FY14 PROGRAM PROJECT
PROPOSAL FORM

Project Title: PWS Herring Research and Monitoring Tracking Seasonal Movements of Adult Pacific Herring in Prince William Sound

Project Period: February 1 2014 – January 31, 2015

Primary Investigator(s):
Dr. Mary Anne Bishop, Prince William Sound Science Center, Cordova , mbishop@pwssc.org
Collaborators:
Dr. Sean Powers, University of South Alabama & Dauphin Island Sea Lab, spowers@disl.org
John Eiler, NMFS, Ted Stevens Marine Research Institute, john.eiler@noaa.gov

Abstract:

Knowledge of fish movements and migrations are critical to understanding fish population dynamics. In Prince William Sound (PWS) adult herring disperse after spawning, however their movement patterns are poorly understood. Currently the only information on adult herring movements are a small number of observations from fishers that suggest PWS herring are regularly migrating out of PWS and onto the shelf. This proposal focuses on verifying adult Pacific herring movements using detections of tagged fish. The Herring Marking Workshop sponsored by EVOS in December 2008, reviewed all potential marking methods for herring and conditionally endorsed acoustic tagging as a method for determining herring movements. This pilot project will acoustic tag wild adult herring for the first time. Herring will be sampled from around Port Gravina, a spring spawning area. We will examine detections from acoustic arrays to determine seasonal movement patterns in and out of Prince William Sound. The proposed project builds on our previous and current research on acoustic-tagged fishes. This project will synergize with efforts of the Ocean Tracking Network (OTN). The ability to track herring is critical to answer many questions including those about stock structure, migration habits, and the occurrence of skip-spawning. Determining the capabilities of this technology will help guide our choice of future research emphasis.

Estimated Budget:
EVOSTC Funding Requested:

FY12	FY13	FY14	FY15	FY16	TOTAL
70,700	17,500	17,400	0	0	105,600

(Funding requested must include 9% GA)

Non-EVOSTC Funds to be used:

FY12	FY13	FY14	FY15	FY16	TOTAL

Date: August 31, 2013

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 is one project of a multi-project 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 overall multi-project program is to improve predictive models of herring stocks through observations and research.

Adult Pacific herring (*Clupea pallasii*) along the eastern Pacific Ocean often overwinter close to spawning areas and in nearshore channels (Hay and McCarter 1997). This behavior has also been observed in PWS herring populations, where historically large schools both overwintered and spawned around northern Montague and Green Islands. More recently however, the major biomass of adult herring during winter has shifted to the northeast and southwest areas of PWS. Currently the largest concentration of adult herring overwinters and spawns around Port Gravina and Port Fidalgo (R. Thorne, PWS Science Center, pers. comm.). Some spring spawning aggregations are not located near known overwintering areas suggesting that: (a) some adult herring populations are overwintering outside of PWS; (b) not all PWS overwintering populations are being detected; or, (c) overwintering schools such as those in northeast PWS break into smaller schools in spring with some schools moving away from their overwintering area to spawn.

Post-spawning behavior of adult PWS herring is poorly understood. Elsewhere, it is common for large herring populations to migrate from nearshore spawning areas to coastal shelf areas for summer feeding habitat (Hay and McCarter 1997, Hay et al. 2008). To date, our only information on adult PWS herring movements comes from a study by Brown et al. (2002) that compiled local and traditional knowledge. In that study, fishers reported herring moving in fall north through Montague Strait prior to the fall bait fishery while whose observations suggest others reported herring moving into PWS in spring through Hinchinbrook Entrance, Montague Strait and the southwest passages of Erlington and LaTouche. These observations suggest that PWS herring are regularly migrating out of PWS and onto the shelf.

