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GEM PROPOSAL SUMMARY PAGE

(To be filled in by proposer)

Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems

Project Period: October 1^{st,} 2003 to September 30^{th,} 2006-- "FY 04-FY 06"

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Study Location: Karluk Lake, Spiridon Lake, Kodiak, Alaska

Abstract: The proposed project is a comprehensive study examining the role of marine-derived nutrients (MDNs) in the productivity of a sockeye nursery lake ecosystem. The research plan integrates studies of nutrient cycling, primary productivity, zooplankton dynamics, and juvenile sockeye abundance and growth, within a framework of stable isotope natural abundance. The study sites are an ideal pair, very similar in characteristics except for access by spawning salmon (anadromous Karluk Lake and control Spiridon Lake). The project will take advantage of the wealth of previous research including relatively long-term limnological data for both sites. Based on previous work, signals from MDNs are anticipated to be relatively strong, which will help elucidate nutrient pathways. The research design is the first to utilize detailed vertical and temporal sampling of the water column, coupled with measurements of rates of primary productivity, and fully integrated stable isotope analyses, with contemporaneous sampling in a well-matched pair of salmon and control lakes. The overall goal of this project is to provide the framework for designing monitoring projects to detect changes in marine terrestrial linkages in Gulf of Alaska sockeye watersheds.

Funding:	EVOS Funding Requested:	FY 04	$ 72,658	
		FY 05	$ 73,286	
		FY 06	$ 74,219	TOTAL: $ 220,163
	Non-EVOS Funds to be Used:	FY 04	$	
		FY 05	$	
		FY 06	$	TOTAL:

Date: June 2003 Date proposal prepared

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GEM WATERSHEDS RESEARCH PLAN:

Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems

I. NEED FOR THE PROJECT

A. Statement of Problem

It has long been recognized that Pacific salmon transport significant quantities of nutrients, which are derived from marine sources, into freshwater systems when they return to spawn and subsequently die (e.g., Juday et al., 1932, Koenings and Burkett 1987a). For example, a mass balance approach indicates that sockeye salmon-derived phosphorus accounts for up to 60% of the annual P loading into Iliamna Lake (Donaldson 1967). As with P, salmon are highly enriched in nitrogen (Mathisen et al., 1988). Because the N derived from adult salmon is highly enriched in ^{15}N ($\delta^{15}N \sim 12$ ‰) relative to terrestrially-derived N (atmospheric $\delta^{15}N = 0$ ‰), stable N isotopic analysis provides a tool to trace marine-derived nutrients (MDN) into freshwater environments (Mathisen et al., 1988, Kline et al., 1990, Bilby et al., 1996). Comparison of biota in salmon systems relative to nearby control systems, that are isolated from salmon, often reveal significant enrichment in $\delta^{15}N$ (Kline et al., 1990, 1993, Bilby et al., 1996). As freshwater productivity is an important control on sockeye production (Koenings and Burkett 1987a) there may be feedbacks between salmon escapement, nutrient loading, aquatic productivity and subsequent salmon production that are effected by climatic change and commercial fishing (Finney et al., 2000). As marine-derived nutrients (MDN) are also important nutrient sources for riparian vegetation and terrestrial fauna such as eagles, bears and mink (e.g., Ben-David et al., 1997, 1998), changes in the strength of the anadromous marine-nutrient pump may have broad impacts in Gulf of Alaska watersheds.

Most of the research examining MDN in watersheds has focused on detecting and measuring MDN utilization by comparing communities in salmon and control systems, and through stable isotope analysis. Few studies, however, have examined the impacts of temporal changes in MDN input on watershed ecosystems, though evidence from long-term limnological monitoring and paleoecology studies indicate substantial changes can occur. Schmidt et al., (1998) used limnological data from Karluk Lake to demonstrate a reduction in freshwater carrying capacity, and subsequent salmon productivity, was linked to decreased escapement. Paleoecological data from this system clearly indicate that past changes in escapement, due to both natural climate change and commercial harvest, have had large impacts on lake primary and zooplankton productivity (Finney et al., 2000, 2002). Thus, holistic ecosystem-based management should consider the role of MDN in determining escapement goals in watersheds where salmon-derived nutrients are important. Any changes in escapement level may result in feedbacks that influence ecosystem processes and productivity in watersheds (e.g., Finney et al., 2000). However, methods by which to assess such changes have not been fully developed.

The project proposed here is a comprehensive study examining the role of MDN in sockeye nursery lake ecosystem productivity. Our research plan integrates studies of nutrient cycling, primary productivity, zooplankton dynamics, and juvenile sockeye abundance and growth, within a framework of stable isotope natural abundance. The study sites are an ideal pair, very similar in characteristics except for access by spawning salmon (anadromous Karluk Lake and control Spiridon Lake). The project will take advantage of the wealth of previous research including relatively long-term limnological data for both sites. This research has demonstrated the important role of MDN in the Karluk ecosystem (e.g. Koenings and Burkett, 1987b, Schmidt et al., 1998, Finney et al., 2000). Thus we anticipate that signals from MDN will be relatively strong, which will help elucidate pathways and robust analytical methods that can be applied to other systems. The research design is the first to utilize detailed vertical and temporal sampling of the water column, coupled with measurements of rates of primary productivity, and fully integrated stable isotope analyses, with contemporaneous sampling in a well-matched pair of salmon and control lakes. The overall goal of this project is to provide the framework for designing monitoring projects to detect changes in marine terrestrial linkages in Gulf of Alaska sockeye watersheds.

