FY12 INVITATION
PROPOSAL SUMMARY PAGE

Project Title: Scales as growth history records for Pacific herring.

Project Period: October 1 2011–May 2014

Primary Investigator(s): Steve Moffitt, ADF&G (steve.moffitt@alaska.gov)

Study Location: Prince William Sound

Abstract:
Robust Pacific herring (*Clupea pallasii*) populations, suitable for exploitation by commercial fisheries, are typically sustained by periodic recruitment of strong year classes into the adult spawning population. However, the Prince William Sound (PWS) herring population has not had a strong recruitment class since 1989, when the *Exxon Valdez* Oil Spill (EVOS) occurred. Identification of conditions limiting herring recovery requires a series of focused process studies combined with monitoring of the natural conditions that affect herring survival.

Fish grow in response to the extrinsic influences of their environment constrained by the intrinsic influences of genetic predisposition for growth and of size already attained. Understanding how these intrinsic and extrinsic sources of variability influence growth is important for several reasons. Variation in growth has a strong affect on the selection of appropriate harvest policies that are based on demographic models that reflect the natural processes.

Analysis of growth increments between annular patterns on scales can provide a means to reconstruct past growth changes that can assist in determining the possible environmental and density-dependent causes of growth variation. Growth increment information incorporates a longitudinal history of growth that increases the effective degrees of freedom and can be used in modeling changes in growth in relationship to environmental and population indices Determining the underlying distribution of individual growth patterns can provide improved inputs into population dynamics models that are used to establish harvest guidelines.

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

FY2012	**FY2013**
$86.15	**$43.24**

Non-EVOSTC Funds to be used:

FY2012	**FY2013**
$5.25	**$5.25**

Date: 5-25-2011

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PROJECT PLAN

I. NEED FOR THE PROJECT

A. Statement of Problem

Robust Pacific herring (*Clupea pallasii*) populations, suitable for exploitation by commercial fisheries, are typically sustained by periodic recruitment of strong year classes into the adult spawning population. However, the Prince William Sound (PWS) herring population has not had a strong recruitment class since 1989, when the *Exxon Valdez* Oil Spill (EVOS) occurred. In the EVOS settlement herring were identified as an injured resource and they remain listed as an unrecovered species by the EVOS Trustee Council (EVOSTC). Understanding why herring have not recovered in Prince William Sound requires understanding potential bottlenecks in the herring life cycle. The identification of the limiting conditions to herring recovery requires a series of focused process studies combined with monitoring of the natural conditions that affect herring survival.

Described here are projects for a program that will enhance the current monitoring efforts of the Alaska Department of Fish and Game (ADF&G), and examine aspects of particular life stages to allow better modeling of herring populations. **The long-term goal of the program is to improve predictive models of herring stocks through observations and research.** While we do not anticipate that there will be a major change in our modeling ability in the next five years, we expect that the combination of monitoring and focused process studies will provide incremental changes over the next twenty years and result in a much better understanding of herring populations by the end of the program.

B. Relevance to 1994 Restoration Plan Goals and Scientific Priorities

The proposed program addresses the goals and priorities outlined in the 1994 Restoration Plan (http://www.evostc.state.ak.us/Universal/Documents/Publications/IHRP%20DRAFT%20-%20July%202010.pdf) and in the FY 2012 invitation for proposals. In particular our program addresses the need to "Conduct research to find out why Pacific herring are not recovering" and "Monitor recovery", listed on page 48 of the 1994 Restoration Plan. It will lead to the development of new tools to improve herring management. The latter will be accomplished by providing the information needed to develop or test biological and physical models of herring growth.

In November 2006, a Herring Steering Committee was formed and tasked with developing a focused Restoration Program that identifies strategies to address recovery and restoration of herring, recognizing that activities in the program must span an ecologically relevant time frame that accounts for herring population dynamics and life history attributes. A draft Integrated Herring Restoration Program (IHRP) was completed in the fall of 2008 and was further refined in July of 2010. The main goal of the program is to determine what, if anything, can be done to successfully recover the Pacific herring in PWS. In order to determine what steps can be taken, the program examines the factors limiting recovery of herring in PWS, identifies and evaluates potential recovery options, and recommends a course of action for achieving restoration.

