FY12 INVITATION
PROPOSAL SUMMARY PAGE

Project Title: PWS Herring Research and Monitoring **– What is the age at first spawning for female herring in PWS?**

Project Period: October 1, 2011 – September 30, 2016

Primary Investigator(s): JJ Vollenweider, Dr. Ron Heintz
Co-operating Investigator: Dr. Gary Marty, Rich Brenner

Study Location: Prince William Sound

Abstract: The predictive capabilities of current population models of herring in Prince William Sound may be improved by validating the estimated proportions of fish in each age class that spawn and knowing the proportions of primiparous individuals in each age class. Determination of age at first spawn has been accomplished via 1) analysis of differential growth increments on scales, 2) histological analysis of egg development in ovaries. While the histological method provides direct observation of the spawning history of individuals it is unlikely that developing oocytes can be observed among spawners. Hence the histological analysis must occur some months after spawning. We propose to examine scales of female herring collected from spawning aggregates in PWS to identify the spawning history of each year class. We will also validate the scale technique by comparing the results of scale analysis with that of histological analysis of oocyte development. The validation will likely be used on fish sampled some time after spawning. In order to identify the optimal time we will iteratively sample ovaries in fish held in the lab after spawning. Estimates of the proportion of primiparous fish in the spawning population will provide a means for adjusting estimates of the total post-spawning biomass in the ASA by indicating proportion of each age class that was not on the spawning grounds in the previous year. This study will consequently serve to develop an inexpensive method for improving the accuracy of spawning stock biomass estimates.

Estimated Budget:
EVOSTC Funding Requested:
(breakdown by fiscal year and must include 9% GA)

Non-EVOSTC Funds to be used:
(breakdown by fiscal year)

Date: May 18, 2011

(NOT TO EXCEED ONE PAGE)

PROJECT PLAN

I. NEED FOR THE PROJECT

A. Statement of Problem

Robust Pacific herring populations, suitable for exploitation by commercial row fisheries are typically sustained by periodic recruitment of strong year classes into the adult spawning population; however, the Prince William Sound 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 (PWS) 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.

What is described here are a series of projects that make up a program that 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 don't 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 it 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 and recruitment rather than relying on empirical models.

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 from the effects of EVOS. 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 lifecycle necessary to move us from an empirical modeling approach towards an analytical modeling approach.

II. PROJECT DESIGN

A. Objectives

The Herring Monitoring Program goal is to improve predictive models of herring stcks through observations and research. To meet this goal 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. 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 were put together 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.

The goal of this study is to determine the age when herring first spawn in Prince William Sound. The goals of this study support the program goal #1, by evaluating the assumption of the ASA model that herring first spawn at age three. The predictive capabilities of current population models of herring in Prince William Sound may be improved by validating the estimated proportions of fish in each age class that spawn and knowing the proportions of primiparous individuals in each age class. This latter number provides a means for adjusting estimates of the total post-spawning biomass in the ASA by estimating the proportion of each age class that was not on the spawning grounds in the previous year. Data regarding the proportions of spawners by age class would improve the accuracy of model estimates of spawning stock biomass.

B. Procedural and Scientific Methods

Determination of age at first spawn has been accomplished via 1) analysis of differential growth increments on scales, and 2) histological analysis of egg development in ovaries. Herring lay down annual growth rings on their scales. In Atlantic herring, growth ring width can be used to differentiate years in which the fish did or did not spawn, where growth rings are relatively wider prior to their first spawning event (and during years of skip-spawn), and are narrower for years in which they spawn (Engelhard & Heino 2005). Thus scales provide a spawning history for an individual fish. The presence of post-ovulatory follicles (POV) after spawning indicates an individual fish has recently spawned while oocyte maturation identifies individuals about to spawn. By sampling at a time when both POV and maturing oocytes are present it is possible to discern immature, primiparous and repeat spawning individuals. While the histological method provides direct observation of the spawning history of individuals it is unlikely that developing oocytes can be observed among spawners. Hence the histological analysis must occur some months after spawning (Saborido-Rey & Junquera 1998).

We propose to examine scales of female herring collected from spawning aggregates in PWS to identify the spawning history of each year class. We will also validate the scale technique by comparing the results of scale analysis with that of histological analysis of oocyte development. The validation will likely be used on fish sampled some time after spawning. In order to identify the optimal time we will iteratively sample ovaries in fish held in the lab after spawning. If scale analysis proves to be a viable means to assess age at first spawn and spawning frequency, it would be a relatively inexpensive monitoring tool that could be used to adjust the ASA model in real time.

OBJECTIVES:

1. Determine the optimal time window (likely a summer month) in which histological analysis can be employed to determine spawning history of Pacific herring using a captive population.
2. Sample fish for scale and histological analysis at the optimal time to determine the age at first spawn for a group of PWS herring. Compare estimates of spawning history obtained from scales and histology.
3. The following spring, use scale analysis to identify the age at first spawn of 500 female herring caught during the 2012 spawning period in PWS.