B. Relevance to GEM Program Goals and Scientific Priorities

This project addresses the main hypotheses and questions regarding watersheds discussed in the GEM program document and current science plan. First, the measurements proposed here will determine how forces that influence salmon escapement (such as climate and fishing) influence marine-related biological production in watersheds, on time-scales from seasonal to multi-decadal (central hypothesis of GEM watersheds program). GEM identified large information gaps relating to how food and energy originating in the offshore marine environments is transported to watersheds, and in detecting changes in the variables that characterize this transfer. Specifically, results from this project will help address the following questions identified in the GEM document:

1. What is the extent to which the functioning and productivity of watersheds depends on marine-nutrient inputs?
2. How can this marine-terrestrial linkage be better detected and understood?
3. Are isotopes such as $\delta^{15}N$, $\delta^{13}C$ and $\delta^{34}S$ valid tools in detecting marine-related indicators and any temporal changes in their influence?
4. How does variability in lake water nutrient composition relate to the salmon spawning cycle, and isotopic signatures in lake biota?
5. What is the temporal and spatial variability in the stable isotopic composition of lake biota, and how does it relate to differences in escapement level between watersheds, and within a watershed over time?
6. Which species are best suited to measuring marine linkages?
7. Where, when and how should these species be sampled?

The results from this project have management implications regarding the effect to which fisheries may influence the overall productivity of watersheds. If transport of nutrients from the marine environment to watersheds by salmon is important for sustaining the overall productivity of some types of watersheds, overfishing will reduce the carrying capacity of the system not only for salmon, but also for other species. The extent of such "oligotrophication" in Gulf of Alaska watersheds is unknown. This study will help develop tools to detect the influence of salmon escapement on the production of biota in coastal watersheds. Such ecosystem process studies are required to implement ecosystem-based management (Mangel et al., 1996), which will require long-term monitoring of the flux of marine-nutrients. The results from this project will provide information critical in developing a monitoring program to detect annual changes in levels of marine nutrients in watersheds.

II. PROJECT DESIGN

A. Objectives

We focus on sockeye salmon (*Oncorhynchus nerka*) systems for this research, acknowledging that different processes are likely to be important in riverine systems. A focus on sockeye is justified, in part, because the sockeye is Alaska's most important salmon in terms of landed value, and productivity in freshwater systems has been shown to be an important control on adult sockeye productivity. We have selected Karluk Lake as the focus of this research for a number of reasons. First, it is a system that is perhaps the most-well studied of all sockeye lakes, and probably has the best long-term limnological and fisheries data sets. The long-term limnological data set covers almost 20 years (starting in about 1980) but has recently been scaled back due to lack of funding. Because of the importance of MDN in this system, this site is ideal for process studies to learn about tracing and quantifying MDN pathways.

The project design utilizes detailed vertical and temporal sampling of the water column, coupled with measurements of rates of primary productivity, which is fully integrated with stable isotope analyses. Furthermore, the project exploits an exceedingly well-matched pair of lakes that are similar in their physical attributes except for access to salmon, with contemporaneous parallel sampling. The project proposed here is the first comprehensive study examining the role of MDN in sockeye nursery lake ecosystem productivity.

The main objectives of this research are:

1. Conduct parallel studies of seasonal and interannual variability in nutrient concentrations, lake primary productivity, zooplankton biomass and composition, and juvenile sockeye (abundance, size and age) in a sockeye (Karluk) and nearby similar control (Spiridon) lakes.
2. Determine the stable isotopic composition ($\delta^{15}N$ and $\delta^{13}C$) of nutrients (nitrate) and lake biota (phytoplankton, zooplankton, juvenile sockeye) corresponding to the sampling in objective (1) both lakes.
3. Determine seasonal and interannual time-series of tributary stream nutrient concentrations and nitrate-$\delta^{15}N$.
4. Compare the data derived from objectives 1-3 to seasonal and interannual changes in sockeye escapement, and to climatic data.
5. Conduct exploratory analyses to determine the utility of $\delta^{34}S$ as a tracer of MDN in lake biota.

6. Conduct exploratory analyses of $\delta^{15}N$ and $\delta^{13}C$ of terrestrial biota (several species of plants, birds and bears) on seasonal and interannual scales to determine relationships to MDN imports.
7. Use multivariate statistical methods to compare results between control and salmon lakes, and to determine relationships between nutrients, productivity, lake biota isotopic composition and controlling factors such as escapement level and physical processes, on seasonal and interannual timescales.
8. Synthesize results with previous limnolgical data to determine long-term trends in productivity and controlling factors.
9. Synthesize results with long-term paleoecological data to assess the state of the system in the longer context.
10. Develop strategies for long-term monitoring of marine-terrestrial linkages based on the results of this study.

The results of this project will test the following hypotheses:
H1: MDN significantly increase primary productivity above the background rates in similar control systems.
H2: The seasonal cycle of primary productivity is different in salmon and control lakes.
H3: Lake biota in salmon systems is enriched in $\delta^{15}N$ and $\delta^{13}C$ relative to that in control lakes, and has higher seasonal variability related to the salmon spawning cycle.
H4: The $\delta^{15}N$ of sockeye smolts outmigrating in the spring reliably integrate relative levels of MDN in the lake during the previous year.
H5: The transfer of MDN to juvenile salmon is dependent on lake food web interactions.