Based on the recommendations of the IHRP the Trustee Council has stated in the FY12 request for proposals that they have chosen Restoration Option #2, Enhanced Monitoring, as the focus for their research interests. The program described below aims to meet the goals of this option by utilizing a combination of monitoring efforts to provide more information about the existing

stock and process studies to elucidate aspects of the herring life cycle necessary to move us towards an analytical modeling approach.

II. PROJECT DESIGN

A. Objectives

Program Goals and Objectives

We have sought input for the design of the first five year proposal from scientists with ADF&G, NOAA, the current PWS herring survey program, and other institutions. Based on that input we have arrived at the following objectives for the first five-year period.

1) *Provide information to improve input to the age-structure-analysis (ASA) model, or test assumptions within the ASA model.* The ASA model is currently used by ADF&G for estimating herring biomass (Hulson et al. 2008). The proposed monitoring efforts are designed to address this objective by either expanding the data available for the existing ASA model or by providing information about factors that determine the size of recruitment events.

2) *Inform the required synthesis effort.* Proper completion of a detailed synthesis means being able to access and manipulate different sources of data and information. We are proposing projects that make data available to all researchers.

3) *Address assumptions in the current measurements.* Many of the existing studies are based on historical or logistical constraints. We are proposing research necessary to put the existing measurements into context spatially and temporally. This effort will allow the design of the most accurate and efficient monitoring program.

4) *Develop new approaches to monitoring.* With technological advances we have the potential to improve our monitoring programs so they require less effort or reduce the need to collect fish.

Because we are at the beginning of a twenty-year effort, we want to maximize the value of any data collected. The objectives listed above are designed to ensure that research and monitoring efforts within the expected twenty-year program are most effective. The programs addressing the objectives provide the information necessary to evaluate existing efforts while continuing to move towards our long-term goal.

Program Objective 2

Herring scale analysis: A very valuable source of information for many PWS herring studies includes approximately 200,000 herring scales (including ancillary data including collection location, date, length, weight, and sex) that are currently maintained in a collection at the Cordova ADF&G office. Unfortunately, only a small portion of these data are converted to an electronic format. We are proposing a project that will examine the growth history contained in scales from PWS. This information will be used to improve our understanding of any temporal and age-specific growth patterns that result in observed changes in size at age. Spatial patterns may also be examined given sufficient sample sizes. Project data can be used to model changes in growth in relation to environmental and population indices.

There is also potential for this information to help identify when fish first spawn as described in the project under Objective 1. There are many more scales than can be analyzed by either of these individual projects and we will ensure that the information collected in each effort can be combined to increase the statistical power of both sets of analyses. We believe that retrospective studies, such as this one, will be extremely useful in improving the quality of the required synthesis.

Project Objectives

1. FY2012:
    a. Standardize scale interpretive criteria, evaluate alternative measurement techniques, and develop semi-automated procedures for measuring scale increments of PWS herring.
    b. Measure scale growth increments on scales subsampled from archived collections.

2. FY2013:
    a. Finish measurements of scale growth increments on subsampled scales.

Fish grow in response to the extrinsic influences of their environment constrained by the intrinsic influences of genetic predisposition for growth and of size already attained (Weathedey and Gill 1987, Weisberg 1993). Understanding how these intrinsic and extrinsic sources of variability influence growth is important for several reasons. The effects of stock size and environmental conditions on growth have been studied by a number of investigators (Anthony and Fogarty 1985, Hagen and Quinn 1991, Kreuz et al. 1982, Martinson et al. 2009, Peterman and Bradford 1987, Rijnsdorp and van Leeuwen. 1992, Stocker et al. 1985), primarily because of the consequences that growth variation can have on reproductive potential through its influences on fecundity and spawn timing (Ware and Tanasichuk 1989), natural mortality, recruitment, and age at maturity (Haist and Stocker 1985, Schmitt and Skud 1978). Haist and Stocker 1985 stated that factors affecting growth rates can be of fundamental importance to the understanding of the dynamics of exploited populations and the responses of natural populations to abundance and environmental influences have remained a central issue in population biology (Tanasichuk 1997). Variation in growth has a strong affect on the selection of appropriate harvest policies that are based on demographic models that reflect the natural processes (Methot 1997, Tanasichuk 1997).

