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

Program Number and Title

21120111 Herring Research and Monitoring

Primary Investigator(s) and Affiliation(s)

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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 currently has seven 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; 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 integration 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
$1,396,200	$1,893,400	$1,996,900	$1,817,200	$1,320,700	$8,424,400

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

FY17	FY18	FY19	FY20	FY21	TOTAL
$157,200	$159,700	$203,200	$225200	$149,400	$894,700

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. Funding for the Studies of Reproductive Maturity project ended in FY20 and no funding is requested in FY21 for that project. Progress of the seven remaining projects follow. More detail can be found in the individual project proposals.

The Bayesian age structure analysis (BASA) model was run (project 20120111-C) and predicted that the recruitment of age-3 herring in 2019 was the highest since 2002; however, the prediction is based on a single observation of the large 2019 age-3 year class. Several studies examined why in recent years the model estimated higher biomasses than mile-days-milt and acoustic surveys. Investigations into this model mis-specification included placing different priors on survey coefficient of variation (CV; fixing the CV to 0.15, 0.2, 0.3, and 0.4), allowing for autocorrelated recruitment, and fixing the sex ratio. As expected, the lower the survey CV was set, the more closely the model fitted to mile-days-milt and acoustic survey data, and estimates a lower biomass in the recent past. This year, additional checks included down-weighting age composition data, an alternative model of disease, and estimating a regime shift in mean recruitment. Down-weighting the age-composition data resulted in much better fits to biomass indices and lowered the estimated biomass in recent years in a manner consistent with the mile-days-milt and acoustic survey data. Incorporating a shift in mean recruitment also lowered the biomass estimate, but to a lesser extent. Analyses are ongoing to improve fits and reduce estimation bias in the model. An analysis of the maturity schedule found that the model results are not sensitive to the maturity schedule and a single maturity schedule is now being estimated across all years rather than estimates for two distinct periods as was previously done.

The work on the global herring meta-analysis has now been published (Trochta et al. 2020). Results highlight the unusually long period of low biomass and low recruitment in PWS herring compared to other herring populations around the world. Project researchers examined factors that may be used to improve estimation of PWS herring recruitment and natural mortality. Initial results show that none of the environmental predictors (Pacific Decadal Oscillation, North Pacific Gyre Oscillation, PWS zooplankton, hatchery release pink salmon, age-1 Walleye pollock, freshwater discharge, age-1 scale growth, and 1989 regime shift) improved model fit with recruitment. Predictors for natural mortality that improved model fits included total pink salmon returns, winter North Pacific Gyre Oscillation (NPGO), and Gulf of Alaska pollock spawning biomass. Project researchers continue to work with the disease researchers to examine the utility of the viral hemorrhagic septicemia virus (VHSV) antibody information in the model. A simulator of VHSV disease outbreaks, and an estimation model, to test whether it is possible to use antibody data to estimate disease prevalence and mortality has been developed and has provided promising results that will help with the incorporation of the antibody information.

The post-doctoral fellow working with the modeling project (Dr. McGowan) examined the spatial and temporal variability in herring spawn within PWS. He has transitioned to a new position with the National Oceanic and Atmospheric Administration (NOAA) and was replaced by Dr. Dias. Dr. McGowan found a movement in the primary spawning location over time and contraction in the spawning area. The spawn timing has shown high interannual variability. The work is now shifting to examining whether the spatial and temporal variations observed in Prince William Sound are observed in other Pacific herring populations and to examine how changes in spawn timing may affect first year survival.

