ATTACHMENT C **EVOSTC Annual Project Report Form**

Form Rev. 8.30.18

1. Program Number:

18160111-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: Ben Gray, Prince William Sound Science Center

4. Time Period Covered by the Report:

February 1, 2018 – January 31, 2019

5. Date of Report:

April 2019

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.

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.

2018 Field Work and Preliminary analyses

For this FY18 report, we summarize the April 2018 tagging work as well as results from the February 2018 uploads of ocean tracking network (OTN) arrays at the entrances to PWS and the spring uploads from Port Gravina and Hawkins Island. In September 2018 we conducted a partial upload, that only includes downloads from VR4 receivers at Hinchinbrook and Montague Strait closest to the shoreline (Table 1). Preliminary results on the 2018 tagged fish are included in this report. Please note that data will be uploaded from all acoustic arrays at the entrance to PWS, including the southwest passages during the annual maintenance cruise scheduled for February 2019. Data from the acoustic arrays in Port Gravina and at Hawkins Island will be uploaded, and receivers redeployed in April 2019.

Table 1. Data uploads from underwater acoustic telemetry arrays 2018.

Location	Month/Yr	Upload description.
OTN arrays: Hinchinbrook Ent, Montague St, SW Passages	2/18	All arrays uploaded, redeployed
Port Gravina	4/18	partial: 5 receivers uploaded, 4 redeployed
Port Gravina	6/18	partial: 3 receivers uploaded, 2 shoreline receivers retrieved, 1 redeployed
Hawkins Island	6/18	full: 3 receivers uploaded, redeployed 9/18
Southwest Passages	6/18 – 8/18	Partial: 2 receivers uploaded – 1 retrieved by recreational boater, other grappled
Hinchinbrook Entrance	9/18	partial: 8 receivers uploaded
Montague Strait	9/18	partial: 8 receivers uploaded
Northwest Montague Strait	9/18	2 months data uploaded from 3 receivers
Hinchinbrook Entrance	11/18	partial: 5 receivers uploaded

2017 Tagged Herring Movements to Entrances

Of the 124 fish tagged in April 2017 at Port Gravina, 59 herring were detected at the arrays located at the entrances to the Gulf of Alaska. Of these, 32 were recorded at one array (Hinchinbrook Entrance n = 28 ; Montague Strait n =4), while 27 were detected at 2 to 4 arrays. Of the 19 herring recorded at the Southwest Passage arrays, 17 were recorded at Elrington Passage, 5 at Prince of Wales, and 4 at LaTouche Passage. No herring were detected at the Bainbridge Passage.

Seasonality of herring detections at OTN arrays varied by location. Among the Southwest Passages, fish were detected only from May through September 2017 (range = 4-10 fish/month) with the peak number of individual fish detected in September. The number of fish detected at Hinchinbrook Entrance ranged from 10 to 21 per month between April and July but decreased to one fish per month during August and September. No fish were detected at Hinchinbrook between October 2017 and the February 2018 upload. Fish were detected at Montague Strait every month from May 2017 through February 2018 (range = 3-19 fish/month; Fig. 2).

We tested our hypothesis that fish in poor body condition would be less likely to migrate to the entrances. Logistic regression was used to determine if the probability of moving from Port Gravina to Gulf of Alaska entrances was associated with individual herring characteristics (weight [g], standard length [mm], condition, and sex) or release cohort. Fulton's Condition factor (k= weight$\cdot$ length^{-3}) was used as a measure of body condition. We constructed a series of univariate models and compared each model to a reduced single mean model using likelihood ratio tests (Wilks 1937).