The intended research is important, as it will be the first to measure rates of productivity, as opposed to standing stocks (e.g. chlorophyll a). By conducting measurements throughout the entire water column over the course of the growing season, we will be able to fully describe the pelagic productivity cycle. A significant new aspect of this research is a fully integrated scheme of isotopic analysis, which will determine the strengths and weaknesses of isotopic tools. Finally, this project represents an important collaboration between the University of Alaska Fairbanks (UAF) and the Alaska Department of Fish and Game (ADF&G) utilizing consistent state-wide fisheries assessment methodologies combined with new approaches, with a unified goal of better understanding of these ecosystems for sustainable management.

B. Procedural and Scientific Methods

Sampling plan. The basic sampling plan will be identical for the sockeye salmon lake (Karluk) and the control lake (Spiridon). Each lake will be sampled 9 times per year for 3 years. Sampling will run from April - October, and the interval between sampling will be no more than ~1 month, with more frequent sampling during important periods.

Sampling localities at each lake consist of two pelagic stations, and two river mouth stations. The pelagic stations at each lake have been carefully selected by previous research by ADF&G. Each pelagic station will be sampled at the following depths (m): 1, 5, 10, 15, 20, 25, 30, 35, 50 and ~ 1 m off bottom. The 1 m and near-bottom depths are the normal sampling depths of the ADF&G limnological protocol (Schrof and Honnold *in press*) so the results of this project will be fully comparable to the long-term data for these lakes, and to the statewide ADF&G

limnological database. Further, the detailed sampling will assess how representative these sampling depths are of overall lake nutrient and productivity cycles.

For each lake, two typical rivers will be sampled at their mouths during each of the sampling trips. These samples are designed to describe the seasonal inputs of riverine nutrients into the lakes, which will be controlled by processes such as terrestrial nutrient cycling, runoff and salmon carcass decomposition.

Water analyses and primary productivity. The following analyses will be conducted on each lake and river water sample:
TP, dissolved P, nitrate, ammonia, TKN, Si, chlorophyll a. Nitrate-$\delta^{15}N$ will also be measured on selected samples. The water will be filtered for POM, which will be analyzed for C%, N%, $\delta^{15}N$ and $\delta^{13}C$.

At each lake station, standard profiles/measurements of temperature, DO, secchi depth, light attenuation and conductivity will be conducted. These variables will also be measured at the river mouths. In addition, at each lake station, continuous profiles of flourescence and nitrate will be measured. Primary productivity will be measured using dual-label nitrogen and carbon productivity measurements six times/year. These rate estimates will be focused around the sockeye returns. Nitrogen productivity will be determined at three light depths (surface, 1% light depth and 0.1% light depth) using ^{15}N-labeled nitrate and ammonium to measure uptake while carbon productivity will be determined by uptake of ^{13}C-labeled bicarbonate. The productivity samples will also provide concentrations of particulate organic carbon and nitrogen as a result of the required mass spectrometric analytical determinations of ^{15}N and ^{13}C. Rates of size-fractionated phytoplankton primary production will be monitored using ^{14}C incubations and natural sunlight using the method of O'Reilly and Thomas (1983).

Zooplankton. Vertical zooplankton hauls covering the entire water column will be conducted at each sampling period at each lake station. Species assemblages, sizes and biomass will be determined. The two main species, Bosmina and Cyclops, will be physically separated under a dissecting microscope for separate $\delta^{15}N$ and $\delta^{13}C$ analyses.

Juvenile sockeye salmon. Smolts outmigrating in the spring will be estimated at each lake using a smolt trap and, where applicable (Karluk), mark-recapture experiments (smolts outmigrating from Spiridon Lake are estimated by a time counting method). In addition, fry stocking levels will be known for each year at Spiridon Lake. Lengths, weights, and ages will be estimated by obtaining samples throughout the outmigration period. Representative samples will be collected for $\delta^{15}N$ and $\delta^{13}C$ analysis (40 per lake per year). Scale pattern analyses will be conducted to determine seasonal and annual variations in growth, which may be related to limnologic conditions.

Adult salmon. Under separate funding, adult salmon returning to Karluk Lake are counted through a weir installed each year in Karluk River (Kuriscak *in press*). There is no escapement to Spiridon Lake because none of the adults returning are able to enter the lake due to impassable barrier falls. Sockeye salmon originally stocked into Spiridon Lake are harvested in traditional fishing areas as they return to Telrod Cove, where the outlet of the lake enters the ocean

(Honnold 1997). Adults not harvested in traditional areas are harvested in the Spiridon Lake Terminal Harvest Area (SLTHA) in Telrod Cove. Commercial, sport, and subsistence harvests are tracked via the ADF&G fish ticket database and are assigned to stock of origin, including the Karluk Lake and Spiridon Lake (Witteveen et al., *in press*). The $\delta^{15}N$ and $\delta^{13}C$ composition of adult sockeye have been determined, but will be further assessed during the course of this study.

Exploratory studies.
a) δ^{34}*S analysis*. We will test the utility of $\delta^{34}S$ analysis in detecting and tracing MDN, through analyses of selected samples. Peterson and Howarth (1987) suggest that such analyses have the potential to trace marine sources, and have different isotopic controls than $\delta^{15}N$ and $\delta^{13}C$.

b) *Terrestrial linkages*. We will explore linkages of MDN in terrestrial sites through several pilot studies. The ability of terrestrial vegetation to respond to MDN inputs will be assessed by sampling several plant species along transects at our river sites for both salmon and control systems. Sampling will be conducted 4 times per year for $\delta^{15}N$ and $\delta^{13}C$ analysis. Growth responses of streamside willows to MDN will be assessed by tree ring analysis of cores collected at these sites following the methods of Drake et al., (2002). We will also attempt to secure non-destructive samples of birds (i.e. feathers) and mammals such as bears (fur, claws) to assess the levels MDN through $\delta^{15}N$ and $\delta^{13}C$ analysis.

