**EVOSTC FY17-FY21 INVITATION FOR PROPOSALS**
**FY20 CONTINUING PROGRAM PROPOSAL SUMMARY PAGE**

**Program Number and Title**

20120111 Herring Research and Monitoring

**Primary Investigator(s) and Affiliation(s)**

W. Scott Pegau, Prince William Sound Science Center

**Date Proposal Submitted**

August 23, 2019

**Program Abstract**

The overall goal of the Herring Research and Monitoring (HRM) program is to: **Improve predictive models of herring stocks through observations and research**. The program objectives are to:

1) Expand and test the herring stock assessment model used in Prince William Sound.
2) Provide inputs to the stock assessment model.
3) Examine the connection between herring condition or recruitment to physical and biological oceanographic factors.
4) Develop new approaches to monitoring.

The program is made up of eight projects; Modeling and Stock Assessment of Prince William Sound Herring; Surveys and Age, Sex, and Size Collection and Processing; Adult Pacific Herring Acoustic Surveys; Herring Disease Program; Studies of Reproductive Maturity among Age Cohorts of Pacific Herring; Annual Herring Migration Cycle; Genomic Mechanisms Underlying Lack of Recovery; and HRM Coordination.

Through these projects we expect to address areas of interest outlined within the HRM section of the FY17-21 invitation for proposals and examine potential long-term impacts of oil exposure. The modeling project and the postdoctoral fellows are the primary integrating efforts that use data and information from all the projects and the Gulf Watch Alaska and Data Management programs, though there is a high level of coordination and integrations between all projects. The primary beneficiaries of our efforts are expected to be Alaska Department of Fish and Game, Prince William Sound herring fishermen, and, through publications, the larger scientific community.

Dr. Pegau serves as the program lead to ensure the proper coordination within the program, with other *Exxon Valdez* Oil Spill Trustee Council (EVOSTC)-funded programs, and as a point person for communications with the EVOSTC. An independent scientific oversight group exists that provides feedback on the program.

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

| FY17 | FY18 | FY19 | FY20 | FY21 | TOTAL |
|---|---|---|---|---|---|
| 1,252.9 | 1,578.8 | 1,996.9 | 1,986.8 | 1,425.1 | 8,240.6 |

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

| FY17 | FY18 | FY19 | FY20 | FY21 | TOTAL |
|---|---|---|---|---|---|
| 157.2 | 159.7 | 203.2 | 225.2 | 149.4 | 894.7 |

## 1. PROGRAM EXECUTIVE SUMMARY

The overall goal of the Herring Research and Monitoring (HRM) program is to: **Improve predictive models of herring stocks through observations and research**. The program objectives are to:

1) Expand and test the herring stock assessment model used in Prince William Sound (PWS).
2) Provide inputs to the stock assessment model.
3) Examine the connection between herring condition or recruitment to physical and biological oceanographic factors.
4) Develop new approaches to monitoring.

The program is made up of eight projects; Modeling and Stock Assessment of Prince William Sound Herring; Surveys and Age, Sex, and Size Collection and Processing; Adult Pacific Herring Acoustic Surveys; Herring Disease Program; Studies of Reproductive Maturity among Age Cohorts of Pacific Herring; Annual Herring Migration Cycle; Genomic Mechanisms Underlying Lack of Recovery; and HRM Coordination. Progress of the eight projects follow.

The Bayesian age structure analysis (BASA) model was run (project 19120111-C) and the model estimated higher biomasses than mile-days-milt and acoustic surveys the last two years. This resulted in examining the priors in the model associated with the survey coefficients of variation. There is continued work on the global herring meta-analysis. The manuscript describing this work has been revised and resubmitted. Results continue to highlight the unusually long period of low biomass and low recruitment in PWS herring compared to other herring populations around the world. Work is underway to examine the utility of the viral hemorrhagic septicemia virus (VHSV) antibody information in the model. Work continues with Drs. Groner and Hershberger to develop a better way to incorporate disease information into the estimation of natural mortality.

The post-doctoral fellow working with the modeling project (Dr. McGowan) has been examining the changes in timing and location of PWS herring spawn. He has also been gathering relevant time series to examine potential reasons for changes in the herring spawn and population biomass. The spawn location data have shown a movement in the primary spawning location over time and contraction in the primary spawning locations. The spawn timing has shown high interannual variability during periods of high and low spawning activity. The work is now shifting to examining whether the variations observed in Prince William Sound are observed in other Pacific herring populations.