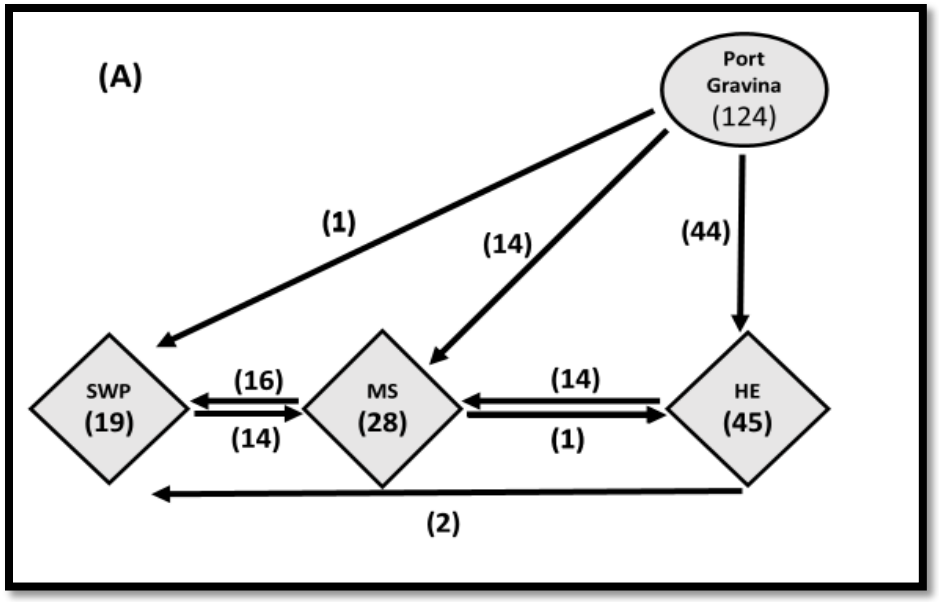

Figure 1. Movements of tagged herring from the Port Gravina spawning grounds to arrays at the entrances to the Gulf of Alaska, April 2017 to February 2018 when data was uploaded. SWP = the four southwest passages (LaTouche, Elrington, Prince of Wales, and Bainbridge); MS = Montague Strait; and HE = Hinchinbrook Entrance.

There was strong evidence that the probability of moving was related to weight, length, and sex, while there was little evidence that condition, or release cohort were associated with movement probability (Table 2). Comparing weight and standard length, movers weighed more (x = 128.1 $\pm$ 21.7 g (sd)) than non-movers (x = 117.4 $\pm$ 18.2 g) and were longer (x = 217.8 $\pm$ 12.8 mm) than non-movers (x = 212.4 $\pm$ 11.2 mm). Between the sexes, males moved more than females . Two multivariable models, one containing weight, sex, and the interaction, the other containing standard length, sex, and the interaction were evaluated by AIC, with the weight-containing model exhibiting the lowest AIC value (AIC=158.2 vs 162.0) thus being the overall most parsimonious model. However, upon evaluating the weight-only model, we found no significant interaction between weight and sex.

Table 2. Likelihood ratio test results examining probability of 2017 tagged herring moving from Port Gravina to the entrances at the Gulf of Alaska.

Model	**df**	χ^2	***p*-value**
move ~ Weight	1	8.55	0.003
move ~ Sex	1	7.10	0.007
move ~ Standard Length	1	5.96	0.015
move ~ Release cohort	9	10.12	0.341
move ~ Condition	1	0.64	0.422
move ~ Weight*Sex	1	0.630	0.427

2017 Tagged Herring Return Movements to Spawning Grounds

With an estimated battery life of 763 d, the V9 tags provided the first opportunity to document return to the spawning grounds by tagged herring. Of the 59 herring tagged in spring 2017 that were subsequently detected at the OTN arrays, 8 were detected returning to Port Gravina after October 2017, including two herring detected monthly in Port Gravina from November 2017 through April 2018 (Figs. 2, 3). Based on the last detection at an OTN array, four of the eight fish returned from Montague Strait, three from Hinchinbrook Entrance, and one from the Southwest Passages (Fig. 4). While the Hawkins Island array was not deployed until April 2018 when it was apparent that spawning would likely occur there, two herring tagged at Port Gravina in April 2017 were detected at the new Hawkins Island array during in April or May 2018 (Fig. 4).

April 2018 Tagging at Port Gravina and Hawkins Island.