Acoustic transmitters make it possible to monitor fish movements both across large distances (Heupel et al. 2006) and in structurally complex habitats like those found in nearshore areas (Bishop et al. 2010). Acoustic tags offer many additional advantages, including: 1) the potential for multiple data points over time and space for each individual fish; 2) minimal handling - fish are captured and handled only once; 3) transmitters can be implanted quickly, with low mortality and with low tag expulsion; 4) transmitters are programmed for individual identification; and 5) the capability to use portable receivers to monitor spawning schools or large wintering schools of herring regardless of the location (Bishop 2008).

Previous efforts to acoustic tag and monitor fish in Prince William Sound over more than a one year period have been proven successful. In October 2008 the Pacific Ocean Shelf Tracking Project (POST), PWS Science Center (M.A. Bishop, Co-PI), University of South Alabama (S. Powers, Co-PI) and the PWS Oil Spill Recovery Institute installed across the mouth of Port Gravina the first long-term, large-scale hydroacoustic array in Prince William Sound, as well as eight portable receivers at pinnacles near

the POST array. In September 2010 an array was installed at the mouth of Zaikof Bay near Hinchinbrook Entrance consisting of six portable receivers. Acoustic-tagged lingcod (*Ophiodon elongatus*) were then successfully monitored at Zaikof and Port Gravina through February and May 2012, respectively (Bishop et al. 2010; Fig. 1).

Following several years of planning and negotiations, in March 2013, PWS Science Center collaborated with Canada's Ocean Tracking Network (OTN) to install two, large-scale arrays including one across the mouth of Hinchinbrook Entrance and one across Montague Strait, and four small arrays at the southwest PWS passages of Erlington, LaTouche, Bainbridge, and Prince of Whales (Fig. 1). These arrays will allow for detections of acoustic-tagged herring moving into and out of Prince William Sound.

B. Summary of Project to Date (if applicable)

All milestones are on track and scheduled to be completed by July 2014 and September 2014.

Our first tagging effort took place from 18-22 November 2011 in conjunction with the Alaska Department of Fish and Game (ADFG) herring bait surveys. Field efforts by ADFG to purse seine were stymied by poor weather conditions (exceptionally cold, or high winds), whales in and around herring schools, and herring schools remaining deeper than the seine. We were provided samples from their final set for tagging. Fish ranged in age from 2.5 to 3+, and were smaller than our pre-determined size restriction for tagging and release, however, we were able to practice our surgical procedures on 20 herring before sacrificing these fish.

Our second tagging cruise coincided with herring spawn aggregations and took place from 8-11 April 2012 in Port Gravina. Compared with November, fish were much larger and were of sufficient size to hold an acoustic tag. We practiced tagging pre-spawning adults and based on our observations and experienced gained on pre-spawners, on our final day (11 April) we jigged 38 adult herring >19 cm TL. We surgically implanted 25 adult herring with coded acoustic transmitters (V9-2L/2H, 69kHz). While a few fish appeared to have spawned, most fish had not yet spawned. The 25 tagged fish and 13 controls (untagged fish) were released simultaneously near the capture site in 25 m of water at ~ 1600h on 11 April (Figs. 1, 2). A singleVR2W receiver (60.68885, -146.39118) was retrieved from 17 m of water on 19 May 2012 to upload the detection data.

This was the first time that wild herring have been tagged with acoustic transmitters. The VR2W receiver near our point of release detected 23 (92%) of the tagged individuals multiple times (≤ 227 detections) on one or more days (≤ 5 d) post release at (Fig. 3). Only 1 of the 25 herring was never detected. Final detections of tagged fish by 15 April coincided with a cessation of spawning in the immediate area suggesting that fish departed from Port Gravina and did not return.

