EVOS PROPOSAL SUMMARY PAGE

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Cluster ACC
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Project Title: Monitoring dynamics of the Alaska coastal current and development of applications for management of Cook Inlet salmon – a pilot study

Project Period: FY03-FY04

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Matching Funds: $96.9 (ADF&G)

Study Location: Cook Inlet

Trustee Agency: ADF&G

Abstract:

This project will demonstrate the technical feasibility of using a vessel of opportunity to collect physical oceanographic and fisheries data along a transect across lower Cook Inlet from Anchor Point to the Red River delta. Logistical support for the field sampling will be provided in part by the Alaska Department of Fish and Game which has chartered a vessel annually to fish along this transect each day during July providing inseason projections of the size of salmon runs returning to the inlet. The work proposed here is for a single year of data collection to demonstrate the feasibility of obtaining oceanographic data as part of a fisheries survey. However, a long-term monitoring program is envisioned. If feasibility is established, investigators will in future years use physical oceanographic data collected by the project to improve management of Cook Inlet salmon through improved inseason salmon run projections. Several hypotheses regarding effects of changing oceanographic conditions on salmon migratory behavior will then be tested. The oceanographic data collected by the project will provide for valuable validation of remote sensing products, improved understanding of ocean dynamics in lower Cook Inlet, and a highly powerful statistical evaluation of the oil spill risk analysis models.

I. INTRODUCTION

This project will demonstrate the technical feasibility of using a vessel of opportunity to collect physical oceanographic and fisheries data along a transect across lower Cook Inlet from Anchor Point to the Red River delta. Logistical support for the field sampling will be provided in part by the Alaska Department of Fish and Game (ADF&G) which has chartered a vessel annually to fish along this transect each day during July providing inseason projections of the size of salmon runs returning to the inlet. If feasibility is established, investigators will in future years use physical oceanographic data collected by the project to improve management of Cook Inlet salmon through improved inseason salmon run projections. The data will also be made available to other researchers studying how the physical dynamics of the Alaska coastal current (ACC) affects the productivity of biological resources in the region. The work proposed here is for a single year of data collection to demonstrate the feasibility of obtaining oceanographic data as part of a fisheries survey. However, a long-term monitoring program is envisioned and applications of the oceanographic data obtained from such a program are also described.

Little research on the circulation within lower Cook Inlet has been conducted. The two main studies on circulation and mixing effects in this region (Burbank 1977, Muench et al. 1978) are based on limited data and show different surface velocities in the lower inlet. In particular, the presence of gyres in the area is different between the two studies and there is not sufficient data to determine the natural variability of the position or temporal extent of the gyres. Circulation in Cook Inlet is driven by the ACC, wind forcing, estuarine flow caused by freshwater input, and strong tidal currents associated with the second largest tidal range in the world. All of these factors are important in setting up the gyres within the region, but to date no study has provided the detailed oceanographic data necessary to begin to elucidate the role of the different forcing mechanisms on the circulation. Knowledge of the circulation is critical for understanding ecosystem dynamics such as larval dispersal, habitat distribution, and the prediction of contaminant transport. The proposed work will develop a mechanism for long-term monitoring of the regional oceanography by supplementing instrumentation and providing protocols for sampling on existing fisheries surveys. This information will then be combined with other monitoring and modeling efforts in Cook Inlet to provide a more complete picture of the important physical processes in the region

II. NEED FOR THE PROJECT

A. Statement of Problem

Since 1979, the ADF&G has conducted an offshore test fishing (OTF) project near the southern boundary of the Upper Cook Inlet (UCI) salmon management area (Figure 1). The objective of this project has been to estimate the total run of sockeye salmon, *Oncorhynchus nerka,* returning to UCI before these fish reach commercial harvest areas. Sockeye salmon returning to UCI have been sampled by fishing geographically fixed stations along a transect between Anchor Point and Red River Delta (Figure 1). These data have been extremely important to ADF&G management biologists as they set and adjust commercial fishing times and areas to most effectively harvest sockeye salmon that are surplus to spawning needs. Test fishing results have been reported annually since 1979 (Waltemyer 1983a, 1983b, 1986a, 1986b, Hilsinger and Waltemyer 1987, Hilsinger 1988, Tarbox and Waltemyer 1989, Tarbox 1990, 1992, 1994, 1995, 1996, 1997, 1998a, 1998b, 1999).