The spring is the primary time for providing inputs to the stock assessment model. This is accomplished through surveys (project 19170111-F) of milt and age-sex-length sampling, acoustic biomass surveys (project 19120111-G), and disease prevalence (project 19120111-E). The beginning of spawn was earlier than expected. We had a vessel near the spawning grounds two days prior to the start of spawn and there was no evidence of fish building up. We were able to respond quickly enough to get aerial milt estimates. Fish from the spawning event were provided by a local subsistence fisherman to allow for age-sex-length analysis. In the same manner, we were also able to obtain a sample of fish from a spawning event that occurred after our sampling cruise ended. The initial estimate of the mile-days of milt is more than double what has been observed the last two years. The prevalence of the three diseases being monitored remained consistent with previous years. Acoustic surveys of the herring biomass were completed. We are awaiting the age and weight data to allow the completion of the biomass estimate from the acoustics survey and then from the BASA model.

The spawn in 2019 was prior to the planned dates for the tagging cruise (19160111-B); however, we tagged 165 herring for a total of 491 herring tagged between 2017 and 2019. The herring have been observed leaving the spawning area through Montague Strait and Hinchinbrook Entrance. Many of the fish spend the summer in the Montague Strait and Southwest passages. Some fish reappear near Port Gravina in November and appear to stay there. We will begin getting information from the expanded receiver array this coming winter.

The herring age-to-maturity project (project 19170111-D) continues to collect samples for histology and is beginning to examine the potential for using scale growth patterns to identify years that a fish is likely to have spawned. The histology results were held up due to issues with a contractor's lab, but those problems appear to have been resolved. June and July were identified as the most appropriate times to sample for the purpose of histology to look for evidence of recent spawning. November was identified as an appropriate sampling month for examining the gonad growth as an indicator of the likelihood to spawn the following spring. The project will begin work on the analysis of scales four specific cohort years to determine if it is likely to be able to identify differences in growth patterns between spawning and non-spawning herring.

Work within the disease project (project 19120111-E) continues to examine the kinetics of the VHSV antibody response by assessing how long antibodies can be detected. The antibodies are still being detected in 70% of the fish exposed to the virus after eighteen months. The technique for identifying if a herring has antibodies to VHSV is continuing to be refined. Working with the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) sponsored lingering oil research of Dr. Whitehead (project 19170115) an experiment to examine the relative susceptibility to VHS of oiled and unoiled herring from three populations (PWS, Sitka, Puget Sound). They found that the susceptibility was similar between oiled and unoiled herring.

The lingering oil project of Dr. Whitehead (project 19170115) was able to complete oil exposure experiments with herring from three locations (PWS, Sitka, Puget Sound) and challenge them with VHSV in collaboration with the disease project (project 1912011-E). Researchers' work on genome sequencing included examining the use of Hi-C technology, but ruled it out after quality control analysis showed the data were not reliable. The genome sequencing was completed through combining the available sequence with that of Atlantic herring. The genomic sequencing for the population libraries was completed. The comparison to the reference genome to identify variants is 95% complete.

The coordination effort (project 19120111-A) has worked on incorporating the Whitehead project into the HRM program. We have ensured the work on the synthesis is underway and designed to incorporate information from all current projects. We worked with an intern from Haverford College to image and measure growth of herring scales from 2016-2018 to update the image library completed by project 13120111-N. This allows us to examine changes in growth with the recent warm ocean conditions. Aerial surveys of forage fish were completed using funding from the Prince William Sound Regional Citizens' Advisory Council. This survey provides additional information on the number and location of age-1 herring schools. Dr. Groner continues to work with Dr. Hershberger on pathogen related studies. With additional funding from the North Pacific Research Board she has been able to examine historic intensities of *Ichthyophonus* to help understand when the infection becomes fatal. Dr. Groner also has been working on modeling of how VHSV may affect the PWS herring population.