Spring is the primary time for gathering data for input into the stock assessment model. This is accomplished through surveys of milt and age-sex-length (ASL) sampling (project 20170111-F), acoustic biomass surveys of pre-spawning herring (project 20120111-G), and disease prevalence in pre-spawning herring (project 20120111-E). The outbreak of COVID-19 and associated work and travel restrictions occurred right at the beginning of the herring spawning season. The acoustic biomass surveys were already underway, and the researchers were able to complete their work. It was determined that the milt surveys could occur, but the normal ASL sampling cruise was canceled. We were able to recruit a local fisherman, and worked with the program vessels that were able to go out, to collect the necessary samples for ASL determination and for the disease project. Fish collections were limited to cast nets and jigs versus the normal seine and cast net collections. Prince William Sound Science Center (PWSSC) and Alaska Department of Fish and Game (ADF&G) personnel were able to process herring for two of the three disease prevalence time series. The preliminary estimate of the mile-days of milt is approximately double what was observed last year. Initial age composition data suggests this was caused by continued recruitment of fish from the 2016 year class into the spawning population. The prevalence of *Ichthyophonus* and VHSV antibodies were both lower than normal and may also be due to the 2016 year class, that has a low prevalence of those diseases, dominating the age composition. 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.

We received permission from the State to conduct the herring tagging work in April 2020 despite the COVID-19 work restrictions. A total of 235 herring were tagged in 2020 for a total of 726 herring tagged between 2017 and 2020. From the detection of tags, we were able to determine that of the 165 fish tagged in 2019, 81% (n = 133) were detected at one or more of the Ocean Tracking Network (OTN) arrays. Among the arrays, Hinchinbrook Entrance was the most common, 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 higher proportion of 2019 fish were detected at Hinchinbrook Entrance. A range test was conducted to determine detection probability.

The Principal Investigator of the herring age-to-maturity project (project 19170111-D) continues to analyze the data collected and is working on a final report. This project is not included in the proposed projects for FY21.

Work within the disease project (project 20120111-E) found that VHSV antibodies were still detectable nearly three years after the herring was exposed to the virus. The refinement to the serological assay (50% plaque neutralization assay [PNT]) technique for identifying if a herring has antibodies to VHSV are complete. The refined PNT technique did not significantly change the percent of fish in PWS samples in which the antibodies were observed but did significantly alter the number of antibodies detected. In field samples, the percent of herring with antibodies present was found to increase with age of the herring. The project is working with the modeling effort (20120111-C) to incorporate the VHSV findings into the model. Dr. Hershberger worked with the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) sponsored lingering oil research of Dr. Whitehead (project

20170115) to conduct an experiment to examine the relative susceptibility to VHS of oiled and unoiled herring larvae after metamorphis. They found that the susceptibility to VHSV is lower in herring exposed to low levels of oil as larvae.

The lingering oil project of Dr. Whitehead (project 20170115) was able to sequence whole transcriptomes from 432 samples gathered from a multi-population oil exposure experiment comprising: 1) three populations of Pacific herring; 2) five levels of oil concentrations; and 3) five developmental time-points during embryogenesis. These fish were challenged with VHSV in collaboration with the disease project (project 2012011-E). Higher throughput and less expensive DNA testing allowed the sample size to be increased. A decision was made to re-do the genome sequence work since longer-read technologies had become affordable enough to justify the new approach. This also overcame the issues with the Hi-C library data that was reported last year. The population genomics work was slowed due to a change in the postdoctoral research associate working on the project. A course resolution analysis is complete and shows a separation of the southern (California and Washington), Gulf of Alaska, and Bering Sea populations. Finer geographic resolution work is underway.

The coordination effort (project 20120111-A) worked with all project to complete and present the synthesis effort. We are currently working to incorporate the EVOSTC Science Panel comments into the synthesis. 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. Groner has been working on modeling of how VHSV may affect the PWS herring population and the role of *Ichthyophonus* in population dynamics.

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													C							
Update on global herring meta-analysis												C								
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				C				X			
Complete sample			C				C				C				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
analysis																				
Complete model run					C				C				C				X			
Examine connection between herring and environment																				
Hire Postdoc					C															
Identify relevant data								C												
Analysis of Environmental linkage											C									
Identify environmental factors to include in model														C						
Herring movement																				
Tag herring	C				C				C				C							
Upload data					C				C				C							
Expand array						C														
Lingering oil																				
Reference genome				C								C								
Exposure experiments									C											
RNA sequence analysis											C			C						
Population genomics								C		C					X		X			
Reporting																				
Annual reports					C				C				C				X			
Annual PI meeting				C				C				C				X				X
EVOSTC Joint Science Workshop Report													C							
FY work plan (DPD)			C				C				C				C				X	
Final Report																				X
Other																				
Website updated				C				C				C				X				X
Previous year data on workspace		C				C				C				C				X		

B. Explanation for not completing any planned milestones and tasks

Updating the BASA model's disease component remains a work in progress. The work on improving the VHSV antibody detection technique (project 19120111-E) has only recently been completed. We were able to develop a simulation model to help us understand how to use the VHSV antibody data.

