EVOSTC FY17-FY21 INVITATION FOR PROPOSALS
FY21 CONTINUING PROJECT PROPOSAL SUMMARY PAGE

Project Number and Title

21170111-B PWS Herring Research & Monitoring: Annual Herring Migration Cycle

Primary Investigator(s) and Affiliation(s)

Mary Anne Bishop, Ph.D., Prince William Sound Science Center, Cordova, Alaska

Date Proposal Submitted

August 14, 2020

Project Abstract

This project is a component of the Herring Research and Monitoring (HRM) program. The goal of the HRM program is to improve predictive models of herring stocks through observations and research. Within Prince William Sound (PWS), adult Pacific herring (*Clupea pallasii*) movements between spawning, summer feeding, and overwintering areas are not well understood. Addressing this knowledge gap will improve our ability to assess biomass trends and recovery of this ecologically important species. In 2013, we documented post-spawn migration of herring from Port Gravina to the PWS entrances by acoustic tagging adult herring and collecting data from the Ocean Tracking Network (OTN) acoustic arrays, which are located in the major entrances and passages connecting PWS with the Gulf of Alaska (GoA). However, the 2013 study could not establish movement direction and if herring were seasonally leaving PWS and migrating into the GoA. With funding from the *Exxon Valdez* Oil Spill Trustee Council in FY16, we obtained the ability to distinguish direction of movements between PWS and the GoA by deploying additional acoustic receivers at the OTN arrays. The primary goal of this 2017-2021 project is to clarify the annual migration cycle of PWS adult herring by leveraging this expanded acoustic infrastructure. The specific objectives of this project are to 1) document location, timing, and direction of Pacific herring seasonal migrations between PWS and the GoA; 2) relate large-scale movements to year class and body condition of tagged individuals; and 3) determine seasonal residency time within PWS, at the entrances to PWS, and in the GoA. From 2017-2019 we tagged 491 fish, and depending on the tag year, 48% (2017) to 81% (2019) of the tagged herring were detected at the acoustic arrays located at the entrances to GoA. Preliminary analyses has shown that fish tended to enter the GoA at Hinchinbrook Entrance during spring and summer after spawning and return to PWS during the fall and winter. Length, weight, and condition have each been found to have a significant effect on the rate at which herring move from PWS to the entrance arrays. Recently, we tagged 235 herring on the spawning grounds during April 2020. With funding from the Alaska Ocean Observing System, University of Alaska will deploy an autonomous underwater vehicle (AUV) in PWS for ~75d this 2020-21 winter with the objective to detect our acoustic tagged Pacific herring. Our FY21 work will focus on uploading data from arrays, analyses, manuscripts, and final report writing.

EVOSTC Funding Requested* *(must include 9% GA)*

FY17	FY18	FY19	FY20	FY21	TOTAL
$381,900	$379,500	$275,800	$434,200	$272,800	$1,744,200

Non-EVOSTC Funds to be used, please include source and amount per source: (see Section 6C for details)

FY17	FY18	FY19	FY20	FY21	TOTAL
$15,000	$15,000	$15,000	$15,000	$15,000	$75,000

1. PROJECT EXECUTIVE SUMMARY

Conservation concerns about the Pacific herring (*Clupea pallasii*) population in Prince William Sound (PWS) make it increasingly important to document migration patterns to inform our understanding of PWS adult herring survival. Little is understood about adult Pacific herring annual migration movements between spawning, summer feeding, and overwintering areas within and between PWS and the Gulf of Alaska (GoA). 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).

In his review of migration in Atlantic herring (*C. harengus*), Corten observed that herring migration patterns tend to be stable over years, despite environmental variation. In PWS, Brown et al. (2002) compiled local and traditional knowledge on adult herring movements. In that study, some fishers reported herring moving into PWS through Montague Strait prior to the fall bait fishery while others reported herring moving into PWS in spring through Hinchinbrook Entrance, Montague Strait and the southwest passages of Elrington and LaTouche. These observations suggest that PWS herring are regularly migrating in and out of PWS and onto the shelf.

For FY21, we will continue to utilize acoustic telemetry to investigate seasonal movement patterns of Pacific herring. Post-spawn feeding, winter movements, and subsequent spawning migrations will be examined for herring tagged during spring 2019 and 2020 on PWS spawning grounds including monitoring their movement patterns with moored acoustic arrays positioned at the entrances to PWS, the spawning grounds, and at other select locations in PWS.

The use of acoustic telemetry will allow us to look at movement patterns on a variety of temporal and spatial scales, filling in significant gaps in our current knowledge of adult herring migration.

2017-2021 Key hypotheses and overall goals: Annual Herring Migration Cycle

The overall program goal of the Herring Research and Monitoring (HRM) program is the continued development and testing of an updated age-structured assessment (ASA) model in collaboration with the Alaska Department of Fish and Game (ADF&G). To address this goal, our tagging study will gather data to clarify the annual migration cycle of PWS adult herring. From 2017-2021 we will use acoustic telemetry to examine movement patterns on a variety of temporal and spatial scales, filling in significant gaps in our current knowledge of herring migration.

Our study will address the following hypotheses:

H_1: Pacific herring populations in PWS make seasonal, post-spawn feeding migrations through major entrances and passages to the GoA.

a) Fish with poor body condition are less likely to migrate.
b) New recruits to the spawning population are less likely to migrate than older herring.

H_2: The PWS herring population is composed of migrant and resident individuals.

a) Resident individuals remain within the confines of PWS.
b) Resident herring are associated with specific spawning grounds.
c) Migrant individuals exit PWS by mid-June and return to the Sound in either fall or spring.