The underlying mechanisms for cyclic changes in annular growth for herring in the northern Gulf of Alaska are currently unknown. A period of the lowest observed average body sizes for PWS herring coincided with a period of historic high abundance followed by a catastrophic population decline associated with outbreaks of viral hemorrhagic septicemia virus (VHSV) and *Ichthyophonus hoferi* (Marty et al. 1998). Although the links between herring energetic condition (growth) and disease susceptibility are not yet well understood, it is postulated that the observed population decline was a result of density dependent growth effects leading to decreased body condition and resistance to disease. Analysis of growth increments between annular patterns on scales can provide a means to reconstruct past growth changes that can assist in determining the possible environmental and density-dependent causes of growth variation. The current picture of growth is based on cross sectional size at age data. In contrast, growth increment information incorporates a longitudinal history of growth that increases the effective degrees of freedom and can be used in modeling changes in growth in relationship to environmental and population

indices (Chambers and Miller 1995, Kreuz et al. 1982, Tanaischuk 1997, Weisberg 1993). Determining the underlying distribution of individual growth patterns can provide improved inputs into population dynamics models that are used to establish harvest guidelines.

B. Procedural and Scientific Methods

Objective 1a.

Extensive scale collections are maintained in the Cordova ADF&G office. Many fish have associated records including location, age, size, weight, and maturation state. Some early collections of scales may not have been collected from the preferred area on the body and their condition and usefulness remains unknown. One task will be to identify the number of scales by year and age class available. To age herring scales consistently and accurately requires experience and training. To help develop consistent criteria for identifying and measuring annuli, sample personnel will meet with experienced age readers in the ADF&G Mark-Tag-Age Lab in Juneau. Side by side comparison and discussion of problems in reading scales and potential biases in measurements will be addressed. Image processing techniques will be used to collect the growth information from scales. Off-the-shelf imaging software will be used where possible, but additional customization of routines maybe necessary, particularly to streamline the data acquisition.

Scale collections were standardized in many locations in the mid 1980s by the identification of a preferred area on body of herring. However for earlier samples there is likely to be considerable variation on scale size and shape. Several approaches will be taken to determine methods for adjusting the growth increment data such that it accurate reflects body growth. The biological intercept model used for back calculation studies represents one possibility (Campana 1990). Other approaches may involve collecting multiple scales from several individuals and determine which transformations based on body size or scale size achieve the greatest reduction of within individual variation of the growth increments using variance component analysis (Sokal and Rohlf 1981). Concurrent studies on herring energetic may also provide samples by which scale growth can be measured in relationship to known somatic growth. If such specimens are available they will be examined. In addition, with the biological intercept approach for back calculation it is necessary to establish the body size at initial scale formation (Campana 1990). Collections of young of the year herring will be examined to determine those values. Once the methodology is established, production measurements will first be collected from the Prince William Sound archive collections.

Sample Collections: The PWS scale collections extend back to 1979, with some older scales from the early 1970's. The archives contain approximately 200,000 scales classified into different groups (harvest or collection types), and the most complete is the commercial harvest collection. The number of scales drawn from these collections will be determined by a power analysis. A preliminary sample size goal is 50 scales from 6 or 7 age classes per year for as many as 35 years (n=10k to 12k). The goal will be to measure a sufficient number of scales such that biologically significant differences in growth increments between cohorts can be detected. Since the scales themselves may not have examined since they were originally stored considerable

effort may have to be expended in pulling out the selected scales to see if they are suitable for digitizing.

Objective 1b.