Our third tagging cruise also coincided with spawn aggregations in Port Gravina. Between 6-7 April 2013 we surgically implanted coded acoustic transmitters (Model V9-2L/2H, 69kHz) into 69 adult herring from 3 separate schools (24, 20 and 25 tagged). All but one herring had not yet spawned. We used the same methodology as in April 2012, including releasing tagged fish and controls (untagged fish) simultaneously and near a herring school. Due to recent technological changes, the VR3 acoustic receiver array at Port Gravina cannot detect the new generation of transmitters. Therefore, we installed a temporary acoustic array from 7 April – 21 May 2013. Of the 69 tagged individuals, 56 (81 %) were detected multiple times (≥8 detections) on one or more days. Most detections occurred over three distinct periods: 7-9, 15-16 and 20-26 April, possibly indicating periods of increased spawning activity

Determining whether or not herring depart from Prince William Sound has been dependent on the installation of acoustic arrays across the major entrances and passages between the Sound and the Gulf of Alaska. When this project was planned, arrays across the entrances and passages were scheduled to be deployed in fall 2011. However due to a series of delays, the equipment did not arrive from Canada

until late December 2012, after the transmitters on herring tagged in April 2012 had expired. In March 2013, the Ocean Tracking Network (OTN) arrays were deployed and acoustic arrays are now installed across Hinchinbrook Entrance, Montague Strait, and four major passages in southwest Prince William Sound.

II. PROJECT DESIGN

A. Objectives

1) Field test the application of recent advances in acoustic telemetry on wild adult herring.

(2) Elucidate herring movement patterns between overwinter and spawning sites.

(3) Utilize the PWS acoustic arrays to monitor herring migration into and out of PWS.

This project will use the preferred marking method for herring. The Herring Marking Workshop sponsored by EVOS in December 2008, reviewed all potential marking methods for herring and stated with regards to acoustic tagging:

A specific recommendation is the conditional endorsement of acoustic tagging, with the caveat that the initial involvement should be limited. Arrays of acoustic receivers have been installed in PWS and there may be opportunities to leverage costs with other organizations, so the present time is an excellent opportunity to pursue this approach…. It seems probable that useful information on herring ecology and migratory movements could be revealed by acoustic tagging (source: draft Integrated Herring Restoration Plan 2010, page 134).

B. Procedural and Scientific Methods

Here we propose to synergize with efforts of the Ocean Tracking Network by undertaking a pilot study to mark adult Pacific herring with acoustic tags. Our tagging efforts will coincide with Alaska Department of Fish & Game (ADFG) surveys for adult herring (known as bait surveys) in November 2011. Our spring 2012 and spring 2013 efforts will coincide with the beginning of spawn in the Port Gravina area. For November efforts, we will use a dipnet to collect herring captured by ADFG purse-seines. For spring 2012 and 2013, we will jig adult herring. Healthy individuals will be transferred to a 40 gallon aquarium containing aerated, ambient seawater aboard our research vessel. Surgical protocol will follow procedures used for implanting acoustic transmitters into age 2 and 3 Pacific herring (average size 180 mm) and similar sized Pacific salmon smolts (Welch et al. 2007; Seitz et al. 2010). Prior to surgery, individual herring will be transferred to a small, aerated bath containing ambient seawater and buffered tricaine methanesulfonate (MS-222; 60 mg/L), an anesthetic. Following sedation, the fish will be weighed, measured for standard and fork length, then placed on a V-shaped surgery board lined with a disposable surgical mat. During surgery the opercular cavity will be gently irrigated with ambient seawater.

For transmitter insertion, we will make a small incision (11-12 mm) along the ventral midline anterior to the pelvic fins. A Vemco series V9-2L/2H acoustic transmitter (Vemco, Halifax, Nova Scotia) programmed to transmit an individually-encoded signal at 40-60 s (high power) and 60-150 s (low power) random intervals will be inserted into the abdominal cavity. Each transmitter measures 24 x 9 mm and weighs 3.6 g, and has an estimated battery life of ~260 d. The incision will be closed with two sutures then swabbed with a broad spectrum antibiotic ointment. The surgical procedure will take less than 2 min per fish. Following surgery, fish will be held for recovery in an aquarium aerated with ambient seawater until equilibrium (upright swimming) and active swimming are observed. Post recovery we will release fish at the capture site. We will tag up to 100 herring around Port Gravina and Port Fidalgo. In spring 2012 and 2013, VR2W acoustic receivers will be temporarily installed to monitor for tagged fish in Port Gravina from April through mid-May. Data from Ocean Tracking

Network arrays at the entrances to Prince William Sound will be uploaded in late February/early March 2014.

