PROPOSAL SIGNATURE FORM

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

By submission of this proposal, I agree to abide by the Trustee Council's data policy (*Trustee Council Data Policy**, adopted July 9, 2002) and reporting requirements (*Procedures for the Preparation and Distribution of Reports***, adopted July 9, 2002).

PROJECT TITLE: HERRING RESTORATION IN PWS: IDENTIFYING NATAL AND NURSERY HABITATS

Printed Name of PI: **Nate Bickford**

Signature of PI: _____ Date _____

Printed Name of co-PI: **Brenda Norcross**

Signature of co-PI: _____ Date _____

* **www.evostc.state.ak.us/Policies/data.htm**

** **www.evostc.state.ak.us/Policies/Downloadables/reportguidelines.pdf**

Trustee Council Use Only
Project No: _____
Date Received: _____

PROPOSAL SUMMARY PAGE

Project Title: **Herring Restoration in PWS: Identifying Natal and Nursery Habitats**

Project Period: October 2006 – September 2009

Proposer(s): **Dr. Nate Bickford,** NSF Polar Programs Post-Doctoral Fellow, Host Institution: University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, PO Box 757220, Fairbanks, Alaska 99775-7220, nate@sfos.uaf.edu

Dr. Brenda Norcross, University of Alaska Fairbanks, School of Fisheries and Ocean Sciences, PO Box 757220, Fairbanks, Alaska 99775-7220, norcross@ims.uaf.edu

Study Location: Prince William Sound

Key Words: herring, juveniles

Abstract: More information is required to understand the life history of Pacific herring and thus success of future enhancement experiments designed to improve the survival rate of juveniles into adulthood. Chemical analysis of trace element concentrations in otoliths can be used to identify geographic signatures of natal habitats used by fishes captured either as juveniles or adults. Because survival of the population is dependent on successful spawning, it is imperative to understand if distinct groups of herring are contributing to the success of the population. If most of spawning success comes from a distinct groups of herring we need to know which population survived and why. This will allow us to protect the most important populations and also identify those environmental variables needed to enhance other populations. With the information gained from this project, we will be able to identify other habitats that may be suitable for herring recolonization projects.

Funding: (including 9% G&A):

FY 07 $122.7 K
FY 08 $134.6 K
FY 09 $ 77.7 K
TOTAL: $335.0 K

Non-EVOS Funds to be Used: $ .00

TOTAL: (without GA 9%) $307.4 K

Date: 4 August 2006

I. NEED FOR THE PROJECT

Statement of Problem

Pacific Herring (*Clupea pallasii*) are an important part of the Prince William Sound both ecologically and economically. Pacific herring are an essential part of the marine food web in the Sound and provide food for birds, marine mammals and invertebrates. It is theorized that the decline of herring has also had disastrous effects on other animals that depend on them for food. Consequently there is a need for a long-term Herring Restoration Plan and implement enhancement activities with the ultimate goal of assisting herring recovery in the Sound. This study will be a step in this restoration plan. Herring have also been pivotal to the people of Prince William Sound (PWS) in south central Alaska for centuries by providing them with an important subsistence food source (J. Fall, Alaska Department of Fish and Game (ADFG) Div. pers. comm.). Beginning in the early 1900s herring also became important commercially (Norcross and Brown 2001).

On 24 March 1989, during the period of high herring biomass, the tanker vessel *Exxon Valdez* ran aground on Bligh Reef in northeastern PWS and spilled 42 million liters of crude oil. Immediately following the oil spill, from 1 to 20 April 1989, herring spawned in PWS. In 1989, herring embryos and larvae had low survival, morphologic and genetic damage and herring larvae had slow growth rates (Hose et al. 1996, Kocan and Hose 1995, Kocan et al. 1996, Norcross et al. 1996). Due to the toxic effects of the Exxon Valdez oil spill had on Pacific herring egg and larval survival (Brown et al., 1996a) the fishery was closed in 1989. The stock also collapsed in 1993 due to viral hemorrhagic septicemia virus (VHSV) and the fishery was closed from 1994-1996 (Marty, 1997). However, the herring stock was expected to recover in 1999 (Morstad, 1999) but instead it crashed again. Many studies have focused on mortality of juvenile herring (Stokesbury, 2002) and the Alaska Department of Fish and Game (ADF&G) Commercial Fisheries Division has estimated abundance of herring in the sound, but the contribution of individual rearing bays to the spawning stock has not been adequately quantified.

Herring are demersal spawners that seek out kelp in sub-tidal waters to fertilize and deposit their eggs (Norcross et al., 1996). Four-year-old adult herring migrate in late March to spawn on 23 – 168 km of coastline in PWS (Norcross et al., 2001a). Herring spawning in mid-April, but many of the herring eggs are lost to predation, wave-action, and exposure. The surviving herring eggs incubate in these natal areas for about 24 days before hatching as larvae in May (Brown et al., 1996b). After herring larvae are advected from natal areas, the planktonic larvae drift counter-clockwise through the open water of PWS pushed by surface currents, buoyant forces, and meteorological forces (Brown et al., 1996b). Metamorphosis of the larval herring begins to occur in June – August of that same year (Stokesbury et al., 2002). By the time most herring reach nursery bays they are nektonic and unable to swim well. In August, the young herring begin to form schools and aggregate at the heads of bays far from coastal waters (Brown et al, 2002; Stokesbury et al., 2000). These populations stay isolated in their respective nursery bays until June of their second year (Stokesbury et al., 2000). At that time these cohorts of herring leaves the bays and join adult schools (Stokesbury et al. 2000).

A valuable tool for conservation of this important fisheries stock is the identification of productive spawning and nursery areas and evaluation of transition patterns among habitats by several cohorts. The contribution to the adult population from each nursery area has not been quantified. Survival of herring is not equally good among nursery areas in PWS (Norcross et al.,

2001a). Any temporal shifts in essential habitat since the first samples from 1995, until 2006 the time of the latest samples could indicate recovery shifts. This information would give fishery managers a better understanding of herring recovery in PWS. Since otolith bands are accrued during the fish's time of residence in these nursery bays, otolith chemistry can be used to track past habitat use of larval and juvenile fish (Kraus & Secor 2004; Campana and Therrold, 2001). Studying herring habitat selection over several year classes can determine the most productive habitats for herring recruits and the changes in habitat selection overtime.

Since herring have not recovered since there decline in 1993 it is critical to identify those habitats that contribute disproportionately large numbers of recruits to future generations. Identifying source habitats or regions will allow researchers the ability identify those environmental factors that help herring survival (Roberts, 1998; Pulliam and Danielson 1991). However, identifying these source regions and distinguishing them from those regions that might contain significant biomass but produce, no recruits (sink habitats) are often quite difficult. Otolith chemistry allows researchers to investigate survivorship, and as a result, identify essential spawning regions. Trace element chemistry signatures preserved by otoliths provide powerful insight into the past habitat use of fishes. For example, otolith chemistry has been utilized to determine population structure and dynamics at a large spatial scale among estuaries (Thorrold et al. 2001), and at very fine spatial scale among seagrass habitats within an estuary (Dorval et al. 2002).

The goal of the proposed research is to combine traditional Pacific herring population estimate methods with otolith chemistry to identify essential regions in PWS, which will be an important step in the restoration of Pacific herring in PWS. Traditional genetic methods of establishing the geographic structure of fish populations cannot directly measure or specify the origin of individuals (Thresher, 1999). However, information gained from otolith chemical composition is unparalleled for its precision at creating retrospective positioning for individual fish in space and time (Campana & Thorrold, 2001). Chemical analysis of trace element concentrations in otoliths can be used to identify the geographic signatures of natal habitats used by fishes captured either as juveniles or adults. In the 2005-2006 the PI was funded to use otolith chemical analysis to determine larval drift from fish collected during the SEA program (95-97) of PWS. The results generated from the 2005-2006 study are very intriguing and indicates that otolith chemistry will be a good tool to identify movement patterns of Herring in PWS (Figure 1). The preliminary data indicates that between 1995 – 1997 that juvenile herring in Simpson Bay came from a distinct source, juvenile fish in Eaglek Bay cam from a distinct source, and juvenile fish from Whale and Ziakof bays come from a distinct source (Figure 1-2). Consequently, during the 1995-1997 time periods there were three distinct spawning groups. this proposed study will be the next step in using otolith chemistry to reconstruct past habitat use, identify essential regions (habitat), regional fidelity, and the connectivity of Pacific herring in PWS (Figure 2).

The identification of essential regions in PWS will have profound consequences for the restoration of Pacific herring. Juvenile fish will in their nursery habitat will have drifted from their natal grounds or in some cases be in the same area that they were spawned (e.g., natal grounds and nursery grounds are the same location). Juvenile fish will consequently have a signature for the natal and nursery grounds. Adults will have a signature for natal, nursery grounds, and spawning grounds. By comparing adults to juvenile we can identify which natal and nursery grounds adults used, therefore identifying which particular natal or nursery grounds

contribute most to the biomass of the recruiting population. We can then identify those environmental variables that help or hinder in the survival of pacific herring during different life stages. This information will help us in future planning to relocate herring in PWS to habitats that will greatly increase their chances of survival.

