ATTACHMENT B. Annual Project Report Form (Revised 11.21.19)

1. Program Number:

20160111-B

2. Project Title:

PWS Herring Research & Monitoring: Annual Herring Migration Cycle

3. Principal Investigator(s) Names:

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

Report Preparation Assistance: Alysha Cypher, Ph.D., Prince William Sound Science Center

4. Time Period Covered by the Report:

February 1, 2020 – January 31, 2021

5. Date of Report:

March 2021

6. Project Website (if applicable):

http://pwssc.org/tracking-seasonal-movements-of-adult-pacific-herring/

7. Summary of Work Performed:

The acoustic tagging component of this study began in FY17. Objectives of this study are to:

1) Document location, timing, and direction of Pacific herring seasonal migrations between Prince William Sound (PWS) and the Gulf of Alaska (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 Gulf of Alaska.

2020 Field Work and Preliminary Analyses

For this FY20 report, we summarize the April 2020 tagging work. We also provide preliminary data analyses from the first 3 1/2 years of acoustic receiver data from April 2017 through September 2020. Importantly, many of the receivers, including the Ocean Tracking Network arrays (Hinchinbrook, Montague, and Southwest Passages), are located at the interface between the GOA and PWS (Fig. 1). These arrays are uploaded annually during the late winter (February/March). As a result, the most recent data available for most receivers is February 2020. The exceptions are the spawning grounds receivers and the outermost receivers at Hinchinbrook Entrance and Montague Strait Ocean Tracking Network arrays. Detection data from these outermost receivers were downloaded in September 2020.

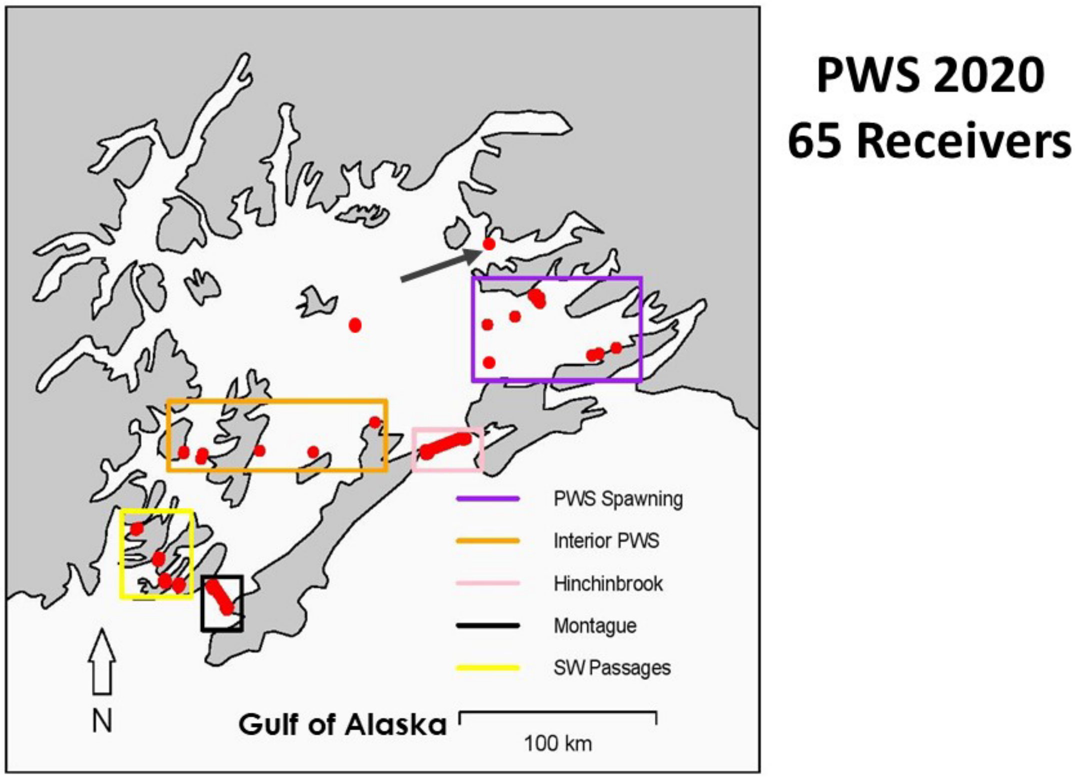

Figure 1. Acoustic array locations in Prince William Sound during 2020.Arrow points to location of receiver at Port Fidalgo that was removed in September 2020.