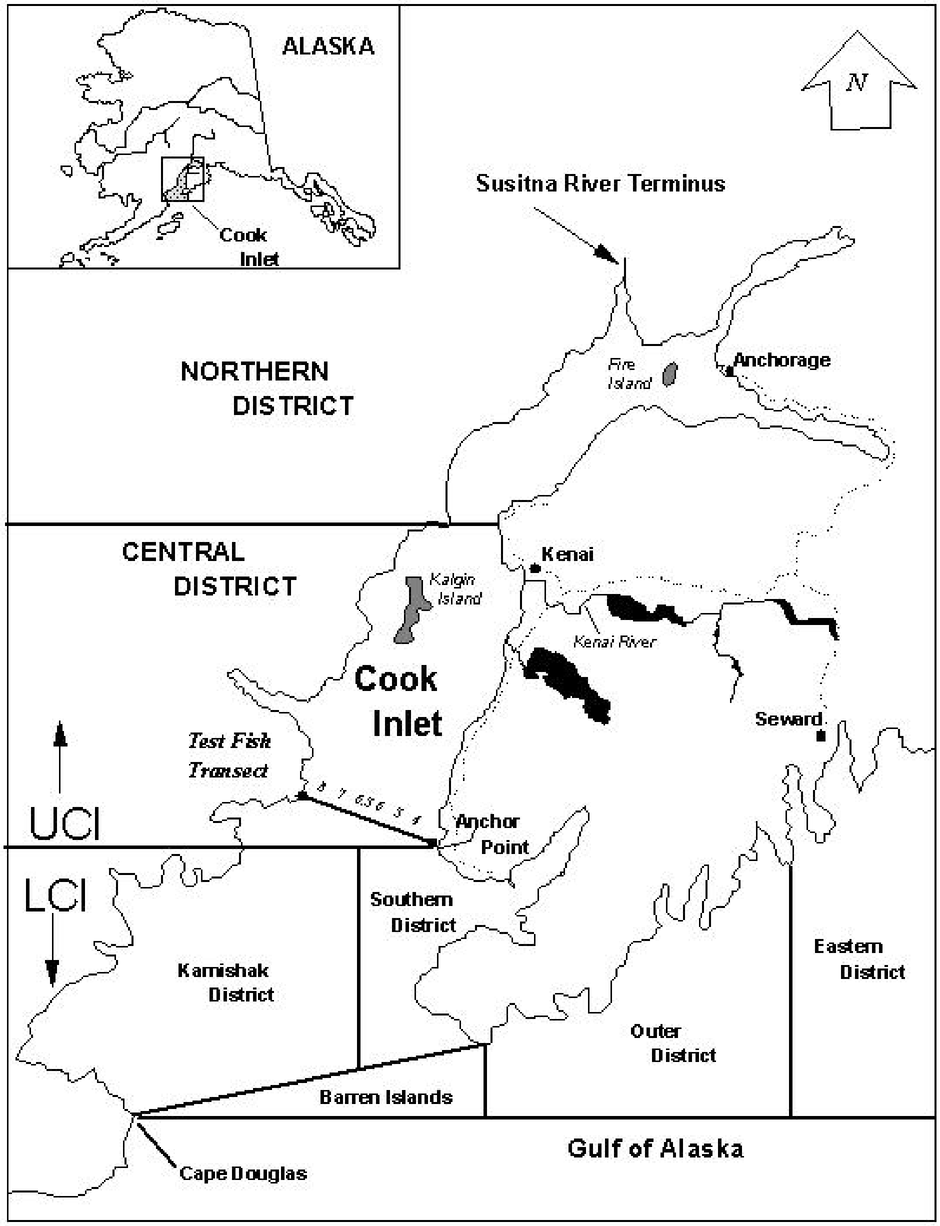

Figure 1. Location of fishing districts and offshore test fish transect in Cook Inlet, Alaska, 2001.

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In 1999, the Alaska Board of Fisheries adopted a sliding range of inriver escapement goals for late-run Kenai River sockeye salmon that were based upon preseason and inseason projections of the annual return of this salmon stock. The OTF project provides the primary source of information used to project the return of this stock inseason. Achievement of inriver escapement goals and allocation of salmon to commercial, personal use, and recreational user groups is thus largely dependent on the accuracy of these projections. The accuracy of the population estimates provided by the OTF project typically increases as the season progresses. Projections made on July 20 have ranged from -5.4% to +103% of the actual run. The program often fails to accurately predict runs that are earlier than normal. Failure to accurately predict very large runs can result in large escapements, loss of revenue to the commercial fishery, and reduced production in future years due to overgrazing of plankton stocks by large fry populations in rearing lakes. Failure to accurately predict weak runs can result in over harvest by the commercial fishery, loss of fishing opportunities in personal use and recreational fisheries, and reduced production in future years. Improving the accuracy of inseason sockeye salmon population estimates will enable ADF&G to better manage for inriver escapement goals and maximum sustained yield thus benefiting the economy of the UCI area.

Errors in OTF program estimates of run size appear to be due to interannual changes in migratory timing and catchability. Migratory timing is defined as abundance as a function of time in a fixed geographic reference frame (Mundy 1982). The sockeye salmon run entering Cook Inlet normally peaks on July 15, but peak migratory timing has varied from July 6 to July 19. Variations in migratory timing are likely due to a range of biotic and physical factors that affect rates of maturation and migration. Ocean temperature (Burgner 1980), the strength of oceanic fronts (Mundy 1982), and tidal currents (Stasko et al. 1973a) are likely important physical factors affecting both the rate of maturation and migration. Catchability is defined as the fraction of the population captured by a unit of fishing gear. The OTF program estimates cumulative catchability to date from the ratio of cumulative catch per unit effort (CPUE) obtained from the test fishing vessel and estimates of total return to date. Cumulative catchability varies by a factor of 2 among years. Variations in catchability are likely due to biotic factors, e.g. fish size, as well as physical factors that affect the vertical and horizontal distribution (Huse and Holm 1993, Winters and Wheeler 1985) and migration rate of salmon (Hakoyama 1995).

The physical oceanography of Cook Inlet is characterized by a net inflow along the eastern boundary and a net outflow along the western boundary (Burbank 1977). Near the entrance of the inlet the inflowing water includes the ACC. The ACC then turns west and joins the outflowing water. The point at which the ACC turns west remains unresolved. Burbank (1977) shows a major portion of the ACC extending north past Anchor Point, while Muench et al. (1978) indicates that only a small portion of the ACC extends northward of Anchor Point. But, since these two studies were conducted in different years, it seems likely that the different current trajectories observed may simply indicate interannual variability. Driftcards released more recently off Point Adam as part of EVOS project 02671 were primarily recovered off Kenai indicating the surface flow of the ACC has a component that extends far northward of Anchor Point. This northward flowing component is then mixed within Cook Inlet and returns along the western boundary. A significant component of the water along the western boundary originates from Knik Arm and the Susitna River and is typically more turbid than the water further east due to the heavy glacial runoff from these drainages. However, the net flow is a minor component of the circulation, tidal currents largely determine current velocities. Tidal current velocities range from 1-2 kts at the entrance to 5-6 kts at the head of the inlet (Whitney 1999). Three distinct convergence zone, known at tide rips, have been identified in the inlet. The east rip is typically located 2-3 km offshore of the eastern boundary. The west and mid-channel rips are located just east of Kalgin Island. These two rips are associated with a 50-80 m deep channel running north to south along the inlet. During flooding and ebbing conditions, water flows faster through the channel due to lower bottom friction compared to the shallower areas east and west. The result is a surface convergence and strong turbulence along the rips.

The migration of salmon into the inlet is clearly influenced by the strength and location of tide rips. Fishermen working the inlet are very aware of tide rips and use the rips to locate and capture migrating salmon (Wilson and Tomlins 1999). Salmon have likely evolved behaviors that allow them to use tide rips and associated current structures to minimize the energy expended to reach their natal rivers (Scholz et al. 1972, Stasko et al. 1973b). Although tide rips clearly result from strong velocity gradients, they also represent boundaries between waters masses and may be associated with strong salinity gradients.

The technical feasibility of using a vessel of opportunity for oceanographic sampling needs to be determined before a long-term physical oceanographic monitoring program can be established. Since the data provided daily by the test-fishing vessel is used inseason to manage Cook Inlet salmon fisheries, the proposed additional sampling effort cannot interfere with existing vessel operations. Technical questions that will be resolved the first year of the project include: (1) what is the additional time required to deploy and retrieve oceanographic equipment, (2) what is the optimal towing speed for the equipment and thus additional time required to complete the transect, and (3) what is the additional space required for an oceanographic technician and equipment. The additional time and space required for the proposed activities is an issue, because at present 18 hours of continuous operation is sometimes required for the vessel to complete the transect, and space on the vessel is very limited. Weather and tides strongly affect the time required to complete the transect. In addition to our data collection we will work with any existing CODAR data and modeling results for the area to determine if those data sources are accurate enough and have sufficient resolution to address the fisheries questions at hand.