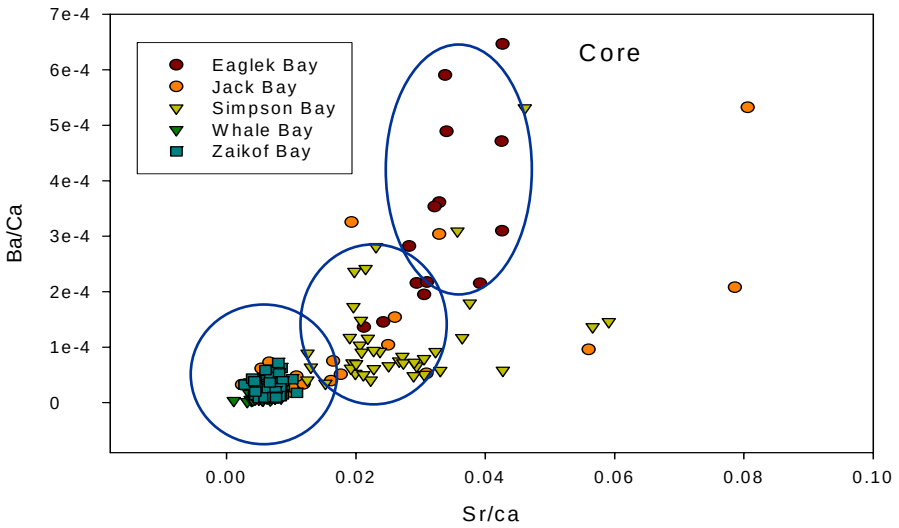


Figure 1. Core (natal signature) chemistry of juvenile Pacific herring collected in nursery bays. There are three distinct spawning signatures; most fish from Eaglek bay come from one source, Simpson Bay fish also come from a distinct source, and fish in Whale and Zaikof Bays come from a similar spawning source. Jack Bay fish did not a have distinct chemical signature.

To date there has been no way to validate the connection between larval, juvenile, and adult populations for Pacific herring in PWS. Traditional mark-recapture techniques are cost prohibitive and ill-suited to identify source habitat, while otolith elemental signature analysis offers a researcher a means of identifying the temporal and spatial migrations of larval, juvenile, and adult herring. Throughout the life of a herring, as it migrates among PWS fjords and bays, the trace element content of the water is recorded in the otolith. This creates a permanent record of habitat use by an individual fish. Otolith bands are accrued during the fish's time of residence in the spawning areas, thus recording the unique spatial chemical signatures. Otoliths are single cellular crystalline deposits of $CaCO_3$, in the form of aragonite, within an otolin-1 protein matrix. There are three calcified otoliths structures found in teleosts; the sagittae is the largest and most studied (Wright et al., 2002). Otoliths are formed in the latter part of the egg stage. The initial deposition of material becomes the core of the otolith (Wright et al., 2002). As the juvenile herring grows it accretes bands of new material, which surrounds its original core deposit. Daily bands, monthly bands, and yearly bands are accrued as layers. Growth is recorded as assorted bandwidths inside the otolith, much as a tree accumulates annual rings. The daily, monthly, and annual bands have long been used as detectors of age and growth rate in fish (Campana & Thorrold, 2001). Otolith tissue is not reabsorbed by the body, as other calcified tissues are; it is this quality that makes otoliths unique in fish (Campana, 1999). Otoliths, unlike other calcified tissues, such as skeletal calcium, are not readily mobilized for homeostasis during times of stress; consequently otoliths are highly suitable for aging (Wright, 2002) and chemical analysis

(Campana, 1999). Otoliths also continue to accrete after somatic growth has naturally ceased (Mugiya & Tanaka, 1992) unlike skeletal tissue.

In recent years the chemical compositions of individual bands have been used to identify past habitat use of the fish (Rooker et al., 2003; Campana & Thorrold, 2001; Thresher, 1999). During crystallization, divalent cations of similar ionic radii to calcium (e.g., Mg^{+2}, Sr^{+2}, and Ba^{+2}) can substitute for calcium in the otolith matrix or in the protein in the otolith (e.g., Campana et al., 1995). The mechanism of substitution and incorporation of trace metals into the otolith are a function of abiotic (i.e., temperature, salinity) and biotic (i.e., diet, fish growth rate) conditions (Thresher, 1999).

A. Relevance to 1994 Restoration Plan Goals and Scientific Priorities

The Exxon Valdez Oil Spill Restoration Plan of 1994 set recovery objectives, strategies and goals for non-recovered species in PWS. Pacific herring is not recovered to a healthy and productive population at pre-spill abundance. The Trustee Council has made herring a priority for recovery and a topic of solicitation in the FY07 Invitation. Our proposed project will target the reproductive success of herring in PWS, an issue of importance identified 12 years ago in the 1994 Restoration Plan. Furthermore, the proposed work will also address advective transport of herring larvae from rearing areas, another topic identified in the 1994 Plan.

This study will contribute greatly to the knowledge of herring recovery in PWS. Our project will determine elemental signatures found in rearing and spawning areas. Migration pathways due to larval drift can be determined by retrospectively examining the chronology of otolith chemistry. Through otolith chemical analysis, the spatial and temporal description of where herring spend their early life history (i.e., advective transport) can be described. After we use otolith chemistry to identify source regions and region fidelity we can identify the factors that make one region better than another. Then the next step would be to identify similar habitats without herring and seed new herring into the environment. The information produced by this study can be used to help on the recovery of the herring population in PWS.

II. PROJECT DESIGN

A. Objectives

The overall objective of this study is to identify elemental signatures of spawning and nursery areas for Pacific herring (*Clupea pallasii*) from PWS. My specific objectives are to:

(1) ascertain trace element signatures of edge portions of juvenile herring otoliths to identify the otolith chemical signature of individual rearing bays within PWS,

(2) ascertain trace element signatures of core portions of juvenile and adult herring otoliths to identify the otolith chemical signature of individual hatch locations within PWS,

(3) ascertain trace element signatures of edge portions of adult herring otoliths to identify the otolith chemical signature of spawning areas within PWS,

(4) compare trace element signatures of core (natal) and outer core (nursery) of adult herring to core (natal) and edge (nursery) portions of juvenile herring to identify whether the adults used the same natal and nursery regions as the juveniles.

We hypothesis:

- that herring from some spawning areas have a better chance of survival,
- that herring from some nursery areas have a better chance of survival, and
- that herring return to favorable areas for spawning

B. Procedural and Scientific Methods

Spawning and juvenile herring will be collected for this study. ADF&G routinely collects herring prior to or during each spawning season, even if there is not a fishery expected and has agreed to provide spawning herring for this project (S. Moffitt, ADF&G, Cordova). There are five spawning survey areas in which ADF&G conducts aerial surveys and has observed herring spawning since 1973 (Figure 1). Samples for adult spawning herring will come from those five approximate areas. Herring have not been document spawning in western PWS in recent years, though spawning was observed there in earlier years (Brown et al. 2002).

We propose to collect juvenile herring in 10 bays around PWS (Figure 2) in fall 2006, 2007 and 2008 and spring 2007, 2008 and 2009. Fall samples will represent juvenile herring (age-0) that had been transported during summer and would spend their first winter in the bay. During the fall we will also collect age-1 herring (Stokesbury et al. 1999) that have spent over one year in the bay. Spring samples will represent age-0 herring that over-wintered in the bay as well as age-1 herring that have spent two years in the bay. Fall 2006 sampling will take place in October or November, prior to notification of funding. The collections will be made under separate funding by Dick Thorne (PWSSC) who has agreed to collect juvenile herring for this project. The remaining fall and spring sampling will be conducted as part of this project. The 10 bays have been selected based historic observations of juvenile herring in spring and fall at some time during the observed time of 1934-1998, as well as specifically being sited in these locations during the 1990s (Brown et al. 2002). Four of the 10 bays, Eaglek, Simpson, Whale and Zaikof Bays, were sampled repeatedly during the SEA program (Norcross et al. 2001). Additionally, for the one larval herring drift model that simulated 1996 conditions, larvae were transported to all 10 of the bays (Norcross et al., 2001). The locations for sampling will be reevaluated after each collection period and may be adjusted based on funding available, time required to sample, numbers captured, within-year spawning locations and output of the larval transport model (Wang and Norcross). Juvenile herring will be collected by purse seine vessels using one of two anchovy nets (250 x 34 m or 250 x 20 m, 25-mm stretch mesh) or with a small salmon fry seine (50 x 8 m, 3-mm stretch mesh) deployed in shallow water from a 6-m skiff. These nets were successfully used during the SEA program to collect juvenile herring (Foy and Norcross 1999; Stokesbury et al. 1999, 2000, 2002). At each of these stations, a portable SeaBird SBE 19 CTD will be deployed .

Past experience in SEA indicates that sampling of the magnitude proposed will likely require 20 days of ship time, with weather making at least 20% of that time unavailable for sampling. Because purse seine boats only have 4 bunks, including the captain, time will be spent fishing and only limited processing of herring will be done at sea. Samples needed for this project (and for "Condition Indices" (Castellini and Norcross)) will be labeled and frozen separately for each collection. Frozen samples will be shipped to the Fisheries Otolith lab at UAF in Fairbanks.