## 2. PROGRAM STATUS OF SCHEDULED ACCOMPLISHMENTS

### A. Program Milestones and Tasks

Table 1. Program milestones and task progress by fiscal year and quarter, beginning February 1, 2017. Yellow highlight indicates proposed fiscal year workplan. C = completed, X = not completed or planned. 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 |
| **Expand and test model** | | | | | | | | | | | | | | | | | | | | |
| Simulate inclusion of new disease info | | | | C | | | | | | | | | | | | | | | | |
| Update model disease component | | | | | | | | | X | | | | | | | | | | | |
| Analysis of survey data to ASA | | | | | | | | | | | | | X | | | | | | | |
| Update on global herring meta-analysis | | | | | | | | | | | | X | | | | | | | | |
| Sample for Maturity | C | C | C | | C | C | C | | | | | | | | | | | | | |
| Decide on timing of maturity sampling | | | | | | | | | C | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| **Estimate spawning biomass** | | | | | | | | | | | | | | | | | | | | |
| Collect measurements during the spawn | C | | | | C | | | | C | | | | X | | | | X | | | |
| Complete sample analysis | | | C | | | | C | | | | X | | | | X | | | | X | |
| Complete model run | | | | | C | | | | C | | | | X | | | | X | | | |
| | | | | | | | | | | | | | | | | | | | | |
| **Examine connection between herring and environment** | | | | | | | | | | | | | | | | | | | | |
| Hire Postdoc | | | | | C | | | | | | | | | | | | | | | |
| Identify relevant data | | | | | | | | C | | | | | | | | | | | | |
| Analysis of Environmental linkage | | | | | | | | | | | X | | | | | | | | | |
| Identify environmental factors to include in model | | | | | | | | | | | | | | X | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| **Herring movement** | | | | | | | | | | | | | | | | | | | | |
| Tag herring | C | | | | C | | | | C | | | | | | | | | | | |
| Upload data | | | | | C | | | | C | | | | X | | | | | | | |
| Expand array | | | | | | C | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | |
| **Lingering oil** | | | | | | | | | | | | | | | | | | | | |
| Reference genome | | | | C | | | | | | | | X | | | | | | | | |
| Exposure experiments | | | | | | | | | C | | | | | | | | | | | |
| RNA sequence analysis | | | | | | | | | | | X | | | X | | | | | | |
| Population genomics | | | | | | | | C | | X | | | | | X | | X | | | |

| Milestone/Task | FY17 | | | | FY18 | | | | FY19 | | | | FY20 | | | | FY21 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| | | | | | | | | | | | | | | | | | | | | |
| **Reporting** | | | | | | | | | | | | | | | | | | | | |
| Annual reports | | | | | C | | | | C | | | | X | | | | X | | | |
| Annual PI meeting | | | | C | | | | C | | | | X | | | | X | | | | X |
| EVOSTC Joint Science Workshop Report | | | | | | | | | | | | X | | | | | | | | |
| FY work plan (DPD) | | | C | | | | C | | | | C | | | | X | | | | X | |
| Final Report | | | | | | | | | | | | | | | | | | | | X |
| | | | | | | | | | | | | | | | | | | | | |
| **Other** | | | | | | | | | | | | | | | | | | | | |
| Website updated | | | | C | | | | C | | | | X | | | | X | | | | X |
| Previous year data on workspace | | C | | | | C | | | | C | | | | X | | | | X | | |

**B. Explanation for not completing any planned milestones and tasks**

Updating the BASA model's disease component remains a work in progress. We are waiting for the work on improving the VHSV antibody detection technique (project 19120111-E) to ensure the highest quality data to feed into the model.

The work on the population genetics (project 19170115) is nearly, but not fully complete. It was delayed due to the work on the reference genome that needed to be completed first. Completion of the reference genome required an unexpected three months of effort to do the long-range ordering and scaffolding of our 10X Pacific herring genome with one provided for the closely related Atlantic herring.

**C. Justification for new milestones/tasks**

We added a milestone and tasks associated with the lingering oil project of Dr. Whitehead as we have incorporated that project into the HRM program. They are not highlighted in red because they represent existing efforts rather than new directions.

## 3. PROGRAM COORDINATION AND COLLABORATION

**A. Within an EVOSTC-funded Program**

*Herring Research and Monitoring*

Dr. Pegau is the program team leader and is responsible for ensuring a coordinated and focused research program that leverages other assets whenever possible. Within-program coordination is primarily through e-mail and phone communications. In-person meetings of participants are expected to occur once a year for exchange of information and to encourage collaboration between projects. The next meeting is scheduled for October 2019. This meeting is expected to be held the same week, but on different days as the Gulf Watch Alaska (GWA) investigator meeting to allow exchange between the groups.