If technical feasibility is established in the first year, we propose to collect data in future years to test the following hypotheses regarding effects of changing oceanographic conditions on the migratory behavior and catchability of salmon entering Cook Inlet.

Hypotheses

1. Salmon migration is delayed when fish encounter strong salinity gradients. Turbulence caused by strong tidal currents or winds breaks down salinity gradients increasing the rate of migration.
2. Interannual changes in freshwater outflow from UCI or the northward extent of the ACC affect salmon migratory timing. A stronger outflow or reduced northward flow of the ACC delays the migration, as salmon require more time to acclimate at frontal zones.
3. The variance of relative salmon density is a function of salmon abundance and the structure of tide rips along the OTF transect. When salmon abundance is low (high), relative salmon density is more contagiously (homogeneously) distributed. Strongly (weakly) developed tide rips cause salmon density to be more contagiously (homogeneously) distributed.
4. Salmon use tidal currents in UCI to facilitate their northward migration. On the flood tide, salmon density is highest between the west and mid rips where current speeds are maximum. On the ebb tide, salmon density is highest immediately east of the mid rip and west of the west rip where turbulence reduces the net southward flow.

B. Rationale/Link to Restoration

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.

Once technical feasibility is established, the proposed project will provide support for long-term monitoring of the dynamics of the ACC as it intrudes into lower Cook Inlet. Improving our understanding of ocean dynamics at the southern boundary of the inlet will provide an opportunity to (1) refine management of salmon resources returning to the inlet, (2) develop our understanding of how physical conditions modify the productivity of other biological resources in the region, e.g. forage fishes and seabirds, and (3) validate models to better predict anthropogenic effects on resources in the region

C. Link to GEM Program Document

This project will monitor the strength, structure, dynamics and mixing of the ACC as it intrudes into lower Cook Inlet (Burbank 1977). The location of the transect off Anchor Point and the high temporal sampling rate provided by the project will enable investigation of interactions between the ACC and processes such as tidal mixing, wind driven circulation, and frontal propagation, improving our understanding of linkages between the ACC and the nearshore estuarine habitat of the inlet.

The physical oceanographic data collected by the project will also be made available to other investigators studying how the dynamics of this current system affect the productivity of the biological resources in the region. The ADCP data in particular will be useful in determining the flow regimes that control larval, sediment, and contaminant dispersal within the inlet. The recent 20-year decline in seabird abundance at Chisik Island on the western end of the OTF transect and a concomitant increase in their abundance at Gull Island in Kachemak Bay (Piatt and Anderson 1996) provides an example of the kind of changes in resource productivity that might be explained by a long time series of physical oceanographic measurements in the region. Increases in turbid, nutrient-poor freshwater inflows into upper Cook Inlet, which flow southward along the west side of the inlet, may be linked to the decline of the Chisik Island seabirds. Studies of the Gull Island population may provide insights into processes sustaining seabird populations throughout the Gulf of Alaska, since this colony is the only one along the coast that has increased in recent years.

The proposed project could also contribute to our understanding of anthropogenic effects on resource productivity in the region by providing data for validation of the Oil Spill Risk Analysis (OSRA) model being developed by the Minerals Management Service for Cook Inlet and Shelikof Strait. The high temporal sampling rate proposed for this project will provide sufficiently numerous observations of temperature, salinity, and current velocity structures along the southern boundary of the inlet for a highly powerful statistical evaluation of the OSRA model.

III. PROJECT DESIGN

A. Objectives

1. Conduct an offshore test fishing (OTF) program to estimate the population size of sockeye salmon returning to Upper Cook Inlet.
2. Measure the horizontal distribution of relative salmon density along the OTF transect using side-looking acoustic equipment and determine the feasibility of using split-beam sonar to measure salmon swimming speeds.
3. Measure environmental variables as well as the vertical distributions of temperature and salinity along the OTF transect and construct cross sections.
4. Measure the vertical distribution of current velocity along the OTF transect using an acoustic doppler current profiler and construct cross sections.
5. Determine the technical feasibility of collecting physical oceanographic data from an existing test-fishing vessel and evaluate sample sizes required to test major hypotheses.
6. Analyze the possibility of using CODAR data and/or modeling results to supplement or replace the oceanographic data.
7. Conduct statistical analyses to test major hypotheses if first-year data are sufficient.

B. Procedural Methods

Objective 1

Sockeye salmon returning to Upper Cook Inlet will be sampled by fishing six geographically fixed stations between Anchor Point and Red River Delta (Figure 1). Stations will be numbered consecutively from east to west, with station locations being determined using a differential global positioning system. A chartered test-fishing vessel will sample stations 4 - 8 daily, traveling east to west on odd-numbered days and west to east on even-numbered days.

Sampling will start on 1 July and continue through 30 July. The chartered vessel will fish a 366 m x 10 m drift gill net with 13 cm multi-filament web at each station. Once deployed at a station, gillnets will be fished 30 min before retrieval is started.

All captured salmon will be identified to species and sex. Fork length (mid-eye to fork-of-tail) will be measured to the nearest millimeter. The number of fish caught at each station will be expressed as a catch per unit of effort (CPUE) statistic for each species:

$$CPUE_s = \frac{100\ fm\ \ x\ 60\,\text{min}\ \ x\ \ number\ of\ fish}{fm\ of\ gear\ \ x\ \ MFT} \tag{1}$$

where $CPUE_s$ = CPUE for station s, and
MFT = mean fishing time.

Mean fishing time will be calculated as:

$$MFT = (C - B) + \frac{(\text{B} - \text{A}) + (\text{D} - \text{C})}{2} \tag{2}$$

where A = time net deployment started,
B = time net fully deployed,
C = time net retrieval started, and
D = time net fully retrieved.

Daily CPUE ($CPUE_d$) will be calculated as:

$$CPUE_d = \sum_{s=1}^{n} CPUE_s\,. \tag{3}$$

Daily CPUE statistics will be used to estimate the size of the migrating salmon population as described by Mundy (1979).

Objective 2

A Biosonics model DT6000 scientific 200 kHz echosounder will be used to measure relative salmon densities along the OTF transect. A 6.6^{o} circular split-beam transducer will be mounted in a side-looking orientation on a 2.0-m long aluminum sled. Fish will be acoustically sampled at 3-5 pings sec^{-1}, at ranges from 0-100 m, using a pulse width of 0.2 ms, and a –47 dB threshold. Data will be stored on a laptop computer and geo-referenced using a differential global positioning system (DGPS). Later in the laboratory, fish targets will be counted by 20 m range bins using autotracking software.

