: 5/12/03-9/30/03

Location of Project: Copper River Delta, Alaska

Months of Your Time Committed to the Project: 1.0 FY04 FY 05 FY 06 Sumr:

Support: x Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Quantifying fisheries benefits of oyster reef restoration in Mobile Bay.

Source of Support: National Marine Fisheries Service

Total Award Amount: $217,000 Total Award Period Covered: 7/1/03-6/30/06

Location of Project: Mobile Bay, Alabama

Months of Your Time Committed to the Project: 1.0 FY 04 1.0 FY 05 1.0 FY 06 Sumr:

*If this project has previously been funded by another entity, please list and furnish information for immediately preceding funding period.

(USE ADDITIONAL SHEETS AS NECESSARY)

CURRENT AND PENDING SUPPORT FORM

The following information must be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Sean P. Powers University of South Alabama	Other agencies to which this proposal has been/will be submitted:

Support: x Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Bay scallop-cow nose ray interactions: application of source-sink models to shellfish

Source of Support: North Carolina Sea Grant

Total Award Amount: $59,000 Total Award Period Covered: 3/1/03 to 2/28/05

Location of Project: Coastal North Carolina

Months of Your Time Committed to the Project: FY04 FY 05 FY 06 Sumr: 0

Support: x Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Assessing trophic linkages between platforms and pelagic fishes using ultrasonic telemetry and active acoustics

Source of Support: Minerals Management Service

Total Award Amount: $60,000 Total Award Period Covered: 10/1/04-9/30/06

Location of Project: Coastal Louisiana

Months of Your Time Committed to the Project: FY04 1.0 FY 05 1.0 FY 06 Sumr:

Support: ☐ Current x Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Renewal: Trophic dynamics of intertidal soft-sediment communities: interaction between top-down and bottom-up processes. (This Proposal)

Source of Support: EVOS-GEM

Total Award Amount: $ 126,800 Total Award Period Covered: 10/1/03-9/30/06

Location of Project: Copper River Delta, Alaska

Months of Your Time Committed to the Project: 1.0 FY04 FY 05 FY 06 Sumr:

Support: Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Months of Your Time Committed to the Project: FY 04 FY 05 FY 06 Sumr:

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*If this project has previously been funded by another entity, please list and furnish information for immediately preceding funding period.

(USE ADDITIONAL SHEETS AS NECESSARY)

CURRENT AND PENDING SUPPORT FORM

The following information must be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Mary Anne Bishop	Other agencies to which this proposal has been/will be submitted: **None**

Support: X Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Ecology of the Copper River Delta

Source of Support: Prince William Sound Oil Spill Recovery Institute
Total Award Amount: $242,800 Total Award Period Covered: 1 Apr 2003 – 31 Mar 2007
Location of Project: Copper River Delta, Alaska
Months of Your Time Committed to the Project: 5.0 FY04 5.0 FY 05 5.0 FY 06 Sumr:

Support: X Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Estuaries as essential fish habitat for salmonids: Assessing residence time and habitat use of coho and sockeye salmon in Alaska's estuaries

Source of Support: North Pacific Research Board
Total Award Amount: $400,000 Total Award Period Covered: 1 Aug. 2003 – 31 July 2005
Location of Project: Copper River Delta, Alaska
Months of Your Time Committed to the Project: 2.0 FY 04 2.0 FY 05 FY 06 Sumr:

Support: X Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Trophic dynamics of intertidal soft-sediment communities: interaction between top-down and Bottom-up processes

Source of Support: EVOS-GEM
Total Award Amount: $ 91,700 Total Award Period Covered: 12 May 2003 – 30 September 2003
Location of Project: Copper River Delta, Alaska
Months of Your Time Committed to the Project: FY04 FY 05 FY 06 Sumr: 2.7 mo FY03

Support: ☐ Current X Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Trophic dynamics of intertidal soft-sediment communities: interaction between top-down and Bottom-up processes

Source of Support: EVOS-GEM
Total Award Amount: $ 464,900 Total Award Period Covered: 1 October 2003 – 30 September 2006
Location of Project: Copper River Delta, Alaska
Months of Your Time Committed to the Project: 3.5 FY 04 3.5 FY 05 4.0 FY 06 Sumr:

*If this project has previously been funded by another entity, please list and furnish information for immediately preceding funding period.