C. Data Analysis and Statistical Methods

Prior to analyses, we will assume a fish was detected only when there are at least two detections of a transmitter at an array during a 24h period. In order to test whether herring are detected more frequently based on size, month of capture, or location, we will calculate the detectability of each herring following a methodology similar to that outlined by Andrews et al. (2010). With this method, we will divide the number of days a herring was detected by the life span of the tag. We will then use detectability as the dependent variable in a linear mixed model.

We will consider a herring as having departed from the Sound if it is detected at one of the arrays at the PWS entrances or passages. Similarly, if that fish is later detected at one of these arrays, it will be considered having returned to PWS. Detections occurring in Port Gravina will be examined to determine the amount of time spent in an area.

D. Description of Study Area

While herring can potentially move throughout the Sound, acoustic receivers will be located in Port Gravina, and across Hinchinbrook Entrance, Montague Strait, and in the four southwest passages of Bainbridge, Prince of Whales, Erlington, and LaTouche.

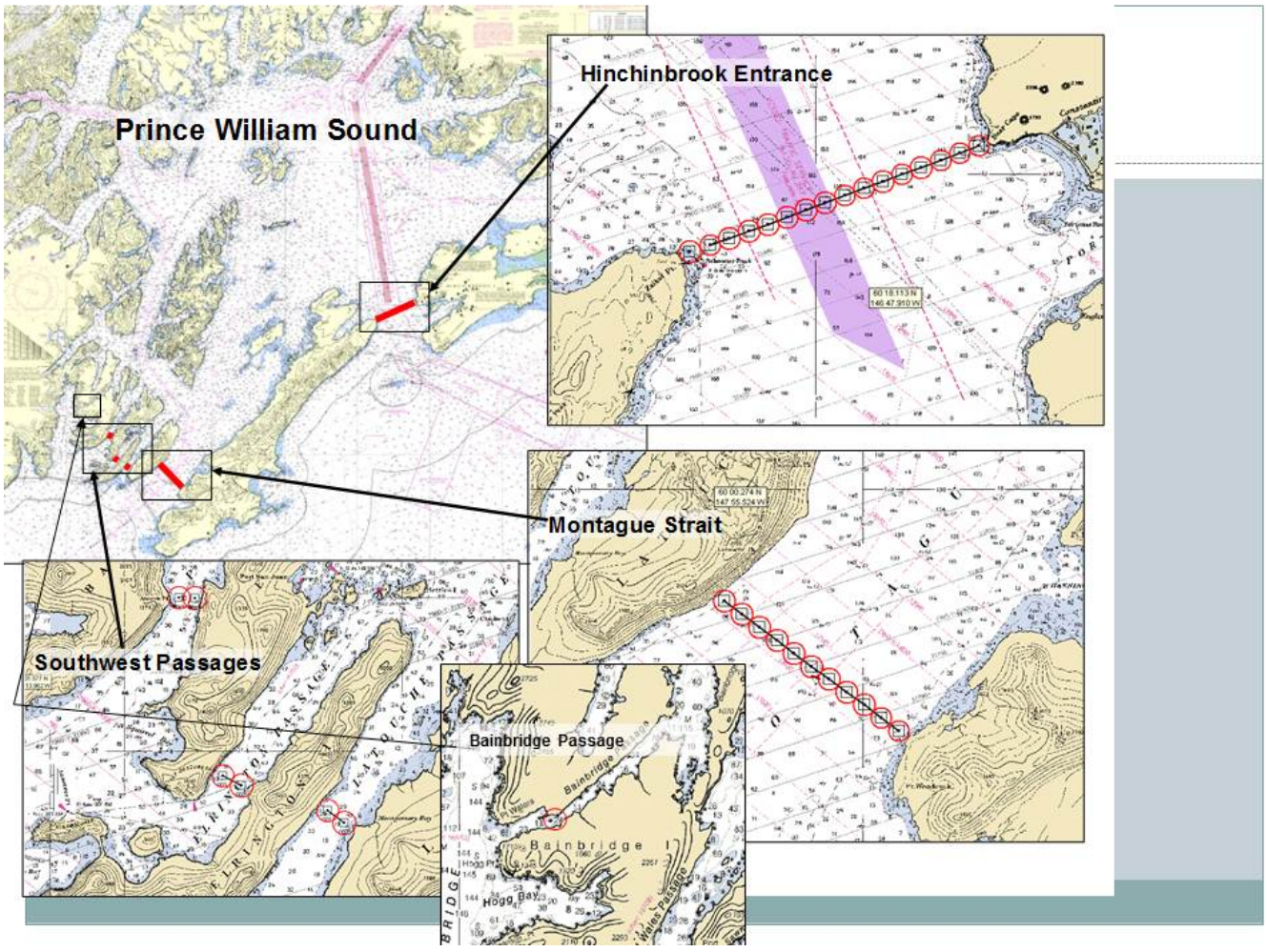

Fig. 1. Location of Ocean Tracking Network acoustic arrays, installed in Prince William Sound in March 2013.

E. Coordination and Collaboration with the Program

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 Gulfwatch Long-Term Monitoring program. This proposal is structured to be a collaborative effort being led by the Prince William Sound Science Center. Program coordination will primarily be through e-mail and phone communications. Annual meetings are planned in Cordova, tentatively in May, for all investigators to share information between themselves and with the community. These in-person meetings are vital to ensure proper communication among programs.