C. Justification for new milestones/tasks

There are no new programmatic milestones/tasks.

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 occur once a year for exchange of information and to encourage collaboration between projects. The next meeting is scheduled for November 2020. 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. Given the current state of the COVID-19 pandemic we are prepared to hold the principal investigator (PI) meeting by videoconference.

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. With the pandemic beginning early this year the coordination of sampling became more critical as not all groups were able to travel and not all vessels were able to go to sea. We were able to collect all the required samples for the various projects through additional collections by the vessels that were able to be at sea and processing of samples for people who were not able to travel. We also worked with a local fisherman to collect additional samples to ensure that we had representative samples for the ADF&G age-sex-length sampling, and the disease project.

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 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. Data from both the HRM and GWA programs were used in the syntheses developed by those programs.

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, McGowan, and Dias) 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 of the GWA program, and top-down forcing using information from the pelagic component of the GWA program.

The HRM coordination project (20120111-A) is using funding from the Prince William Sound Regional Citizens' Advisory Council to conduct forage fish surveys in conjunction with the GWA forage fish project (20120114-C).

The HRM modeling (project 20120111-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 predator-prey surveys that conduct fall surveys for forage fish, humpback whales, and marine birds.

Data Management

We continue to work with the Data Management team to ensure data are 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 within the HRM program.

B. With Other EVOSTC-funded Projects

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 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.

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.
3) Examine the connection between herring condition or recruitment to physical and biological oceanographic factors.
4) Develop new approaches to monitoring.

B. Changes to Program Design and Objectives

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 20120111-E. The additional samples will be used to determine if there is age- or year- dependency to patterns of VHS outbreaks. We extended the tagging effort (project 20160111-B) by a year to meet the sampling suggestions from the EVOSTC Science Panel. Sampling for the Herring Maturity (19170111-D) project ended at the recommendation of the EVOSTC Science Panel. That project is currently completing analysis of existing data and working on a final report.

The outbreak of the COVID-19 pandemic caused travel and work restrictions during the height of the busiest portion of the HRM field season. We were able to arrange sampling from the field programs that were able to go to sea and with a local fisherman to collect samples for projects that were not able to do their regular sampling. Personnel in Cordova were trained to process disease samples to allow the collection of data for that project. In this manner we were able to collect all the sampling that we had planned for 2020.

5. PROGRAM PERSONNEL – CHANGES AND UPDATES

Dr. David McGowan left his position as the Postdoc working with the modeling project. He completed his analysis of changes in spawn timing and location. He has been replaced by Dr. Beatriz Dias who is continuing to examine how changes in the herring population are related to environmental conditions.

Dr. Alysha Cypher has been added to the tagging project.

6. PROGRAM 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	$592.1	$928.4	$961.4	$987.8	$795.7	$4,265.4	$0.0
Travel	$37.1	$49.1	$45.4	$44.5	$40.9	$216.9	$0.0
Contractual	$198.7	$221.9	$218.7	$200.9	$175.1	$1,015.3	$0.0
Commodities	$247.0	$261.3	$159.0	$196.7	$100.8	$964.8	$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	$258.3	$1,525.0	$0.0
SUBTOTAL	$1,280.9	$1,737.1	$1,832.0	$1,822.8	$1,370.7	$8,043.5	N/A
General Administration (9% of subtotal)	$115.3	$156.3	$164.9	$164.0	$123.4	$723.9	
PROJECT TOTAL	$1,396.2	$1,893.4	$1,996.9	$1,986.8	$1,494.1	$8,767.4	
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 FY21.