H_3: Survival is related to age and body condition.

H_4: Fine-scale spatial use patterns are associated with individual biological characteristics and vary seasonally.

Background and FY 2020 Update

Our project builds on the previous HRM project 14120111-B, a pilot project of Principal Investigator (PI) M.A. Bishop and collaborator J. Eiler (National Oceanic and Atmospheric Administration [NOAA]). During 2012 our pilot project developed handling and tagging methods designed to minimize physical injuries and stress to wild Pacific herring (Eiler and Bishop 2016). Subsequently, the February 2013 installation of the Ocean Tracking Network's (OTN's) six acoustic receiver arrays across the entrances to the GoA provided the first opportunity to detect movements from the spawning grounds to the GoA entrances. In April 2013, we tagged and released 69 adult herring from the Port Gravina spawning area. Tags had an expected life of 263 days. Post-release we detected 93% of the tagged herring (64 of 69 individuals) either at Port Gravina and/or the OTN arrays (Eiler and Bishop 2016, Bishop and Eiler 2018). With funding from the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) in FY 2016 (project 16160111-S), during February 2017 we deployed additional receivers at the OTN arrays in a configuration that will allow us to determine what direction tagged herring travel after detection at the OTN arrays (i.e., back into PWS or out towards the GoA). During 2018 we placed additional receivers in northern Montague Strait, Knight Island Passage, Hawkins Island, RedHead, on the profiler near Naked Island, and at Glacier Island. In 2019 we removed Glacier Island receiver and placed a receiver near Johnstone Point (Hinchinbrook Island; Fig. 1).

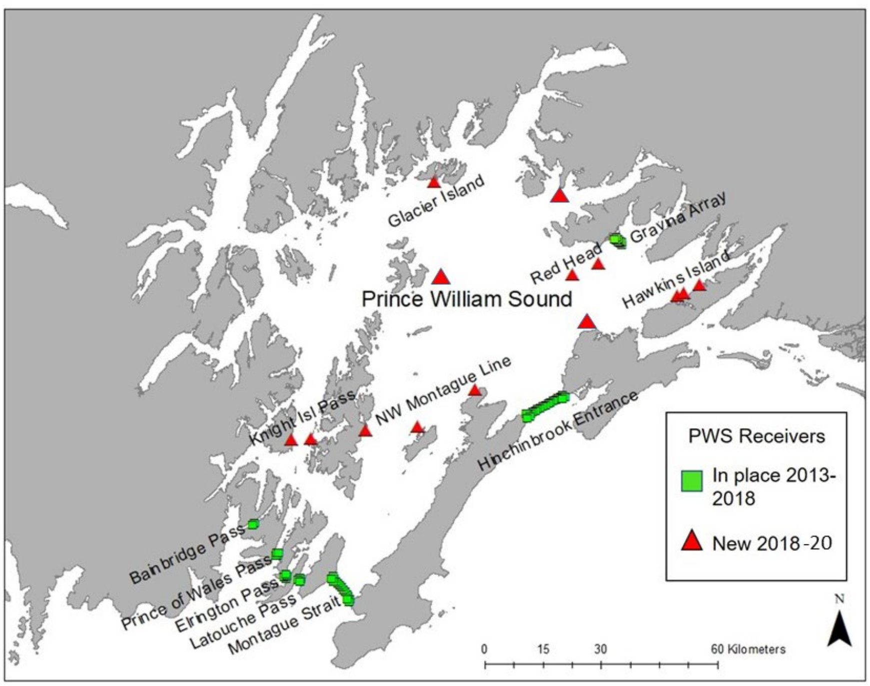

Figure 1. Location of underwater receivers in Prince William Sound.

Since April 2017, we have tagged 726 herring on their spawning grounds (Table 1), including most recently 235 fish during April 2020 (Table 2). While V8 tags have a battery life of ~8 months, the most recent V9 tags have a battery life of almost 28 months providing the potential to track some fish through August 2022.

Table 1. Number of fish tagged on the spawning grounds by year, acoustic tag type, and location. Canoe Pass is at Hawkins Island, Double Bay at Hinchinbrook Island, and Rocky Bay at Montague Island.

Tag Mo/Year	V8-4X	V9-2x	Total	Tagging Locations
Apr 2017		124	124	Port Gravina
Apr 2018	60	142	202	Port Gravina, Canoe Pass
Apr 2019	40	125	165	Port Gravina, Canoe Pass, Double Bay, Rocky Bay
Apr 2020	50	185	235	Port Gravina, Canoe Pass
Total	**150**	**446**	**726**	

Table 2. Mean SL (mm), and mass (g) of Pacific herring by tag type for April 2019 and 2020 tagged herring.

	V-8 x $\pm$ sd; min, max		V-9 x $\pm$ sd; min, max	
	2019 n = 40	2020 n = 50	2019 n = 125	2020 n = 185
SL (mm)	199.1 $\pm$ 5.2 189, 211	201.9$\pm$ 4.5 190, 214	213.1 $\pm$ 9.3 198, 240	212.3 $\pm$ 7.6 201, 242
Mass (g)	91.0 $\pm$ 5.6 80, 99	97.6$\pm$ 4.5 91, 110	117.3 $\pm$ 18.1 97, 180	117.4 $\pm$ 14.5 95, 173

For the HRM program synthesis report we analyzed data through February 2019 from the OTN arrays for the 2017 and 2018 tagged fish. We used an empirical Bayesian approach to develop a model that incorporated directional movement information into the Arnason-Schwartz modeling framework. We found a seasonal migratory pattern at Hinchinbrook Entrance. At this entrance, fish tended to enter the GoA during spring and summer after spawning and return to PWS during the fall and winter. This same Arnason-Schwartz modeling framework also allowed us to separate movement from survival by incorporating two additional parameters (ψ and S) into the model. The movement parameter ψ_{ij}^{rs} is interpreted as the probability that the i^{th} fish is alive and in state s at detection occasion j + 1 given that the fish was alive and in state r at time j. The survival parameter S_{ij}^{r} is interpreted as the probability that the i^{th} fish survives to time j +1 given that the fish is alive and in state r at time j. Incorporating these two parameters into the model, we found that fish mortality was higher during spring and summer than fall and winter in both PWS and GoA (Bishop and Bernard 2019; Bernard and Bishop *in review*).