Alaska Department of Fish and Game (ADF&G) flights (HRM Project 18160111-F) documented herring spawn along the southwest coast of Port Gravina on 7-8 April 2018 and at Canoe Pass (Hawkins Island) on 16-17 April 2018. We captured and acoustically tagged herring in Port Gravina on April 8 and 9 (n = 83) and at Hawkins Island from April 11-13 (n = 119) for a total of 202 herring released in 8 cohorts at their respective tagging site (Table 3). We tagged equal numbers of males and females at Port Gravina (n = 39 males, 39 females, 5 unknown). However, at Hawkins Island we tagged a preponderance of males (n = 67 males, 55 females, 0 unknown). Our results at Hawkins Island may be due to the fact our tagging took place 3-5 d before the initial spawn event at Hawkins Island, whereas our tagging efforts at Port Gravina coincided with spawning.

Table 3. Numbers of herring tagged by release date, April 2019, Port Gravina & Hawkins Island. "Buddies" refers to herring not acoustic-tagged but held and released with acoustic-tagged herring.

Cohort	Location	2018 Release date	Tagged	"Buddies"
1	Port Gravina	4/8	46	50
2	Port Gravina	4/9	10	10
3	Port Gravina	4/9	27	34
4	Hawkins Id.	4/11	37	47
5	Hawkins Id.	4/12	30	52
6	Hawkins Id.	4/12	19	45
7	Hawkins Id.	4/12	5	16
8	Hawkins Id.	4/13	28	50
Totals			202	304

Figure 2. Calendar plot of detections by tag identification number for 59 Pacific herring detected at Ocean Tracking Network and Port Gravina arrays between 9 April 2017 and 6 February 2018. Each dot represents presence for each day a given fish was detected.

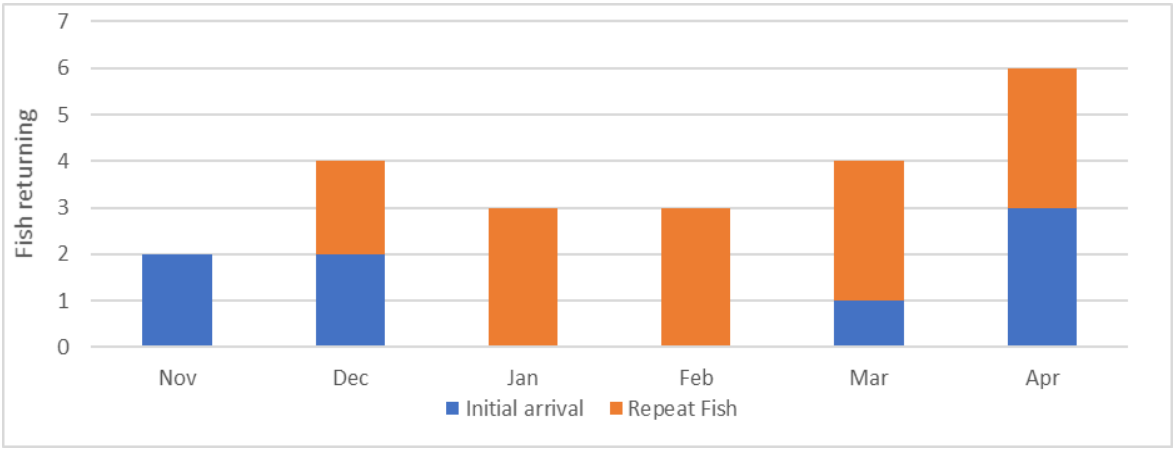

Figure 2. Number of herring acoustic-tagged during April 2017 and returning to Port Gravina by month from November 2017 through April 2018.