(USE ADDITIONAL SHEETS AS NECESSARY)

CURRENT AND PENDING SUPPORT FORM

The following information must be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Mary Anne Bishop	Other agencies to which this proposal has been/will be submitted: None

Support: ☐ Current **X** Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Promoting Ecotourism in Tibet Through a Culturally Responsive Conservation Education Program & Nature Guide Training

Source of Support: U.S. State Department
Total Award Amount: $ 110,000 Total Award Period Covered: 1 October 2003 – 30 May 2005
Location of Project: Tibet Autonomous Region, PR China
Months of Your Time Committed to the Project: 1.5 FY04 1.5 FY 05 FY 06 Sumr:

Support: ☐ Current **X** Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title: Impacts of seafood waste discharge in Orca Inlet, Prince William Sound

Source of Support: EVOS-GEM
Total Award Amount: $269,100 Total Award Period Covered: 1 October 2003-30 September 2006
Location of Project: Cordova, Alaska
Months of Your Time Committed to the Project: 0.5 FY 04 1.0 FY 05 1.0 FY 06 Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Months of Your Time Committed to the Project: FY04 FY 05 FY 06 Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Months of Your Time Committed to the Project: FY 04 FY 05 FY 06 Sumr:

*If this project has previously been funded by another entity, please list and furnish information for immediately preceding funding period.

(USE ADDITIONAL SHEETS AS NECESSARY)

Budget Narrative

G-040635 -Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes – renewal submitted under BAA
PRINCE WILLIAM SOUND SCIENCE CENTER
CORDOVA, ALASKA

Personnel Costs

Co-Principal Investigator Bishop:
3.5 mo/FY04 @ 7350; 3.5 mo/FY05 @ 7550; 4.0 mo/FY06 @ 7700/mo.
Bishop will oversee the project and coordinate with other intertidal studies. She will have primary responsibility for contract management, field work (benthic & epibenthic sampling), data integration, quality assurance and quality control and completion of final products. She will supervise the biological technician including invertebrate sorting and identification. Along with Powers and Peterson, she will be responsible for project design, statistical analysis and data interpretation, and preparation of manuscripts.

Biological technician: 6 mo/FY04 @3900; 7.5 mo/FY05 @ 4000; 6.0mo/FY06 @ 4100.
A field technician will be employed at PWSSC to assist with field work, analyses of the benthic samples (primarily the preliminary sorting and picking of the samples) and data entry. Increased time in FY05 for benthic samples associated with the nutrient experiment. Efforts will be made to hire a qualified, local Cordovan for this position.

Travel

Travel + perdiem for Annual Gem Workshop FY04, 05, 06 Co-Principal Investigators Bishop (Cordova-Anchorage) approx $800/yr
Travel +per diem Soc.Conservation Biology FY04, Bishop (Cordova-NewYork City) $1600

Contractual/Consultants

University of South Alabama $42,500 FY04, $43,100 FY05; $41,200 FY06
This contract is to the Co-Principal Investigator, Sean Powers.
Under this contract Dr. Powers will receive partial compensation for his summer salary (1 mo/FY04 @ 5000; 1mo/FY05 @ 5400; 1mo/FY06 @ 5800), support for technician to run chlorophyll samples (2mo/yr @ 3425/mo FY 04-06), supplies (jars, collection vials, 3000/yr) funds to pay for nutrient analyses (8700/yr FY 04-06), and travel funds all 3 years (1 rt to annual EVOS meeting,1400/yr; 1 rt Mobile to Cordova w per diem 2200/yr), and vessel charter (11 d @ 700/d FY 04 & 05, 8 d @ 700/d FY 06). Indirect Costs are 22% = Because all field work will be performed using the resources of the Prince William Sound Science Center the off campus F&A rate is applied (22% MTDC) to the University of South Alabama's subcontract.