In 2020, we uploaded data from the OTN arrays at the entrances to the GoA during February and March, and from receivers at the Port Gravina array (n = 4) and from 1 of the 3 receivers at Hawkins Island in late May. From the OTN data we were able to determine that of the 165 fish tagged in 2019, 81% (n = 133) were detected at one or more of the OTN arrays. Among the arrays, Hinchinbrook Entrance was the most important, and was used by >68% (n = 113) of the 2019 tagged fish. By comparison, 25% (n = 42 fish) and 10% (n = 17) of the tagged fish were detected at Montague Strait and the Southwest Passages arrays, respectively. When compared to the fish tagged in April 2018, a much larger percent of the 2019 were detected at Hinchinbrook Entrance (Fig. 1).

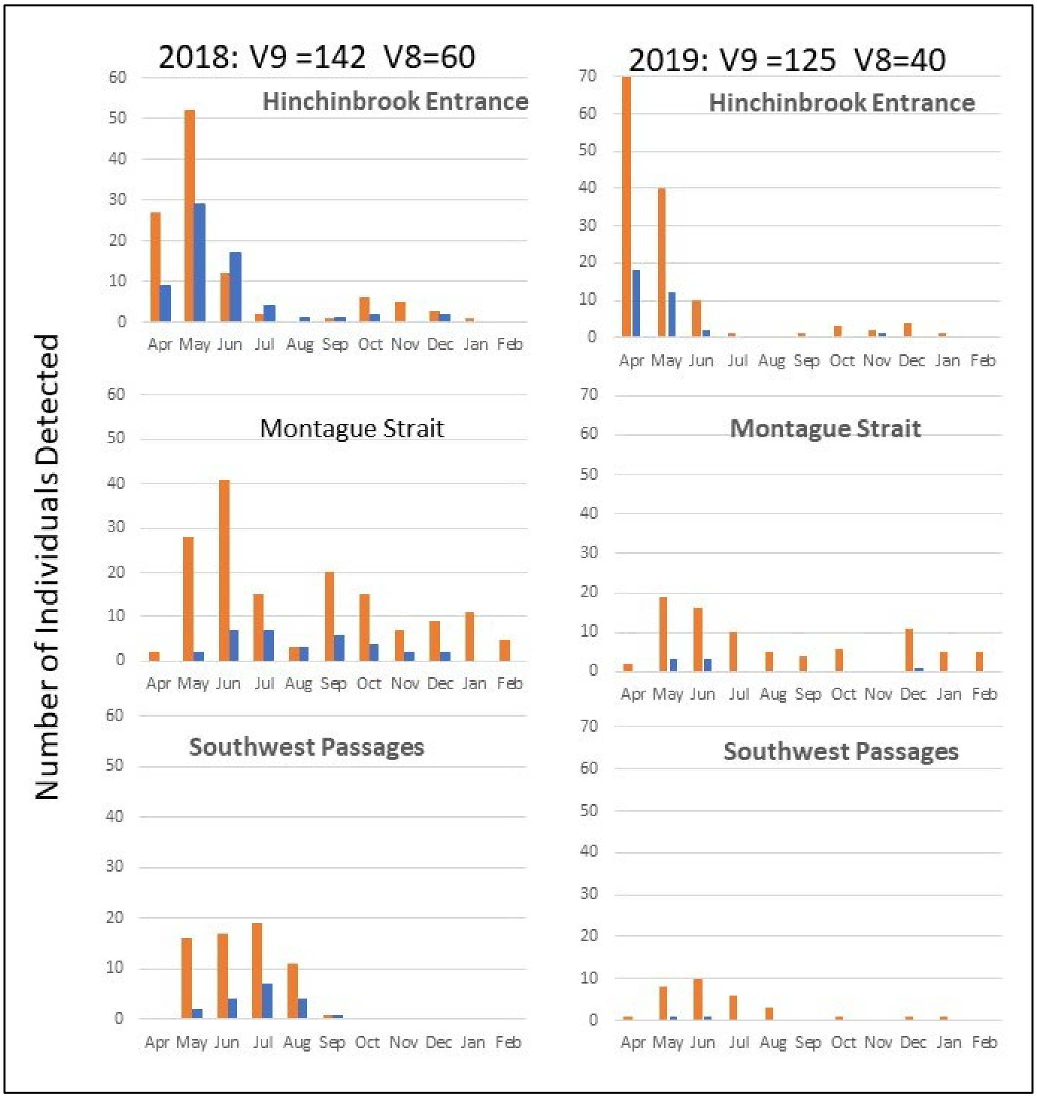

Figure 2. Number of individual herring tagged in April 2018 and 2019 and subsequently detected by tag type, array location, and month, April 2018 - April 2019. Orange = V9 tag (~25.1-month life), Green = V8 tag (8.2-month life, expired mid-Dec 2018 or 2019).