Acoustic equipment will be operated along transects between the 6 stations fished with the drift gill net each day. Transects will be traversed at 3-6 m sec^{-1} depending on sea state. The area swept by the sonar along each transect will be calculated by multiplying each 20 m range strata by the length of the transect. Relative salmon densities (no. m^{-2}) will be estimated for 500 m by 20 m report areas. The data from each range strata will be used to evaluate the detection characteristics as a function of range. Tarbox and Thorne (1996) have established the feasibility of using side-looking sonar to estimate densities of migrating adult salmon in Cook Inlet.

The feasibility of using split-beam sonar to measure swimming speeds of migrating adult salmon will be evaluated by sampling with the sonar while the vessel is drifting on station with the sonar beam oriented perpendicular to the presumed direction of migration. The speed of the salmon over the bottom will be calculated by subtracting the swimming speed of the target through the beam from the speed of the vessel's drift over the bottom as determined by DGPS. The speed of the salmon through the water will be calculated by subtracting the swimming speed of the target through the beam from the current velocity as measured by the ADCP. Sources of error in the calculations will be evaluated.

Objective 3

A conductivity-temperature-depth profiler (CTD) equipped with a fluorometer and transmissometer will be used to measure the vertical distribution of temperature, salinity, fluorescence and turbidity from the surface to the bottom at each fixed station. Additional CTD casts will be made on each side of obvious frontal zones. The data will be used to construct a cross section of the distribution of these variables along the OTF transect each day. A continuously-recording CTD equipped with a transmissometer will also be towed along the entire transect each day. The data from this instrument will enable investigators to better define the location of frontal structures.

Air temperature, wind velocity, tide stage, water depth, and water clarity will also be measured at each station using methods employed over the past 20 years of the OTF program. Wind speed will be measured in knots and direction recorded as 0 (no wind), 1 (north), 2 (northeast), 3 (east), 4 (southeast), 5 (south), 6 (southwest), 7 (west), or 8 (northwest). Tide stage will be classed as flood, ebb or slack by observing the movement of the vessel while drifting with the gill net. Water depth will be measured in fathoms using a Simrad echo sounder, and water clarity will be measured using a 17.5 cm secchi disk.

Objective 4

A 300 kHz acoustic doppler current profiler (ADCP) will be used to measure the vertical distribution of current velocity along the OTF transect. The ADCP will be mounted in a down-looking orientation on a 2-m long aluminum sled. A 2-m cell depth size will be used providing a velocity measure with a standard deviation of 66 mm sec^{-1}. A bottom-tracking algorithm will be used to measure the survey vessel's velocity over the bottom. Absolute current velocity will be calculated in real time by subtracting the vessel's velocity from the relative current velocities measured by the ADCP. Data will be stored on a laptop computer and geo-referenced using a DGPS. Acoustic equipment will be operated along transects between the 6 stations fished with the drift gill net each day. Transects will be traversed at 3-6 m sec^{-1} depending on sea state.

Objective 5

The technical feasibility of using a vessel of opportunity for oceanographic sampling needs to be determined before a long-term physical oceanographic and fisheries monitoring program can be established. Technical questions that will be resolved the first year of the project include: (1) what is the additional time required to deploy and retrieve oceanographic and fisheries acoustic equipment, (2) what is the optimal towing speed for the equipment and thus additional time required to complete the transect, and (3) what is the additional space required for an oceanographic technician and equipment. The combined answers to these questions will determine whether the proposed additional sampling can be conducted without inferring with existing vessel operations.

The data collected the first year will also be used to conduct power analyses to evaluate likely sample sizes required to test major hypotheses in future years. However, the number of years of data required to test major hypotheses will be affected by the variability in physical conditions and salmon abundance and behavior among years.

Objective 6

In addition to the oceanographic variables being measured, we will examine the possibility of using CODAR data and modeling results. We will use any CODAR data that overlaps our study in time and space to determine if the resolution and accuracy is sufficient to replace the shipboard measurements. At this point it is unclear if CODAR data will be available in the region. The University of Alaska systems are scheduled to be moved away before our study begins, but a group from NOAA may install systems that overlook our study region. We will also collaborate with the SALMON project and the MMS funded work of Mark Johnson to evaluate the accuracy and resolution of oceanographic modeling results. The optimal data set is likely to be a mixture of high resolution shipboard measurements and the non-ship intensive studies of CODAR and modeling.

C. Statistical Methods

Hypothesis 1:

Salmon migration is delayed when fish encounter strong salinity gradients. Turbulence caused by strong tidal currents or winds breaks down salinity gradients increasing the rate of migration.

The gradient of salinity (Δo/oo m^{-1}) across tide rips will be calculated using CTD data collected on each side of the rip zones. The gradient of salinity across the tide rips will then be plotted against wind speed and tidal current velocities measured using the ADCP. Linear and non-linear regression analyses will be conducted to determine the model that best fits the data and test the hypothesis that strong tidal currents or winds are associated with weaker salinity gradients. We will also examine the feasibility of using our split-beam acoustic system to measure salmon swimming speeds. If practical, this will provide the data needed to directly test whether migration rate is related to salinity gradients. It is unlikely that sufficient data will be available the first year to test this hypothesis. However, the next hypothesis addresses this same issue although many years of data will be required to test it.

Hypothesis 2:

Interannual changes in freshwater outflow from UCI affect salmon migratory timing. A stronger (weaker) outflow delays (accelerates) the migration.

Salmon migratory timing will be estimated using CPUE data from the OTF drift gill net vessel. Cumulative daily $CPUE_t$ will be calculated as:

$$CPUE_t = \sum_{d=1}^{n} CPUE_d \qquad (4)$$

Daily estimates of $CPUE_t$ and $CPUE_d$ will be used to estimate cumulative proportions of $CPUE_t$, and the data will be fit to a non-linear model (Mundy 1979):

$$y_d = 1/(1 + e^{-(a + bd)}) \qquad (5)$$

where: y_d = cumulative proportion of $CPUE_t$ on day d,

a and b = coefficients of model,
d = day of observation.

The mean date of the salmon migration (*M*) is then estimated as (Tarbox 1999):

$$M = a/b \tag{6}$$

Average salinity measured west of the west rip will be calculated using all data collected during July each year. The mean date of migration (M) will then be plotted against average salinity. Linear, non-linear, and multiple regression analyses will be conducted to determine the model that best fits the data and test the hypothesis. Covariates in multiple regressions will include salinity in Cook Inlet, and sea surface temperature in the Gulf of Alaska (Burgner 1980). Multiple years of data will be required to test this hypothesis.

Hypothesis 3:

The variance of relative salmon density is a function of salmon abundance and the structure of tide rips along the OTF transect. When salmon abundance is low (high), relative salmon density is more contagiously (homogeneously) distributed. Strongly (weakly) developed tide rips cause salmon density to be more contagiously (homogeneously) distributed.