Dr. Powers will be responsible for the design and execution of the experimental components of the project as well as assisting Dr. Bishop in the survey component of the project. He will also have primary responsibility for statistical analysis, data interpretation and preparation of manuscripts. Dr. Powers will also assist Dr. Bishop and the PWSSC technician in the identification of benthic invertebrates. Nutrient and chlorophyll *a* analyses will be performed under Dr. Powers supervision through the Dauphin Island Sea Lab.

Charles “Pete” Peterson, Ph.D., 1 mo/yr @ 8000/mo.
Peterson will serve as a consultant for this study. Dr. Peterson will assist on all aspects of experimental design, data analysis, and publication. Peterson is a Principal Investigator along with Powers and Bishop on the companion top-down study funded by Prince William Sound Oil Spill Recovery Institute (OSRI) supported study of the Delta.

Helicopter Time FY04 & FY06: 13h; FY05 21 h.
To conduct intertidal invertebrate & macroagal sampling, April & September, and macroalgal sampling in June. In FY05 extra 8 hours to deploy and retrieve exclosure experiments.

Computer Network Costs - based on $100/mo x PWSSC staff mo. - direct cost

Phone/Fax/& copying Charges - direct cost based on use only

Page costs @ $1000/manuscript: 1 manuscript FY05, 2 manuscripts FY06

Supplies
Office & lab supplies $1100/yr: includes jars, collection vials, chemical preservatives (formalin and ethyl alcohol), personnel equipment.

Nutrient experiment cages: $2500 FY03 to have full exclosures and partial exclosures fabricated from rebar.

Mail/Freight/Shipping samples $350/yr to airfreight samples to Univ. S. Alabama

Equipment No equipment purchases are anticipated

Indirect Costs

FY04 MTID estimated 26% pending FY02 IDC proposal submission (Current IDC is 26.45%). First year excludes $17.2k of University of South Alabama subcontract ($42.5 – 25k) from IDC Formula as per MTDC rules.
FY05 MTID estimated 27% pending FY03 IDC proposal submission. Second year excludes University of South Alabama subcontract from IDC Formula as per MTDC rules.
FY06 MTID estimated 27% pending FY04 IDC proposal submission. Third year excludes University of South Alabama subcontract from IDC Formula as per MTDC rules

Cost Share
Objective 3, Characterize the spatial and temporal abundance of demersal and avian consumers and assess the role of epibenthic predation on recruitment of intertidal macroinvertebrates, will be conducted using funds provided by the Prince William Sound Oil Spill Recovery Institute (OSRI) under the companion study, “Ecology of the Copper River Delta.” Objective 4 will be accomplished using resources from both OSRI and GEM-EVOS.

Quality Assurance Statement for GEM –040635 (renewal)

Study Design: Summarized in the text of the proposal.

Map of sampling stations: page 10
Benthic Invertebrate Sampling, Page 7, para 1-3
Sediment Sampling Page 7, para 1&3, Page 8, para 4
Chlorophyll *a* & Nutrient Sampling Page 8, page 9, para 1
Physical/Chemical CTD Sampling: Page 9, para 2
Nutrient Experiment: page 9, para 3, page 10
Fish predators: page 11 para 1-3
Data Analysis, page 12-13

Data Validation

The data quality will be monitored on a continuing basis. Because of the large number of replicate samples and experiments and the rigorous statistical analyses, conditions that require action to correct them will be immediately obvious to the staff. To assure consistency in data analyses, appropriate controls (positive and negative) and standards will be used in every phase. Controls will be run with each experiment to account for treatment effects. A probability level of 0.05 will be considered significant. Errors will be detected by abnormally high coefficients of variation between replicates. In the event of an error, the analyses will be repeated. If high variability is still observed this will indicate a problem in materials used in the analysis or procedures followed by the personnel. Should this case arise an immediate and thorough review of materials and procedures will be conducted by the Principal Investigators and appropriate changes made.