Dr. Pegau will act as the team leader and be responsible for ensuring a coordinated and focused research program that leverages other assets whenever possible. He will be responsible for ensuring proper scientific oversight of individual projects and reporting to the EVOSTC. He will lead the development of annual work plans and the synthesis of findings from these programs. He will be responsible for coordinating the efforts of the herring research program with those of the Long-term Monitoring program. He will also be responsible for outreach and public input efforts.

Dr. Pegau currently is the coordinator of the existing EVOSTC funding PWS Herring Survey program. This program consists of ten individual projects that provide a coordinated examination of juvenile herring in Prince William Sound. This proposal is heavily influenced by the early findings from that effort. Dr. Pegau also serves as the Research Program Manager for the Oil Spill Recovery Institute (OSRI). In that capacity he is responsible for developing annual work plans, ensuring proper reporting, making reports available, developing partnerships to leverage funding, and to ensure outreach of OSRI activities. All activities that provide experience delivering the team leader duties outline in the request for proposals.

One of his duties is to ensure proper scientific oversight of the research programs. To accomplish this we will be setting up a four-person scientific oversight panel that will help guide the program and ensure the research is relevant to the long-term goal. The team will consist of people representing Alaska Department of Fish and Game, the National Oceanic and Atmospheric Administration, academia, and the local fishing community. There will be annual Principal Investigator meetings in Cordova each year to provide updates to the oversight panel, improve coordination between projects, and provide outreach and public input opportunities. This meeting will be in the spring so that there is opportunity to provide input on the development of the next year's work plan. In an effort to be proactive in the scientific oversight we sought input on the development of this proposal from ADF&G, NOAA, Cordova District Fishermens United (CDFU), and others. Team development and input on research direction was also sought at the 2011 Alaska Marine Science Symposium.