Methodological details.
Stable isotopes. Stable isotopes will be measured using standard techniques on a Finnnigan Delta Plus mass spectrometer housed at UAF. Accuracy and precision of the $\delta^{15}N$ and $\delta^{13}C$ analyses is within 0.1-0.3 o./oo. Briefly, POM is scraped of combusted GF/F filters for isotopic analyses. Separated zooplankton samples, or fish muscle samples are dried and homogenized prior to analysis.

Water column sampling. Vertical gradients of temperature and conductivity will be gathered with a SBE19 SeaCat CTD equipped with a fluorometer and an *In Situ* Ultraviolet Spectrometer (ISUS) for the direct determination of nitrate. The continuous profiles will determine distributions at approximately 5 cm resolution from surface to the bottom. Underwater light intensity (foot-candles) or downward irradiance will be measured using an International Light model 1350 submersible photometer sensitive to the visible spectral range (400-700 nm) as described by Honnold et al., (1996) and Schrof et al., (2000). For each survey at each station, dissolved oxygen concentrations will be measured at 1-m increments throughout the water column or to a maximum depth of 50 m using a YSI model 57 or 53 oxygen analyzer (Honnold 1997, Schrof et al., 2000). Water samples and CTD profiles will be collected nine times each year at two pelagic stations in each lake and two river stations per lake. Water samples will be collected at between the surface and bottom at 5 m intervals and will include the past sampling depths of ADF&G of 1 m below the surface and 1 m above the bottom according to standards developed by the former Statewide Limnology Section of the ADF&G (Koenings et al., 1987). The water samples collected to parallel previous ADF&G sampling will be handled, preserved and processed according to Koenings et al., (1987) as described by Schrof et al., (2000).

Sub-samples of the water collected from 1 m and 1 m above the bottom will be processed in the laboratory for conductivity, pH (Koenings et al. 1987), and alkalinity (mg L^{-1} as $CaCO_3$; AHPA

1985). Calcium and magnesium (Golterman 1969), as well as total iron concentrations will be analyzed (Golterman 1969; Strickland and Parsons 1972). Turbidity, expressed as nephelometric turbidity units (NTU), will be measured with a calibrated HF model DRT100 turbidimeter (Koenings et al. 1987). The water color will be calculated after Koenings et al. (1987). Filterable reactive phosphorus (FRP) will be analyzed by the molybdate blue-ascorbic acid method (Murphy and Riley 1962) as modified by Eisenreich et al. (1975) and total phosphorus (TP) as described by Eisenreich et al. (1975). Nitrate + nitrite (NO_3^- + NO_2^-), ammonia (NH_4^+), and total Kjeldahl nitrogen (TKN) will also be analyzed (Stainton et al. 1977; Crowther et al. 1980). Soluble reactive silicon (SR-Si) concentrations will be determined using the automated ascorbic acid reduction procedure (Stainton et al., 1977). Samples for particulate organic carbon (POC) analysis will use the wet oxidation technique with dichromate (Newel 1982). Chl a samples will be processed, filtered, and analyzed using methods described by (Koenings et al., 1987, Honnold 1997, *Schrof* et al., 2000).

Lake Productivity. Six times each year dual label nitrogen and carbon productivity measurements will be obtained at the 4 lake/river locations at times focused around the sockeye returns. Nitrogen productivity will be determined at three light depths (surface, 1% light depth and 0.1% light depth) using ^{15}N-labeled nitrate and ammonium to measure uptake while carbon productivity will be determined by uptake of ^{13}C-labeled bicarbonate. The productivity samples will also provide concentrations of particulate organic carbon and nitrogen as a result of the required mass spectrometric analytical determinations of ^{15}N and ^{13}C. Chlorophyll and nutrient (nitrate, ammonium, nitrite, silicate and phosphate) concentrations will be determined at each productivity depth. All chlorophyll samples will be fractionated into >5um and <5um sizes to estimate the contribution of microplankton to the production cycle. If significant chlorophyll biomass is obtained in the <5um size fraction of chlorophyll, then ^{14}C-labeled bicarbonate may be utilized to measure the rate of primary productivity of both the large and small sizes of phytoplankton. A water sample of phytoplankton will also be preserved for general taxonomy, size distributions and abundance from each of the productivity stations.

Ambient nutrient concentrations. For calibration of the ISUS nitrate instrument, nutrient samples will be quick frozen in a salt-ice mixture in the field and kept frozen until analysis in the UAF chemical laboratory. The samples will be quick thawed in cold water and analyzed with an Alpkem Model 300 Rapid Flow Analyzer using methods modified for small volume glassware (Whitledge et al., 1981). Prior to analysis of field samples, calibration of the automated nutrient channels will be performed before each set of samples using five concentrations for each nutrient analyte. Detailed protocols of standards and their preparation are described by Whitledge et al., (1981) and have been used for freshwater/marine samples from 1975 through the present.

Zooplankton. Vertical zooplankton hauls will be collected using a 0.2-m diameter, 153 ? m mesh, conical net (Honnold et al., 1996, Honnold 1997) using standard collection techniques (Schrof et al 2000). Net contents from each tow will be preserved (Schrof et al., 2000) and cladocerans and copepods identified according to taxonomic keys in Pennak (1989) and Thorp and Covich (1991). Zooplankton will be enumerated and measured and the mean body length for each taxon calculated (Honnold 1997, Schrof et al., 2000). Zooplankton biomass will be estimated from specie-specific linear regression equations between length and dry weight derived by Koenings et al., (1987).