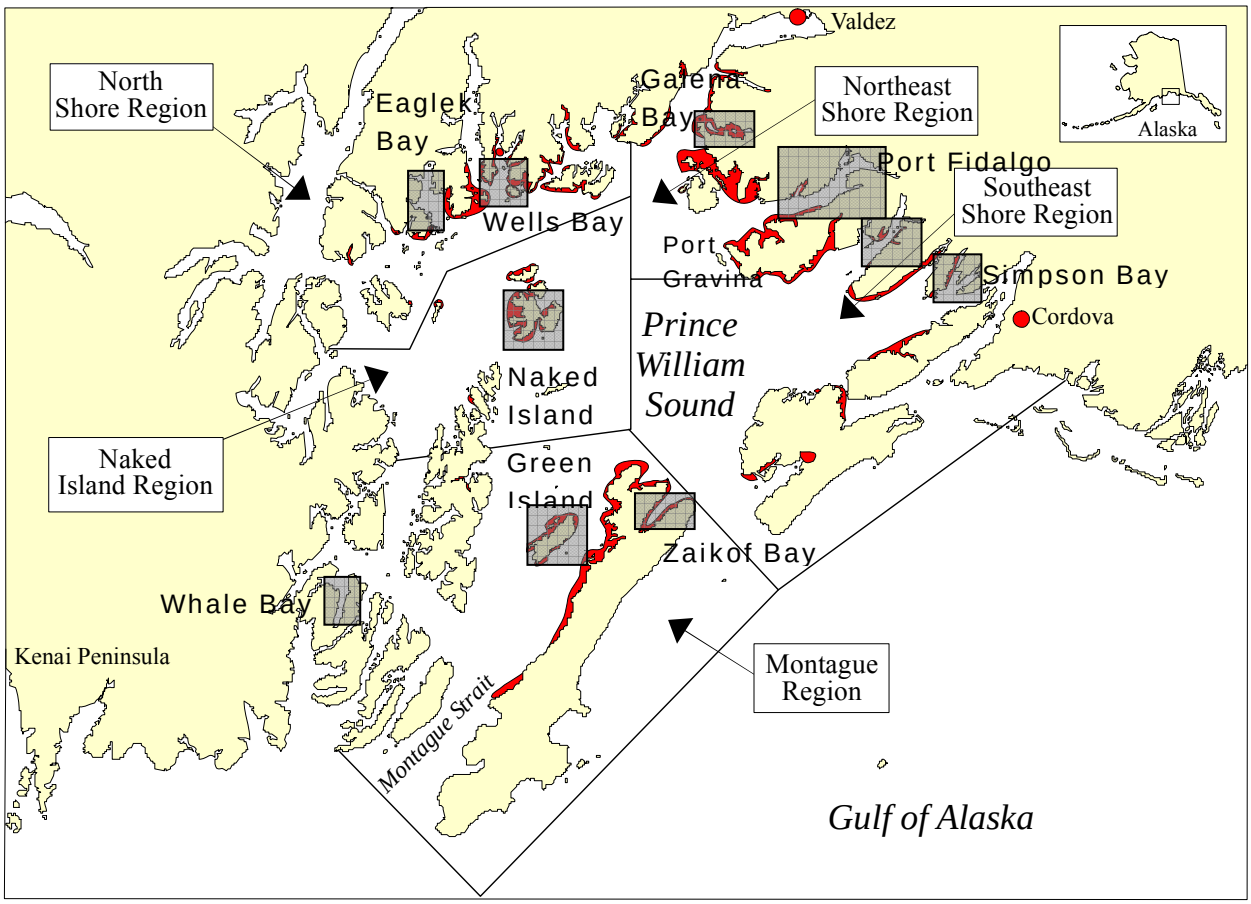


Figure 2. PWS is divided into the five areas for ADF&G aerial surveys of spawning herring. Red shorelines are all places that herring have been known to spawn 1973-2006 (ADF&G). Samples for adult spawning herring will come from approximately five of those areas. Grey boxes are proposed areas of collection for juvenile herring in fall 2006, 2007 and 2008 and spring 2007, 2008 and 2009. These locations are based on the sites sampled during SEA and modeled dispersal of herring larvae (Norcross et al. 2001), and of historic observations of juvenile herring in spring and fall since the 1930s as well as specifically during the 1990s (Brown et al. 2002).

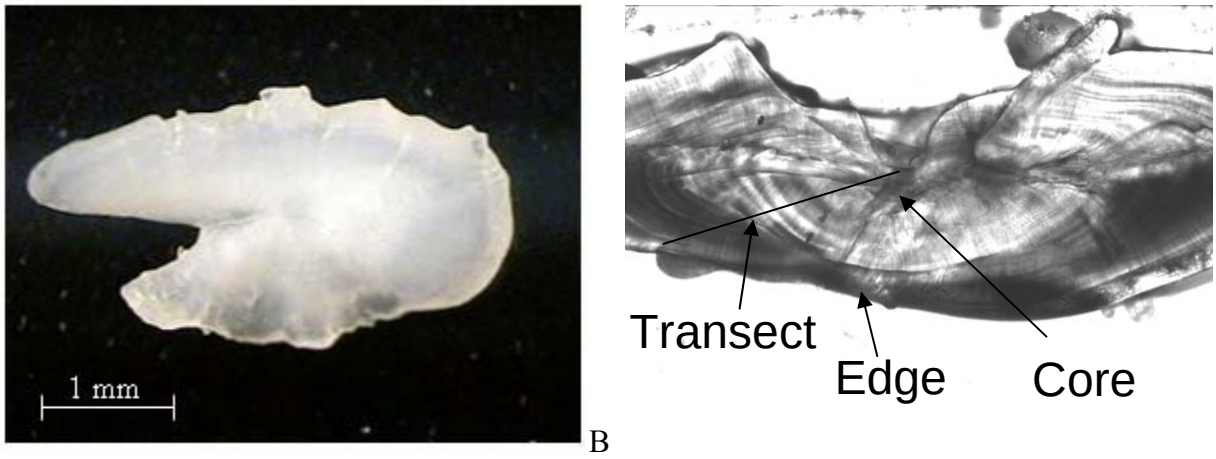
Fish processing

Frozen fish collected in the field will be stored in freezers until processing. Before fish processing a database will be developed for biological information such as weight and length. During fish processing fish will be removed from the freezer and weight and length measurement will be taken. We will then remove the cranial cap of the fish to expose the otoliths for removal. During this whole process fish will remain frozen. The fish will be returned to the freezer for future tissue studies (Castellini and Norcross).

Otolith processing

Sagittal otoliths will be extracted from the heads of adult and juvenile Pacific herring in a clean environment using standard techniques (Bickford et al., 2003; Campana, 1999; Campana, et al., 1995). All tools used for extraction will be made of Teflon and acid washed prior to use to minimize contamination with additional trace elements. Thin sectioning using a Beuhler isomet

low speed saw will expose the otolith core and edge (objective 1 - 3) for chemical analysis and aging (Campana, 1999) (Figure 3).



A B

Figure 3. A. The whole otolith sulcus side up before it is thin sectioned and polished. B. Same otolith thin sectioned and polished for age and laser analysis

Otolith chemical analysis

The elemental ratios found in the edge portions of juvenile and adult herring otoliths will be distinct to the area of collection (i.e., adult – spawning site and juvenile – nursery grounds) (objectives 1 and 3). We can use the collection site signature as known signature to compare to the core portions of the juvenile and adult herring. This allows us to identify where adult spawning survivors were hatched (objective 2). Using this technique we can identify those areas and habitats that contribute more biomass to the survivors (i.e., source regions) (objective 4). For example we will compare juvenile edge signatures (nursery) with the corresponding areas (just outside core) on adults to identify which nursery grounds contribute the most to the adult populations.

Concentration of all trace metals in otoliths will be measured using a laser ablation (LA; New Wave UP 213nm Nd:YAG) inductively coupled plasma – mass spectrometry (ICP-MS; Agilent 7500c) in the Advanced Instrumentation Laboratory on the UAF campus. Laser beam size will be 25u at 10 MHz for a speed of 35u/sec. The Chemistries of the core, the edge, and a transect extending from the core across to the otolith edge will be performed on the thin sections of the otolith. All analyses will be calibrated using the external matrix-matched standard USGS MACS-1 (carbonate standard). Each sample measurement will be preceded by a gas blank measurement with re-calibration (gas blank and MACS-1) every 10 samples. Concentrations of all elements will be calculated relative to MACS-1 after proper correction for gas blank, matrix, and drift effects. Elemental abundances will be compared relative to Ca content among otolith samples (Campana, 1999; Campana & Neilson, 1985).

ICP-MS instruments can assay inter-element ratios, such as Sr/Ca, with precision (0.05% relative standard deviation [RSD]) approaching that of thermal ionization mass spectrometry. Mg/Ca, Mn/Ca, Sr/Ca and Ba/Ca ratios will be assayed in the otoliths to provide a distinguishable signature. Finally, a relational database will be constructed and the data statistically

parameterized so that individual fish can be classified to their nursery area based on these geochemical signatures.