Tagging

Since April 2017, we have tagged 726 herring on their spawning grounds (Table 1), including most recently 235 fish during April 2020 (Table1). We have used two transmitter models: the Vemco V8-4x and the V9-2x. While the V8-4x has battery life of ~8 months, the most recent V9-2x tags have a battery life of almost 28 months providing the potential to track some fish through August 2022.

<u>2020 Tagging</u>. Between 1 and 7 April 2020, we jigged 676 herring and acoustically tagged 235 herring (144 females, 84 males, 7 unknown sex). Tagging occurred around western Port Gravina (n = 198; Knowles Bay to Hell's Hole) and Hawkins Island (n = 37; Canoe Pass). Over the 7-d period, herring were released in 10 cohorts with each cohort consisting of tagged fish and control fish (not sedated nor tagged).

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

	Transmitter			
Mo/Year	**V8**	**V9**	**Total**	**Tagging Location**
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**	

We targeted fish <200 mm and <100 g for the smaller V8-4x Vemco transmitters (n = 50; battery life = 231d). The V9-2x Vemco transmitters deployed in 2020 have an estimated battery life of 755 d (n = 55) or 832 d (n = 130). Measurements for tagged fish included standard length and weight (Table 2). We took a scale sample from each tagged fish and were able to estimate the age of 67% (n =157) of the 235 fish (Table 2). Our age results for 2020 showed that 4-year-olds were the dominant age class.

Table 2. Mean standard length (SL) (mm), mass (g), and age, including standard deviation (1sd) and the minimum and maximum, of Pacific herring by transmitter type for April 2019 and 2020 tagged herring. Age determined from scales for 144 of 165 fish tagged in 2019 and 157 of 235 fish tagged in 2020.

	V-8 x ± 1sd min, max		V-9 x ± 1sd min, max	
	2019 n = 40	2020 n = 50	2019 n = 125	2020 n = 185
SL (mm)	199.1 ± 5.2 189, 211	201.9± 4.5 190, 214	213.1 ± 9.3 198, 240	212.3 ± 7.6 201, 242
Mass (g)	91.0 ± 5.6 80, 99	97.6± 4.5 91, 110	117.3 ± 18.1 97, 180	117.4 ± 14.5 95, 173
Age (y)	3.6 ± 0.9 3, 6	4.1 ± 0.4 4, 6	4.6 ± 1.2 3, 9	4.5 ± 0.8 3, 8

Phenology and use of entrance arrays

The proportion of tagged herring detected at the Ocean Tracking Network entrance arrays has ranged by tag year from 0.48 (year 2017) to 0.81 (year 2019). Across all four tag years, herring were detected at Hinchinbrook Entrance more than any other array. This is not surprising given that our modeling efforts show that fish tend to migrate out from Hinchinbrook Entrance to the Gulf of Alaska during spring (Bishop and Bernard *in press*).

Proportions of fish using Hinchinbrook Entrance and Montague Strait were most similar during 2017 (Hinchinbrook = 0.36, Montague = 0.26). However, since then, much higher proportions of tagged fish have been detected at Hinchinbrook Entrance (range = 0.56 – 0.69) than Montague Strait (range = 0.20 – 0.32; Figure 2). The high proportion of fish detected at Hinchinbrook Entrance in 2019 (n = 0.69) is most likely due to its proximity to where fish were tagged. In 2019, 111 of the 165 fish were tagged around Double Bay (Hinchinbrook Island), locations that are 15-20 km closer to Hinchinbrook than the next closest tagging location (Canoe Pass). Additionally, 12 of the 165 fish were tagged at Rocky Bay (northern Montague Island) which is only 10 km from the Hinchinbrook Entrance array.