Smolt Abundance and Size at Age. The study design will include continuing smolt trapping programs at the outlet streams of Karluk (proposed for funding here) and Spiridon (will be funded by the Kodiak Regional Aquaculture Association) lakes. Site descriptions and trapping configurations are similar to other smolt enumeration and sampling projects in the Kodiak Island, Alaska Peninsula, and Aleutian Island regions (Honnold 1999, Schrof et al., 2000, ADF&G 2002, *in press*; Bouwens 2003, Bouwens and Newland 2003, Sagalkin and Honnold *in press,* Schrof and Honnold *in press*). The traps will be fished daily for the duration of the smolt outmigration (~1 May until ~31 June). The trapping system at Spiridon is designed to trap all outmigrating smolt, which are diverted around a series of stream barriers (waterfalls) through a pipeline. The Karluk Lake program only traps a portion of the outmigrating smolt. Detailed methods for trap installation, operation, and maintenance are described in ADF&G (2002, *in press*) and Sagalkin and Honnold (*in press*).

Since smolt primarily migrate at night, a single trapping (and sampling) day will be the 24-hour period from noon to noon and will be identified by the calendar date corresponding to the first noon. All fish caught in the smolt trap will be enumerated. In an event where direct enumeration is not possible (Karluk) due to high migration levels, it will be necessary to estimate trap catch using the Catch-Weight Method (ADF&G 2002, *in press*). Species identification will be determined according to Pollard et al., (1997).

A random sample of 40 sockeye salmon smolt will be collected per day for five consecutive days per statistical week and sampled for age, weight, and length (AWL) data as described in ADF&G (2002, *in press*). Age, weight, and length data will be summarized by week and condition factor will be determined for each smolt sampled (Bagenal and Tesch 1978).

In order to estimate the total sockeye salmon smolt outmigration from Karluk Lake, the trap efficiency will be determined. Mark-recapture techniques will be utilized using Bismark Brown Y dye according to Carlson et al., (1998) and ADF&G (2002, *in press*). Once a week, a sample of about 1,000 sockeye salmon smolt will be collected for marking. Data collected from mark-recapture trials will be analyzed according to Carlson et al., (1998) to generate smolt outmigration estimates by age class.

C. Data Analysis and Statistical Methods

A number of approaches will be used in analyzing the data from this project. Multivariate statistical techniques as well as time series techniques will be employed to determine differences between control and salmon systems, and relationships to possible controlling factors. As some of the measurements and techniques we will employ are similar to those used by ADF&G in the past, our results will extend historical observations for these systems, and be compared with historical observations from other lakes in the ADF&G database. It is envisioned that these results will describe the variability in key variables, such that future studies can be designed with adequate statistical power to detect significant changes.

D. Description of Study Area

Karluk Lake is located on the southwest end of Kodiak Island, Alaska (57.40 N – 154.08 W) and has a surface area of 39.5 km^2, a mean depth of 49 m, and a maximum depth of 126 m (Schrof and Honnold, *in press*). The lake is considered oligotrophic and has a water residence time of about 4.8 years, and a light compensation point (euphotic zone depth) of 23 m (Koenings and Burkett, 1987b). The Karluk Lake watershed (282 km^2) is surrounded by rolling hills and small mountains with predominantly shrub tundra vegetation and is located in an area with a mean annual precipitation of about 170 cm. The Karluk Lake sockeye salmon escapement was about 850,000 in 2002, which is higher than the long-term average escapement of about 650,000 sockeye salmon.

Spiridon Lake is located on the southwest side of Kodiak Island, Alaska (57.67 N– 153.65 W) about 56 km north of Karluk Lake (Schrof and Honnold, *in press*). The lake has a surface area of 9.2 km^2, a mean depth of 34.7 m, a maximum depth of 82 m, and is characterized as an oligotrophic system (Kyle et al., 1990). Runoff from Spiridon Lake flows in a southeasterly direction via the 2.4 km Telrod Creek emptying into Spiridon Bay at Telrod Cove located approximately 7.2 km northwest from the head of the bay (KNWR 1991). The watershed drains an area of approximately 60 km^2, and with a mean annual precipitation of 101.5 cm, the lake-water residence time is 7.1 years. Adult salmon cannot access Spiridon Lake due to a series of barrier falls. The lake has been stocked with juvenile sockeye salmon each year since 1990 and all returning adults are harvested in traditional fisheries and in a designated terminal harvest area (Schrof and Honnold, *in press*). The annual run, as a result of stocking, is about 270,000 adult sockeye salmon.

E. Coordination and Collaboration with Other Efforts

This project will coordinate with ongoing Kodiak Management Area (KMA) ADF&G salmon research and management projects. Specific projects include: the ongoing KRAA funded smolt enumeration and sampling program at Spiridon Lake (Steve Schrof, PI, ADF&G); the ADF&G weir program at Karluk River (Kevin Brennan, Area Management Biologist, ADF&G); the overall Division of Commercial Fisheries, Westward Region limnology sampling program (Patricia Nelson, Finfish Research Supervisor, ADF&G); the KMA catch sampling program (Mark Witteveen, PI, ADF&G); and the KRAA funded Frazer Lake fish pass project (Patricia Nelson, Finfish Research Supervisor, ADF&G). Collaboration will occur in terms of field logistics, personnel sharing, equipment sharing, and field sampling, where appropriate. The project will also coordinate with the managers of the ADF&G Westward Region limnology database in terms of data sharing and inclusion of the data collected throughout this project.