Characteristics of Data

a) *Metadata*: See attached GEM Metadata Form
b) *Data sets*

Physical measurements:

CTD: date, site, time, depth, salinity, temp, (PAR), fluorescence, current velocity
Sediment: date, site, elevation, replicate, wt. sand, wt. Silt, wt. Clay, total wt., % sand, %silt, % clay, % organics
Chlorophyll *a*: date, site, elevation, replicate, ml sampled, chlorophyll *a* milligrams/l
Nutrients: date, site, elevation, replicate, replicate, ml sample, concentrations (milligrams/l) for: nitrate, ammonia, phosphate, silicate, total inorganic, organic carbon
Trawl station: date, site, replicate, tidal stage, start time, end time, total time, speed, depth, temp

Species specific measurements

Invertebrate Cores: date, site, elevation, treatment (if core from experiment), replicate, for each species total numbers, for each bivalve species #s by 5 mm increments. eg: turbellarians, nemerteans, total macoma, macoma <5, macoma <10, Macoma <15, Macoma <20.
Macoma: date, clam no., shell height, shell length, shell weight, age
Macroalgae: date, site, elevation, replicate, quadrat size, species, wet weight, dry weight
Fish Trawls: date, site, replicate, tidal stage, start time, end time, total time, speed, depth, temp, salinity, fish spp. (listed with total nos. per trawl)

Fish Stomachs: date, fish spp., trawl loctn, trawl rep, standard length (cm), total length (cm), weight (g), stomach (g), stomach lining (g), all contents (g), unidentified contents (g), followed by a list of prey species (g)

Fish (by species): date, site, replicate, specimen #, total length (cm), standard length (cm), wt (g)

Procedures for Handling Samples:
All samples will be clearly marked with a unique identifying label. Labels will include information describing the date of collection, treatment (if any), origin of the sample, and a code number. Samples will be obtained from field sites and transported to PWSSC. Data books will contain a reference to the code number and indicate the nature of the samples as well as when, by whom, and under what conditions the samples were obtained. Benthic samples will be in custody of PWSSC. Chlorophyll *a* and nutrient samples will be frozen for later shipment to Univ. S. Alabama for analyses. Both PWSSC and Dauphin Island Sea Lab laboratory buildings will be routinely locked after hours and safe standard laboratory practices will be observed by all laboratory staff.

Calibration Procedures:
CTD's will be routinely calibrated to maintain a history of sensor drift, and hence changes in accuracy.
Nutrient & chlorophyll a samples and analyses: Following filtering, glassware will be placed in a 10% HCl bath following washing and the rinsed manually 3 times with deionized water.
Use of Turner Designs Model 10 Fluorometer and Alpkem RFA/2 Nutrient Autoanalyzer will be monitored on a daily basis and information will be obtained on performance in conjunction with each utilization of equipment. This information will be stored in log books kept with each piece of equipment. The information will be reviewed weekly by the staff and monthly by Powers.

Data Reduction and Reporting As the personnel collect data, Bishop and Powers will immediately review it. Following tabulation of the data, Bishop and Powers will review it again. Experiments and data will be recorded daily in bound laboratory notebooks. Information entered into notebooks from machine printouts will be verified twice and the originals will be filed. Data entered from notebooks into computer files will be verified and validated. This operation will be repeated until two consecutive verification checks yield no errors. Two copies (backup and original) will be kept of all computer files at all times.

EXXON VALDEZ OILSPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 04 - FY 06

Budget Category:	Proposed FY 04	Proposed FY 05	Proposed FY 06		TOTAL PROPOSED	
Personnel	$49,125.0	$56,425.0	$55,400.0		$160,950.0	
Travel	$2,411.0	$811.0	$811.0		$4,033.0	
Contractual	$59,500.0	$66,470.0	$60,460.0		$186,430.0	
Commodities	$1,450.0	$3,950.0	$1,450.0		$6,850.0	
Equipment	$0.0	$0.0	$0.0		$0.0	
Subtotal	$112,486.0	$127,656.0	$118,121.0		$358,263.0	
Indirect (rate will vary by proposer)	$24,696.4	$22,830.1	$20,768.7		$68,295.2	
Project Total	$137,182.4	$150,486.1	$138,889.7		$426,558.2	
Trustee Agency GA (9% of Project Total)	$12,346.4	$13,543.7	$12,500.1		$38,390.2	
Total Cost	$149,528.8	$164,029.8	$151,389.8		$464,948.4	

Prince William Sound Science Center will be purchasing one Microcat Seabird 37-SM and a YSI 6000 multi-parameter recorder fitted with a Sontek acoustic doppler-velocity meter. Both will be available for use in the project along with 2 other Seacats currently owned by the Science Center. PWSSC will also install the moorings.