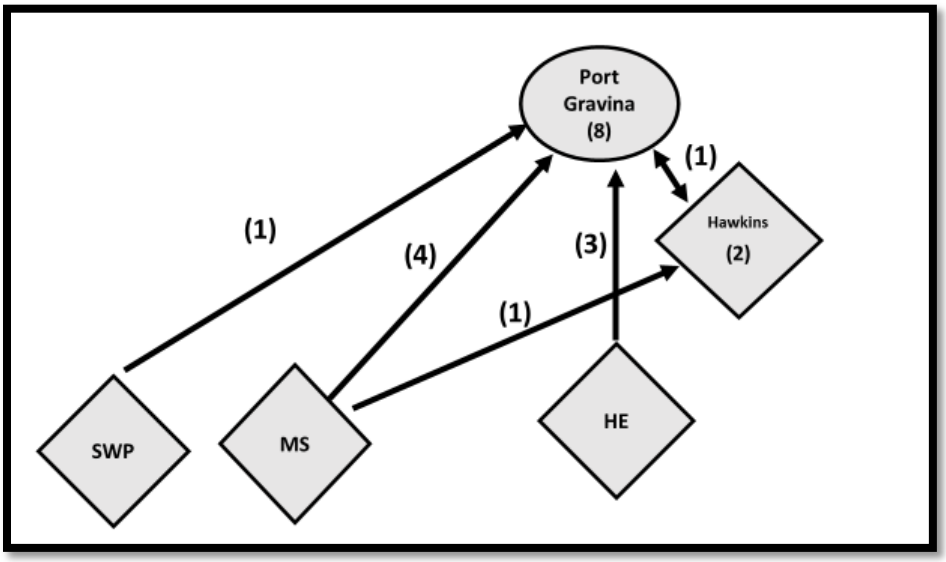

Figure 3. Return movements to the spawning grounds of herring acoustic-tagged at Port Gravina during April 2017. SWP = the four southwest passages (LaTouche, Elrington, Prince of Wales, and Bainbridge); MS = Montague Strait; HE = Hinchinbrook Entrance, Hawkins=Hawkins Island. The array at Hawkins Island was not installed until April 2018.

During our 2017 tagging efforts, the dominant herring age class in the population was 3-years old, and as a result we had difficulties finding and jigging larger (>200 mm) herring. Therefore, for 2018 we purchased 60 Vemco V-8 acoustic tags (8 mm diameter, 2 g air weight) with an estimated tag life of 246 d in addition to 150 of the larger (9 mm diameter) and heavier (4.7 g air weight) Vemco V-9 tags that have an estimated tag life of 755 d. For the V-8 tags, our target tagging size was herring ≤200 mm SL and <100 g mass, the average weight of a 5-year old in 2017 (S. Haught, ADF&G, unpubl. data). In all, 20 of the 60 fish tagged with V-8 tags weighed >100 g (max = 117 g). However, none of the 142 fish tagged with V-9 tags weighed <100 g (Table 4). Similar to 2017, larger fish were in low numbers. Only 10 of the 142 fish tagged with the V-9 tags were ≥ 230 mm SL with the largest herring captured 245 mm SL and 187 g mass (Fig. 5).

Table 4. Mean SL (mm) and mass (g) of Pacific herring by tagged April 2018 by tag type.

	V-8 n = 60		V-9 n = 142	
	x + sd	min, max	x + sd	min, max
SL (mm)	200.0 ± 5.6	185, 214	215.9 ± 8.5	199, 245
Mass (g)	96.8 ± 9.4	79, 117	129.3 ± 17.0	100, 187