Scale Measurements:

Each scale selected for the study will be examined to confirm the original age estimate. Scales will be examined through a microfiche equipped with a scanner. The scanner feeds the image into a framegrabber board in a computer. Using software calibrated to the magnification of the image, a line or series of lines will be overlaid on the scale image from the focus to the scale edge by the reader and they will mark the annuli on the image. The number of annuli and the spacing between annuli will be collected in a database and collated with the existing information about the herring. The image and the overlaid measurements maybe saved for future reference. It is anticipated that this step can occur relatively quickly during the production phases.

C. Data Analysis and Statistical Methods

This proposal is to collate and collect data for future analysis. This could occur as part of the synthesis or as part of a graduate student program. The budget for this project does not provide money for analysis. This data will allow comparisons with historical data on scale growth increments, but comparisons with other regions would require a similar project to measure scale growth increments.

The number of scales drawn from these collections will be determined by a power analysis. A preliminary sample size goal is 50 scales from 6 or 7 age classes per year for as many as 35 years (n=10k to 12k). The goal will be to measure a sufficient number of scales such that biologically significant differences in growth increments between cohorts can be detected.

D. Description of Study Area

The study area includes all of Prince William Sound. However, most of the projects will focus on the four bays (Zaikof, Whale, Eaglek, and Simpson) that were extensively studied during the Sound Ecosystem Assessment study and PWS Herring Survey program (Figure 1). This allows the work to build upon the historical research completed in those bays. These bays also cover four different quadrants of the Sound. We anticipate a potential build out to include other bays or contraction based on the results from the synthesis. As part of the synthesis effort we will be reviewing the question “What is the appropriate sampling distribution?” as applied to the questions of juvenile herring condition and providing an index of juvenile abundance.

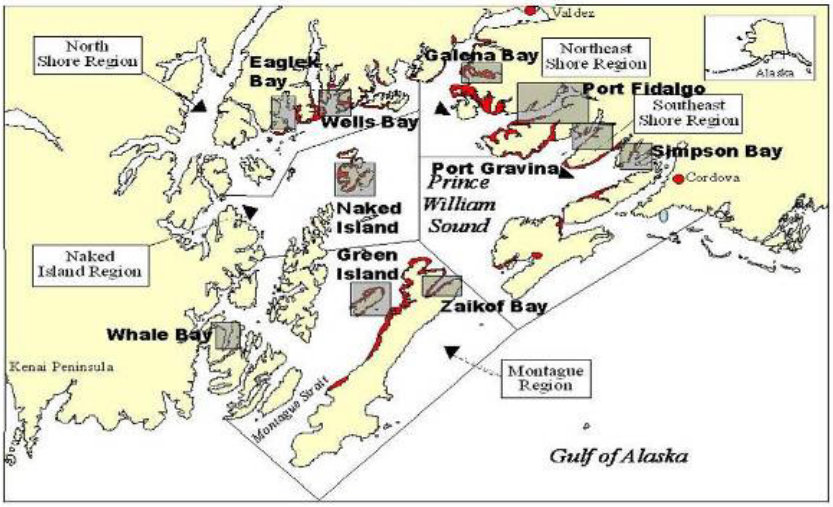

Figure 1. PWS study area, including the four SEA bays (Whale, Zaikof, Eaglek, and Simpson, as well as other bays historically important for juvenile herring.

E. Coordination and Collaboration with Other Efforts

This proposal is part of the integrated "PWS Herring Research and Monitoring" proposal submitted by the Prince William Sound Science Center to the Exxon Valdez Oil Spill Trustee Council. It includes the collaboration and coordination described there for work within the herring research group and with the Long-Term Monitoring proposal submitted by the Alaska Ocean Observing System.

III. SCHEDULE

A. Project Milestones

Objective 1. Standardize scale interpretive criteria, evaluate alternative measurement techniques, and develop semi-automated procedures for measuring scale increments of PWS herring.

To be met by March 2012

Objective 2. Measure scale growth increments on scales subsampled from archived collections.

To be met by August 2013.