This project is also related to GEM research project 02649: Reconstructing Sockeye Populations in the Gulf of Alaska over the Last Several Thousand Years: The Natural Background to Future Changes. Both projects are concerned with measuring marine-related phenomena in the GEM area watersheds, though the ongoing project is a retrospective study of sockeye abundance in Prince William Sound and the Kenai River watershed using the stable isotope tracers present in the sediments of spawning lakes.

We will also synthesize our results with ongoing ADF&G research on limnological aspects of sockeye salmon productivity such as those conducted by Ken Bouwens (Chignik Lake watershed; Bouwens and Finkle 2003) and Jim Edmundson (statewide lake systems).

III. SCHEDULE

A. Project Milestones

Milestone 1. Conduct year 1 field sampling.
To be met by October 2004

Milestone 2. Complete analyses of year 1 samples.
To be met by March 2005

Milestone 3. Preliminary data analysis and planning for year 2 sampling.
To be met by April 2005

Milestone 4. Conduct year 2 field sampling.
To be met by October 2005

Milestone 5. Complete analyses of year 2 samples.
To be met by March 2006

Milestone 6. Preliminary data analysis and planning for year 3 sampling.
To be met by April 2006

Milestone 7. Conduct year 3 field sampling.
To be met by October 2006

Milestone 8. Complete analyses of year 3 samples. This will result in completion of objectives 1-3, 5 and 6.
To be met by March 2007

Milestone 9. Complete data analysis and begin manuscript preparation.
To be met by April 2007

Milestone 10. Complete statistical analyses to meet objectives 4, 7-10. Submit manuscript.
To be met by August 2007

B. Measurable Project Tasks

FY 04, 1st quarter (October 1, 2003-December 31, 2003)
October: Project funding approved by Trustee Council

FY 04, 2nd quarter (January 1, 2004-March 31, 2004)
January 12-16 (tentative): Annual GEM Workshop

FY 04, 3rd quarter (April 1, 2004-June 30, 2004)
April: Prepare gear for field season.
June 30: Complete 3 field samplings, begin analyses.

FY 04, 4th quarter (July 1, 2004-September 30, 2004)
September 30: Continue year 1 field work and sample analyses.
Submit annual report to Trustee Council Office.

FY 05, 1st quarter (October 1, 2004-December 31, 2004)
December 31: Finish year 1 field work, and continue lab analyses.

FY 05, 2nd quarter (January 1, 2005-March 31, 2005)
(dates not yet known) Annual GEM Workshop

March: Complete analyses of year 1 samples.

FY 05, 3rd quarter (April 1, 2005-June 30, 2005)
April: Prepare gear for field season.
June 30: Begin year 2 field samplings, begin analyses.

FY 05, 4th quarter (July 1, 2005-September 30, 2005)
September 30: Continue year 2 field work and analyses.\
Submit annual report to Trustee Council Office

FY 06, 1st quarter (October 1, 2005-December 31, 2005)
December 31: Finish year 2 field work, and continue lab analyses.

FY 06, 2nd quarter (January 1, 2006-March 31, 2006)
(dates not yet known) Annual GEM Workshop
March: Complete analyses of year 2 samples.

FY 06, 3rd quarter (April 1, 2006-June 30, 2006)
April: Prepare gear for field season.
June 30: Begin year 3 field sampling and analyses.

FY 06, 4th quarter (July 1, 2006-September 30, 2006)
September 30: Continue year 3 field work and sample analyses.

FY 07, 1st quarter (October 1, 2006-December 31, 2006)
December 31: Finish year 3 field work, and continue lab analyses.

FY 07, 2nd quarter (January 1, 2007-March 31, 2007)
(dates not yet known) Annual GEM Workshop
March: Complete analyses of all samples.

FY 07, 3rd quarter (April 1, 2007-June 30, 2007)
April 15 Submit final report (which will consist of draft manuscript for publication) to Trustee Council Office

IV. RESPONSIVENESS TO KEY TRUSTEE COUNCIL STRATEGIES

A. Community Involvement and Traditional Ecological Knowledge (TEK)

The ADF&G will present the project design to the Kodiak/Aleutians Federal Subsistence Regional Advisory Council, the Kodiak National Wildlife Refuge Staff, the Kodiak Regional Salmon Planning Team, Kodiak Subsistence Councils, Kodiak Native Associations, the Kodiak Sport Fishing Association, and the U.S. Coast Guard for review and comment. The results of these consultations will be considered prior to writing any reports, finalizing operational plans, and implementing the field project. Data collected will also be shared with these groups through copies of inseason and annual reports. The ADF&G will give preference to local residents, including qualified residents of the Villages of Karluk, when hiring sampling crews. If appropriate, internships will be developed through the University of Alaska to provide career-track positions. Local employees will be trained in various biological data collection techniques and will be educated in many research applications that assist with salmon management. The study site will be located in an area of high recreational use and frequent interaction with the public will occur. Employees will be encouraged to provide accurate information to the public regarding the goals and objectives of the project, which will promote increased interaction among subsistence users, organizations, the community, and agencies.

B. Resource Management Applications

As stated earlier in the section "Need for the Project," the results from this project have management implications regarding the effect to which fisheries may influence the overall productivity of watersheds. The results from this project will provide information critical in developing a monitoring program to detect annual changes in levels of marine nutrients in watersheds.

V. PUBLICATIONS AND REPORTS

We will prepare annual reports by September 1 of each fiscal year for which funding is received, and a final report upon project completion. We anticipate several publications of project results in peer-reviewed journals during the course of this project, including a major paper synthesizing key results.