STUDY DESIGN:

Lab Study: *determine field sampling schedule*

Live adult herring will be collected from Lynn Canal spawning aggregations in May 2011 and maintained at Auke Bay Laboratories for up to a year. Monthly collections (n=15) will be taken for histological examination of ovaries. Our objective is to identify the optimal time in which histological analysis can distinguish immature, recruit and repeat spawners, as has been done in Atlantic cod (Saborido-Rey & Junquera 1998). Immature females will be identified when all the oocytes are in the primary growth stage. Recruit females will be identified as those with developing oocytes but no post-ovulatory follicles. Repeat females will be identified as those individuals simultaneously having physiological evidence of prior spawning (post-ovulatory

follicles) and new oocyte development. Histological samples will preserved and sent to Dr. Gary Marty for analysis beginning in FY12.

Field Collections:

1. *Summer 2012: Histological assessment of age at first spawn*
   In order to validate the use of scales for detecting age at first spawn, the age of females will be identified and compared with the results of a histological analysis of their ovaries. Wild adult herring will be collected from PWS according to the timeline of female maturation determined in the lab study. Individuals will be classified according to their current maturation state: immature, primiparous or repeat spawner. An immature is regarded as a fish that does not show any sign of imminent or previous maturation, a primiparous fish shows no sign of recent spawning but has developing oocytes, a repeat spawner has post-ovulatory follicles and developing oocytes. The proportion of each state will be recorded for each age class. Note that immature and primiparous fish were all immature during the previous spawning event. Ages will be constrained to 2-5 year-olds based on the assumption that all primiparous females will occur in this age range.

   At the same time, spawning histories will also be examined from scale growth patterns. Based on the developmental state ascertained with histological analysis females will be identified as being mature or immature the previous spawning event. Scale growth patterns will be examined to determine the proportion of fish that were mature or immature during the last spawning event. We will compare the maturation histories obtained by both methods. We recognize that this comparison only verifies that scales can be used to identify fish that have recently spawned. However, the scale method is based on changes in the growth increment during the year previous to spawning. If scales reliably identify individuals that have spawned then it should be possible to use the growth pattern to project entire spawning history of the fish.

2. *Spring 2013: Scale analysis to detect age at first spawn*
   Pending the outcome of the first field study, 500 female spawning herring will be collected in the spring of 2013 in PWS for scale analysis. At this time, spawning history for the spawning cohorts will be constructed from the scale growth patterns. At this time fish will have completed laying down an annulus, so we will be able to identify those individuals that were spawning for the first time in addition to repeat spawners. The proportion of primiparous fish identified in each age class will be compared with the proportions determined from the histological analysis the previous summer.

   Samples will be collected during the ADF&G vessel-based spawning survey. All fish will be measured for length, mass, gonadosomatic index (GSI), and gonad development stage (Modified Hjort scale), and scales will be preserved for microscopic analysis. Aging of scales will be conducted by ADF&G, Cordova for consistency with current aging protocols. Growth increments of scales will be measured by Auke Bay Labs using Nikon NIS-Elements imaging software.

C. Data Analysis and Statistical Methods

Lab Study: A minimum of 500 herring will be collected from the wild and transferred live and held captive in tanks at NOAA's facility in Juneau, Alaska. A sample size 20 females will be analyzed each week for 10 weeks (n=200) after spawning to determine the time window during which there is histological evidence of prior spawning. Dr. Gary Marty, a histology expert, recommended this sampling schedule based on previous experience with Pacific herring histology. Histological evidence of spawning (presence or absence) in samples will be quantified as a percentage of the 20 samples assessed each week.

Field Collections: Approximately 4000 herring will be collected from each field collection, of which approximately 1,600 of which are expected to be females (ADF&G AWL data). Of the 1,600, approximately 800 are expected to be within the targeted age group of 2-5 year olds (ADF&G AWL data). Of the 800 fish, expected sample sizes by age are: 100 age-2's, 224 age-3's, 244 age-4's, 232 age 5's. One hundred fish from each age group will be used for comparison of histological indices of spawning to evidence of spawning in the scales.

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.