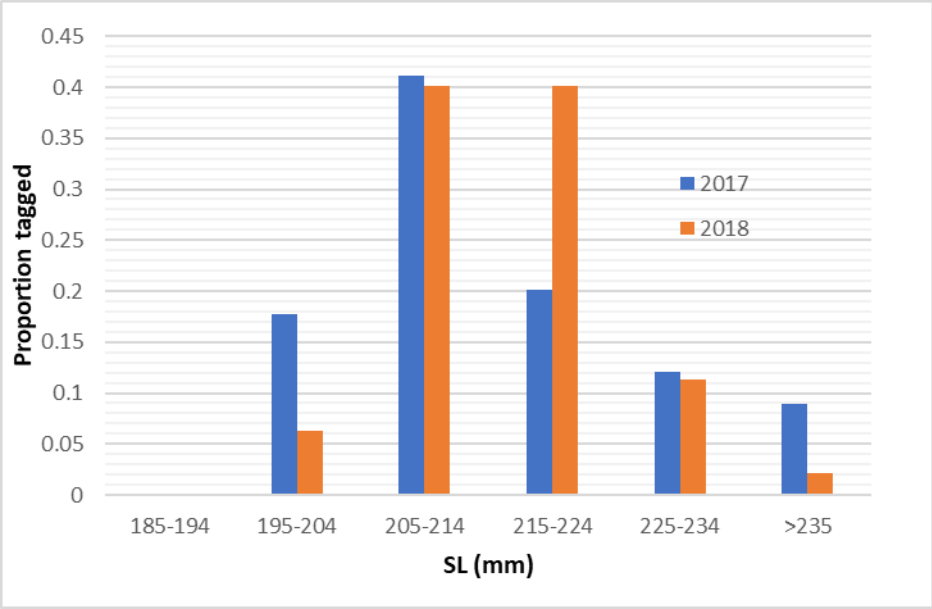

Figure 4. Proportion of tagged herring by year and standard length (SL, mm).

Over 90% of the herring tagged at Port Gravina were subsequently detected at the Port Gravina array that is located near Hells Hole and close to most release sites (Table 5). At Hawkins Island, the three receivers were not in close proximity to each other and the capture and release sites were not close to the receivers. Not surprisingly, a lower proportion of fish was detected. We did document movements between the two spawning areas. Of the 83 fish tagged at Port Gravina, 22 later moved and were recorded at Hawkins Island. Of the 119 herring tagged at Hawkins Island, 22 were detected at Port Gravina (Table 5).

Table 5. Number of herring by tag location and tag type, and subsequent number detected by location. Fish were tagged at Port Gravina on 8-9 April and at Hawkins Island 11-13 April 2018.

		Number Detected	
Tag location /Tag model	# Tagged	Port Gravina	Hawkins Island
Port Gravina			
V8	35	32 (91%)	7 (20%)
V9	48	43 (90%)	15 (31%)
Hawkins Island			
V8	25	6 (24%)	10 (40%)
V9	94	16 (17%)	69 (73%)

2018 Tagged Herring Movements to Entrances (preliminary results)

Based on partial uploads of the Hinchinbrook Entrance and Montague Strait arrays during September and November (Hinchinbrook only) 2018, as well as data uploaded from one receiver at LaTouche, 129 of the 202 (64%) herring tagged in April 2018 have been detected at the OTN arrays. These include 65% (93/142) of the V9 tagged fish, and 60% (36/60) of herring tagged using the smaller, V8 tags. More than one-half (102/202) of the 2018 tagged herring were first detected at Hinchinbrook Entrance. Twenty-two of the 202 tagged herring were first detected at Montague Strait. Similar to previous years, we observed a high number of movements to Montague Strait by fish first detected at Hinchinbrook Entrance (37 of 103), while only one fish moved from Montague Strait to Hinchinbrook Entrance (Fig. 6). While data from the Southwest Passages is still minimal (data from the 14 receivers in the passages are uploaded in February), data from the one receiver at LaTouche suggests high use (Fig. 6), especially when compared to the 2017 fish (Fig. 1).

While our results from the OTN arrays at entrances are not complete (because they are based on only a portion of the receivers uploaded) we do have some very interesting results. First detection at Hinchinbrook Entrance occurred on 19 April, while at Montague Strait the first detection occurred on 18 April (Fig. 7). Importantly, we detected five herring at Hinchinbrook Entrance between 19 October and 1 November. During our previous work, we had detected a fish only once during the fall months, in October 2013. Our February 2019 upload will elucidate if these were fish returning from the Gulf of Alaska.