VI. PROFESSIONAL CONFERENCES

We hope to present project results at professional conferences, though no funds are requested here. We will have representation at the annual GEM workshops during this project.

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EDUCATION

Ph.D. Geological Oceanography, Oregon State University, Corvallis	1986
B.S. Geology (with honors), University of Minnesota, Minneapolis	1979

PROFESSIONAL EXPERIENCE

Professor, Institute of Marine Science, University of Alaska Fairbanks	2002-
Associate Professor, Institute of Marine Science, University of Alaska Fairbanks	1998-
Assistant Professor, Institute of Marine Science, University of Alaska Fairbanks	1991-1998
Research Associate, Duke University, Marine Laboratory	1989-1991
Research Associate, Marine Chemistry, Oregon State University	1987-1988
Research Assistant, Geological Oceanography, Oregon State University	1980-1986

RESEARCH

Research Experience

Stable isotope and chemical analysis of sediments. Quaternary dating techniques including radiocarbon, ^{210}Pb, ^{137}Cs, tephrochronology and uranium-series. Determination of organic carbon, calcium carbonate and biogenic silica abundances. Mineralogical studies.

Field experience in box, gravity and piston coring, water quality surveys, and hydrologic monitoring. Description and curation of geological samples. Computer-based statistical applications to geological data sets. Partitioning models of chemical composition using statistical approaches and chemical leaching studies. Time-series analysis and statistical testing.

Five Publications Relevant to this Research

Finney, B.P., Gregory-Eaves, I., Sweetman, J., Douglas, M.S.V. and Smol, J. (2000). Impacts of climatic change and fishing on Pacific Salmon abundance over the past 300 Years. *Science* **290**: 795-799.

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1986-1998, Senior Research Scientist, Marine Science Institute, The Univ. of Texas at Austin
1980-1986, Guest Investigator, Woods Hole Oceanographic Institution
1977-1986, Oceanographer, Brookhaven National Laboratory
1975-1977, Associate Oceanographer, Brookhaven National Laboratory
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Recent Related Publications:

Weingartner, T.J., K. Coyle, B. Finney, R. Hopcroft, T.E. Whitledge, R. Brodeur, M. Dagg, E. Farley, D. Haidvogel, L. Haldorson, A. Herman, S. Hinckley, J. Napp, P. Stabeno, T. Kline, C. Lee, E. Lessard, T. Royer and S. Strom. 2002. The Northeast Pacific GLOBEC Program: Coastal Gulf of Alaska. Oceanography. 15:48-63.

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CURRICULUM VITAE

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Ph.D., Oceanography, University of Rhode Island, Kingston, RI, 1987
M.S., Oceanography, Texas A&M University, College Station, TX, 1982
B.S., Oceanography, Humboldt State University, Arcata, CA, 1972

Professional Experience:

2000-Present	Assistant Research Professor, University of Alaska Fairbanks, Institute of Marine Science
2000-2001	Associate Program Director, NSF, Antarctic Biology & Medicine, 1 year rotator.
1998-2000	Assistant Research Professor, University of Alaska Fairbanks, Institute of Marine Science, pigment distributions Gulf of Alaska and Bering Sea
1990-1998	Research Associate, The University of Texas, Phytoplankton Primary Productivity, HPLC and Pigment analyses, and Brown Tide studies.
1991	Instructor for class entitled "Marine Phytoplankton", Oregon Institute of Marine Biology, University of Oregon, Summer Program.
1987-1990	Post-doctoral fellow, The University of Texas, Marine Science Institute, Port Aransas, TX.
1982-1987	Teaching and research assistant in oceanography, Marine Education and Public Relations Assistant, University of Rhode Island.
1980-1987	Consultant with Paul Hargraves to Dunes Club, Narragansett, R.I. Monitoring bacterial water quality along Rhode Island beaches.
1984-1986	Employee, SAIC, Newport, R.I. Worked on seismic traces and digitized navigational charts as part of DMA contract.
1984	Consultant to Roger Williams Park & Museum. A cataloging of Diatom slides belonging to the Kendall Diatom Collection.
1974-1978	Teaching and research assistant in oceanography, TAMU.
1972-1974	U.S. Army, "Vulcan" gun mechanic.

Research Interests:
Diatom taxonomy and biostratigraphy; marine phytoplankton ecology; polar marine geology and biology; coastal upwelling. Nutrient cycles associated with uptake and regeneration processes in the marine environment

Other Significant Experience and Awards:
National Science Foundation Arctic Service Award, March 1995
National Science Foundation Antarctic Service Award, 1976
Review Proposals for: National Science Foundation (Biological Oceanography, Polar Programs), National Oceanographic and Atmospheric Administration (Sea Grant)
Review Manuscripts: Limnology and Oceanography, Diatom Research, Journal of Phycology, Estuaries.

Recent Publications:

Stockwell, D.A., T.E. Whitledge, S.I Zeeman, K.O. Coyle, J.M. Napp, R.D. Brodeur, A.I. Pinchuk and G.H. Hunt, Jr. 2001. Anomalous conditions in the southeastern Bering Sea, 1997: nutrients, phytoplankton and zooplankton. Fish. Oceanogr. 10:99-116.

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Winter, A., D.A. Stockwell, and P.E. Hargraves. 1986. Tintinnid agglutination of coccoliths: a selective or random process? *Marine Micropaleont.* 10(4):375-379.