To understand the detection range of the V8 tags, we recently analyzed data from range tags tethered to moorings deployed at the Hinchinbrook Entrance and Montague Strait acoustic arrays. Detection range for this analysis was defined as "the relationship between the detection probability and the distance between the receiver and tag." Range tags were deployed at distances of ~150 m, 300 m, and 500 m from the selected receivers. A logistic regression model only considering distance was used to model the probability of detection given distance from the receiver. The receivers Hinchinbrook D (HD; depth = 36 m) and Montague 11 (M11; depth = 131 m) had similar detection probabilities at distances up to almost 200m, but at distances greater than that, Montague 11 had a higher probability of detection than Hinchinbrook D. This is not surprising, given that Hinchinbrook D was much shallower, and as a result, more likely to be impacted by wind-generated noise and a more uneven bottom topography.

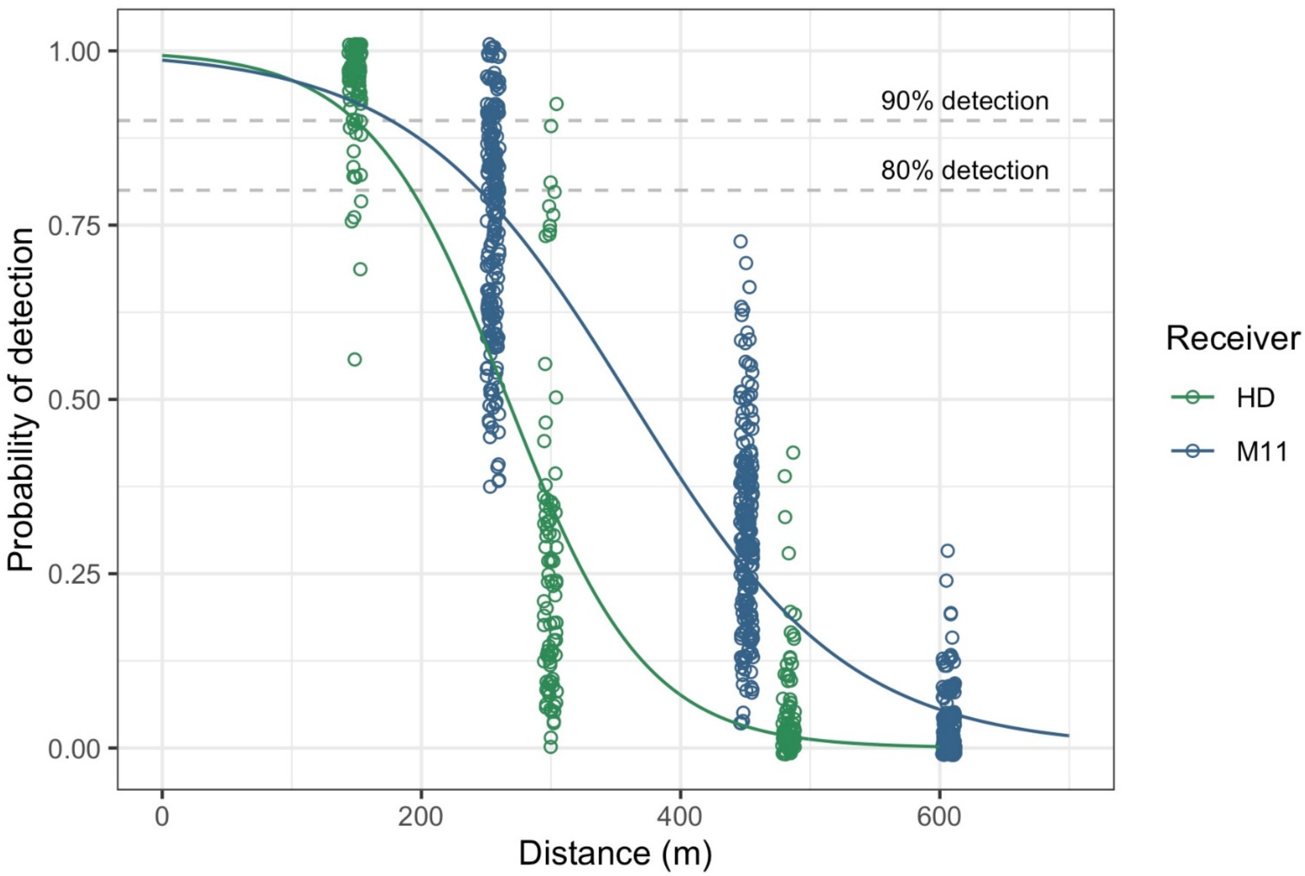

Figure 3. Estimated probability of detection for range tags deployed at Hinchinbrook D (HD; green) and Montague 11 (M11; blue). Each dot represents the daily detection proportions (proportion of total pings detected by the receiver over a 24 h period).

Currently, we are collaborating with the University of Alaska (UAF) and the Alaska Ocean Observing System (AOOS) on a project to detect overwintering herring. From November 2020 through early January 2021 (~75 d), AOOS is funding the UAF to deploy an autonomous underwater vehicle (AUV) (Slocum G2 glider) in PWS equipped with an acoustic receiver. The AUV will follow transects that target the tagging effort area in Orca Bay and Port Gravina with a route distance of ~100 km which can be surveyed every 5 days. Our preliminary analyses has shown that lighter herring are more likely to move from PWS to the spawning grounds arrays during the fall and winter season, suggesting that Orca Bay and/or Port Gravina may support primary herring overwintering area(s) within PWS.