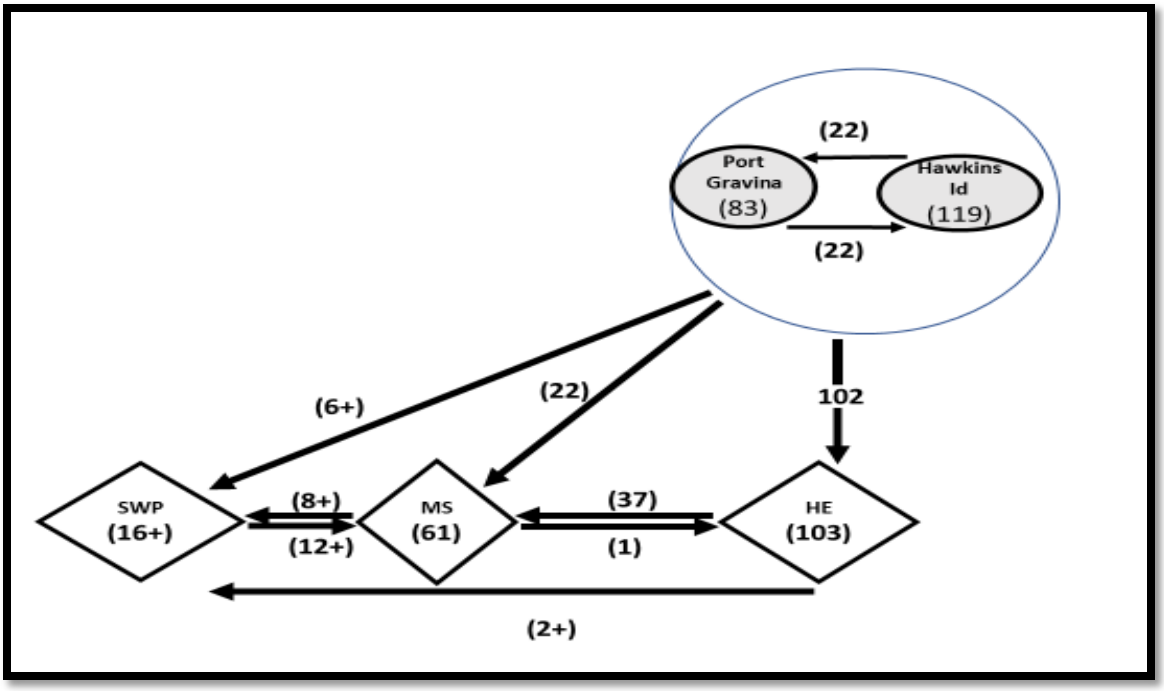

Figure 5. Preliminary results showing movements of tagged herring from the spawning grounds (Port Gravina and Hawkins Island) to arrays at the entrances to the Gulf of Alaska based on partial uploads of arrays at Hinchinbrook Entrance (HE), Montague Strait (MS), and Southwest Passages (SWP) April through November 2018. Southwest Passages data is from 1 receiver only at LaTouche Passage. Results from that receiver are followed by a + sign.

Future Work

Currently, April 2019 is scheduled to be the final tagging effort. The EVOSTC Science Panel has shown an interest in our efforts being continued. In their response to our FY19 workplan, the science panel asked, "*What would it take to tag 500 fish?".*

During the 2017 and 2018 tagging seasons, the spawning population was dominated by younger fish and the spawning period was relatively short. These conditions made it challenging to find schools to jig on and tag. Based on our experience, we feel we can comfortably tag 200-250 fish in a season, and of those, we estimate approximately 60-65% will be detected at the entrances.

By 2020, the dominant age class will be larger, and it will be easier to find and tag larger herring. If we were to add a 4th year of tagging in 2020 it would boost our sample size of fish that move to the entrances to between 470-500 fish (based on a minimum of 60% moving to the entrances). Estimated cost for FY20 would be ~$510K and for FY21 ~$265K.

Literature Cited

Wilks, S. S. 1937. The large-sample distribution of the likelihood ratio for testing composite hypotheses. Annals of Mathematical Statistics 9:60–62.