Coordination with the EVOSTC Long-term Monitoring program is critical to the success of the herring program. The ability to develop a predictive tool using the juvenile condition component requires an understanding of when feeding may occur and hence the need to coordinate with the oceanographic monitoring component. Predation by whales, fish, and birds are also considered potential factors inhibiting the recovery of herring. In that regard we will be looking to the monitoring program for information on the changes in the predator population base. That information will be critical if the herring program chooses to focus on predation during future efforts. The forage fish component and our efforts to develop an index of juvenile herring populations must inform each other. We expect that our hydroacoustic surveys and direct capture efforts will help provide measures of total fish biomass as well as forage fish populations. We will also work together to identify historical data that both programs

would benefit from as part of the data management efforts. Throughout the proposal writing effort, the herring and long-term monitoring efforts led by Kris Holderied have been working together to identify how the two programs can inform and complement each other.

Other important programs for coordinating with are the existing PWS herring survey program and existing ADF&G herring research. This program has been developed with input from both of these programs and the focus of this proposal is extending the interpretation of the data from those two programs. The Herring Survey program will still be operating in FY12 and FY13. There are field observations scheduled in FY12 and in FY13 funds are strictly for analysis and report writing. Included in the report writing is a synthesis of previous and current research. This report will be finished in FY13 and be the basis for the synthesis required under this request for proposals.

Dr. Mary Anne Bishop (PWSSC) will oversee the seasonal movements study and will coordinate with other studies that are part of the *PWS Herring Research & Monitoring* program as well as our collaborators. She will have primary responsibility for field work (fish tagging) data integration, preparation of a manuscript and completion of final products for *PWS Herring Research & Monitoring* synthesis. Initially a PI on this project, Dr. Sean Powers (University of South Alabama) is now a collaborator on this project due to unforeseen circumstances relating to the obligations relating to investigating impacts of the Deep Water Horizon oil spill. John Eiler, of NOAA Ted Stevens Marine Research Institute is also a collaborator on this project. This project will rely on obtaining data from the Ocean Tracking Network arrays proposed that were installed at major entrances to Prince William Sound in March 2013. We collaborated with Alaska Department of Fish and Game for our November 2011 tagging efforts that coincided with their fall herring bait surveys.

III. CV's/RESUMES

MARY ANNE BISHOP, Ph.D.
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EDUCATION

Ph.D. Department of Wildlife and Range Sciences, University of Florida, Gainesville, 1988.
M.S. Wildlife and Fisheries Sciences, Department of Wildlife and Fisheries Sciences, Texas A & M University, College Station, 1984.
B.B.A. School of Business, University of Wisconsin, Madison, 1974.

RECENT PROFESSIONAL EXPERIENCE

Research Ecologist, Prince William Sound Science Center, Cordova, Alaska, Jun 1999-present
Research Wildlife Biologist, Copper River Delta Institute, Pacific Northwest Research Station, U.S. Forest Service, Cordova, Alaska, 1990-1994 and 1997- May1999
Research Wildlife Biologist, Center for Streamside Studies and Dept. Fisheries, University of Washington, assigned to Copper River Delta Institute, Cordova, Alaska, 1994-1997
Acting Manager, Copper River Delta Institute, Pacific Northwest Research Station, U.S. Forest Service, Cordova, Alaska, 1992-1993.

SELECTED SCIENTIFIC PUBLICATIONS (10 of 53)

- = publication resulting from either acoustic or radio telemetry study (13 total)

***Bishop, M.A.**, B.F. Reynolds, S.P. Powers. 2010. An *in situ*, individual-based approach to quantify connectivity of marine fish: ontogenetic movements and residency of lingcod. *PLoS ONE* 5(12): e14267

***Bishop, M.A.**, N. Warnock, and J. Takekawa. 2004. Differential spring migration of male and female Western Sandpipers at interior and coastal stopover sites. *Ardea* 92: 185-196.

***Bishop, M.A.**, N. Warnock, and J.Y. Takekawa. 2006. Spring Migration Patterns in Western Sandpipers *Calidris mauri.* Pages 545-550 in G.C. Boere, C.A. Galbraith, and D.A. Stroud (eds.) *Waterbirds around the world*. The Stationery Office, Edinburgh, U.K.

Bishop, M.A. and S.P. Green. 2001. Predation on Pacific herring (*Clupea pallasi*) spawn by birds in Prince William Sound, Alaska. *Fisheries Oceanography* 10 (1): 149-158.