Finally, during FY20 PI Bishop worked closely with J. Bernard to revamp the chapter that was part of the synthesis into a manuscript for submission. The manuscript entitled, "An empirical Bayesian approach to incorporate directional movement information from a forage fish into the Arnason-Schwartz mark-recapture model" is currently in review at *Movement Ecology*. In addition, Bishop has been working closely with E. Gallenberg at analyzing detection data from receivers that were biofouled compared with replacements that were not.

2. PROJECT STATUS OF SCHEDULED ACCOMPLISHMENTS

A. Project Milestones and Tasks

Table 3. Project milestones and task progress by fiscal year and quarter, beginning February 1, 2017. Additional milestones and/or tasks have been added in red. C = completed, X = planned or not completed. Fiscal year quarters: 1 = Feb 1 – April 30; 2 = May 1 – July 31; 3 = Aug. 1 – Oct. 31; 4 = Nov. 1 – Jan. 31.

	FY17				FY18				FY19				FY20				FY21			
Milestone/Task	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Milestone 1: Data Collection																				
Herring capture/tagging	C				C				C		X		C							
Upload data from arrays			C		C				C				C	C	X	X	X	X	X	
Milestone 2: Data Processing/Mgmt																				
Data summary/analysis			C	C	C	C	C	C	C	C	C	C	C	C	X	X	X	X	X	X
Upload data workspace					C				C				C				X			
Metadata/data published																X				
Milestone 3: Reporting																				
Annual reports					C				C				C				X			
Annual PI meeting				C			C				c					X				X
FY work plan (DPD)			C				C				C				C					
5-Year Final Report																				X
Journal Publications												X								X

B. Explanation for not completing any planned milestones and tasks

We have completed all planned milestones and tasks on schedule, except our fall 2019 herring captures which were not successful, and our first journal publication, which is currently in review.

C. Justification for new milestones/tasks

We tagged 235 herring during April 2020. As a result, we need to upload data during FY21.

3. PROJECT COORDINATION AND COLLABORATION

A. Within an EVOSTC-funded Program

Gulf Watch Alaska

Our project informs, receives data from, and contributes data to the Gulf Watch Alaska (GWA) program. The GWA Pelagic component's Integrated Predator-Prey surveys are co-conducted by three existing GWA Pelagic projects:

- Forage fish distribution, abundance, and body condition in PWS, U.S. Geological Survey (USGS; project 20120114-C)
- Humpback whale predation, NOAA and University of Alaska Southeast (project 20120114-O)
- Fall and winter seabird abundance and distribution, PWS Science Center (PWSSC; project 20120114-E)

Understanding movements by adult herring throughout the annual cycle provides valuable data on trophic interactions between herring and piscivorous waterbirds (in particular loons and common murres, the major avian consumers of adult herring), humpback whales, and other forage fish competitors.

The GWA Environmental Drivers Program also provides valuable data for our project. The availability of oceanographic data from PWS collected at approximately monthly intervals from April-November (project 20120114-G, PI Campbell), as well as the oceanographic and biological data made available from the GoA (projects 20120114-D, I, and L, PIs Batten, Danielson, and Hopcroft) allow this project to explore if environmental drivers influence the timing and location of Pacific herring seasonal migrations between PWS and the GoA. In addition, the GAK1 monitoring project (20120114-I, PI Danielson) has deployed VR2W receivers on two of their moorings in the GoA, providing us with an opportunity to determine if tagged herring are using these areas in the GoA.

Herring Research and Monitoring

Our study, PWS Herring Annual Migration Cycle, is an ongoing component of the larger, EVOSTC-funded HRM program. We continue to coordinate and collaborate with, inform, and contribute data to the other HRM projects. Our tagging work informs the herring disease studies project (20120111-E, PI Hershberger) by establishing the migration and feeding locations of herring. During April 2020 we captured pre-spawn herring for the herring disease study because their cruise was cancelled because of the pandemic. Our data contributes to identifying where and when exposure to the pathogens is occurring. This exposure information is a first step in helping to identify possible intermediate hosts for *Ichthyophonus*. From the Herring hydroacoustic surveys project (20120111-G, PI Rand) we receive data on adult school locations and provide data to them on return timing of tagged fish. Our project has informed and contributed data to the herring condition connection to environmental factors project (20120111-A, postdoc position) through identifying where the adult herring are at different times of year. Our project contributes movement and survival rate data to the modeling and stock assessment project (20120111-C, PI Branch). For the herring age at reproductive maturity project (20170111-D, PI Gorman) we have shared vessel space and have provided samples opportunistically. For the herring age, sex, and size collection project (20160111-F, PI Haught, ADF&G) we receive and supply available information on timing and location of herring spawn. We also receive and utilize the ADF&G age, weight, and length data. Before spring 2020, we obtained opportunistically seined herring for tagging from the ADF&G *RV Solstice* (their field season was cancelled in 2020 due to COVID-19). Finally, we are in constant collaboration and coordination with our HRM Coordinator/leader Scott Pegau, in order to improve and maintain all collaborative aspects of this project with other HRM projects. This includes attending PI meetings, making our data available in a timely matter, and completing reports in a timely matter.

Data Management

This project coordinates with the data management program by submitting data and preparing metadata for publication on AOOS Gulf of Alaska Data Portal and DataONE within the timeframes required.

B. With Other EVOSTC-funded Projects

Except for the HRM and GWA programs, there are no other EVOSTC-funded collaborations.