FY 04-06

Date Prepared: 12-Jun-03

Project Number: G-040635
Project Title: Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes
Proposer: Prince William Sound Science Center

FORM 4A NON-TRUSTEE SUMMARY

EXXON VALDEZ OILSPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 04 - FY 06

Personnel Costs:			Months	Monthly		Personnel
Name	Description		Budgeted	Costs	Overtime	Sum
M.A. Bishop	Principal Investigator		3.5	7350.0		25,725.0
Research Technician	Research Technician		6.0	3900.0		23,400.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
		Subtotal	9.5	11250.0	0.0	
					Personnel Total	$49,125.0

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
Cordova to Anchorage - EVOS Workshop, January 2004 Co-Pi Bishop	325.0	1	3	162.0	811.0
Cordova to New York City - Soc. Conservation Biology, (presentation) June 2005	1000.0	1	3	200.0	1,600.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$2,411.0

FY 04

Project Number: G-040635
Project Title: Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes
Proposer: Prince William Sound Science Center

FORM 4B
Personnel
& Travel
DETAIL

EXXON VALDEZ OILSPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 04 - FY 06

Contractual Costs:	Contract
Description	Sum
Univ. S. Alabama Dauphin Island Marine Lab, Co-Pi Powers	42,500.0
C. Pete Peterson, consultant 1.0 mo	8,000.0
Field plot sampling Helicopter flights (13h @ $600 ea)	7,800.0
network costs (based on $100/mo x staff mo)	950.0
phone/fax/and copying charges	250.0
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$59,500.0

Commodities Costs:	Commodity
Description	Sum
office supplies, field notebooks, cd & diskettes	100.0
lab supplies (jars, formalin, etc)	1,000.0
mail/freight/shipping	350.0
Commodities Total	$1,450.0

FY 04

Project Number: G-040635
Project Title: Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes
Proposer: Prince William Sound Science Center

FORM 4B
Contractual &
Commodities
DETAIL

EXXON VALDEZ OILSPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 04 - FY 06

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: Description	Number of Units	Inventory Agency
YSI/Sontek CTD w integrated acoustic doppler-velocity meter (PWSSC)	1	
Microcat Seabird 37-SM (PWSSC)	1	
Computers & software (PWSSC 2, Univ. S. Alabama 2)	4	
Laboratory - Prince William Sound Science Center	1	
Laboratory - Dauphin Island Sea Lab, Univ. S. Alabama	1	
Safety equipment - Prince william Sound Science Center & Univ. S. Alabama	2	
CHN Analyzer - Univ. S. Alabama	1	

FY 04

Project Number: G-040635
Project Title: Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes
Proposer: Prince William Sound Science Center

FORM 4B
Equipment
DETAIL

***EXXON VALDEZ* OILSPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 04 - FY 06

Personnel Costs:			Months	Monthly		Personnel
Name	Description		Budgeted	Costs	Overtime	Sum
M.A. Bishop	Principal Investigator		3.5	7550.0		26,425.0
Research Technician	Research Technician		7.5	4000.0		30,000.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
		Subtotal	11.0	11550.0	0.0	
					Personnel Total	$56,425.0

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
Cordova to Anchorage - EVOS Workshop, January 2005 Co-Pi Bishop	325.0	1	3	162.0	811.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$811.0

FY 05

Project Number: G-050635
Project Title: Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes
Proposer: Prince William Sound Science Center

FORM 4B
Personnel
& Travel
DETAIL

EXXON VALDEZ OILSPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 04 - FY 06

Contractual Costs:	Contract
Description	Sum
Univ. S. Alabama Dauphin Island Marine Lab, Co-Pi Powers	43,100.0
C. Pete Peterson, consultant 1.0 mo	8,000.0
Field plot sampling Helicopter flights (21h @ $620 ea)	13,020.0
network costs (based on $100/mo x staff mo)	1,100.0
phone/fax/and copying charges	250.0
Page costs for 1 manuscript	1,000.0
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$66,470.0