Coordination between projects is also taking place through scheduling of vessels and aircraft. All the investigators are required to work together to determine vessel type and number of days needed. The primary overlap we have identified is during the spring adult herring surveys. In that case the vessel will be

shared by the Alaska Department of Fish and Game (ADF&G) age-sex-length sampling, and disease sampling. Aircraft used for externally funded forage fish surveys also help guide sampling efforts for collecting samples for the maturity project (19170111-D).

*Gulf Watch Alaska*

We will continue our collaborations with the GWA. The GWA science leads are included on the HRM email list so they are aware of what is going on in the HRM program. Administratively, the annual work plans and reports continue to be developed together. Our principal investigator (PI) meetings are scheduled in a manner to encourage individuals to work with people in the other programs. We will continue to work together to design topics for analysis and development of joint scientific manuscripts and cross-program synthesis proposals.

The HRM program is collecting detailed information on herring and processes that affect them. GWA monitors the oceanographic conditions that drive the growth and recruitment of the herring. One of the strongest connections between programs is through the HRM postdoctoral researchers (Drs. Groner and McGowan) whose research efforts bridge the HRM and GWA programs. Those efforts are looking at the impacts of biological and physical oceanographic conditions on herring populations in PWS. They continue to use the detailed information on herring collected in HRM to test the impacts of bottom-up forcing, using information from the environmental drivers component, and top-down forcing using information from the pelagic component.

The HRM modeling (project 19120111-C) effort includes expanding the BASA model to include environmental drivers and predation components of GWA. This creates a connection to the environmental drivers group and the GWA Pelagic Integrated Fall/Winter Predator Prey Surveys that conduct surveys for forage fish, humpback whales, and marine birds.

*Data Management*

We continue to work with the Data Management team to ensure data is submitted in a timely manner. The data management lead is on the general mailing list for HRM to ensure they are aware of what is happening.

### B. With Other EVOSTC-funded Projects

We have integrated the lingering oil project of Dr. Whitehead into the HRM program. We do not have connections to other EVOSTC-funded projects.

### C. With Trustee or Management Agencies

ADF&G is the primary trustee and management agency that the HRM program interacts with. The success of the program is highly dependent on the historical information collected by ADF&G and the expertise within the agency, so it is imperative that we work with the agency. We will continue to have an ADF&G employee (Dr. Sherri Dressel) on our scientific oversight group. ADF&G sampling within the program ensures we have the data needed to understand recovery of herring. Interactions with Stormy Haught, in Cordova, have provided a close connection between the HRM program and ADF&G. In the past year, we participated in the discussion of aging herring using scales to try and get greater reader agreement. We have also worked with an intern to update the scale image library originally put together by ADF&G (10100132-N). They imaged and measured scale growth from fish collected in 2016 through 2018 to update the database.

## 4. PROGRAM DESIGN

### A. Overall Program Objectives

The overall goal of the HRM program is to: **Improve predictive models of herring stocks through observations and research**. The program objectives are to:

1) Expand and test the herring stock assessment model used in Prince William Sound.
2) Provide inputs to the stock assessment model.
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4) Develop new approaches to monitoring.

### B. Changes to Program Design and Objectives

For the most part, we intend to continue with the originally proposed approach for addressing each of these objectives. We incorporated the lingering oil project of Dr. Whitehead (20170115) to provide better connections to related herring projects. We added samples for disease analysis to project 19120111-E. The additional samples will be used to determine if there is age- or year- dependency to patterns of VHS outbreaks. We are also looking to extend the tagging effort (project 19160111-B) by a year to meet the sampling suggestions from the EVOSTC Science Panel.

This past year the herring spawn began before expected and we missed some early spawning with the acoustics and age-sex-length sampling. We had a vessel in the area two days before the spawn and there was no indication of a buildup of fish that would indicate that spawning was likely to occur soon. We were fortunate to receive fish samples from Tatitlek and Cordova residents who were in the area of the spawn, which will allow us to have an idea of the age-structure of those early spawners. The sample from the Cordova residents was collected using a cast net in a manner similar to ADF&G and the sample from Tatitlek is from a subsistence gill net. Based on the size of the fish, it appears that these early spawners were older fish that we have not observed the past couple of years. We await official age estimates, but the discussion about why we might not have observed these fish in the past has already begun.

## 5. PROGRAM PERSONNEL – CHANGES AND UPDATES

There have not been any changes to the PIs or senior personnel.