C. With Trustee or Management Agencies

Our project relies on information from ADF&G to locate adult herring schools in spring for acoustic surveys and sampling (HRM project 20160111-F). To that extent, we work closely with Stormy Haught at the Cordova office of ADF&G. Information learned about herring migrations is shared with ADF&G and the USGS herring disease project (HRM project 20120111-E, PI Hershberger). We also receive information on adult herring schools observed during summer and fall from the GWA Pelagic components - in particular the forage fish monitoring project (USGS, GWA project 20120114-C) and the humpback whale monitoring project (NOAA, GWA project 20120114-O). For the glider project in November 2020-January 2021, we are collaborating with Dr. John Eiler, of NOAA Auke Bay Labs, as well as our UAF colleague Dr. Seth Danielson. Recently we received a letter of support from ADF&G for our complementary funding application request to AOOS that if funded will support annual maintenance of the OTN arrays for a five-year period.

Collaborations with Other Organizations

Ocean Tracking Network: This project synergizes with efforts of the OTN (Fred Whoriskey, PhD. Executive Director, Dalhousie University) and with the AOOS (Molly McCammon, Executive Director). In March 2013, OTN installed 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 Latouche, Elrington, Prince of Wales, and Bainbridge. Since then, OTN has replaced lost receivers, and in February 2018 provided 18 VR2AR receivers to replace VR4 receivers that are tilting due to biofouling. In August 2020, they will provide another 11 VR2AR receivers to replace missing, lost, or aging receivers. With FY16 EVOSTC funding, the PWSSC expanded the OTN array in February 2017. Equipment is assembled and configured by PWSSC personnel in Cordova. Currently PWSSC maintains the array for OTN/AOOS (see next section) on an annual basis. OTN maintains a database with detections from their worldwide network. Our data are archived in the OTN databases, as per their guidelines.

AOOS: In 2017, PWSSC received funding from AOOS to cover the costs of annual, regular maintenance of the OTN arrays. Funding will be for through June 2021. We have also applied to AOOS to cover the next five years of maintenance.

From November 2020 through early January 2021 (~75 d), AOOS is also funding UAF to deploy an AUV (Teledyne Webb Research; Slocum G2 glider) in PWS to detect this project's acoustic tagged Pacific herring. This shallow water glider with a 200 m depth rating will be equipped with a pumped seabird CTD, a three channel Wetlabs ecopuck (with chl and cdom fluorescence, backscatter sensor), a Rinko oxygen sensor, a photosynthetically active radiation sensor, and a Vemco RXLive passive acoustic receiver. The AUV will follow transects that target the tagging effort area in Orca Bay and Port Gravina with a route distance of ~100 km which can be surveyed every 5 days.

4. PROJECT DESIGN

A. Overall Project Objectives

Our previous tagging efforts suggest that herring are emigrating from PWS into the GoA and then returning (Eiler and Bishop 2016, Bishop and Eiler 2018). As part of the HRM program, during FY21 this acoustic tagging project will contribute to the HRM program objective #2 *Provide inputs to the stock assessment model,* and objective #3 *Examine the connection between herring condition or recruitment to physical and biological oceanographic factors.*

Our acoustic-tagging project objectives are:

1) Document location, timing, and direction of Pacific herring seasonal migrations between PWS and the GoA.
2) Relate large-scale movements to year class and body condition of tagged individuals.
3) Determine seasonal residency time within PWS, at the entrances to PWS, and in the GoA.

Our study will provide a better understanding of the migratory patterns of herring and the potential factors affecting herring movements, survival, and population structure. In addition to peer-reviewed publications, our project will provide valued and requested information to the fishing community, the general public, and resource managers regarding latest research results and Pacific herring ecology.

B. Changes to Project Design and Objectives

In our original 2016 proposal, 2019 was scheduled to be the third, and final year for tagging. However, the EVOSTC Science Panel and Chief Scientist showed support for adding a fourth year to increase our sample size. As a result, in April 2020 we acoustic-tagged 235 fish for a total of 726 fish over four years.

The additional receivers installed in 2018 in parts of the Sound (Knight Island, northern Montague Strait, Hawkins Island, Red Head) and more recently at Johnstone Point and in Port Fidalgo will continue to provide new information on residency within PWS. At the same time, the partial, second line of receivers at the OTN arrays will continue to provide an opportunity to determine if and when fish return to PWS from the GoA.

5. PROJECT PERSONNEL – CHANGES AND UPDATES

In April 2020, Alysha Cypher joined this project as a post-doc. Dr. Cypher will take over data compilation, acoustic array management and data uploads, and will assist Bishop with the final report and publications related to the project.

ALYSHA D. CYPHER

EDUCATION

2012- 2017 PhD in Integrated Bioscience, The University of Akron (UA)
Thesis titled "The Interaction of Chemical and Natural Stressors on Cardiovascular Dynamics in Teleost Fish"

2008-2012 B.S. in Biology with Minor in Chemistry, Clarion University of PA (CU)

PROFESSIONAL

2018-present National Research Council Post-Doctoral Research Associate
NOAA Northwest Fisheries Science Center, Ecotoxicology Program

RESEARCH EXPERIENCE

Refereed Publications

Cypher, A. D., Fetterman, B., Bagatto, B., 2018. Vascular parameters continue to decrease post-exposure with simultaneous, but not individual exposure to BPA and hypoxia in zebrafish larvae. Comp. Bioch. And Phys. Part C 11-16. http://dx.doi.org/10.1016/j.cbpc.2018.02.002

Cypher, A. D., Consiglio, J. C., Bagatto, B., 2017. Hypoxia exacerbates the cardiotoxic effect of the polycyclic aromatic hydrocarbon, phenanthrene in *Danio rerio*. Chemosphere 574-581. https://doi.org/10.1016/j.chemosphere.2017.05.109

Cypher, A. D., Ickes, J. Bagatto, B., 2015. Bisphenol A alters the cardiovascular response to hypoxia in *Danio rerio* embryos. Comp Bioch and Phys Part C 174-175, 39-45. http://dx.doi.org/10.1016/j.cbpc.2015.06.006

Current Research

2018-pres Crude oil-induced cardiovascular pathology varies with source population in larval *Clupea pallasi* (In preparation).