C. Data Analysis and Statistical Methods

Using UnifyPow, a SAS module for sample-size analysis with elemental signatures (Sr/Ca, Ba/Ca, Mg/Ca) from ten bays, my power test has shown that we will need to analyze the chemical signature of at least 25 herring otoliths from each bay to have significant results. We will need 25 otoliths from each age class (minimum 2 age classes) from each nursery bay (10 bays), which is 500 fish. We will also need 25 fish from each spawning group (estimate 5 sites), which is 125 fish. Total fish analyzed per year will be 625 fish

Analysis of Variance (ANOVA $\alpha = 0.05$) (SAS module) will be used to distinguish differences between the chemistries:

- Juvenile edge (nursery) vs. juvenile core (natal) (each juvenile tested against itself) if the signature is the same then the fish has not left spawning grounds. (objective 1-2)
- Juvenile core (natal) vs. juvenile core (natal) (all juveniles tested against other juveniles) if the signature is the same then the fish were spawned in the same area. (objective 1-2)
- Juvenile edge (nursery) vs. adult area just outside the core (nursery) (all juveniles tested against other juveniles) if the signature is the same then the adult used the same nursery habitat as the juvenile. (objective 2 and 4)
- Adult edge (spawning area) vs. adult core (natal) (each adult tested against itself) if the signature is the same then the adult returned to spawn in the same area it was hatched in. (objective 3-4)
- Adult core (natal) vs. adult core (natal) (all adults tested against other adults) if the signature is the same then the adults were hatched in the same area. (objective 2 and 4)

Linear discriminant analysis (LDA) will be used to model the difference between classes of data (Bickford and Hannigan 2005). LDA will be performed in SAS using the elemental chemistries from each otolith structure (core, edge, etc) at each collection site. The LDA results will distinguish geographically the distinct groups of herring and allow us to classify the individuals into groups (i.e., natal group, nursery group).

D. Description of Study Area

Prince William Sound is a semi-enclosed sea separated from the Gulf of Alaska by a series of mountainous islands (Figure 1). The rocky coastline has numerous islands, inlets, bays, and deep fjords. About half of the locations sampled during this study, though named and referred to as bays, were classified as small fjords. These fjords are characterized as steep-sided basins with maximum depths over 100 m; entrance sills varying in depth were present in some but not all fjords. Fjords generally have slow tidal currents (< 15 cm sec^{-1}) and are stratified during periods of freshwater runoff. By late winter, the subsurface and deep waters are well mixed, but the surface layers can exhibit slight stratification. Other shallower (< 100 m) locations classified as bays are more prone to vertical mixing from both winds and strong tidal currents. Bays may exhibit partial to strong stratification briefly during the summer. In comparison to fjords, by early fall bays are typically well mixed vertically, and by late winter their water columns become

homogeneous from surface to bottom. At 60^{o} N, primary production in PWS is typical for high latitude neritic systems with a strong spring phytoplankton bloom and a short growing season (McRoy *et al*., 1997). In this northern location the combination of light and temperature restrictions create environmental conditions for Pacific herring that are somewhat different from those experienced by Atlantic herring (*Clupea harengus*) or by Pacific herring found in more southerly regions of the west coast of North America.

E. Coordination and Collaboration with Other Efforts

To date there has been no satisfactory answer to explain the lack of recovery of herring in PWS. Therefore, a unified group of proposals from the University of Alaska Fairbanks is being submitted that will address Herring Restoration in PWS. The "Enhancement Workshop" (Allee and Norcross) will bring together international herring experts to share knowledge about restoration techniques. This "Identifying Natal and Nursery Habitats" proposal will use trace elements in herring otoliths as markers to identify successful spawning and juvenile habitats as well as to validate Wang and Norcross's proposed transport model. "Condition Indices" will examine the energetic quality of herring from the same individual herring from which otoliths were taken from this study, thus reducing variability for comparing results of these two studies. The "Modeling Circulation and Larval Transport" effort will use updated PWS circulation and larval herring growth models to predict trajectories that would move larval herring from spawning grounds to nursery bays. All the proposed projects will simultaneously use information from and supply information to each of the other projects. Regardless of technical prowess, enhancement of herring cannot take place without knowing the location of successful spawners and of productive nursery areas. Each of the other three proposals will provide a piece of puzzle to reveal that critical information.

The PIs of this proposal will integrate results from other studies of herring in PWS. Sean-Bob Kelly's OSRI Graduate Fellowship "Identifying past habitat use and essential habitat of Pacific herring", is active from 2005 through 2007 and is producing some background information on which to base the present study. Keifer is proposing to EVOS to create a "Life-stage specific ecosystem model of PWS Pacific herring" for which we will contribute our results. We will share sample collections with Dick Thorne (PWSSC) and Steve Moffitt (ADF&G, Cordova). While we do not anticipate immediate collaboration with Sonia Batten's project Acquisition of Continuous Plankton Recorder (CPR) data", we do believe that future application of this project to examine the migration of herring out of PWS will make us of the CPR data now being collected.

III. SCHEDULE

A. Project Milestone

Task 1. Analyze trace elements of edge and core portions of juvenile herring otoliths as indicator of nursery grounds and natal areas.
To be met by September 2007 and 2008

Task 2. Analyze trace elements of edge and core portions of adult herring otoliths as indicator of spawning area.
To be met by September 2007 and 2008

Task 3. Use otolith data to identify source and sink regions in PWS.
To be met by March 2009

Measurable Project Tasks

FY 07, 1st quarter (October 1, 2006-December 31, 2006)

December	receive funding notice
	collect juveniles
December	quarterly report

FY 07, 2nd quarter (January 1, 2007-March 31, 2007)

February	50% of fish collected in 1st quarter processed and otolith removed
March	collect juvenile and spawners
March	quarterly report

FY 07, 3rd quarter (April 1, 2007-June 30, 2007)

May	complete removal of otoliths from fish collected in 06 and 07
June	complete otolith preparation for laser analysis
June	quarterly report

FY08, 4th quarter (July 1, 2007-September 30, 2007)

August	Laser and data analysis of otoliths from 06 and 07
September 1st	First draft annual Report
September 30th	Final draft annual Report

FY 08, 1st quarter (October 1, 2007-December 31, 2007)

October:	collect juveniles
December	quarterly report

FY 08, 2nd quarter (January 1, 2008-March 31, 2008)

February	50% of fish collected in 1st quarter processed and otolith removed
March	collect juvenile and spawners
March	quarterly report

FY 08, 3rd quarter (April 1, 2008-June 30, 2008)

May	complete removal of otoliths from fish collected in 08
June	complete otolith preparation for laser analysis
June	quarterly report

FY09, 4th quarter (July 1, 2008-September 30, 2008)

August	Laser and data analysis of otoliths from 08
September 1st	First draft annual Report
September 30th	Final draft annual Report

FY 09, 1st quarter (October 1, 2008-December 31, 2008)

December	data integration and statistically analyses
December	quarterly report

FY 09, 2nd quarter (January 1, 2009-March 31, 2009)

March	data integration and statistically analyses
March	quarterly report

FY 08, 3rd quarter (April 1, 2009-June 30, 2009)

June	Report and peer review article first draft
June	quarterly report

FY09, 4th quarter (July 1, 2009-September 30, 2009)

September	Report and peer review article final draft

IV. RESPONSIVENESS TO KEY TRUSTEE COUNCIL STRATEGIES

A. Community Involvement and Traditional Ecological Knowledge (TEK)

This study is the first step in a community developed Pacific herring restoration plan. The PI is working very closely with local fishermen and Prince William Sound Fisheries Research Applications and Planning (PWSFRAP). This study will be part of the herring restoration plan that will work toward developing a sustainable herring fishery in the future. All results from this project will be shared with local communities (via PWSFRAP) especially those involved with the herring restoration planning.

B. Resource Management Applications

This study will determine elemental signatures found in rearing, spawning areas, and migration pathways due to larval drift. Through otolith chemical analysis, the spatial and temporal description of where herring spend their early life history (i.e., advective transport) can be described. After we use otolith chemistry to identify source regions and region fidelity we can identify the factors that make one region better than another. The next step in herring restoration would be to identify similar habitats without herring and seed new herring into the environment (recolonization plan). Consequently the information produced by this study can be used to help on the restoration and recovery of the herring population in PWS.

V. PUBLICATION AND REPORTS

Funding is requested for this publication. Results from this study will be used to publish a paper in the Canadian Journal if Fisheries Science in 2008. The subject of the journal article will be identifying natal and nursery ground for Pacific herring. All reports from this study will be completed as per the timeline. Quarterly reports will be sent each quarter and annual reports will be finalized and sent in September.

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

The overall objective of this study is to identify elemental signatures of spawning and nursery areas for Pacific herring (*Clupea pallasii*) from PWS. My specific objectives are to:

(1) ascertain trace element signatures of edge portions of juvenile herring otoliths to identify the otolith chemical signature of individual rearing bays within PWS;
(2) ascertain trace element signatures of core portions of juvenile and adult herring otoliths to identify the otolith chemical signature of individual hatch locations within PWS;
(3) ascertain trace element signatures of edge portions of adult herring otoliths to identify the otolith chemical signature of spawning areas within PWS;
(4) compare trace element signatures of core (natal) and outer core (nursery) of adult herring to core (natal) and edge (nursery) portions of juvenile herring to identify whether the adults used the same natal and nursery regions as the juveniles.

1. Describe the study design, including sample type(s) and location requirements, all statistical analyses that were or will be used to estimate the types and numbers of physical samples required or equivalent information for studies using survey and interview techniques. Include a description of the metadata essential to interpretation of the results of your work.

The study design is a stratified random sample. The sampling strata include chemistry of otolith hard part, habitat use and times. Sample sizes are based on the results of previous studies and using UnifyPow, a SAS module for sample-size analysis, my power test has shown that we will need to analyze the chemical signature of at least 25 herring otoliths from each bay to have significant results.

Sample types will include; fish data (i.e., lengths, weights, ages and sex of herring,) and data on the chemistry (Sr/Ca, Ba/Ca, and Mg/Ca) of the otolith extracted from Pacific herring of selected individuals.