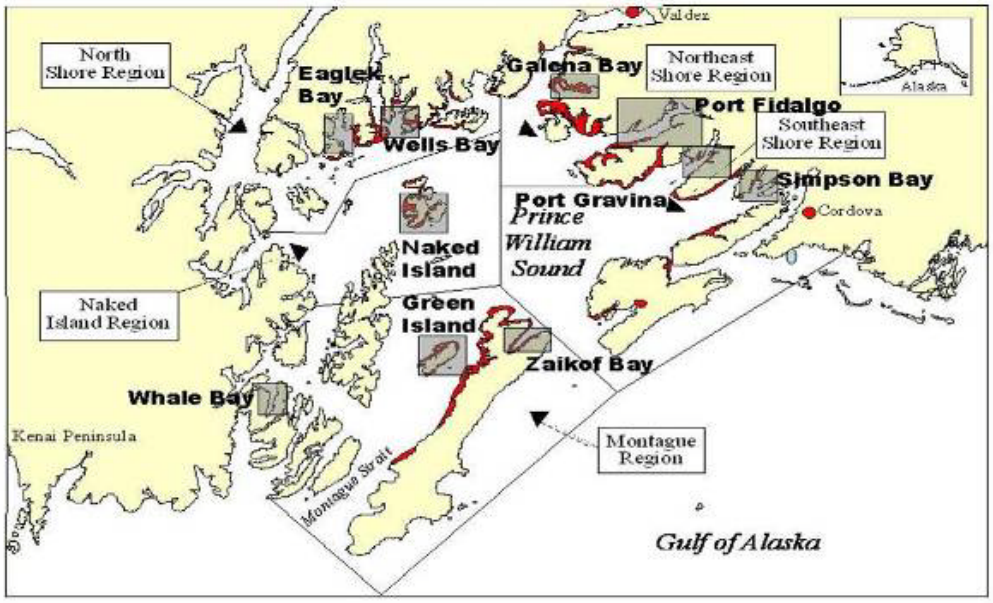

Figure 1. PWS study area, including the four SEA bays (Whale, Zaikof, Eaglek, and Simpson, as well as other bays historically important for juvenile herring.

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

May 2011:	Obtain herring for laboratory study
October 2011:	Receive funding, begin analysis of laboratory samples
June 2012:	Collect scale and histology samples from PWS females (timing depends on results of laboratory study)
January 2013:	Initial results at Alaska Marine Sciences Symposium
March 2013:	Collect scales from spawning herring
January 2014:	Final results at Alaska Marine Sciences Symposium\
March 2014:	Submit final report

B. Measurable Project Tasks

2011	
3rd Quarter (Apr – Jun)	• Collect live herring from Lynn Canal and commence lab study at Auke Bay Labs (In-kind contribution) • Collect monthly samples from lab study
4th Quarter (Jul – Sept)	• Collect monthly samples from lab study
2012	
1st Quarter (Oct – Dec)	• Histological examination of lab samples
2nd Quarter (Jan – March)	• Histological examination of lab samples
3rd Quarter (Apr – Jun)	• Field collections for histological analysis (charter)
4th Quarter (Jul – Sept)	• Histological & scale examination of field collections
2013	
1st Quarter (Oct – Dec)	• Histological & scale examination of field collections
2nd Quarter (Jan – March)	• Collect spawning PWS herring for scale analysis (ADF&G *R/V* Solstice)
3rd Quarter (Apr – Jun)	• Age scales and measure growth increments • Data analysis
4th Quarter (Jul – Sept)	• Data analysis • Submit final report

LITERATURE CITED

Engelhard, G.H. and M. Heino. 2005. Scale analysis suggests frequent skipping of the second reproductive season in Atlantic herring. Biology Letters **1**:172–175.

Junquera, S. and F. Saborido-Rey. 1996. Histological assessment of sexual maturity of the Flemish Cap cod in 1995. NAFO Scientific Council Studies 27:63-67.

III. BUDGET NARRATIVE

Funds are requested for only two years; outlying years are not shown as they incur no cost to the Trustee Council.

Budget Category:	Proposed FY 12	Proposed FY 13	TOTAL PROPOSED
Personnel	$0.0	$0.0	$0.0
Travel	$4,000.0	$3,100.0	$7,100.0
Contractual	$38,000.0	$14,400.0	$52,400.0
Commodities	$3,500.0	$2,500.0	$6,000.0
Equipment	$0.0	$0.0	$0.0
TOTAL	$31,500.0	$20,000.0	$65,500.0

Budget Justification:

FY12

Personnnel ($0):

No funds requested

Travel ($4,000.0):

Funds are requested for Vollenweider and Sewall to travel to Cordova for sample collection trip ($2,110.0).

Funds are requested for Vollenweider and Heintz to travel to the 2013 AMSS meeting in Anchorage ($1,890.0).

Contractual ($38,000.0):

Funds are requested for a contract to Dr. Gary Marty for 3.0 months of scientific consultation ($19,200), travel to Alaska (two trips = $2,400) and analysis of histological samples ($13.50/sample x (1000 field samples + 200 laboratory samples) = $16,200).

Commodities ($3,500.0):

Sample preservation supplies: formalin, storage bags, shipping ($3,500.0)

Equipment ($0):

No funds requested

FY13

Personnnel ($0):

No funds requested

Travel ($3,100.0):

Funds are requested for Vollenweider travel to Cordova for sample collection ($1,110.0).

Funds are requested for Vollenweider to travel to the annual herring meeting in Cordova ($995.0).

Funds are requested for Vollenweider to travel to the 2013 AMSS meeting in Anchorage ($995.0).

Contractual ($14,400.0):

Funds are requested for a contract for scale reading and scanning ($12,000.0)

Funds are requested for a contract for data consolidation ($2,400.0)

Commodities ($2,500.0):

Sample preservation supplies: formalin, storage bags, shipping ($2,500.0)

Equipment ($0):

No funds requested

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Equipment ($0):

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FY13

Personnnel ($0):

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Travel ($3,100.0):

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Funds are requested for Vollenweider to travel to the annual herring meeting in Cordova ($995.0).

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Contractual ($14,400.0):

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Commodities ($2,500.0):

Sample preservation supplies: formalin, storage bags, shipping ($2,500.0)

Equipment ($0):

No funds requested