The mean and variance of relative salmon density along the OTF transect will be calculated for each day and plotted against one another. If the abundance hypothesis is correct, a plot of the variance against the mean density should indicate an asymptote at high salmon densities. Various transformations of the data will be explored to satisfy assumptions for regression analysis (Zar 1984). Linear, non-linear and multiple regression analyses will be conducted to determine the model that best fits the data and test the hypothesis. Covariates in multiple regressions will include the relative salmon density, and the gradients of salinity (Δo/oo m^{-1}) and velocity (Δm/sec m^{-1}) across tide rips (as a measures of the strength of the rips). Sufficient data may be available the first year for a preliminary test of this hypothesis.

Hypothesis 4:

Salmon use the tidal currents in UCI to facilitate their northward migration. On the flood tide, salmon density is highest between the west and mid rips where current speeds are maximum. On the ebb tide, salmon density is highest immediately east of the mid rip and west of the west rip where turbulence reduces the net southward flow.

The gradients of salinity, current velocity, and visual observations will be used to determine the location of the west and mid rips each day. The ratio of the mean relative salmon density between and outside of the two rips will be calculated for each day. An analysis of variance will be conducted to test whether the ratio of the two densities is significantly different during the flood versus the ebb tide. Various transformations of the data will be explored to satisfy assumptions for analysis of variance (Zar 1984). Sufficient data may be available the first year for a preliminary test of this hypothesis.

D. Description of Study Area

This project will be conducted in lower Cook Inlet along a transect running from Anchor Point on the east to the Red River delta on the west. The vessel will operated out of Homer and will return to Homer every other day. All of the communities along the perimeter of the inlet may realize benefits from the project, because improvements in the accuracy of inseason salmon population estimates will allow ADF&G to better manage for inriver escapement goals and maximum sustained yield.

E. Coordination and Collaboration with Other Efforts

The physical oceanographic data collected by this project will be made available to others studying the dynamics of the ACC. The data collected by this project will complement the dataset being accumulated by project 02340, which is measuring physical conditions at station GAK 1 near the mouth of Resurrection Bay. The data will also be used to validate remote sensing products as proposed by Pegau and will contribute to the marine geographical information system proposed by Keifer and Schoch. The proposed project could also provide data for validation of the Oil Spill Risk Analysis (OSRA) model being developed by the Minerals Management Service for Cook Inlet and Shelikof Strait. The high temporal sampling rate provided by the proposed project increases the likelihood of encountering clear weather conditions for validation of remote sensing products and will provide sufficiently numerous observations of temperature, salinity, and current velocity structures along the southern boundary of the inlet for a highly powerful statistical evaluation of the OSRA model. We will collaborate with the SALMON projects modeling and monitoring efforts in the region. We hope that CODAR units are installed during the pilot study so that we can compare in-water measurements against the surface measurements of CODAR. Given adequate data it may be possible to develop relationships between the surface and subsurface currents.

IV. SCHEDULE

A. Project Milestones

Objective 1. Conduct an offshore test fishing (OTF) program to estimate the population size of sockeye salmon returning to Upper Cook Inlet.

To be met by August 2003.

Objective 2. Measure the horizontal distribution of relative salmon density along the OTF transect using side-looking acoustic equipment and determine the feasibility of using split-beam sonar to measure salmon swimming speeds.
. To be met by December 2003.

Objective 3. Measure environmental variables as well as the vertical distributions of temperature and salinity along the OTF transect and construct cross sections. To be met by December 2003.

Objective 4. Measure the vertical distribution of current velocity along the OTF transect using an acoustic doppler current profiler and construct cross sections. To be met by December 2003.

Objective 5. Determine the technical feasibility of collecting physical oceanographic data from an existing test-fishing vessel and evaluate sample sizes required to test major hypotheses. To be met by April 2004.

Objective 6. Analysis of model and CODAR accuracy and resolution. To be met by April 2004.

B. Measurable Project Tasks

FY 03, 2nd quarter (January 1, 2003-March 31, 2003)
January 13-17: Annual EVOS Workshop (joint symposium with GLOBEC and NMFS)

FY 03, 3rd quarter (April 1, 2003-June 30, 2003)
May 1: Complete purchase of ADCP
June 1: Award contract for vessel charter

FY 03, 4th quarter (July 1, 2003-September 30, 2003)
August 1: Complete field sampling

FY 04, 1st quarter (October 1, 2003-December 31, 2003)
December 31: Complete analyses of fisheries acoustic and ADCP data

FY 04, 2nd quarter (January 1, 2004-March 31, 2004)
(dates not yet known) Annual EVOS Workshop
March 31: Complete preliminary tests of major hypotheses if possible.

FY 04, 3rd quarter (April 1, 2004-June 30, 2004)

June 30: Submit final report (which will consist of draft manuscript for publication) to EVOS

V. RESPONSIVENESS TO KEY TRUSTEE COUNCIL STRATEGIES

A. Community Involvement and Traditional Ecological Knowledge (TEK)

This project will utilize the traditional knowledge of local fishers who have observed the migratory behavior of salmon entering the inlet for many years. This knowledge will help the investigators interpret the quantitative data collected during the course of the project. A local hire preference will be employed for all contracts and technicians recruited during the course of the project. The Kachemak Bay Research Reserve will design a program of public education to disseminate knowledge obtained from the project to the community.

B. Resource Management Applications

This project will conduct research needed to improve the accuracy of inseason projections of migratory salmon populations entering Cook Inlet. The tools developed by the project will help ADF&G better manage for inriver escapement goals and maximum sustained yield of the salmon resource in the inlet. The physical oceanographic data collected by the project will also be used by resource managers to better understand the dynamics of the ACC system and how physical conditions affect the productivity of the biological resources in the region.

VI. PUBLICATIONS AND REPORTS

A manuscript describing the "Effects of oceanographic conditions on the migratory behavior of salmon entering Cook Inlet" will be submitted to the Alaska Fisheries Research Bulletin during spring of 2004.

VII. PROFESSIONAL CONFERENCES

A manuscript entitled "Effects of oceanographic conditions on the migratory behavior of salmon entering Cook Inlet" will be presented at the annual meeting of the American Fisheries Society, Alaska Chapter in 2004. The location of the meeting is not known at this time.

VIII. PERSONNEL

A. Principal Investigator (PI)

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W. Scott Pegau, Kachemak Bay Research Reserve, 2181 Homer, Alaska 99603. ph: 907-235-4799 ext. 6, fax 907-235-4794, email: spegau@coas.oregonstate.edu

B. Other Key Personnel

Robert Decino, Fishery Biologist II, ADF&G, Soldotna, Alaska. Primary responsibility is operation of fisheries acoustic equipment and analysis of acoustic data.