We propose to collect herring in 10 bays around PWS in fall 2006, 2007 and 2008 and spring 2007, 2008 and 2009. Fall samples will represent juvenile herring (age-0) that had been transported during summer and would spend their first winter in the bay. During the fall we will also collect age-1 herring (Stokesbury et al. 1999) that have spent over one year in the bay. Spring samples will represent age-0 herring that over-wintered in the bay as well as age-1 herring that have spent two years in the bay. The 10 bays have been selected based historic observations of juvenile herring in spring and fall at some time during the observed time of 1934-1998, as well as specifically being sited in these locations during the 1990s (Brown et al. 2002). Four of the 10 bays, Eaglek, Simpson, Whale and Zaikof Bays, were sampled repeatedly during the SEA program (Norcross et al. 2001).

Statistical measurements will include Analysis of Variance and Linear Discriminant Functions. Important metadata will include fish weight, length, age, location of capture, and date of capture

2. Discuss criteria for determining acceptable data quality in terms of the activities to be performed or hypotheses to be tested.

Data will be measured using a laser ablation (LA; New Wave UP 213nm Nd:YAG) inductively coupled plasma – mass spectrometry (ICP-MS; Agilent 7500c) in the Advanced Instrumentation Laboratory on the UAF campus. These analyses will be preformed on thin sections of otoliths

on a transect extending from the core across to the otolith margin. All analyses will be calibrated using the external matrix-matched standard USGS MACS-1 (carbonate standard). Each sample measurement will be preceded by a gas blank measurement with re-calibration (gas blank and MACS-1) every 10 samples. Concentrations of all elements will be calculated relative to MACS-1 after proper correction for gas blank, matrix, and drift effects. Software used for analysis also contain QA/QC measures which will halt analysis if data starts to drift.

If we are not able to distinguish between natal sites or nursery grounds with otolith chemistry then we will not be able to identify whether herring from some spawning areas have a better chance of survival, or that herring from some nursery areas have a better chance of survival, nor that herring return to favorable areas for spawning

3. Discuss the characteristics of the data that your project is going to be producing. Part (a) describes the production of a minimally compliant FGDC metadata record which needs to be submitted by all proposers. Part (b) is specific to projects producing quantitative data and provides specifications for categorizing quantitative data into one of three data groups: physical measurements, species specific measurements, and taxonomic sampling.
(a) Copy of planned metadata file is attached (Appendix A).

(b) This project will collect fish at various locations. Each fish collected will have biological (weight, length, etc) data and also chemical (Sr/Ca, Ba/Ca, and Mg/Ca) data. The fish otolith will be analyzed for chemical measurements and chemicals signatures of fish will compared to each other. The chemical measurements will consist of calcium, strontium, barium, magnesium, etc using inductively coupled plasma – mass spectrometry (ICP-MS; Agilent 7500c).

4. Define each algorithm to be used to convert signals from sensors to observations. Examples of algorithms of interest would be the conversion of pressure to depth and the conversion of integrated voltages to biomass at depth. When conversion algorithms are lengthy (i.e., computer programs) substitute a source location, such as an ftp site, for the full text. In the case of proprietary conversion algorithms, identify the proprietor and describe how the accuracy of conversion is verified under calibration (see #6 below).
No algorithms will be used in this project.

5. Describe the procedures for the handling and custody of samples, including sample collection, identification, preservation, transportation and storage.
Biological information for each sample will be entered onto a custody sheet. The custody sheet has columns for sample identification number (SIN), fish length, weight, age, sex, date of processing, processor's sample identification number, the processor's name, and a column for any comments that might be important in interpretation. Examples of commentary would be any noticeable evidence of disease or parasites. Processors will be issued custody sheets, which will be shipped to Fisheries Otolith Group (FOG) with the samples. The sample numbers will be assigned in the field and correlated with the processor's sample identification number. Sample identification numbers on custody sheets will be used to track the progress of samples through the analytical process and to correlate those results with the initially collected biological information. Otolith Chemistry and biological data will be maintained in FOG's database, after completion of the report, a copy of the data will be issued to ADF&G.

6. Describe the procedures that will be used in the calibration and performance evaluation of all analytical instrumentation and all methods of analysis to be used during the project.
The LA-ICP-MS must be calibrated before analysis of any samples with at least a blank and multiple standards. A Linear through zero curve type is used for all analyses. The calibration blank will be run as a blank, before the analysis of any actual calibration standards. MACS-1 will be used (Table D.1; Trace Elements in calcite) as an external standard to monitor precision. In addition, a calibration gas blank monitored the process and re-calibration will be done every 6 samples. Concentrations of all elements will be calculated from the calibration curve after proper correction for control blank, matrix and drift effects using the Newwave Glitter software. Based on measurements of MACS-1 the reported values will be better than 3% error for all elements of interest. The following isotopes will be monitored with isobaric correction equations built-into the analytical method as specified by EPA 200.8. ^{24,25,26}Mg, ^{44}Ca, ^{55}Mn, ^{86,87,88}Sr, ^{135,137,138}Ba, and ^{235,238}U. Whole element concentrations will be calculated based on calibrations and relative abundance of isotopes. In the case of multi-isotope elements the reported concentration represents an average of the measured concentrations calculated independently for each isotope. All multi-isotope concentrations will be within 1% of each other.

7. Discuss the procedures for data reduction and reporting, including a description of all statistical methods, with reference to any statistical software to be used, to make inferences and conclusions. Discuss any computer models to be designed or utilized with associated verification and validation techniques.
All data will be tabulated by fish collection site, life stage (i.e., juvenile and adult) and time. Data will be compared using ANOVA, to test for differences within collection sites with respect to life stage. For example:

- Juvenile edge (nursery) vs. juvenile core (natal) (each juvenile tested against itself) if the signature is the same then the fish has not left spawning grounds. (objective 1-2)
- Juvenile core (natal) vs. juvenile core (natal) (all juveniles tested against other juveniles) if the signature is the same then the fish were spawned in the same area. (objective 1-2)
- Juvenile edge (nursery) vs. adult area just outside the core (nursery) (all juveniles tested against other juveniles) if the signature is the same then the adult used the same nursery habitat as the juvenile. (objective 2 and 4)
- Adult edge (spawning area) vs. adult core (natal) (each adult tested against itself) if the signature is the same then the adult returned to spawn in the same area it was hatched in. (objective 3-4)
- Adult core (natal) vs. adult core (natal) (all adults tested against other adults) if the signature is the same then the adults were hatched in the same area. (objective 2 and 4)

Differences will be further evaluated by discriminant function analysis. The statistical software will be SAS.

LITERATURE CITED

Bickford, N., Hannigan, R., & Bogdevich, O. (2003). Otolith microchemisty of freshwater fish: stock discrimination of Brown Trout and Walleye. Proceedings of the Sixth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe and the Commonwealth of Independent States Prague, Czech Republic, 132-144.

Bickford, N., and Hannigan, R. 2005. Stock identification of Walleye (*Sander vitreum*) using otolith chemistry in the Eleven Point River, AR North American Journal of Fisheries Management. 25: 1542-1549.

Brown, E. D., Norcross, B. L., & Short, J. W. (1996). An introduction to studies on the effects of the *Exxon Valdez* oil spill on the early life history stages of Pacific herring, *Clupea pallasi*, in Prince William Sound, Alaska. Canadian Journal of Fisheries and Aquatic Sciences, 53(10), 2337-2342.

Brown, E. D., Seitz, J., Norcross, B. L., & Huntington, H. P. (2002). Ecology of Herring and Other Forage Fish as Recorded by Resource Users of Prince William Sound and the Outer Kenai Peninsula, Alaska. Alaska Fisheries Research Bulletin, 9(2), 75-101.

Campana, S. E. (1999). Chemistry and composition of fish otoliths: pathways, mechanisms and applications. Marine Ecology Progress Series, 188, 263-297.

Campana, S. E., Gagne, J. A., & McLaren, J. W. (1995). Elemental fingerprinting of fish otoliths using ID-ICP-MS. Marine Ecology Progress Series, 122, 115-120.

Campana, S. E., & Neilson, J. D. (1985). Microstructure of fish otoliths. Canadian Journal of Fisheries and Aquatic Science, 42, 1014-1032.

Campana, S. E., & Thorrold, S. R. (2001). Otoliths, increments, and elements: keys to a comprehensive understanding of fish populations. Canadian Journal of Fisheries and Aquatic Sciences, 58, 30-38.

Cooney, R.T., Allen, J.R., Bishop, M.A., Eslinger, D.L., Kline, T.C., Jr., McRoy, C.P., Milton, J., Norcross, B.L., Olsen, J., Patrick, E.V., Salmon, D., Scheel, D., Thomas, G.L., Vaughan, S.L., and Willette, T.M. (2001). Ecosystem controls of pink salmon (Oncorhynchus gorbuscha) and Pacific herring *(*Clupea pallasi*)* production in Prince William Sound, Alaska: a Sound Ecosystem Assessment (SEA) synthesis. Fisheries Oceanography, 10 (Suppl. 1), 42-57.