## 6. PROGRAM BUDGET

### A. Budget Forms

***EXXON VALDEZ* OIL SPILL TRUSTEE COUNCIL**
**PROGRAM 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 | $515.1 | $741.7 | $961.4 | $987.8 | $747.3 | $3,953.3 | $0.0 |
| Travel | $37.1 | $47.9 | $45.4 | $44.5 | $40.6 | $215.4 | $0.0 |
| Contractual | $198.7 | $221.9 | $218.7 | $200.9 | $175.1 | $1,015.3 | $0.0 |
| Commodities | $192.6 | $160.6 | $159.0 | $196.7 | $100.8 | $809.7 | $0.0 |
| Equipment | $5.9 | $0.0 | $50.3 | $0.0 | $0.0 | $56.2 | $0.0 |
| Indirect Costs (*will vary by proposer*) | $200.1 | $276.5 | $397.3 | $392.9 | $243.7 | $1,510.4 | $0.0 |
| **SUBTOTAL** | $1,149.5 | $1,448.5 | $1,832.0 | $1,822.8 | $1,307.4 | $7,560.2 | N/A |
| General Administration (9% of subtotal) | $103.5 | $130.4 | $164.9 | $164.0 | $117.7 | $680.4 | |
| **PROJECT TOTAL** | $1,252.9 | $1,578.8 | $1,996.9 | $1,986.8 | $1,425.1 | $8,240.6 | |
| Other Resources (Cost Share Funds) | $157.2 | $159.7 | $203.2 | $225.2 | $149.4 | $894.7 | N/A |

### B. Changes from Original Project Program

The following modifications are requested in FY20.

The addition of $22,500 to the Hershberger proposal (project 20120111-E) to collect and analyze addition samples for the presence of VHSV neutralizing antibodies to examine if there is an age-related component. This was a budget modification requested, and granted, in 2018.

Funding for the third year for the postdoctoral researcher working with Trevor Branch (project 20120111-C). The addition of the postdoctoral position was requested, and granted, in 2018 with the understanding that it is a three-year position.

We are requesting $10,000 (+3,000 indirect) for ship time to be added to the acoustic survey proposal (project 20120111-G) to allow better survey coverage. This request was originally approved in FY18 with an understanding we would make the same request in subsequent years.

Project 20160111-B (herring tagging) is requesting funding for an additional year of tagging effort in response to the EVOSTC Science Panel recommendation for additional samples. Originally FY20 was planned as an analysis year with no funding requested in FY21. To complete the additional tagging effort we budgeted $398,300 in FY20 for tagging and $250,300 in FY21 for completing the analysis.

We are requesting an additional $10,000 in salary (+$3,000 overhead) in the coordination project (20120111-A) to hire Donna Aderhold to provide additional review of HRM documents being submitted to the EVOSTC.

### C. Sources of Additional Program Funding

Please see individual work plans for a full description of matching funds.

## 7. FY17-19 PROGRAM PUBLICATIONS AND PRODUCTS

*Publications*

Aderhold, D. G. R., M. R. Lindeberg, K. Holderied, and W. S. Pegau. 2018. Spatial and temporal ecological variability in the northern Gulf of Alaska: What have we learned since the *Exxon Valdez* oil spill? *Deep Sea Research II.* 147:3-8. DOI 10.1016/j.dsr2.2017.11.015

Ben-Horin, T., Groner, M. L., Bidegain, G., McCallum, H., Powell, E., Hofmann, E. *In press.* Modeling and forecasting disease dynamics in the sea. *Marine disease ecology.* Ed. Lafferty, K.

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. 2018. Tracking Seasonal Movements of Adult Pacific Herring in Prince William Sound. *Exxon Valdez* Oil Spill Restoration Project Final Report (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 Restoration Project Final Report (Project 16160111-S), *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Brown, C. J., A. Broadley, M. F. Adame, T. A. Branch, M. P. Turschwell, and R. M. Connolly. 2019. The assessment of fishery status depends on fish habitats. Fish and Fisheries 20:1-14.

Gephart, J. A., H. E. Froehlich, and T. A. Branch. 2019. To create sustainable seafood industries, the United States needs a better accounting of imports and exports. Proceedings of the National Academy of Sciences U.S.A. 116:9142-9146.