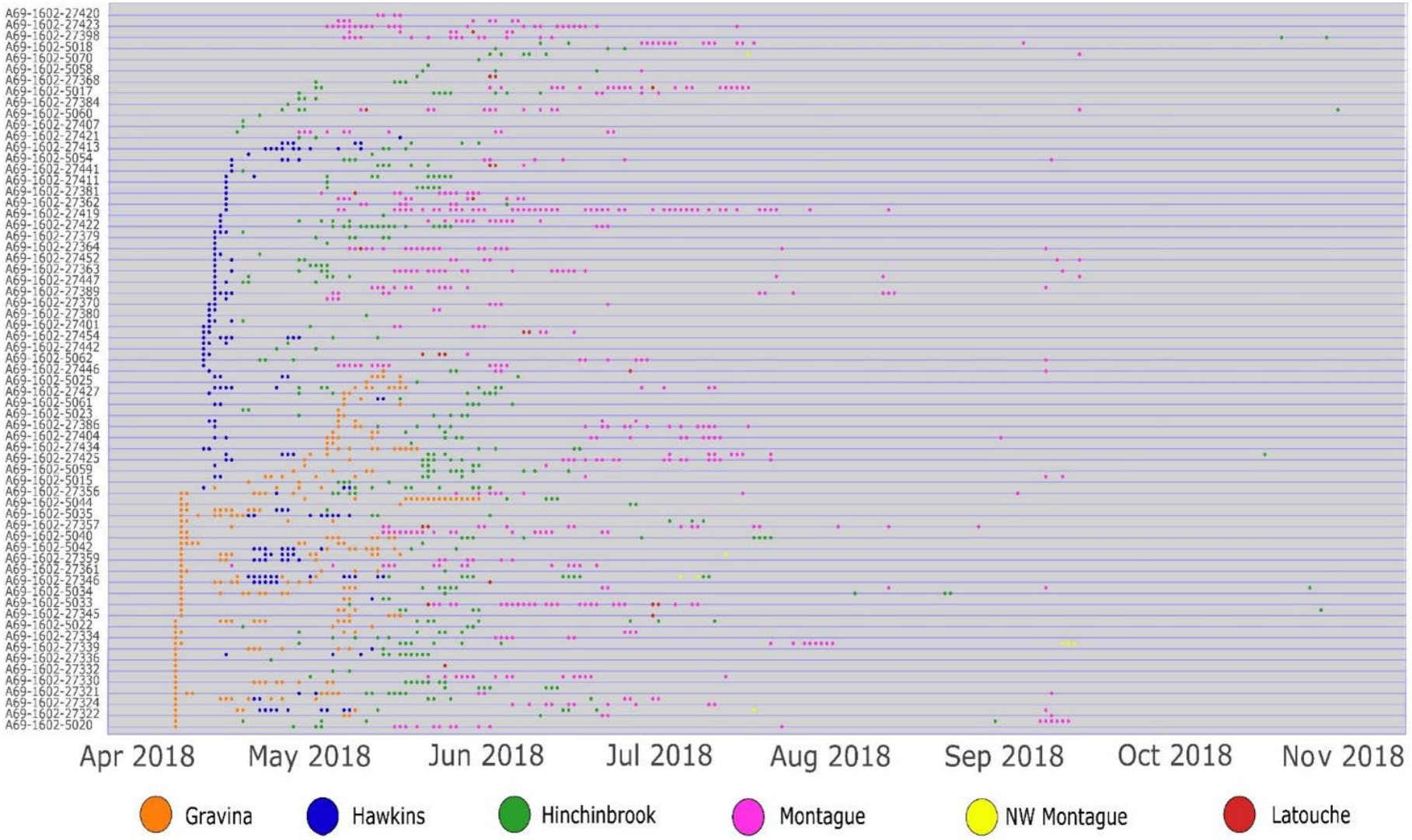

Figure 6. Calendar plot of detections by tag id for 129 Pacific herring tagged at Port Gravina and Hawkins Island spawning grounds, April-November 2018 and based on partial uploads from arrays. See Table 1 for upload dates and locations. Each dot represents a day a given fish was detected.

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 18160111-F, ADF&G, principal investigator (PI) Haught: During April 2018, we received critical information on timing and location of herring spawn.

Herring hydroacoustic surveys, Project 18120111-G, PWS Science Center, PI Rand: In April 2018, we received information from PI Rand's project on adult school locations.

Herring age at reproductive maturity, Project 18170111-D, PWS Science Center, PI Gorman: In July 2018, we assisted PI Gorman with sample processing of several hundred herring. In November 2018, we assisted PI Gorman with adult herring captures at Port Gravina, and in the lab with sample processing.

Herring Disease, Project 18120111-E, U.S. Geological Survey, PI Herschberger: In April 2018 we provided water samples from our tagging totes that were analyzed by PI Herschberger for presence of herring viruses.