B. Measurable Project Tasks

FFY 12, 1st quarter (October 1, 2011-December 31, 2011)

October *Project funding approved by Trustee Council*
November *Purchase scanning microfiche and software*

December *Develop criteria for selection of scales to be processed*

FFY 12, 2rd quarter (January 1, 2012-March 31, 2012)
January *Annual Marine Science Symposium*
February *Meet with ADF&G Age Lab staff in Juneau*
March *Conduct trial scale processing, finalize scale processing design*

FFY 12, 3th quarter (April 1, 2012-June 30, 2012)
May *Conduct annual PI meeting*
June *Begin production scale processing*

FFY 12, 4st quarter (July 1, 2012-September 30, 2012)
July–Sept. *Production scale processing*
August *Submit annual report*

FFY 13, 1st quarter (October 1, 2012- December 31, 2012)
Oct.–Dec. *Production scale processing*

FFY 13, 2rd quarter (January 1, 2013-March 31, 2013)
January *Annual Marine Science Symposium*
Oct.–Dec. *Production scale processing*

FFY 13, 3th quarter (April 1, 2013-June 30, 2013)
May *Conduct annual PI meeting*
June *Begin production scale processing*

FFY 13, 4st quarter (July 1, 2013-September 30, 2013)
July–August. *Finish scale processing*
August *Submit annual report*

FFY 14, 2rd quarter (January 1, 2014-March 31, 2014)
January *Annual Marine Science Symposium*

FFY 14, 3th quarter (April 1, 2014-June 30, 2014)
April 15 *Submit final report. This will consist of a draft manuscript for publication to the Trustee Council Office.*

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BUDGET JUSTIFICATION: Fiscal Year: 2012

Personnel:

Funds are requested ($58.8 K) to support ADF&G Fish and Wildlife Technician (FWT) II positions in Prince William Sound (12 months or 1.00 FTE). The technician will identify the number scales available by age class and collection year, standardize scale interpretive criteria, assist with equipment setup and calibration, and begin measuring scales growth increments (*Objectives 1a*).

ADF&G will provide an in-kind contribution of 0.5 months of staff time ($2.0 K) to supervise the technician in Cordova and 0.1 months (0.008 FTE) of staff time ($5.25 K) to supervise the technician in Cordova. (*Objective 1a*).

Travel:
Funds are requested for a technician to travel from Cordova to Juneau to meet with Alaska Department of Fish and Game Age Laboratory staff about scale aging criteria, scale measurement procedures, and software use ($0.57 K). Funds are requested for travel from Cordova to Anchorage for the Alaska Marine Science Symposium ($0.470 K) (*Objectives 1a).*

Contractual:
Funds are requested to retrofit scanner plate to accommodate the larger herring scales ($0.2 k) (*Objective 1a*).

Commodities:
Funds are requested to purchase Optimas Image Pro software for measuring scale growth increments ($3.5 K) and external hard drives to store data ($0.5 K) (*Objective1a).*

Equipment:
Funds are requested to purchase the Indus Model 4601-11 microfiche with screen scan model PC ($15.0 K) for capturing digital images of herring scales (*Objective1a).*

ADF&G will provide the following equipment as an in-kind contribution (*Objective 1a*): Dell desktop computers and software ($10.0 K).

Indirect:
The indirect for the Trustee Agency costs were calculated at 9% ($7.1K).

BUDGET JUSTIFICATION: Fiscal Year: 2013

Personnel:

Funds are requested ($39.2 K) to support ADF&G Fish and Wildlife Technician (FWT) II position in Prince William Sound (8.0 months or 0.67 FTE). The technicians will work on the production scanning and measuring the growth increments of selected herring scales. ADF&G will provide an in-kind contribution of 0.5 months of staff time ($5.25 K) to supervise the technician in Cordova (*Objective 1b*).

Travel:

S. Moffitt Sampling for High Density DNA Sequencing to Detect Population Structure of Pacific Herring

Funds are also requested for travel to the annual PI meeting ($0.470 K).

Contractual:
No funds requested in FY 2013.

Commodities:
No funds requested in FY 2013.

Equipment:
ADF&G will provide the following equipment as an in-kind contribution (*Objectives 1b)*:
Dell desktop computers and software ($10.0 K).

Indirect:
The indirect for the Trustee Agency costs were calculated at 9% ($3.6K).