Gorman, K. B., T. C. Kline, M. E. Roberts, F. F. Sewall, R. A. Heintz, and W. S. Pegau. 2018. Spatio-temporal variation in stable carbon and nitrogen isotope signatures and condition of juvenile herring (*Clupea pallasii*) in Prince William Sound, Alaska: teleconnections with the Gulf of Alaska. *Deep Sea Research II* 147:116-126. DOI 10.1016/j.dsr2.2017.10.010

Gorman, K. B., T. C. Kline Jr., F. F. Sewall, R. A. Heintz, and W.S. Pegau. *In prep*. Changes in condition of Pacific Herring (*Clupea pallasii*) during their first overwinter period. *EVOS juvenile herring intensives project.*

Gorman, K. B., M. E. Roberts, T. C. Kline Jr., and W. S. Pegau. *In prep*. Comparing calorimetric and stable isotope-derived measures of energy density among juvenile Pacific herring (*Clupea pallasii*). Fisheries Research.

Gorman, K. B., F. F. Sewall, and R. A. Heintz. *In prep*. Winter foraging among juvenile Pacific herring in Prince William Sound, Alaska: Stable isotope ellipses and diet composition. *EVOS juvenile herring condition monitoring project.*

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

Gray, B., M.A. Bishop, and S.P. Powers. *In prep*. Winter variability in the diets of groundfish predators of Pacific Herring and Walleye Pollock in a subarctic sound.

Harris, B.P., S.R. Webster, J.L. Gregg, P.K. Hershberger. 2018. *Ichthyophonus* in sport-caught groundfishes from southcentral Alaska. Diseases of Aquatic Organisms 128:169-173.

Hart, L.M., M.K. Purcell, R. Powers, A. MacKenzie, P.K. Hershberger. 2017. Optimization of a plaque neutralization test to identify the exposure history of Pacific herring to viral hemorrhagic septicemia virus (VHSV). Journal of Aquatic Animal Health 29:74-82.

Hart, L.M., N. Lorenzen, K. Einer-Jensen, M. Purcell, P.K. Hershberger. 2017. Influence of temperature on the efficacy of homologous and heterologous DNA vaccines against viral hemorrhagic septicemia (VHS) in Pacific herring. Journal of Aquatic Animal Health 29:121-128.

Hershberger PK, MacKenzie AH, Gregg JL, Lindquist A, Sandell T, Groner ML, Lowry D. *In press.* A geographic hot spot of *Ichthyophonus* infection in the southern Salish Sea, USA. Diseases of Aquatic Organisms.

Lowe, V.C., P.K. Hershberger, C.S. Friedman. 2018. Analytical and diagnostic performance of a qPCR assay for *Ichthyophonus* spp. compared to the tissue explant culture 'gold standard'. Diseases of Aquatic Organisms 128:215-224.

McGowan, D. W., T. A. Branch, and S. Haught. *In prep*. Multi-decadal space and time shifts in Pacific herring spawning in Prince William Sound, Alaska. Canadian Journal of Fisheries and Aquatic Sciences.

Monnahan, C. C., T. A. Branch, J. T. Thorson, I. J. Stewart, and C. S. Szuwalski. 2019. Overcoming long Bayesian run times in integrated fisheries stock assessments. ICES Journal of Marine Science https://doi.org/10.1093/icesjms/fsz059.

Muradian, M. L., T. A. Branch, S. D. Moffitt, and P.-J. F. Hulson. 2017. Bayesian stock assessment of Pacific herring in Prince William Sound, Alaska. PLoS One 12:e0172153.

Muradian, M. L., T. A. Branch, and A. E. Punt. *In review*. A framework for assessing which sampling programs provide the best trade-off between accuracy and cost of data in stock assessments. ICES Journal of Marine Science.

Oziolor, E.M., N.M. Reid, S. Yair, K.M. Lee, S. Guberman VerPloeg, P.C. Bruns, J.R. Shaw, A. Whitehead, and C.W. Matson. 2019. Adaptive introgression enables evolutionary rescue from extreme environmental pollution. *Science* 364:455-457.

Russell, C. W., J. Botz, S. Haught, and S. Moffitt. 2017. 2016 Prince William Sound area finfish management report. Alaska Department of Fish and Game, Fishery Management Report No. 17-37, Anchorage.

Shore-Maggio, A., M. L. Groner, C. A. Burge, R. Carnegie, and P. Hershberger. *In prep.* Disease transmission in managed marine systems.