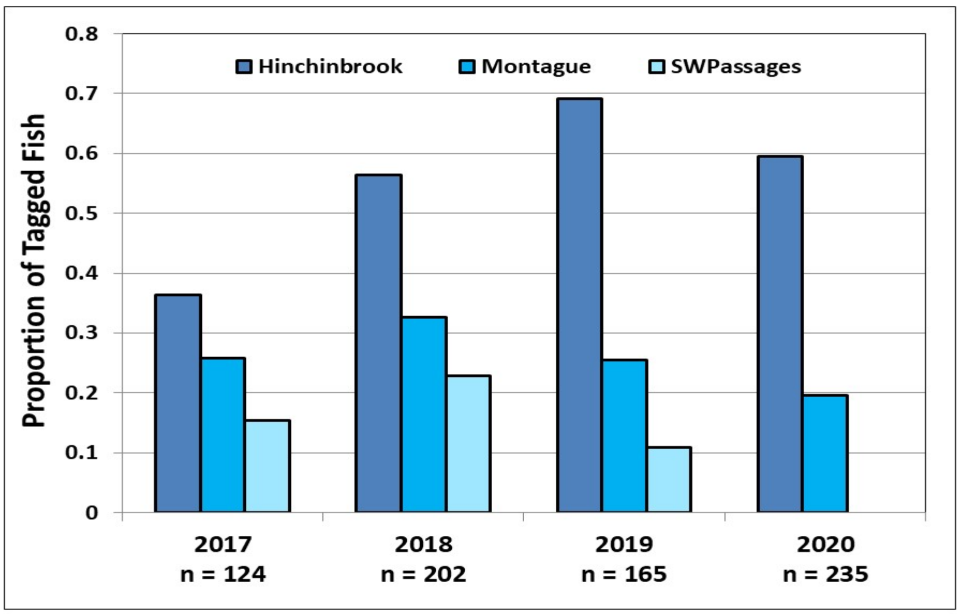

Figure 2. Proportion of acoustic-tagged herring using the Ocean Tracking Network Arrays (Hinchinbrook Entrance, Montague Strait, and Southwest [SW] Passages) by tag year. n = total tagged fish. For 2020 tagged fish, proportions shown are based on limited receiver uploads at Hinchinbrook Entrance and Montague Strait arrays through September 2020.

Arrival dates at the PWS entrances were protracted across the spring/summer season, with recently tagged arrivals during 2018 and 2019 occurring over a 70-82 d period between April and early July (Fig. 3). During 2018, initial detections at the two major entrances to the Sound were recorded as early as 14 April (Hinchinbrook Entrance) and 18 April (Montague Strait) while the first detection at the SW Passages did not occur until 10 May, more than 3 weeks later. During 2019, first detection of a recently tagged fish occurred