2018-pres Lipid metabolism and composition in embryonic, larval, and juvenile Pacific herring after crude oil exposure (In preparation).

2018-pres First year overwinter survival and bioenergetics in juvenile *Clupea pallasi* after an embryonic exposure to crude oil (In preparation).

2018-pres Latent effects of embryonic oil exposure on cardiogenesis and juvenile heart structure in Pacific herring.

2018-pres Reduced cardiorespiratory performance after oil exposure is associated with altered heart structure rather than bioenergetics.

2018-pres Embryonic oil exposure alters viral disease tolerance and innate immunity in juvenile stages of Pacific herring (*Clupea pallasi*).

2014-pres	Utilizing tissue-specific lipidomics to identify lipid dysfunction in *Danio rerio* exposed to an endocrine disruptor (In preparation).

Past Research

The University of Akron

2017-2018	Evaluation of critical oxygen concentration in early development of *Danio rerio*.
2016-2017	Structural equation modeling as a unique approach for assessing cardiovascular dynamics in larval fish.
2014	Evaluating the material properties of zebrafish chorion using a tensor tester after exposure to an endocrine disruptor.

Clarion University of Pennsylvania

2011-pres	Development of a novel detection method for the amphibian-killing fungus *Batrachochytrium dendrobatidis* (Bd).
2011	Survivorship and growth of *Anaxyrus americanus* with heavy metal exposure.
2010-2011	Chemosensory effects of heavy metals on *Ictalurus punctatus*.
2010	Stream health assessment by observation of biochemical indicators in *Campostoma anomalum* (University of Akron REU).
2009-2010	Chemosensory effects of fracturing fluid on of *Astyanax mexicanus*.
2008-2009	Mammal dispersal in forested corridors in northern Clarion County.

Additional Research Experience

2010-2016	Founded 'The Center for Conservation Studies' (501(c)(3) non-profit) *Funded small grants for high school and undergraduate students to provide STEM opportunities for women in rural Pennsylvania.*
2010-2016	Co-founder of The Clarion-Limestone Amphibian Research Center *Funded a research lab on the grounds of a high school in rural PA to provide lab space for high school and college students.*

6. PROJECT BUDGET

A. Budget Forms

Budget Category:	Proposed FY 17	Proposed FY 18	Proposed FY 19	Proposed FY 20	Proposed FY 21	TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	$121.5	$139.9	$135.6	$153.9	$157.9	$708.8	
Travel	$1.2	$1.2	$1.2	$3.1	$1.6	$8.1	
Contractual	$23.6	$46.3	$52.9	$50.3	$31.1	$204.2	
Commodities	$118.7	$80.5	$5.0	$99.1	$2.0	$305.3	
Equipment	$5.9	$0.0	$0.0	$0.0	$0.0	$5.9	
Indirect Costs (*will vary by proposer*)	$79.5	$80.3	$58.4	$91.9	$57.8	$367.9	
SUBTOTAL	$350.3	$348.1	$253.0	$398.3	$250.3	$1,600.2	$0.0
General Administration (9% of subtotal)	$31.5	$31.3	$22.8	$35.8	$22.5	$144.0	N/A
PROJECT TOTAL	$381.9	$379.5	$275.8	$434.2	$272.8	$1,744.2	
Other Resources (Cost Share Funds)	$15.0	$15.0	$15.0	$15.0		$60.0	

B. Changes from Original Project Proposal

The FY21 budget adds a fifth year to the project (originally it was a 4-year project).

Personnel: a postdoctoral research associate replaces the fisheries biologist who left the project.

Travel: includes the cost for the postdoc and the PI to attend the annual PI meeting.

Contractual: includes the cost for vessel time for uploading data from arrays that are not part of the OTN arrays as well as for a September data upload from the OTN arrays.

Commodities: mooring supplies to cover the cost to redeploy receivers that are recovered for data downloads.

Sources of Additional Project Funding

This project uses Dalhousie University's OTN, a series of acoustic arrays that are in place at Hinchinbrook Entrance, Montague Strait, and four smaller passages in southwest PWS. The value of the OTN acoustic arrays is estimated at $337,200. This project also piggybacks on the annual OTN maintenance cruise (funded by AOOS starting in FY 17) which includes 6d@$3/k day. PWSSC will also provide in-kind equipment (9 VR2W acoustic receivers, 9 acoustic releases, and 9 floats) for an array that will be deployed at the tagging site as well as 9 VR3 refurbished receivers. The value of this equipment is estimated at $108k.

7. FY17-20 PROJECT PUBLICATIONS AND PRODUCTS

Publications

Bernard, J.W., and M.A. Bishop. In review. An empirical Bayesian approach to incorporate directional movement information from a forage fish into the Arnason-Schwartz mark-recapture model. Movement Ecology.