Trochta, J. T., T. A. Branch, A. O. Shelton, and D. E. Hay. *In review*. The highs and lows of herring: A meta-analysis of patterns in herring collapse and recovery. Fish and Fisheries.

Trochta, J. T., and T. A. Branch. *In prep*. Bayesian analysis of oceanographic and ecological drivers of Pacific herring population dynamics. ICES Journal of Marine Science.

Trochta, J. T., M. Pons, M. B. Rudd, M. Krigbaum, A. Tanz, and R. Hilborn. 2018. Ecosystem-based fisheries management: Perception on definitions, implementations, and aspirations. PLoS One 13:e0190467.

Vega, S. L., C. W. Russell, J. Botz, and S. Haught. 2019. 2017 Prince William Sound area finfish management report. Alaska Department of Fish and Game, Fishery Management Report No. 19-07, Anchorage.

Ward, E. J., M. Adkison, J. Couture, S. C. Dressel, M. A. Litzow, S. Moffitt, T. Hoem Neher, J. Trochta, and R. Brenner. 2017. Evaluating signals of oil spill impacts, climate, and species interactions in Pacific herring and Pacific salmon populations in Prince William Sound and Copper River, Alaska. PLoS One 12:e0172898.

*Published and updated datasets*

The forage fish aerial survey data collected in 2019 were added to the forage fish data available from the Alaska Ocean Observing System Gulf of Alaska data portal.

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

The 2018 BASA stock assessment has been uploaded to the AOOS research workspace, together with the model formulation and underlying data.

Sequence reads for all 1,237 Pacific herring genomes have been uploaded to the European Nucleotide Archive (Study ID PRJEB27171 (ERP109223))

*Presentations*

Bravo, E., C. Conway, P. Hershberger, J. Gregg, M. Groner. October 11-13, 2018. Poster. Do histological analyses of herring infected with *Ichthyophonus* sp. suggest a shift from endemic to epidemic disease? Society for the Advancement of Chicanos / Hispanics and Native Americans in Science. San Antonio, TX.

Cypher, A. D., P. Hershberger, N. Scholz, J. P. Incardona. January 3-7, 2019. Larval cardiotoxicity and juvenile performance are likely contributors to the delayed fishery collapse of Pacific herring after the *Exxon Valdez* oil spill. Society for Integrative & Comparative Biology Annual Meeting. Tampa, FL.

Gray, B. P., M. A. Bishop, and S. P. Powers. 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. Alaska Marine Science Symposium, Poster, January 2018. Anchorage

Groner, M., E. Bravo, C. Conway, J. Gregg, and P. Hershberger. January 28-31, 2019. Poster. A quantitative histological index to differentiate between endemic and epidemic ichtyhophoniasis in Pacific herring. Alaska Marine Science Symposium. Anchorage, AK.

Hershberger, P. K., A. H. MacKenzie, J. L. Gregg, M. D. Wilmot, R. Powers, M. K. Purcell. June 20-22, 2017. Platform. Long term shedding of viral hemorrhagic septicemia virus from Pacific herring. 58th Western Fish Disease Workshop. Suquamish, WA.

Hershberger, P. K., L. Hart, A. MacKenzie, R, Powers, M. Purcell. January 23-27, 2017. Poster. Quantifying the potential for disease impacts to Pacific Herring. Alaska Marine Science Symposium. Anchorage, AK.

MacKenzie, A. H., J. L. Gregg, M. D. Wilmot, T. Sandell, D. Lowry, P. K. Hershberger. June 20-22, 2017. Poster. Temporal and spatial patterns of *Ichthyophonus* in Pacific herring throughout the southern Salish Sea. 58th Western Fish Disease Workshop. Suquamish, WA.

McGowan, D. W. January 2019. Spatial and temporal variations in Pacific herring spawning in Prince William Sound, presented at AMSS, Poster, Anchorage, AK.

Trochta J. T, and T. A. Branch. January 2019. Evaluating the effects of a changing ecosystem on Pacific herring (*Clupea pallasii*) in Prince William Sound, Alaska, presented at AMSS, Poster, Anchorage, AK.

Trochta J. T., A. D. MacCall, D. W. McGowan, and T. A. Branch. October 2018. Incorporating spawn surveys in a semi-spatial stock-recruitment model, presented at CAPAM Spatial Workshop, La Jolla, CA.