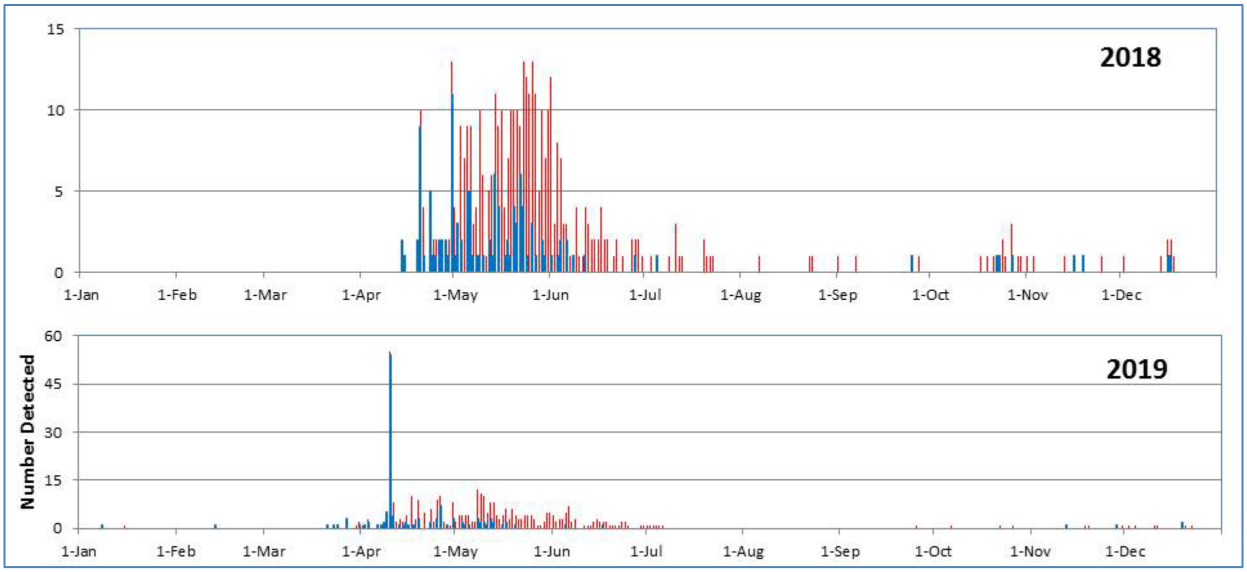

Figure 3. Number of tagged herring detected by date and year at the Hinchinbrook Entrance acoustic array, 2018 and 2019. Blue = Initial detection of individual fish for that year. Red = Total fish detected by date that had been previously detected in that year.

8 April at Hinchinbrook Entrance, 25 April at Montague Strait, and 27 April at the SW Passages. Strikingly, on 10 April 2019, a total of 54 tagged herring arrived at Hinchinbrook Entrance – the largest group of tagged herring ever recorded at an array during five years of tagging. These tagged fish represented 14 of the 18 cohorts released between 3 and 9 April around Double Bay and Canoe Pass area, suggesting that a very large herring school had formed and migrated to the entrance.

Residence at Ocean Tracking Network Entrance Arrays

We also evaluated the amount of time tagged herring spent near the Ocean Tracking Network arrays during and after expected time of migration. This was accomplished by using the 'glatos' package in R (https://rdrr.io/github/jsta/glatos/man/glatos.html; R Studio 1.3.1093) which generated detection events, time periods where individual fish stayed at an array without being detected elsewhere or going undetected for more than 48 hours. Detection events were then categorized into 'days' (> 23.9 hours), 'hours' (>59.9 minutes), and 'minutes.'

For the 2018 tag year, the longest detection events were 8.7 days and 20.4 days for the Hinchinbrook and Montague Strait entrances, respectively. For Hinchinbrook Entrance (Fig. 4A), the most detection events occurred in May after spawning with approximately 47% of detection events being between 1 and 23 hours. At this time, about 30% of tagged herring spent more than 1 day at the Hinchinbrook array while 23% percent moved through the array within a span of minutes.

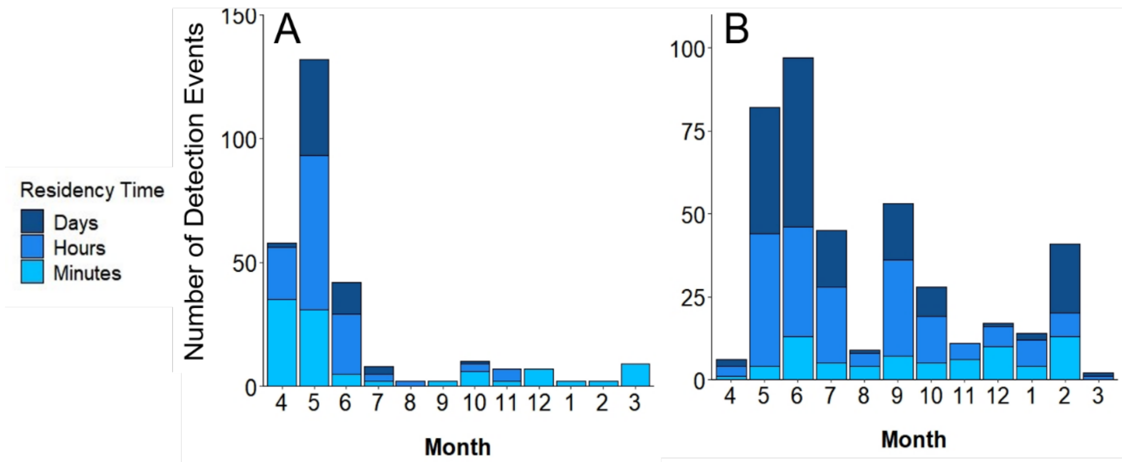

Figure 4. Residency plots for herring at Hinchinbrook Entrance (A) and Montague Strait (B) that were fit with an acoustic tag in 2018. A detection event is a period during which a herring is detected within an array without moving to a different array or going undetected for more than 48 hours. Data are presented as cumulative events (n=202 tagged herring).