Bishop, M.A., and J.W. Bernard. 2020. Annual Herring Migration Cycle. Pages 4-1 to 4-10 in W.S. Pegau and D.R. Aderhold, eds. Herring Research and Monitoring Science Synthesis. Herring Research and Monitoring Synthesis Report, (*Exxon Valdez* Oil Spill Trustee Council Program 20120111). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Bishop, M.A., and J.H. Eiler. 2018. Migration patterns of post-spawning Pacific herring in a subarctic sound. Deep-Sea Research Part II 147:108-115. https://doi.org/10.1016/j.dsr2.2017.04.016

Bishop, M.A., and E. Gallenberg. In prep. The effect of biofouling on acoustic receiver detections in a subarctic sound. Journal Tbd.

Bishop, M.A., and S. Lewandoski. 2018. Validation of acoustic surveys for Pacific herring (*Clupea pallasii*) using direct capture. *Exxon Valdez* Oil Spill Long-Term Herring Research and Monitoring Program Final Report (*Exxon Valdez* Oil Spill Trustee Council Project 16120111-A), *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Gray, B., M.A. Bishop, and S.P. Powers. 2019. Structure of winter groundfish feeding guilds in Pacific herring *Clupea pallasii* and walleye pollock *Gadus chalcogrammus* nursery fjords. Journal of Fish Biology 95:527-539. https://doi.org/10.1111/jfb.13984.

Gray, B.P., M.A. Bishop, and S.P. Powers. In review. Winter variability in the diets of groundfish inhabiting a subarctic sound with a focus on Pacific herring and walleye pollock piscivory Deep-Sea Research Part II.

Lewandoski, S., and M.A. Bishop. 2018. Distribution of juvenile Pacific herring relative to environmental and geospatial factors in Prince William Sound, Alaska. Deep Sea Research II 147:98-107. http://dx.doi.org/10.1016/j.dsr2.2017.08.002

Published and updated datasets

A tagging log with accompanying age, sex, and length of each herring tagged along with a unique tag ID number. These data were recorded in April 2020 and have been uploaded to the Research Workspace. Detection data has been uploaded (vrl files) and includes data from OTN receiver arrays through February 2020 and the May 2020 upload of a portion of the spawning ground receivers. These files include detections of the unique tag ID numbers at each receiver with the accompanying time and date. Our data will be publicly available on the data portal by February 2021.

Bishop, M.A. 2017. Tracking seasonal movements of adult Pacific Herring in Prince William Sound, 2012-2014, EVOSTC Herring Program. Axiom Data Science. https://doi.org/10.24431/rw1k1x

http://portal.aoos.org/gulf-of-alaska.php#metadata/c1e401be-8d52-477b-a76b-acf5cd817686/project

Presentations

Bishop, M.A. 2020. Annual herring migration cycle. Review of the Herring Research and Monitoring Program by the EVOSTC Science Panel. February, Anchorage.

Bishop, M.A. 2019. Annual herring migration cycle. Herring Research and Monitoring and Gulf Watch Alaska joint Principal Investigators annual meeting, November, Homer.

Bishop, M.A. 2018. Annual herring migration cycle. Herring Research and Monitoring and Gulf Watch Alaska joint Principal Investigators annual meeting. November, Anchorage.

Bishop, M.A. 2017. Annual herring migration cycle. Herring Research and Monitoring Program, annual meeting. November, Cordova.

Bishop, M.A., and B. Gray. 2019. How to tag a herring and where do they go afterwards? PWS Science Center Tuesday night lecture series. January, Cordova.

Gray, B.P., M.A. Bishop, S.P. Powers. 2018. Identifying key piscine predators of Pacific herring (*Clupea pallasii*) and walleye pollock (*Gadus chalcogrammus*) during winter months in bays of Prince William Sound, Alaska through multivariate analysis of stomach contents. Poster. Alaska Marine Science Symposium, January, Anchorage.

Outreach

Bishop, M.A. 2019. Time to spawn. Delta Sound Connections. Prince William Sound Science Center.

Bishop, M.A. 2018. How to tag a herring. Delta Sound Connections. Prince William Sound Science Center.

Bishop, M.A. 2017. Pacific herring: Once done spawning – Where to next? Delta Sound Connections. Prince William Sound Science Center.

Gray, B. 2019. Ping! Tracking fish using passive acoustic technology. Delta Sound Connections. Prince William Sound Science Center.

Gray, B. 2018. Herring on the menu. Delta Sound Connections. Prince William Sound Science Center.

Pearson, A. 2020. Sound Science: Where are the herring going? The Cordova Times. April 4.

8. LITERATURE CITED

Bishop, M.A., and J.H. Eiler. 2018. Migration patterns of post-spawning Pacific herring in a subarctic sound. Deep-Sea Research Part II 147:108-115. https://doi.org/10.1016/j.dsr2.2017.04.016

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 Peninsula, Alaska. Alaska Fishery Research Bulletin 9:75-101.

Corten, A. 2002. The role of “conservatism'' in herring migrations. Reviews in Fish Biology and Fisheries 11:339-361.

Eiler, J., and M.A. Bishop. 2016. Determining the post-spawning movements of Pacific herring, a small pelagic forage fish sensitive to handling, with acoustic telemetry. Transactions of American Fisheries Society 145:427-439. DOI: 10.1080/00028487.2015.1125948

Hay, D., and S.M. McKinnell. 2002. Tagging along: association among individual Pacific herring (*Clupea pallasi*) revealed by tagging. Canadian Journal of Fisheries and Aquatic Sciences 59:1960-1968.

Hay, D.E., K.A. Rose, J. Schweigert, and B.A. Megrey. 2008. Geographic variation in North Pacific herring populations: Pan-Pacific comparisons and implications for climate change impacts. Progress in Oceanography 77:233-240.