***Bishop, M.A.** and N. Warnock. 1998. Migration of Western Sandpipers: links between their Alaskan stopover areas and breeding grounds. *Wilson Bulletin* 110: 457-462.

Powers, S.P., **M.A. Bishop**, S. Moffitt, and G.H. Reeves. 2007. Variability in Freshwater, Estuarine and Marine Residence of Sockeye Salmon (*Oncorhynchus nerka*) within the Copper and Bering River Deltas, Alaska. Pages 87-99 in C. A. Woody (ed) *Sockeye salmon evolution, ecology and management*. American Fisheries Society, Symposium 54, Bethesda, MD.

Powers, S.P., **M.A. Bishop**, J.H. Grabowski, and C.H. Peterson. 2002. Intertidal benthic resources of the Copper River Delta, Alaska, USA. *Journal Sea Research* 47: 13-23.

*Reynolds, B.F., S.P. Powers, **M.A. Bishop.** 2010. Application of Acoustic Biotelemetry to Assess Quality of Created Habitats for Rockfish and Lingcod in Prince William Sound, Alaska. *PLoS One* 5(8): e12130.

Watson, J.T., **M.A. Bishop**, and S.P. Powers. Pacific cod predation on pacific herring during winter in Prince William Sound. *Fisheries Oceanography*. (in press).

Zuur, A.F., N. Dawson, **M.A. Bishop**, K. Kuletz, A.A Saveliev and E.N. Ieno. 2012. Two-stage GAMM applied on zero inflated Common Murre density data. Pages 155-188 *in* A.F. Zuur, A.A.Saveliev, E.N. Ieno (eds). *Zero Inflated and Generalized Linear Mixed Models with R.* Highland Statistics Ltd, Newburgh, United Kingdom.

PROFESSIONAL COLLABORATIONS

M. Buckhorn (PWSSC), K. Carpenter (CRWP), N. Dawson (PWSSC), J. Eiler (NOAA), R. Heintz (NOAA), N. Hill (MIT), E.N. Ieno (Highland Statistics), K. Kuletz (USFWS), A. Lang (Memorial Univ.), F. Li (Intl. Crane Foundation), J. Moran (NOAA), T. Morgan (PWSSC), E. Nol (Trent Univ.), W.S. Pegau (OSRI), S. Powers (U. S. Alabama), B. Reynolds (PWSSC), G. Robertson (CA), D. Roby (OSU), J. Runstadler (MIT), A Saveliev (Highland Statistics), S. Senner (Audubon), Y. Suzuki (OSU), A. Taylor (UAA), R. Thorne (PWSSC), D. Tsamchu (Tibet Plateau Institute of Biology, PR China), J. Vollenweider (NOAA), J. Watson (PWSSC), M. Wille (Memorial Univ.), A. Zuur (Highland Statistics)

IV. SCHEDULE

A. Project Milestones

1) Field test the application of recent advances in acoustic telemetry on wild adult herring. ***To be completed July 2014.***

(2) Utilize the PWS acoustic arrays to monitor herring migration into and out of PWS. ***To be completed July 2014.***

(3) Elucidate herring movement patterns between overwinter and spawning sites. ***To be completed September 2014.***

B. Measurable Project Tasks

FY 14, 1st quarter (February 1 – May 31, 2014)

February, 2014	*Project funding available*
late Feb/early Mar	*Upload data from Ocean Tracking Network array*
Mar-May	*Process and analyze data*

FY 14, 2nd quarter (June 1, 2014-August 30, 2014)

Jun-Aug	*Process and analyze data, prepare final report*

FY 14, 3rd quarter (September 1, 2014-November 30, 2014)

September 30	*Submit final report*

FY 14, 4th quarter (December 1, 2015 – January 31, 2015)

V. BUDGET

Budget Form (Attached)

Please complete the budget form for each proposed year of the project.