While further analysis is pending, there did not appear to be a pattern between the duration of detection events and fish condition, gender, or age. Detection events at Montague Strait were fewer than at Hinchinbrook in the most prevalent months, May and June, but occurred throughout the year (Fig. 4B). Approximately 49 and 53% of tagged herring spend more than 1 day at the Montague Strait array during May and June, respectively. This further supports our findings that adult herring spend time in Montague Strait presumably for feeding. Together, these residency plots show us that the behavior of individual herring at arrays is variable with some herring traveling quickly and others residing by the array, potentially for feeding.

Tagged fish detected after one year

The 2-year life of the V9 transmitters have provided our first information on return rates after one year. Of the 124 fish tagged in 2017, 8% were detected ≥ 12 months later. Of the 142 fish tagged with V-9 tags in 2018, 16% were detected ≥ 12 months later. While receiver uploads are not yet complete, preliminary data indicates at least 10% of the 125 fish tagged in 2019 with V9 tags have been detected ≥ 12 months post-tagging. Fish were more likely to be detected at the entrance arrays than on the spawning grounds (Table 3). This is likely due to our limited number of receivers on the spawning grounds as well as the shifting location of spawning areas between years.

Table 3. Number of fish with 2-year V-9 Transmitters by tag year, detection location (Ocean Tracking Network [OTN] and spawn arrays), and year. Year 1 is the 12 months following tagging (~1 April – 31 March). For fish tagged in 2019, year 2 data are incomplete.

Tag Year	V-9 Tags	Year 1 OTN Arrays	Year 2 Spawn Arrays	Year 2 OTN Arrays	Year 2 Total Detected
2017	124	59	8	7	10
2018	142	100	17	22	23
2019	125	105	5	12	12

8. Coordination/Collaboration:

A. Projects Within a Trustee Council-funded program

1. Within the Herring Research & Monitoring (HRM) Program

Herring age, sex, and size collection, Project 20160111-F, Alaska Department of Fish and Game (ADF&G), principal investigator (PI) Haught: During April 2020, we received critical information on timing and location of herring spawn from the aerial surveys.

Herring hydroacoustic surveys, Project 20120111-G, PWS Science Center, PI Rand: In April 2020, we received information from PI Rand's project on adult school locations.

Herring age at reproductive maturity, Project 19170111-D, PWS Science Center, PI Gorman: We gave PI Gorman samples of jigged fish that were injured and could not be released.

Herring Disease, Project 19120111-E, U.S. Geological Survey (USGS), PI Hershberger: In April 2020 we provided water samples from our tagging totes that were analyzed by PI Hershberger for presence of herring viruses. Because ADF&G and USGS could not conduct field work due to the pandemic, we jigged and delivered to ADF&G a total of 202 herring for the herring disease study.

2. Across Programs

a. Gulf Watch Alaska

PWS Oceanographic conditions, 20120114-G, PWS Science Center, PI Campbell: We have collaborated regularly with PI Campbell's project, both assisting him in the field, and PI Campbell assisting us with data uploads and grappling for missing receivers.

Long-term monitoring of oceanographic conditions in the Alaska coastal current from hydrographic station GAK1, 20120114-I, University of Alaska-Fairbanks, PI Danielson: We are collaborating with PI Danielson during FY20/21 to use a glider equipped with a Vemco acoustic receiver to search in PWS for tagged herring. The glider study is funded by the Alaska Ocean Observing System through a grant to University of Alaska-Fairbanks (see Section 8B, below). From 20 January through early March 2021 (~75 d) an automated underwater vehicle (Teledyne Webb Research; Slocum G2 glider) will follow transects that target the locations of our previous tagging efforts in Orca Bay and Port Gravina (Fig. 5). This shallow water glider with a 200 m depth rating will be equipped with a pumped Seabird CTD, a three channel Wetlabs ecopuck (chlorophyll, colored dissolved organic matter fluorescence, and backscatter sensors), a Rinko oxygen sensor; a photosynthetically active radiation sensor, and a Vemco RXLive passive acoustic receiver. Data are uploaded to a satellite link every 2 hours. We have automated the data download so that we are notified whenever a transmitter is detected.