C. Contracts

An approximately 48' drift gill net vessel will be contracted for 34 days (June 26 to July 30) to provide logistical support for the project. The contractor will provide and operate a drift gill net to sample migrating salmon and will support oceanographic sampling. The contract will be awarded through a competitive bidding procedure.

In past years, approximately 12 hrs have been required for the contractor to complete fisheries sampling along the transect each day. We estimate that at least an additional 4 hrs per day will be required to complete the oceanographic sampling proposed in this project. In addition, the contractor will be required to provide room and board for an oceanographic technician ($15/day) and provide other logistical support for the technician's work. We estimate that these costs will result in approximately a 34% increase in the daily charter cost.

The funds requested for the charter include this increment to the daily charter cost plus the cost of 4 additional charter days in late June to test oceanographic equipment and establish sampling protocols before the vessel begins its normal operations providing data for inseason fisheries management.

The funds requested from the EVOS TC will provide for an enhancement of the existing ADF&G project, but the charter vessel will also provide logistical support for oceanographic sampling that may not otherwise be available at no cost. The oceanographic data collected by the project will provide for valuable validation of remote sensing products, improved understanding of ocean dynamics in lower Cook Inlet, and a highly powerful statistical evaluation of the OSRA model. Therefore, this project will be a collaborative effort between the

GEM program and ADF&G providing data for various scientists studying the marine ecosystem while also developing applications of these data for improved resource management.

IX. PRINCIPAL INVESTIGATORS QUALIFICATIONS

RESUME: T. Mark Willette

Educational Background:

Bachelor of Science, Fisheries Science, 1983, University of Alaska Fairbanks.
Master of Science, Fisheries Oceanography, 1985, University of Alaska Fairbanks.

Professional Background:

Employer:	Alaska Department of Fish and Game
Address:	Commercial Fisheries Division 43961 Kalifornsky Beach Rd, Soldotna, Alaska 99669-8367
Title:	Research Project Leader
Supervisor:	Brian Bue, Regional Research Biologist, (907)267-2123
Duration:	June, 2000 to present

Duties: Design and implement research projects to assess the abundance, size and age composition of salmon returning to Upper Cook Inlet. These projects include sonar enumeration of sockeye salmon in the Kenai, Kasilof, Crescent, and Yentna rivers, sampling of commercial catches and escapements to estimate size and age composition, acoustic assessment of juvenile salmon populations in rearing lakes, preseason and inseason forecasting of salmon returns using test fishery statistics, and evaluation of biological escapement goals. Prepare written reports and scientific papers describing methods, results, and conclusions from projects. Present project results at public meetings and communicate with the public regarding projects as necessary.

Employer:	Alaska Department of Fish and Game
Address:	Commercial Fisheries Management and Development Division P.O. Box 669 Cordova, Alaska 99574
Title:	Research Biologist
Supervisor:	Dr. Stephen Fried, Regional Research Biologist, (907)267-2130
Duration:	1994 to June, 2000

Duties: Principal Investigator, SEA: Salmon Growth and Mortality, 1994-1995; Principal Investigator SEA: Salmon Predation, 1994-1999. Design and implement two research projects to determine the cause of pink salmon run failures experienced in Prince William Sound in 1992 and 1993. These projects were conducted as part of a larger program called Sound Ecosystem Assessment (SEA) involving fisheries acousticians, physical and biological oceanographers, and numerical modelers. The first project examined the growth, diet composition and migratory pathway of juvenile pink salmon. The second project estimated the juvenile salmon consumption rate of important fish predators in Prince William Sound in several nearshore and offshore strata and six sampling periods. Conduct field sampling and data analyses to estimate the growth rate, diet composition, distribution and migration of juvenile pink salmon. Field sampling and data analyses were also conducted to estimate the species and size composition, diet composition, and feeding rate of fish predators on juvenile salmon. Conduct statistical analyses with assistance from project biometrician. Prepare papers for publication in peer reviewed scientific journals, as well as project final report. Present methods, results and conclusions of research project at professional meetings.

Principal Investigator, Forage Fish Influence on Recovery of Injured Species - Dietary Overlap, 1994-1995. Design and implement a research project to examine dietary overlap among several species of forage fish in Prince William Sound. Conduct field sampling and data analyses to estimate diet composition of each fish species as well as dietary overlap among several species. Conduct statistical analyses with assistance from project biometrician. Prepare papers for publication in peer reviewed scientific. Present methods, results and conclusions of research project at professional meetings.

Principal Investigator, Pink Salmon Embryo Mortality, 1996-1999. Conduct a research project to monitor the effects of the *Exxon Valdez* oil spill on mortality of pink salmon embryos. Manage project budget and supervise one fishery biologist responsible for field sampling. Assist with field sampling. Work with project biometrican conducting statistical analyses of field data. Prepare project study plans and reports with the assistance from project biologist.

Principal Investigator, Herring Natal Habitats, 1996-1998. Conduct a research project to estimate the biomass of herring spawning in Prince William Sound using spawn deposition and acoustic survey techniques. Manage project budget and supervise one fishery biologist responsible for conducting field sampling. Assist with spawn deposition and acoustic surveys. Work with project biometrican conducting statistical analyses of field data. Prepare project study plans and reports with the assistance from project biologist.

Principal Investigator, Otolith Thermal Mass Marking of Hatchery Pink Salmon in PWS, 1994-1995. Design and implement a research project to develop otolith thermal mass marking as a salmon fishery management tool in Prince William Sound. Assist with development of otolith thermal banding codes for application to 500 million pink salmon embryos. Present methods and results of project at professional meetings.

Employer: Alaska Department of Fish and Game
Address: Fisheries Rehabilitation and Development Division
P.O. Box 669

Cordova, Alaska 99574
Title: Area Resource Development Biologist
Supervisor: Dr. Bill Hauser, Regional Biologist, (907)267-2172
Duration: 1991 - 1994

Duties: Principal Investigator, Fish\Shellfish Study No. 4A, Early Marine Salmon Injury Assessment in PWS, 1991-1993. Design and implement a research project to determine the effects of the *Exxon Valdez* oil spill on the growth and survival of juvenile salmon in Prince William Sound. Conduct field sampling and data analyses to estimate growth rate, diet composition, and migration rate of juvenile salmon. Develop a bioenergetic model to evaluate whether growth of juvenile salmon was likely limited by low food abundance. Prepare final report and peer reviewed professional journal article summarizing methods and results of research. Present methods, results and conclusions of research project at professional meetings.