Commodities Costs:	Commodity
Description	Sum
office supplies, field notebooks, cd & diskettes	100.0
lab supplies (jars, formalin, etc)	1,000.0
exclosures for nutrient experiment	2,500.0
mail/freight/shipping	350.0
Commodities Total	$3,950.0

FY 05

Project Number: G-050635
Project Title: Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes
Proposer: Prince William Sound Science Center

FORM 4B
Contractual &
Commodities
DETAIL

EXXON VALDEZ OILSPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 04 - FY 06

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: Description	Number of Units	Inventory Agency
YSI/Sontek CTD w integrated acoustic doppler-velocity meter (PWSSC)	1	
Microcat Seabird 37-SM (PWSSC)	1	
Computers & software (PWSSC 2, Univ. S. Alabama 2)	4	
Laboratory - Prince William Sound Science Center	1	
Laboratory - Dauphin Island Sea Lab, Univ. S. Alabama	1	
Safety equipment - Prince william Sound Science Center & Univ. S. Alabama	2	
CHN Analyzer - Univ. S. Alabama	1	

FY 05

Project Number: G-050635
Project Title: Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes
Proposer: Prince William Sound Science Center

FORM 4B
Equipment
DETAIL

EXXON VALDEZ OILSPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 04 - FY 06

Personnel Costs:			Months	Monthly		Personnel
Name	Description		Budgeted	Costs	Overtime	Sum
M.A. Bishop	Principal Investigator		4.0	7700.0		30,800.0
Research Technician	Research Technician		6.0	4100.0		24,600.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
		Subtotal	10.0	11800.0	0.0	
					Personnel Total	$55,400.0

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
Cordova to Anchorage - EVOS Workshop, January 2006 Co-Pi Bishop	325.0	1	3	162.0	811.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$811.0

FY 06

Project Number: G-060635
Project Title: Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes
Proposer: Prince William Sound Science Center

FORM 4B
Personnel
& Travel
DETAIL

EXXON VALDEZ OILSPILL TRUSTEE COUNCIL
DETAILED BUDGET FORM FY 04 - FY 06

Contractual Costs:	Contract
Description	Sum
Univ. S. Alabama Dauphin Island Marine Lab, Co-Pi Powers	41,200.0
C. Pete Peterson, consultant 1.0 mo	8,000.0
Field plot sampling Helicopter flights (13h @ $620 ea)	8,060.0
network costs (based on $100/mo x staff mo)	950.0
phone/fax/and copying charges	250.0
Page costs 2 manuscripts	2,000.0
Contractual Total	$60,460.0

Commodities Costs:	Commodity
Description	Sum
office supplies, field notebooks, cd & diskettes	100.0
lab supplies (jars, formalin, etc)	1,000.0
mail/freight/shipping	350.0
Commodities Total	$1,450.0

FY 06

Project Number: G-060635
Project Title: Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes
Proposer: Prince William Sound Science Center

FORM 4B
Contractual &
Commodities
DETAIL

***EXXON VALDEZ* OILSPILL TRUSTEE COUNCIL**
DETAILED BUDGET FORM FY 04 - FY 06

New Equipment Purchases:	Number	Unit	Equipment
Description	of Units	Price	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:	Number	Inventory
Description	of Units	Agency
YSI/Sontek CTD w integrated acoustic doppler-velocity meter (PWSSC)	1	
Microcat Seabird 37-SM (PWSSC)	1	
Computers & software (PWSSC 2, Univ. S. Alabama 2)	4	
Laboratory - Prince William Sound Science Center	1	
Laboratory - Dauphin Island Sea Lab, Univ. S. Alabama	1	
Safety equipment - Prince william Sound Science Center & Univ. S. Alabama	2	
CHN Analyzer - Univ. S. Alabama	1	

FY 06

Project Number: G-060635
Project Title: Trophic dynamics of intertidal soft-sediment communities: interaction between bottom-up & top-down processes
Proposer: Prince William Sound Science Center

FORM 4B
Equipment
DETAIL