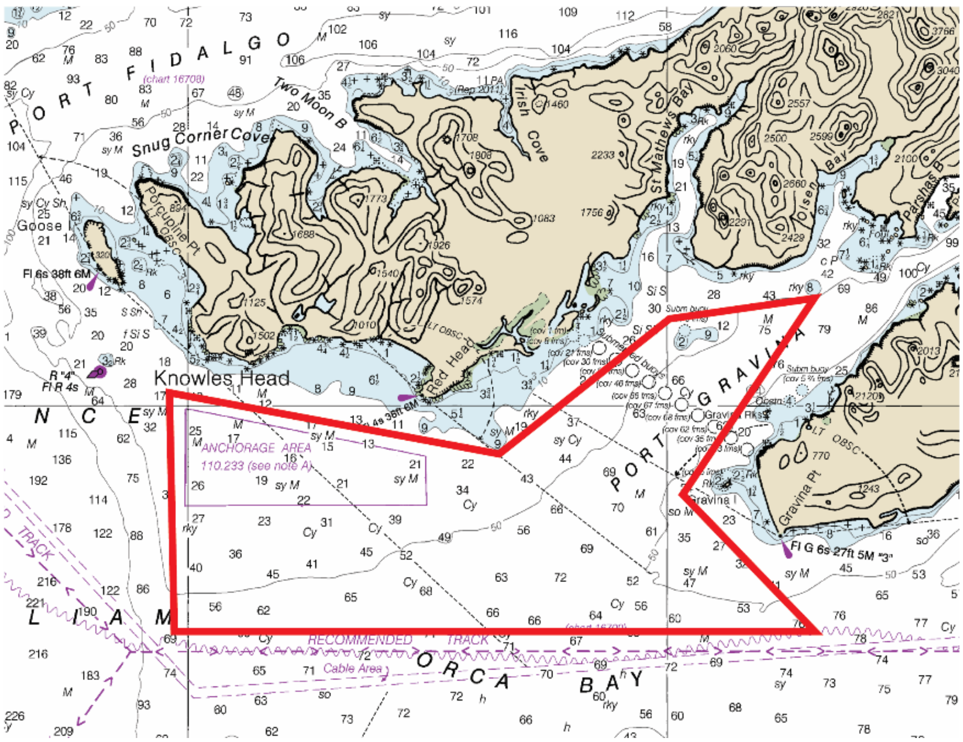

Figure 5. Initial route of the autonomous glider equipped with an acoustic receiver.

b. Data Management

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

B. Individual Projects

This project synergizes with efforts of the Ocean Tracking Network (Fred Whoriskey, Ph.D. Executive Director, Dalhousie University) and with the Alaska Ocean Observing System

(AOOS; Sheyna Wisdom, Executive Director). In March 2013, the Ocean Tracking Network 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 Whales, and Bainbridge. With FY16 *Exxon Valdez* Oil Spill Trustee Council funding, in February 2017, PWS Science Center expanded the Ocean Tracking Network array. Because biofouling was impacting detections by some of the receivers originally deployed in 2013, in 2018, the Ocean Tracking Network provided 18 additional VR2AR receivers to maintain the integrity of the array. In 2020 another three VR2AR receivers were provided to replace lost receivers, and an additional eight receivers arrived in late January 2021 for March deployment.

Currently, PWS Science Center maintains the array for Ocean Tracking Network on an annual basis. The Ocean Tracking Network maintains a database with detections from their worldwide network. Our data are archived in their databases, as per their guidelines. For 2017-2021 AOOS has provided funding to cover the costs of maintaining the Ocean Tracking Network arrays. While the budget is not yet finalized, maintenance of these arrays is currently listed as a line item in the 2022-2026 AOOS budget.

AOOS is also providing the University of Alaska Fairbanks with funding for glider work. The first project began on 20 January 2021 in PWS and includes a glider equipped with a Vemco acoustic receiver to search in PWS for wintering tagged herring (see Section 8A2a., *Long-term monitoring of oceanographic conditions in the Alaska coastal current from hydrographic station GAK1*, above).

C. With Trustee or Management Agencies

We work closely with Stormy Haught at the Cordova office of ADF&G. Our project relied on information from Haught's program in 2020 to help locate adult herring schools in spring for capture and tagging. We also receive age, weight, and length data from ADF&G that has helped us with aging the herring we captured. Information derived from this project about herring migrations will be shared with ADF&G and will inform management about population connectivity.