Principal Investigator, Instream Habitat and Stock Restoration, 1991-1993. Design and implement a research project to identify instream habitat and stock rehabilitation techniques for the restoration of salmon stocks injured by the *Exxon Valdez* oil spill. Conduct field sampling and data analyses to estimate numbers of salmon likely to be produced from specific projects. In coordination with ADF&G engineer prepare project designs and estimate costs of implementing specific projects. Present methods, results and conclusions of research project at professional meetings.

Principal Investigator, Coghill Lake Sockeye Salmon Restoration, 1993-1994. Design and implement a research project to monitor the effects of lake fertilization on sockeye salmon production at Coghill Lake in northwest Prince William Sound. Conduct field sampling and data analyses to estimate water quality (nutrients, temperature, salinity, light penetration), phytoplankton standing stock, zooplankton biomass and species composition, sockeye fry feeding rate, diet composition, and growth rate, sockeye smolt population size, size-at-age, and condition factor. This project involved acoustic surveys to estimate sockeye fry population size in the lake as well as operation of traps to estimate numbers, size, and age of smolts. Conduct statistical analyses to test for pre- and post-fertilization differences in measured parameters. Prepare final report summarizing methods and results of research project.

Chairman of the Prince William Sound\Copper River Regional Planning Team. Member of the Board of Directors and Executive Committee of the Prince William Sound Aquaculture Corporation.

Employer: University of Alaska Fairbanks
Address: School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
Fairbanks, Alaska 99574
Title: Instructor of Fisheries\Assistant Research Professor
Supervisor: Dr. Donald Kramer, Professor of Fisheries, (907) 274-9691

Duration: 1986 - 1991

Duties: Design and implement a program of education, research, and public service to promote fisheries development in northwest Alaska. Teach college level course in oceanography. Teach vocational training program in herring fishing at Unalakleet during three consecutive school years. Teach courses in marine safety at villages throughout northwest Alaska. Assist local fishermen to acquire financial assistance and prepare tax returns. Assist local fisherman's association on plans to process salmon caviar and build a salmon smoking plant. Prepare and defend proposals for scientific research before reviewers. Conduct various research projects funds through grants and contracts. Hire, supervise and evaluate a personal secretary.

Co-investigator, Distribution, Abundance, Age and Growth of Fishes in the Southeast Chukchi Sea and Kotzebue Sound, 1987-1988. Co-investigator, Conceptual Model of the Ecosystem of Kasegaluk Lagoon, Alaska, 1989-1990.

Design and implement a research project to determine the effects of the *Exxon Valdez* oil spill on juvenile salmon in Prince William Sound. Design and implement a research project to determine the feasibility of a herring spawn-on-kelp fishery in the Kotzebue Sound region. Conduct field sampling to evaluate the distribution, abundance, and growth of juvenile salmon and other fishes near the mouth of the Yukon River. Operate drift gill nets, beam trawls and plankton nets on board the R\V Oshoro Maru. Conduct age-weight-length and stomach content analysis of fish samples.

Design and implement a research project to examine ocean temperature variability in the North Pacific Ocean and relationships with survival of pink salmon. Perform and standard and complex empirical orthogonal functions analysis of ocean temperatures and pink salmon returns in the North Pacific region. Prepare scientific paper for publication and present project results at scientific meetings.

Selected Publications:

Willette, T.M., R.T. Cooney, V. Patrick, D.M. Mason, G.L. Thomas, and D. Scheel. 2001. Ecological processes influencing mortality of juvenile pink salmon (*Oncorhynchus gorbuscha*) in Prince William Sound, Alaska. *Fish. Oceanogr.* 10 (suppl. 1): 14-41.

Willette, T.M. 2001. Foraging behavior of juvenile pink salmon (*Oncorhynchus gorbuscha*) and size-dependent predation risk. *Fish. Oceanogr.* 10 (suppl. 1): 110-131.

Willette, T.M., R.T. Cooney, K. Hyer. 1999. Predator foraging mode shifts affecting mortality of juvenile fishes during the subarctic spring bloom. *Can. J. Fish. Aquat. Sci.* 56: 364-376.

Willette, T.M., R.T. Cooney, K. Hyer. 1999. Some processes affecting mortality of juvenile fishes during the spring bloom in Prince William Sound, Alaska. In *Proceedings of the International Symposium on Ecosystem Considerations in Fisheries Management*, Alaska Sea Grant Program, Report **99-01**, pp137-142.

Willette, T.M., M. Sturdevant, and S. Jewett. 1997. Prey resource partitioning among several species of forage fishes in PWS, Alaska. In *Proceedings of the International Symposium on the Role of Forage Fishes in Marine Ecosystems*, Alaska Sea Grant Program, Report **97-01**, pp 11-30.

Willette, T.M., G. Carpenter, J. Wilcock, K. Hyer. 1997. Herring Natal Habitats, 1996 Annual Report to the *Exxon Valdez* Trustee Council, Anchorage, Alaska.

Willette, T.M. 1996. Impacts of the Exxon Valdez Oil Spill on the migration, growth, and survival of juvenile pink salmon in PWS. In *Proceedings of the Exxon Valdez Oil Spill Symposium*, American Fisheries Society Symposium **18**: 533-550.

R.T. Cooney, T.M. Willette, S. Sharr, D. Sharp, J. Olsen. 1995. The effect of climate on Pacific salmon production in the northern Gulf of Alaska: examining the details of a natural experiment. In *Proceedings of the International Symposium on Climate Change and Northern Fish Populations, Can. Spec. Publ. Fish. Aquat. Sci.* **121**: 475-482.

Willette, T.M., G. Carpenter, P. Sheilds, S. Carlson. 1994. Early marine injury assessment in PWS, Final Report the *Exxon Valdez* Trustee Council, Anchorage, Alaska, 78 p.

Willette, T.M. and R.T. Cooney. 1991. An empirical orthogonal functions analysis of sea surface temperature anomalies in the North Pacific Ocean and cross-correlations with pink salmon (*Oncorhynchus gorbuscha*) returns to southern Alaska. In *Proceedings of the 1991 Pink and Chum Salmon Workshop*, Parksville, British Columbia.

CURRICULUM VITAE: **W. Scott Pegau**

Professional Preparation:

University of Alaska, Fairbanks	Physics	B.S./1990
Oregon State University	Oceanography	Ph.D./1996
Oregon State University	Oceanography	Post doc./1996-1997

Appointments:

Senior Scientist, Kachemak Bay Research Reserve (KBRR)	2002-present
Assistant Professor (tenure track), Oregon State University	1999-present

Faculty Research Associate, Oregon State University	1997-1999
Faculty Research Associate (Post Doc), Oregon State University	1996-1997
Graduate Research Assistant, Oregon State University	1990-1996
Research Assistant, University of Alaska, Fairbanks	1987-1990

Current duties:

Current duties at KBRR include maintaining and expanding the in-situ monitoring program, and developing new research programs examining the circulation and primary production in Kachemak Bay and lower Cook Inlet. I am maintaining a quarter time position at OSU while completing grants from the Navy and NASA to investigate uses of hyperspectral remote sensing data, developing an autonomous underwater vehicle program, and discrimination of phytoplankton taxa using ocean color remote sensing.