Dorval, E., Jones, C. Montfrans, J. and Hannigan, R. 2002. Identifying Essential Seagrass Habitats In Chesapeake Bay For Juvenile Spotted Seatrout From Surface Water and Otolith Trace Element Chemistry. American Fisheries Society National Meeting. Baltimore MD

Foy, R.J. and B.L. Norcross. 1999. Spatial and temporal differences in the diet of juvenile Pacific herring (Clupea pallasi) in Prince William Sound, Alaska. Can. J. Zoolog. 77(5) 697-706.

Marty, G. D., Quinn, T. J. I., Carpenter, G., Meyers, T. R., & Willits, N. H. (2003). Role of disease in abundance of a Pacific herring *(Clupea pallasi)* population. Canadian Journal of Fisheries and Aquatic Sciences, 60(10), 1258-1265.

Morstad, S., Sharp, D., Wilcock, J., Joyce, T., & Johnson, J. (1999). Prince William Sound management area 1998 annual finfish management report. Vol. 2A99-20.

Mugiya, Y., & Tanaka, S. (1992). Otolith development, increment formation, and uncoupling of otolith to somatic growth rates in larval and juvenile goldfish. Nippon Suisan Gakkishi/Bull. Jap. Soc. Sci. Fish, 58(5), 845-851.

Norcross, B. L., Brown, E., Foy, R., Gay, S., Kline, T., Mason, D., Patrick, E., Paul, A. J., & Stokesbury, K. (2001a). A synthesis of the life history and ecology of juvenile Pacific herring in Prince William Sound, Alaska. Fisheries Oceanography, 10 (Suppl. 1), 42-57.

Norcross, B. L., & Brown, E. D. (2001b). Estimation of First-Year Survival of Pacific Herring from a Review of Recent Stage-Specific Studies. Alaska Sea Grant College Program, AK-SG-01-04, 535-558.

Norcross, B. L., Hose, J. E., Fransen, M., & Brown, E. D. (1996). Distribution, abundance, morphological condition, and cytogenetic abnormalities of larval herring in Prince William Sound, Alaska, following the *Exxon Valdez* oil spill. Canadian Journal of Fisheries and Aquatic Sciences, 53, 2376-2387.

Pulliam, H.R. and Danielson, B.J. 1991. Sources, Sinks, and Habitat Selection: A Landscape Perspective on Population Dynamics. American Naturalist. 137, 50-66

Roberts, C.M. 1998. Sources, sinks, and the design of marine reserve networks. Fisheries [Fisheries]. 23, 6-19.

Rooper, C.N., Haldorson, L.J., and Quinn, T.J. II (1999) Habitat factors controlling Pacific herring (*Clupea pallasi*) egg loss in Prince William Sound, Alaska. *Can. J. Fish. Aquat. Sci.* 56:1133-1142.

Rooker, J. R., Secor, D. H., Zdanowicz, V. S., De Metrio, G., & Relini, L. O. (2003). Identification of Atlantic bluefin tuna (*Thunnus thyhhus*) stocks from putative nurseries using otolith chemistry. Fisheries Oceanography, 12(2), 75-84.

Stokesbury, K.D.E., Foy, R.J. and Norcross, B.L.. 1999. Spatial and temporal variability in juvenile Pacific herring (Clupea pallasi) growth in Prince William Sound, Alaska. Environ. Biol. Fish. 56:409-418.

Stokesbury, K. D. E., Kirsch, J., Brown, E. D., Thomas, G. L., & Norcross, B. L. (2000). Spatial distributions of Pacific herring, *Clupea pallasi,* and walleye pollock, *Theragra chalcogramma* , in Prince William Sound, Alaska. Fisheries Bulletin, 98 , 400-409.

Stokesbury, K. D. E., Kirsch, J., Patrick, V., & Norcross, B. L. (2002). Natural mortality estimates of juvenile Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska. Canadian Journal of Fisheries and Aquatic Sciences, 59, 416-423.

Thresher, R. E. (1999). Elemental composition of otoliths as a stock delineator in fishes. Fisheries Research, 43, 165-204.

Wright, P. J., Panfili, J., Morales-Nin, B., & Geffen, A. J. (2002). Types of calcified structures. A. otoliths. Manual of Fish Sclerochronology, 31-57.

Nate A. Bickford, Ph D
Institute of Marine Science
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks
P.O. Box 757220
Fairbanks, Alaska 99775-7220
Office: 907-474-6469
E-mail: nate@sfos.uaf.edu
https://www.sfos.uaf.edu/people/research/

Education:

NSF Polar Post – Doctoral Work - University of Alaska Fairbanks. Research: Movement patterns of fish in the Bering Sea and Gulf of Alaska, *2004 - Present*

PhD - Environmental Science (emphasis in biology and chemistry) Arkansas State University. Research: "Linkages between Hydrology and Essential Fish Habitat" *2000 - 2004*

M.S. - Biology Appalachian State University. Research: "Survey of Gastrointestinal Helminths in Small Mammals in Watauga County, NC and Changes in Parasite Populations Due to Changes in Host Species and Changes in the Season" *1997 -2000*

B.S. – Biology Lenoir-Rhyne University. Research: "The Caloric Content of Wild and Captive Bears Diet and the Difference in Calories Used by Captive Bears and Wild Bears" *1993 -1997*

Experience

Affiliated Research Faculty: ESTES Department in the College of Natural Sciences and Mathematics – UAF *2005 – Present*

Laboratory Manager: the Inductively Coupled Plasma-Mass Spectrometer (ICP-MS) located in the Advanced Instrumentation Laboratory in the College of Natural Sciences and Mathematics – UAF *2005 – Present*

NSF Polar Regions Post Doctoral program Post-Doc: Identifying movement patterns and stock identification in fish from the Bering Sea and Gulf of Alaska. *2004 - Present*

Water Rock Life Lab (ASU) Post Doc: CRUI: Environmental Life History of Freshwater Fish using Otolith Microchemistry *2004*

Environmental Sciences Program (ASU) Graduate Assistant: *2001 - 2004*

Current research Interest

Tracing fish past habitat movement and identification of essential habitat
Marine fish age and growth
Fisheries oceanography
Life history of marine fish
Fisheries ecology and habitat characterization

Grant and Contract Funding

AYK-SSI - Factors Affecting Juvenile AYK Chum Salmon Growth and Condition $1,955,486 Co-Pi

Sea Grant – Mentoring Undergraduates in Fisheries Techniques $10,000 PI

EVOS – Pacific Herring study - Using otolith chemical analysis to determine larval drift of Prince William Sound Pacific herring (*Clupea pallasii*). $52,000 PI

OSRI – Pacific Herring in Prince William Sound - Identifying past habitat use and essential habitat of Pacific herring (*Clupea pallasii*).-$33,000 Co-Pi.

Sitka herring and salmon study – Stock delineation and natal homing in herring and sockeye salmon. $30,000 Co-Pi.

NSF Polar Programs Post Doctoral Fellowship – "Identifying movement patterns and stock identification in fish from the Bering Sea and Gulf of Alaska." $140,000. Principal Investigator.

Arkansas Water Resources – "Otoliths and Environmental Life History of Freshwater Fish", $20,000. Co-Principal Investigator.

NSF DBI 0328832 (2003-2007) "CRUI: Assessing Environmental Life Histories of Freshwater Fish: Applications of Otolith Microchemistry". $698,626. Project Manager (2003-2004).

Relevant Publications

Journal Articles

Bickford, N., and Hannigan, R. 2005. Stock identification of Walleye (*Sander vitreum*) using otolith chemistry in the Eleven Point River, AR North American Journal of Fisheries Management. 25: 1542-1549.

Sako, A., O'Reilly, C.M., Hannigan, R., **Bickford**, N., and Johnson, R.L. 2004. Stock identification of two clupeid species, *Stolothrissa tanganicae* and *Limnothrissa miodon* in Lake Tanganyika using otolith microchemistry. Geochemistry: Exploration, Environment, Analysis. 5.

Bickford, N.A. and Hannigan, R.E. 2003. Trace element chemistry of fish tissues: Uptake routes in genus *Moxostoma*. Environmental Geoscience 11(2): 226-236.

Christian, A.D., Bouldin, J., **Bickford**, N., McCord, S.B., Sako, A., and Ferris, J. 2003. Winter and spring water quality of Big Creek watershed, Craighead County, AR: Nutrients, habitat, and macroinvertebrates. Journal of the Arkansas Academy of Sciences 57: 27-36

Book Chapter

B. Hamilton, N. **Bickford**, and R. Hannigan, "Elemental chemistry of endolymph and otolith: Passive recorder or active writer", bibl. Geological Society of America Special Publication, GSA Press, Denver CO., (). *Book* Submitted of Collection: D. Sarkar, R. Datta and R. Hannigan, "Current Perspectives in Environmental Geochemistry."

Invited Presentations

Howard, R, **Bickford**, N., and Hannigan, R. Environmental life history of walleye (*Sander vitreum*) in Greer's Ferry Lake. ASLO Aquatic Science Meeting, Salt Lake City, Utah 2005.

Bickford, N., and Hannigan, R. "Hydrochemical variations in a Spring-Fed River, Spring River Arkansas". Southwest regional meeting of the American Chemical Society Oklahoma City, OK. 2003.

Bickford, N.A., Hamilton, B., and Hannigan, R.E Trace elements chemistry in a spring-fed river (Spring River, Arkansas): Ecotoxicological implications of chemical weathering. Southcentral-Southeast sectional meeting of the Geological Society of America. Memphis TN. 2003.