9. Information and Data Transfer:

A. Publications Produced During the Reporting Period

1. Peer-reviewed Publications

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

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., 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.*

2. Reports

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

3. Popular articles

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

B. Dates and Locations of any Conference or Workshop Presentations where EVOSTC-funded Work was Presented

1. Conferences and Workshops

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

Cypher, A., and M.A. Bishop. Annual herring migration cycle. Herring Research and Monitoring and Gulf Watch Alaska joint Principal Investigators annual meeting, November 2020. Online presentation (due to the pandemic)

2. Public presentations

None.

C. Data and/or Information Products Developed During the Reporting Period, if Applicable

Our project's page on the PWS Science Center website was updated:

https://pwssc.org/tracking-seasonal-movements-of-adult-pacific-herring/

D. Data Sets and Associated Metadata that have been Uploaded to the Program's Data Portal

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.

https://workspace.aoos.org/files/7835346/2017 to 2020 herring tag data for workspace - master list .xlsx

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 2022.

herring_detections_2017 to fall 2020_adc csv w mab corrections.csv | Research Workspace (aoos.org)

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

Ocean Tracking Network

https://members.oceantrack.org/project?ccode=NEP.PWS

https://members.oceantrack.org/project?ccode=NEP.PWSPH

10. Response to EVOSTC Review, Recommendations and Comments:

Sept 2020: Science Panel Comment – FY21 This project has provided solid evidence that PWS herring use the GOA as a summer feeding area. Other results indicate that migration out of PWS, to feeding areas on the shelf, may depend on the condition of herring. If so, this is valuable information and confirmatory evidence of similar, earlier results from Norwegian work by Slotte and Fiksen (2000) on state-dependent spawning migration (J. Fish Biol. 56: 138-162). Further, the results of this work indicate that migration is complex and may provide a sharp contrast to A. MacCall's hypothesis that young fish simply follow the older fish. The SP looks forward to discussion of these and other findings in future publications and reports. The new postdoc should be an excellent addition to this project.

Bishop response to Science Panel:

We thank the Science Panel and Science Director for their funding recommendation and compliments. We feel confident that this project will benefit from the addition of the new postdoc and that the project will continue to provide novel insights into Pacific herring migration.

Sept 2020: Science Panel Comment – FY21 What are the program and project contingency plans for FY21 in regard to accomplishing goals and field activities?

Bishop response to Science Panel:

During the COVID-19 pandemic, the PWSSC has been able to successfully conduct field and lab work. The remaining field work for this project includes uploading data from the underwater acoustic arrays. We can conduct this work safely by reducing the number of people aboard vessels and receiving COVID testing prior to longer trips. COVID testing in Cordova can be completed most days of the week with results received within a few hours. The community has also been successful with contact tracing and maintaining a low infection rate. In 2021, we will continue to exercise caution while generating mitigation plans that allow us to conduct field work. Under the worst case scenario (a local outbreak or other extenuating circumstances) our regular charter boat captain is trained and able to recover and redeploy the acoustic arrays as well as upload data from the receivers.

Sept 2020: Science Panel Comment – FY21 Will any unused funds for FY21 be repurposed for additional lab and/or data analyses?

Bishop response to Science Panel:

We deployed > 230 acoustic tags in April 2020 that have a battery life of up to 2 years. We foresee the final data upload from our receiver arrays taking place during winter 2021/22. We would therefore carryover any unused funds for the final upload, as well as data analyses and manuscript preparation.

11. Budget:

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	$ 420.8
Travel	$1.2	$1.2	$1.2	$3.1	$1.6	$8.1	$ 6.2
Contractual	$23.6	$46.3	$52.9	$50.3	$31.1	$204.2	$ 122.6
Commodities	$118.7	$80.5	$5.0	$99.1	$2.0	$305.3	$ 287.3
Equipment	$5.9	$0.0	$0.0	$0.0	$0.0	$5.9	$ 17.2
Indirect Costs (*will vary by proposer*)	$79.5	$80.3	$58.4	$91.9	$57.8	$367.9	$ 251.1
SUBTOTAL	$350.3	$348.1	$253.0	$398.3	$250.3	$1,600.2	$1,105.2
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	

LITERATURE CITED

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