Expertise:

My primary area of expertise is the interpretation of in-situ and remote optical measurements to determine types of materials in the water column, determination of vertical distributions from space, water masses, and circulation patterns. I have extensive experience in the conceptual design and deployment of sensors on a number of platforms ranging from traditional cages, ferry vessels, and autonomous vehicles. I also have experience determining heat fluxes using meteorological and oceanographic measurements.

5 recent or significant publications:

Pegau, W. S., Inherent optical properties in the Central Arctic surface waters, in press *J. Geophys. Res.* (in press)

Pegau, W. S., E. Boss, and A. Martinez. 2002. Ocean color observations of eddies during the summer in the Gulf of California, *Geophys. Res. Lett.,* **29**, 10.1029/2001GL014076.

Bartlett, J. S., M. R. Abbott, R. M. Letelier, and W. S. Pegau. 2001. Analysis of a method to estimate chlorophyll-a concentration from irradiance measurements at varying depths, *J. Atmos. Ocean. Tech.*, **18**, 2063-2073.

Twardowski, M. S., E. Boss, J. B. MacDonald, W. S. Pegau, A. H. Barnard, J. R. V. Zaneveld. 2001. A model for estimating bulk refractive index from the optical backscattering ratio and the implications for understanding particle composition in case I and case II waters, *J. Geophys. Res.,* **106**, 14129-14142.

Paulson, C. A., and W. S. Pegau. 2001. The summertime thermohaline evolution of an Arctic lead: Heat budget of the surface layer, in *Preprints, Sixth Conference on Polar Meteorology and Oceanography*, 271-274,

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Scholz, A., D.M. Madison, A.B. Stasko, R.M. Horrall and A.D. Hasler. 1972. Orientation of salmon in response to currents in or near the home stream. *Amer. Zool.* **12**: 654p.

Stasko, A.B., R.M. Horrall, A.D. Hasler, and D. Stasko. 1973a. Coastal movements of mature Fraser River pink salmon (*Oncorhynchus gorbuscha*) as revealed by ultrasonic tracking. *J. Fish. Res. Board Can.* **30**: 1309-1316.

Stasko, A.B., A.M. Sutterlin, S.A. Rommel, and P.F. Elson. 1973b. Migration orientation of Atlantic salmon (*Salmo salar L.*). Int. Atl. Salmon Symp. 1972, *Int. Atl. Salmon Found., Spec. Publ.* **4**(1): 119-137.

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Tarbox, K.E. 1997. An estimate of migratory timing and abundance of sockeye salmon into Upper Cook Inlet, Alaska, in 1996. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 2A97-01, Anchorage.

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***EXXON VALDEZ* OILSPILL TRUSTEE COUNCIL**
PROJECT BUDGET

Budget Category:	Proposed FY 03
Personnel	$10.7
Travel	$0.0
Contractual	$37.5
Commodities	$1.0
Equipment	$25.0
Subtotal	$74.2
General Administration	$6.7
Project Total	$80.9
Other Funds	

Comments:

We estimate that additional oceanographic sampling will result in an approximately a 34% increase in the daily charter cost (see contract section of DPD). The funds requested for the charter include this increment to the daily charter cost plus the cost of 4 additional charter days in late June to test oceanographic equipment and establish sampling protocols before the vessel begins its normal operations. We request that the EVOS TC fund one half of the total charter cost, because the oceanographic data collected by the project will provide for valuable validation of remote sensing products, improved understanding of ocean dynamics in lower Cook Inlet, and a highly powerful statistical evaluation of ocean circulation models. Similar logistical support for oceanographic sampling in this area may not otherwise be available at no cost. If actual daily charter costs are lower than anticipated, we will extend the number of charter days at the beginning and end of the project.

FY03

Received 4/2/03

Project Number: G-030670 (FY 03)
Project Title: Monitoring dynamics of the Alaska coastal current and development of applications for management of Cook Inlet salmon
Agency: Alaska Dept. of Fish and Game

FORM 3A
TRUSTEE
AGENCY
SUMMARY

EXXON VALDEZ **OILSPILL TRUSTEE COUNCIL**
PROJECT BUDGET

Personnel Costs:		GS/Range/	Months	Monthly		Personnel
Name	Description	Step	Budgeted	Costs	Overtime	Sum
Scott Pegau	Senior Scientist	18C	1.0	5.5		5.5
Robert Decino	Fishery Biologist II	16C	1.0	5.2		5.2
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
						0.0
	Subtotal		2.0	10.7	0.0	
					Personnel Total	$10.7

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

FY03

Prepared:

Project Number:
Project Title: Monitoring dynamics of the Alaska coastal current and development of applications for management of Cook Inlet salmon
Agency: Alaska Dept. of Fish and Game

FORM 3B
Personnel
& Travel
DETAIL

***EXXON VALDEZ* OILSPILL TRUSTEE COUNCIL**
PROJECT BUDGET

Contractual Costs:	Contract
Description	Sum
Vessel charter for 34 days (1/2 of total cost requested)	37.5
When a non-Trustee organization is used, the 4A and 4B forms are required. **Contractual Total**	$37.5

Commodities Costs:	Commodity
Description	Sum
Field and laboratory supplies (rigging for two body, diskettes, rite-in-rain paper)	1.0
Commodities Total	$1.0

FY03

Prepared:

Project Number:
Project Title: Monitoring dynamics of the Alaska coastal current and development of applications for management of Cook Inlet salmon
Agency: Alaska Dept. of Fish and Game

FORM 3B
Contractual &
Commodities
DETAIL

***EXXON VALDEZ* OILSPILL TRUSTEE COUNCIL**
PROJECT BUDGET

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
			0.0
300 kHz portable acoustic doppler current profiler	1	25.0	25.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
Indicate replacement equipment purchases with an R.		**New Equipment Total**	$25.0

Existing Equipment Usage: Description	Number of Units	Inventory Agency
200 kHz DT 6000 echosounder with split-beam transducer	1	ADFG
Conductivity-temperature-depth (CTD) profiler w/ fluorometer & transmissometer	1	ADFG
Vessel charter for 34 days (1/2 of total cost)	1	ADFG

FY03

Prepared:

Project Number:
Project Title: Monitoring dynamics of the Alaska coastal current and development of applications for management of Cook Inlet salmon
Agency: Alaska Dept. of Fish and Game

FORM 3B
Equipment
DETAIL