Collaborators not listed in publications:

Dr. R. Benner	Dr. S. Okkonen (UAF)	Dr. J. Schumacher
Dr. T. Royer	Dr. P. Stabeno	Dr. T. Weingartner (UAF)
Dr. M. Dagg	Dr. D. Musgrave (UAF)	Dr. Greta A. Fryxell

***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	$33,896.0	$35,049.0	$36,255.0		$105,200.0	
Travel	$5,980.0	$5,980.0	$5,980.0		$17,940.0	
Contractual	$13,750.0	$13,300.0	$12,800.0		$39,850.0	
Commodities	$4,500.0	$4,500.0	$4,500.0		$13,500.0	
Equipment	$0.0	$0.0	$0.0		$0.0	
Subtotal	$58,126.0	$58,829.0	$59,535.0		$176,490.0	
Indirect (rate will vary by proposer)	$14,532.0	$14,707.0	$14,884.0		$44,123.0	
Project Total	$72,658.0	$73,536.0	$74,419.0		$220,613.0	
Trustee Agency GA (9% of Project Total)	$6,539.2	$6,618.2	$6,697.7		$19,855.2	
Total Cost	$79,197.2	$80,154.2	$81,116.7		$240,468.2	

FY 04-06

Date Prepared:

Project Number:
Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems
Proposer: Finney, Whitledge, Stockwell

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
Finney			1.0	9727.0		9,727.0
Stockwell			1.0	6782.0		6,782.0
Whitledge			0.5	11674.0		5,837.0
Technician			2.0	5775.0		11,550.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
		Subtotal	4.5	33958.0	0.0	
					Personnel Total	$33,896.0

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
RT Fairbanks/Kodiak	600.0	6			3,600.0
lodging			12	100.0	1,200.0
per diem			12	40.0	480.0
Travel to PI meeting	700.0	1			700.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$5,980.0

FY 04

Project Number:
Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems
Proposer: Finney, Whitledge, Stockwell

FORM 4B
Personnel
& Travel
DETAIL

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

Contractual Costs: Description	Contract Sum
communication costs	$800
shop services	$1,000
analytical services (mass spec)	$6,500
outreach & education	$1,000
other (mainenance, shipping)	$4,450
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$13,750.0

Commodities Costs: Description	Commodity Sum
materials & supplies	4,500.0
Commodities Total	$4,500.0

FY 04

Project Number:
Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems
Name: Finney, Whitledge, Stockwell

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

FY 04

Project Number:
Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems
Proposer: Finney, Whitledge, Stockwell

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
Finney			1.0	9979.0		9,979.0
Stockwell			1.0	6959.0		6,959.0
Whitledge			0.5	11974.0		5,987.0
Technician			2.0	6062.0		12,124.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
		Subtotal	4.5	34974.0	0.0	
					Personnel Total	$35,049.0

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
RT Fairbanks/Kodiak	600.0	6			3,600.0
lodging			12	100.0	1,200.0
per diem			12	40.0	480.0
Travel to PI meeting	700.0	1			700.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$5,980.0

FY 05

Project Number:
Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems
Proposer: Finney, Whitledge, Stockwell

FORM 4B
Personnel
& Travel
DETAIL

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

Contractual Costs: Description	Contract Sum
communication costs	800.0
shop services	1,000.0
analytical services (mass spec)	6,500.0
outreach & education	1,000.0
other (mainenance, shipping)	4,000.0
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$13,300.0

Commodities Costs: Description	Commodity Sum
materials & supplies	4,500.0
Commodities Total	$4,500.0

FY 05	Project Number: Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems Proposer: Finney, Whitledge, Stockwell	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

FY 05

Project Number:
Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems
Proposer: Finney, Whitledge, Stockwell

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
Finney			1.0	10239.0		10,239.0
Stockwell			1.0	7139.0		7,139.0
Whitledge			0.5	12288.0		6,144.0
Technician			2.0	6366.5		12,733.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
		Subtotal	4.5	36032.5	0.0	
					Personnel Total	$36,255.0

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
RT Fairbanks/Kodiak	600.0	6			3,600.0
lodging			12	100.0	1,200.0
per diem			12	40.0	480.0
Travel to PI meeting	700.0	1			700.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$5,980.0

FY 06

Project Number:
Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems
Proposer: Finney, Whitledge, Stockwell

FORM 4B
Personnel
& Travel
DETAIL

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

Contractual Costs: Description	Contract Sum
communication costs	800.0
shop services	1,000.0
analytical services (mass spec)	6,500.0
outreach & education	1,000.0
other (mainenance, shipping)	3,500.0
Contractual Total	$12,800.0

Commodities Costs: Description	Commodity Sum
materials & supplies	4,500.0
Commodities Total	$4,500.0

FY 06

Project Number:
Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems
Proposer: Finney, Whitledge, Stockwell

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

FY 06

Project Number:
Project Title: Marine-terrestrial linkages in northern Gulf of Alaska watersheds: Towards monitoring the effects of anadromous marine-derived nutrients on biological production in sockeye salmon systems
Proposer: Finney, Whitledge, Stockwell

FORM 4B
Equipment
DETAIL

Budget Justification

Salary is requested for one month each year for Drs. Finney and Stockwell and a half-month for Dr. Whitledge to support the anticipated field collection of samples. Three months of technician time is requested each year to prepare and process samples and to perform maintenance and equipment calibrations. Travel requests are for six roundtrips from Fairbanks to Kodiak each year to transport and lodge personnel for sample collections/experiments. Service funds are requested to support publication costs, mass spectrometer analysis, maintenance and calibration of CTD's and nitrate sensors. Requested supplies are required for the purchase of all chemicals, glassware, stable and radioactive isotopes, filters, expendable supplies and sample bottles. No equipment is being requested.