BRENDA L. NORCROSS
Institute of Marine Science
School of Fisheries and Ocean Sciences
University of Alaska Fairbanks, P.O. Box 757220
Fairbanks, Alaska 99775-7220
http://www.sfos.uaf.edu/directory/faculty/norcross/
norcross@ims.uaf.edu

Education:

Ph.D., Marine Science, Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, Virginia, 1983
M.S., Biology, St. Louis University, St. Louis, Missouri, 1976
A.B., Biology, MacMurray College, Jacksonville, Illinois, 1971

Experience:

Acting Science Director, *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska, 2005
Professor, Institute of Marine Science, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, 2001-present; Associate Professor, 1996-2001; Assistant Professor, 1989-1996
Assistant Professor, Division of Biological Oceanography and Fisheries Science, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia, 1984-1988

Professional Honors:

Aldo Leopold Leadership Program Fellow, 2001 Cohort
Professional training in: leadership, policy, communication, and interactions with corporate & NGOs
Harriman Scholar, 2001

Service Activities:

Co-Chair (2002-2006), Science and Technical Advisory Committee (STAC), Gulf of Alaska Ecosystem Monitoring and Research Program (GEM), *Exxon Valdez* Oil Spill (EVOS) Trustee Council; Member, Public Advisory Committee (PAC), 2002-2006
Member, Bering Sea/Aleutian Islands Groundfish Plan Team, North Pacific Fisheries Management Council, 1995-present
Member, Committee to Review the Gulf of Alaska Ecosystem Monitoring Program and Plan, National Research Council, Polar Research Board, 2000-2002
Member, Scientific Steering Committee, PICES-GLOBEC Climate Change and Carrying Capacity (CCCC) Program, 1995-present; Member, CFAME (Climate Forcing and Marine Ecosystem Response) Task Team, 2004-present; REX (Recruitment Experiment) Subcommittee, 1996-2004; Small Pelagics Working Group, 1993-1995.

Relevant Publications:

Brown, E.D., J. Seitz, B.L. Norcross and H.P. Huntington. 2002. Ecology of herring and other forage fish as recorded by resource users of Prince William Sound and the Outer Kenai, Alaska. *Alaska Fish. Res. Bull.* 9(2):75-101.

Stokesbury, K.D.E., J. Kirsch, E.V. Patrick and B.L. Norcross. 2002. Mortality estimates of juvenile Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska. *Can. J. Fish. Aquat. Sci.* 59:416-423.

Norcross, B.L., E.D. Brown, R.J. Foy, M. Frandsen, S. Gay, T.C. Kline Jr., D.M. Mason, E.V. Patrick, A.J. Paul and K.D.E. Stokesbury. 2001. A synthesis of the life history and ecology of juvenile Pacific herring in Prince William Sound, Alaska. *Fish. Oceanog.* 10 (Suppl. 1):42-57.

Norcross, B.L. and E.D. Brown. 2001. Estimation of first year survival of Pacific herring from a review of recent stage-specific studies. In: F. Funk, J. Blackburn, D. Hay, A.J. Paul, R. Stephenson, R. Toresen, and D. Witherell (eds.). Herring: Expectations for a New Millennium. University of Alaska Sea Grant, AK-SG-01-04, Fairbanks, pp.535-558.

Brown, E.D. and B.L. Norcross. 2001. Effect of herring egg distribution and ecology on year-class strength and adult distribution: preliminary results from Prince William Sound. In: F. Funk, J. Blackburn, D. Hay, A.J. Paul, R. Stephenson, R. Toresen, and D. Witherell (eds.). Herring: Expectations for a New Millennium. University of Alaska Sea Grant, AK-SG-01-04, Fairbanks, pp. 335-345.

Foy, R.J. and B.L. Norcross. 2001. Temperature effects on zooplankton assemblages and juvenile herring feeding in Prince William Sound, Alaska. In: F. Funk, J. Blackburn, D. Hay, A.J. Paul, R. Stephenson, R. Toresen, and D. Witherell (eds.). Herring: Expectations for a New Millennium. University of Alaska Sea Grant, AK-SG-01-04, Fairbanks, pp. 21-35.

Cooney, R.T., J.R. Allen, M.A. Bishop, D.L. Eslinger, T.C. Kline, Jr., B.L. Norcross, C.P. McRoy, J. Milton, J. Olsen, V. Patrick, A.J. Paul, D. Salmon, D. Scheel, G.L. Thomas, S L. Vaughan, and T.M. Willette. 2001. Ecosystem Controls of Juvenile Pink Salmon (*Onchorynchus gorbuscha*) and Pacific Herring (*Clupea pallasi*) Populations in Prince William Sound, Alaska: a sound ecosystem assessment (SEA) synthesis. *Fish. Oceanog.* 10 (Suppl. 1):1-13.

Stokesbury, K.D.E., J. Kirsch, E.D. Brown, G.L. Thomas and B.L. Norcross. 2000. Seasonal variability in Pacific herring (*Clupea pallasi*) and walleye pollock (*Theragra chalcogramma*) spatial distributions in Prince William Sound, Alaska. *Fish. Bull. (US)* 98:400-409.

Foy, R.J. and B.L. Norcross. 1999. Spatial and temporal differences in the diet of juvenile Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska. *Can. J. Zoolog.* 77(5) 697-706.

Stokesbury, K.D.E., R.J. Foy and B.L. Norcross. 1999. Spatial and temporal variability in juvenile Pacific herring (*Clupea pallasi*) growth in Prince William Sound, Alaska. *Environ. Biol. Fish.* 56:409-418.

Collaborators:

Monica K.H. Bando (Veterinary School, NZ)
Allison E.M. Barns (NOAA/NMFS)
Evelyn D. Brown (Flying Fish Consulting)
Morgan Busby (NMFS/AFSC)
Sherri C. Dressel (ADF&G, Juneau)
Christine A. Frazier (US Army)
Brandee L. Gerke (NMFS/PIFSC)
Tim Loher (IPHC)
Franz J. Mueter (Sigma Plus)
Jennifer Nielson (USGS/BRD)
Olav Ormseth (UAF/SFOS)
Terry Quinn (UAF/SFOS)
Andrew C. Seitz (UAF/SFOS)
Tom Wildebuer (NMFS/AFS)

Appendix A

Identification Information:

Citation:

Citation Information:

Originator: Nate Bickford

Publication Date: 20060412

Title: Herring Restoration in PWS: Identifying Natal and Nursery Habitats *Edition:* 1

Geospatial Data Presentation Form: map

Publication Information:

Publication Place: University of Alaska Fairbanks

Publisher:

Description:

Abstract:

Purpose:

To identify natal and nursery habitat

Time Period of Content:

Time Period Information:

Range of Dates/Times:

Beginning Date: 20060601

Ending Date: 20070530

Currentness Reference:

Status:

Progress: Planned

Maintenance and Update Frequency: Monthly

Spatial Domain:

Bounding Coordinates:

West Bounding Coordinate: 147

East Bounding Coordinate: 154.2

North Bounding Coordinate: 60.5

South Bounding Coordinate: 56.5

Keywords:

Theme:

Theme Keyword Thesaurus: herring

Theme Keyword: Pacific herring

Theme Keyword: otolith

Theme Keyword: spawning

Theme Keyword: nursery

Theme Keyword: chemistry

Theme Keyword: oil

Place:

Place Keyword Thesaurus: Prince William Sound

Place Keyword: Simpson Bay

Place Keyword: Boulder Bay

Place Keyword: Whale Bay

Temporal:
Temporal Keyword Thesaurus: 2006 and 2007
Temporal Keyword: May 2006
Temporal Keyword: June 2006
Temporal Keyword: July 2006
Temporal Keyword: August 2006
Temporal Keyword: ....
Access Constraints: password
Use Constraints: upon request

Spatial Data Organization Information:
Direct Spatial Reference Method: Point

Distribution Information:
Distributor:
Contact Information:
Contact Person Primary:
Contact Person: Nate Bickford
Contact Organization: Institute of Marine Science, University of Alaska Fairbanks
Contact Address:
Address Type: Address
Address:
245 O'Neill Bldg. University of Alaska Fairbanks
City: Fairbanks
State or Province: AK
Postal Code: 99775
Country: USA
Contact Voice Telephone: 907-474 6469
Contact Facsimile Telephone:
Contact Electronic Mail Address: nate@sfos.uaf.edu
Distribution Liability:

Metadata Reference Information:
Metadata Date:
Metadata Contact:
Contact Information:
Contact Person Primary:
Contact Person: Nate Bickford
Contact Organization: Institute of Marine Science, University of Alaska Fairbanks
Contact Address:
Address Type: Physical Address
Address:
245 O'Neill Bldg. University of Alaska Fairbanks
City: Fairbanks
State or Province: AK
Postal Code: 99775

Country: USA
Contact Voice Telephone: 907-474 6469
Contact Facsimile Telephone:
Contact Electronic Mail Address: nate@sfos.uaf.edu
Metadata Standard Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata Standard Version: FGDC-STD-001-1998

Generated by mp version 2.6.0 on Tue Apr 13 14:39:06 2004

University of Alaska Fairbanks Budget Justification

F. Project Costs: Budget Summary and Justification = $335,000

Salaries and Fringe Benefits ($216K):
Dr. Nate Bickford is a National Science Foundation Polar Regions Post Doctoral Fellowship (October 2004 – November 2006) in the School of Fisheries and Ocean Sciences, UAF. His duties (1.5 months per year the first two years and 2 months the third year) as PI include: analytical analysis, data QA/QC, data interpretation, technician coordination and manuscript preparation. Total funding requested for his salary is approximately $40,700.