Trochta J. T, and T. A. Branch. April 2017. An investigation of popular hypotheses on the survival of Pacific herring in Prince William Sound, Alaska using Bayesian model selection, presented at SAFS Think Tank, Seattle, WA.

Trochta J. T., T. A. Branch, A. O. Shelton, and D. E. Hay. March 2017. Insights into the Dynamics of Atlantic and Pacific Herring Following Population Collapse, presented at the PICES International Symposium on Drivers of dynamics of small pelagic fish resources, Victoria, British Columbia, Canada.

Wendt, C., P. Hershberger, C. Wood. January 28-31, 2019. Poster. Patterns of *Ichthyophonus* sp. infection in age zero Pacific herring. Alaska Marine Science Symposium. Anchorage, AK.

*Outreach*

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

Bishop, M.A. 2018. How to tag a herring. *Delta Sound Connections*

Bishop, M.A. 2019. Time to spawn! *Delta Sound Connections*

Gorman, K. 2018. Reproductive Maturity of Pacific Herring. *Delta Sound Connections*

Gorman, K. 2019. Variability in Seasonal Gonad Development of Herring. *Delta Sound Connections*

Gray, B. 2019. Ping! Tracking fish using passive acoustic technology. *Delta Sound Connections*

Gray, B. 2018. Herring on the menu. *Delta Sound Connections*

Groner, M. 2019. 'Ich-Y' Diseases in Pacific Herring. *Delta Sound Connections*

Hershberger, H. 2017. Assessing the Impacts of Disease in Pacific Herring. *Delta Sound Connections*

Hershberger, H. 2018. Forecasting Disease Potential in Pacific Herring. *Delta Sound Connections*

Haught, S. 2018. Aerial Surveys of Pacific Herring. *Delta Sound Connections*

Haught, S. 2019. Mile-Days of Milt. *Delta Sound Connections*

Hoover, H. 2017, 2018, 2019. The need for Herring Research and Monitoring. *Delta Sound Connections*

Pegau, S. 2019. Changes in Forage Fish. *Delta Sound Connections*

Rand, P. 2018. The dynamics of Herring and Predators in Prince William Sound. *Delta Sound Connections*

Trocta, J. and T. Branch. 2017. Comparing and Contrasting Herring Collapse. *Delta Sound Connections*

Trocta, j. 2019. Herring Models: Why and How They Are Used. *Delta Sound Connections*

Bishop, M. A. and B. Gray. 2019. How to tag a herring and where do they go afterwards? PWSSC Tuesday Night Science Lecture Series. January 2019. Cordova.

Haught, S. "ADF&G PWS Herring Surveys." Prince William Sound Science Center Tuesday Night Talk Series, December 18, 2018, Cordova.

Branch continues to maintain an active science outreach program on a wide variety of fisheries-related topics on social media (Twitter, @TrevorABranch), with 10,800 followers, and 6.3 million views of his tweets during FY19 to date.

We completed updates to the website (http://pwssc.org/research/ ) for all of the ongoing projects within the HRM program and continue updating past projects to include more findings.

We drafted additional podcasts of current HRM projects and are working on modifying the length to make them appropriate for broadcast on the local public radio station. The podcasts can be found at http://pwssc.org/education/field-notes/ and linked within the individual project posts.

In 2018 Hayley Hoover attended a meeting with Chugachmiut Heritage Preservation local education coordinators and elders from Tatitlek, Chenega Bay, Port Graham, and Nanwalek. That was followed by Dr. Groner participating in a listening session with members of GWA in Port Graham in 2018.

Two herring research programs presented on their work during the Prince William Sound Science Center (PWSSC) sponsored Tuesday Night Talks.

Dr. Groner, in collaboration with Dr. Paul Hershberger (project 19120111-D), used both *Ichthyophonus* and Viral Hemorrhagic Septicemia (VHS) in herring as case studies in a 5-week graduate-level course on infectious marine diseases that she co-taught at the University of Washington's marine field station, Friday Harbor Labs. In addition to receiving lectures by both Groner and Hershberger on both diseases, students learned how to dissect herring and set up plaque assays to evaluation VHS infections. In addition, students in the course worked with Dr. Groner to develop an epidemiological model examining the influence of fishing and temperature on VHS outbreaks and related mortality in herring populations. This work is being further developed for publication. These students will be co-authors on the final project.