2. Across Programs

a. Gulf Watch Alaska

PWS Oceanographic conditions, 18120114-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.

b. Data Management

Metadata is on file with Axiom (Research Workspace)

Research Workspace:

https://researchworkspace.com/project/283150/files

Ocean Tracking Network

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

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

c. Lingering Oil

None.

B. Projects not Within a Trustee Council-funded program

This project synergizes with efforts of the OTN (Fred Whoriskey, Ph.D. Executive Director, Dalhousie University) and with the Alaska Ocean Observing System (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 Whales, and Bainbridge. With FY16 *Exxon Valdez* Oil Spill Trustee Council funding, in February 2017, PWS Science Center expanded the OTN array.

Because biofouling was impacting detections by some of the receivers originally deployed in 2013, in 2018, OTN provided 18 additional VR2AR receivers to maintain the integrity of the array.

Currently, PWS Science Center maintains the array for OTN 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. For 2017-2021 the Alaska Ocean Observing Network has provided funding to cover the costs of maintaining the OTN arrays.

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 2018 to help locate adult herring schools in spring for capture and tagging. We also received age, weight, and length data from ADF&G that has helped us with aging the herring we captured during 2017 and 2018. Information derived from this project about herring migrations will be shared with ADF&G.

9. Information and Data Transfer:

A. Publications Produced During the Reporting Period

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

Gray, B., M.A. Bishop, and S.P. Powers. Structure of winter groundfish feeding guilds in Pacific herring *Clupea pallasii* and walleye pollock *Gadus chalcogrammus* nursery fjords *Journal of Fish Biology*. Accepted pending revisions, Jan 2019

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

Popular Science Articles:

2018 Delta Sound Connections

Bishop, M.A. How to tag a herring

Gray, B. Herring on the menu

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

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

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

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

Bishop, M.A. 2018. Tracking seasonal movements of adult Pacific herring in Prince William Sound. *Exxon Valdez* Oil Spill Long-Term Herring Research and Monitoring Program Final Report (*Exxon Valdez* Oil Spill Trustee Council Project 14120111-B), *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Bishop, M.A. 2018. Annual herring migration cycle: expanding acoustic array infrastructure. *Exxon Valdez* Oil Spill Long-Term Herring Research and Monitoring Program Final Report (*Exxon Valdez* Oil Spill Trustee Council Project 16160111-S), *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

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.

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 2018 and have been uploaded to the Research Workspace. Detection data were uploaded from OTN receivers through February 2018, our most recent, complete upload. 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.

10. Response to EVOSTC Review, Recommendations and Comments:

Sept 2017: Science Panel Comments - FY18 The Panel is once again very pleased with the quality of this proposal. These results are relevant and important; the PI has answered the questions that were asked.

Bishop response to Science Panel: Thank you.

11. Budget:

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
PROGRAM PROJECT BUDGET PROPOSAL AND REPORTING FORM

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	$138.1	$0.0	$535.0	$ 229.1
Travel	$1.2	$1.2	$1.2	$1.2	$0.0	$4.6	$ 1.9
Contractual	$23.6	$46.3	$52.9	$5.5	$0.0	$128.3	$ 58.0
Commodities	$118.7	$80.5	$5.0	$0.1	$0.0	$204.3	$ 121.0
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	$43.4	$0.0	$261.7	$ 123.0
SUBTOTAL	$350.3	$348.1	$253.0	$188.2	$0.0	$1,139.8	$550.2
General Administration (9% of subtotal)	$31.5	$31.3	$22.8	$16.9	$0.0	$102.6	N/A
PROJECT TOTAL	$381.9	$379.5	$275.8	$205.2	$0.0	$1,242.3	
Other Resources (Cost Share Funds)	$15.0	$15.0	$15.0	$15.0		$60.0	

Please note that our current balance does not reflect an outstanding invoice for our 2019 herring tags that accounts for the difference in the commodities. In addition, we have budgeted vessel charter costs to try and retrieve moorings that have not yet occurred because we are waiting for a weather window. These two costs, along with overhead, accounts for more than $100k.