Dr. Brenda L. Norcross is a Professor of Fisheries Oceanography in the School of Fisheries and Ocean Sciences, UAF. Her duties (0.5 months the first year and 1 month the second and third year) as Co-PI include: coordination of the components of the project, data interpretation, and manuscript preparation. Total funding requested for her salary is approximately $34,800.

A research technician (11 months each the first and second years and 4 months the third year) will be responsible for organization of samples, sample preparation and analysis, GIS processing, and coordination with other projects from which the samples were obtained. Total funding requested for the research technician's salary is approximately $140,500.

Benefits:
Staff benefits are applied according to UAF's benefit rates for FY07, negotiated with the Office of Naval Research (ONR). A copy of the rate proposal is available at: http://www.alaska.edu/ controller /cost-analysis/cost_reports.html.

Travel ($7.2K):
Domestic
Travel support is requested for PI to travel to EVOS research meetings each year, to give a presentation to disseminate the results of this study. Total costs associated to attend the meeting are approximately $7,200 and include registration, airfare, ground transportation, hotel and per diem.

Supplies ($9.1K):
Funds in the amount of $6,600 are requested for the purchase of materials and supplies related to the proposed project. Supplies include argon gas, ultra-pure acids, saw blades for otolith preparation, freezer space, petrographic slides, and miscellaneous lab and project supplies. Funds are also requested in the amount of $2,500 for a computer for this project. This computer will be used for data analysis, report writing, and database storage.

Services/Contractual ($13.6K)
Otolith trace elements processing costs $10 per sample for 625 (per year) for a total of $12,600. Otolith samples to run the LA-ICP-MS, which will include the associated costs of the running the ICP-MS, including electricity, water demands, micro-pipettes, sample and skimmer cones,

torch, and ultra-pure carrier gas and ICP-MS standards as the project dictates. Because Dr. Bickford has access to the LA-ICP-MS, sample cost only includes maintenance cost of the instrument**.**

Funds have been requested for publication costs for journal page costs, report copies, etc. in the amount of $1,000.

Indirect Costs: Facilities and Administrative (F&A) Costs are negotiated with the Trustee Council and are calculated at 25% of the Total Direct Costs (TDC). TDC includes Total Direct Costs minus subcontracts in excess of $25,000 and equipment. Regarding subcontracts, the indirect rate is 25% of the first $25,000 of each subcontract, plus 5% of each subcontract's cost in excess of $25,000 and less than $250,000, plus 2% of each subcontract's cost in excess of $250,000. A copy of the agreement is available at: http://www.alaska.edu/ controller/cost-analysis/negotiated_agreements.html. To cover costs through the Trustee Council's general administration (GA), an additional 9% indirect is added to the budget to be paid to Alaska Department of Fish and Game per RFP instructions.

No match funds are included in this project.

FY 2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

Budget Category:	Authorized FY 2006	Proposed FY 2007	Proposed FY 2008	Proposed FY 2009	Proposed FY 2009
Personnel		$75.5	$86.5	$54.0	$216.0
Travel		$2.6	$2.8	$1.8	$7.2
Contractual		$6.3	$6.3	$1.0	$13.6
Commodities		$5.7	$3.2	$0.2	$9.1
Equipment		$0.0	$0.0	$0.0	$0.0
Subtotal		$90.1	$98.8	$57.0	$245.9
UAF Indirect (25%)		$22.5	$24.7	$14.3	$61.5
Total w/o G&A		$112.6	$123.5	$71.3	$307.4
ADFG GA (9%)		$10.1	$11.1	$6.4	$27.6
Project Total		$122.7	$134.6	$77.7	$335.0
Full-time Equivalents (FTE)		1.1	1.1	0.6	
	Dollar amounts are shown in thousands of dollars.				
Other Resources					

Comments:

Originally budgeted out-of-state travel was removed during the proposal review processes, totaling $7,000. This resulted in an additional reduction of $2,600 in UAF Indirect and ADF&G G&A. Unauthorized travel removed: FY 07: Fairbanks to San Francisco = $1,800; FY 08: Fairbanks to Ottawa, ON = $2,700; FY 09: Fairbanks to Nashville = $2,500.

FY07 - FY 09

Prepared:

Project Number: 070782
Project Title: Herring Restoration in PWS: Identifying Natal and Nursery Habitats
Name: Bickford/Norcross

FY 2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

Personnel Costs:				Months	Monthly		Proposed
	Name	Position Description		Budgeted	Costs	Overtime	FY 2007
	Bickford Nate	Principal Investigator		1.5	7.8	0.0	11.7
	Norcross Brenda	Principal Investigator		0.5	13.2	0.0	6.6
	Research Assistant			11.0	5.2	0.0	57.2
		Subtotal		13.0	26.2	0.0	
						Personnel Total	$75.5

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FY 2007
	Fairbanks to Anchorage	0.3	2	5	0.2	2.6
						0.0
					Travel Total	$2.6

FY07

Project Number: 070782
Project Title: Herring Restoration in PWS: Identifying Natal and Nursery Habitats
Name: Bickford/Norcross

Prepared:

Contractual Costs:		Proposed
Description		FY 2007
Instrument time (LA-ICP-MS)	625 samples yr 1 x $10/sample	6.3
	Contractual Total	$6.3

Commodities Costs:	Proposed
Description	FY 2007
Computer	2.5
Lab supplies	3.0
Project supplies	0.2
Commodities Total	$5.7

FY07

Project Number: 070782
Project Title: Herring Restoration in PWS: Identifying Natal and Nursery Habitats
Name: Bickford/Norcross

Prepared:

FY 2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

New Equipment Purchases:	Number of Units	Unit Price	Proposed FY 2007
Description			
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage:	Number of Units	
Description		
This section was modified to accommodate University needs.		

FY07

Prepared:

Project Number: 070782
Project Title: Herring Restoration in PWS: Identifying Natal and Nursery Habitats
Name: Bickford/Norcross

FY 2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

Personnel Costs:				Months	Monthly		Proposed
	Name	Position Description		Budgeted	Costs	Overtime	FY 2008
	Bickford Nate	Principal Investigator		1.5	8.1	0.0	12.2
	Norcross Brenda	Principal Investigator		1.0	13.8	0.0	13.8
	Research Assistant			11.0	5.5	0.0	60.5
		Subtotal		13.5	27.4	0.0	
						Personnel Total	$86.5

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FY 2008
	Fairbanks to Anchorage	0.4	2	5	0.2	2.8
						0.0
					Travel Total	$2.8

FY08

Prepared:

Project Number: 070782
Project Title: Herring Restoration in PWS: Identifying Natal and Nursery Habitats
Name: Bickford/Norcross

Contractual Costs:		Proposed
Description		FY 2008
Instrument time (LA-ICP-MS)	625 samples yr 1 x $10/sample	6.3
	Contractual Total	$6.3

Commodities Costs:	Proposed
Description	FY 2008
Lab supplies	3.0
Project supplies	0.2
Commodities Total	$3.2

FY08

Prepared:

Project Number: 070782
Project Title: Herring Restoration in PWS: Identifying Natal and Nursery Habitats
Name: Bickford/Norcross

FY 2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

New Equipment Purchases:	Number of Units	Unit Price	Proposed FY 2008
Description			
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage:	Number of Units
Description	

FY08

Prepared:

Project Number: 070782
Project Title: Herring Restoration in PWS: Identifying Natal and Nursery Habitats
Name: Bickford/Norcross

FY 2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

Personnel Costs:				Months	Monthly		Proposed
	Name	Position Description		Budgeted	Costs	Overtime	FY 2009
	Bickford Nate	Principal Investigator		2.0	8.4	0.0	16.8
	Norcross Brenda	Principal Investigator		1.0	14.4	0.0	14.4
	Research Assistant			4.0	5.7	0.0	22.8
		Subtotal		7.0	28.5	0.0	
						Personnel Total	$54.0

Travel Costs:		Ticket	Round	Total	Daily	Proposed
	Description	Price	Trips	Days	Per Diem	FY 2009
	Fairbanks to Anchorage	0.4	2	5	0.2	1.8
						0.0
					Travel Total	$1.8

FY09

Prepared:

Project Number: 070782
Project Title: Herring Restoration in PWS: Identifying Natal and Nursery Habitats
Name: Bickford/Norcross

Contractual Costs:	Proposed
Description	FY 2009
Publication costs	1.0
Contractual Total	$1.0

Commodities Costs:	Proposed
Description	FY 2009
Project supplies	0.2
Commodities Total	$0.2

FY09

Prepared:

Project Number: 070782
Project Title: Herring Restoration in PWS: Identifying Natal and Nursery Habitats
Name: Bickford/Norcross

FY 2007 EXXON VALDEZ TRUSTEE COUNCIL PROJECT BUDGET
October 1, 2006 - September 30, 2007

New Equipment Purchases:	Number of Units	Unit Price	Proposed FY 2009
Description			
Those purchases associated with replacement equipment should be indicated by placement of an R.		**New Equipment Total**	$0.0

Existing Equipment Usage:	Number of Units
Description	

FY09

Prepared:

Project Number: 070782
Project Title: Herring Restoration in PWS: Identifying Natal and Nursery Habitats
Name: Bickford/Norcross