The addition of $22,500 to the Hershberger proposal (project 21120111-E) to collect and analyze additional 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 21120111-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 21120111-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 21160111-B (herring tagging) requested funding for an additional year of tagging effort in response to the EVOSTC Science Panel recommendation for additional samples. That funding was granted in FY20. Originally FY20 was planned as an analysis year with no funding requested in FY21. To complete the tagging effort, we budgeted $250,300 in FY21 for completing the analysis.

The budget for the Herring Maturity Project was ended at the end of FY19 and we are not requesting the funds in FY21 that we had in the original budget. This has led to a $173,300 reduction in FY21 requested funding originally planned for this project.

We are requesting an additional $10,000 in salary (+$3,000 overhead) in the coordination project (21120111-A) to hire Donna Aderhold to provide additional review of HRM documents being submitted to the EVOSTC. We are also requesting an additional $56,900 for four additional months of salary for Dr. Groner to allow her to work to the end of the current program cycle.

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., G. Bidegain, G. de Leo, M.L. Groner, E. Hofmann, H. McCallum, and E. Powell. 2020. Modelling marine diseases. Marine Disease Ecology p.233.

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.W. Bernard. 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.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.

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.

Burge, C.A., and P.K. Hershberger. 2020. Chapter 5: Climate change can drive marine diseases. pp. 83-94 *In:* Marine Disease Ecology. D.C. Behringer, B.R. Silliman, and K.D. Lafferty, (Eds.) Oxford University Press. New York.

Cantrell, D.L., M.L. Groner, T. Ben-Horin, J. Grant, and C.W. Revie. 2020. Modeling pathogen dispersal in marine fish and shellfish. Trends in Parasitology 36:239-249.

Dias, B., D.W. McGowan, R. Campbell, M. Scheuerell, and T.A. Branch. In prep. Influence of environmental and population factors on herring spawn timing in Prince William Sound. Canadian Journal of Fisheries and Aquatic Sciences.

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., 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.

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 prep. Winter variability in the diets of groundfish predators of Pacific Herring and Walleye Pollock in a subarctic sound. Targeted journal: Deep-Sea Research Part II

Groner, M.L., E. Bravo-Mendosa, C.M. Conway., D.G. Elliot, and P.K. Hershberger. In prep. Host response and infection load mediate lethal infectious dose of *Ichthyophonus* in Pacific herring.

Groner, M.L., E. Bravo-Mendosa, C.M. Conway., D.G. Elliot, A.H. McKenzie, J.L. Gregg, S. Dressel, and P.K. Hershberger. In prep. Environmental and demographic correlates of *Ichthyophonus* severity and prevalence in Pacific herring from 2009-2019.

Gross, L., J. Richard, P. Hershberger, and K. Garver. 2019. Low susceptibility of sockeye salmon *Oncorhynchus nerka* to viral hemorrhagic septicemia virus genotype IVa. Diseases of Aquatic Organisms 135:201-209.

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

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Hershberger, P.K., A.H. MacKenzie, J.L. Gregg, A. Lindquist, T. Sandell, M.L. Groner, and D. Lowry. 2019. A geographic hot spot of Ichthyophonus infection in the southern Salish Sea, USA. Diseases of Aquatic Organisms 136:157-162.

Hershberger, P.K., A.H. MacKenzie, J.L. Gregg, M.D. Wilmot, R.L. Powers, and M.K. Purcell. Ready for Submission. Long-term shedding and asymptomatic carriers indicate that Pacific herring are a marine reservoir for viral hemorrhagic septicemia virus. Diseases of Aquatic Organisms.

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Published and updated datasets

The forage fish aerial survey data collected in 2020 were added to the forage fish data available from the Alaska Ocean Observing System Gulf of Alaska 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. Detection data has been uploaded (vrl files) and includes data from Ocean Tracking Network 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

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

Metadata and data describing infection prevalence results from herring health surveillance have been provided to Axiom annually.

Raw data from adult acoustic biomass survey uploaded to HRM Research Workspace during July 2020.Sequence reads for all 1,237 Pacific herring genomes have been uploaded to the European Nucleotide Archive (Study ID PRJEB27171 (ERP109223))

The 2019 BASA stock assessment has been uploaded to the AOOS research workspace, together with the model formulation and underlying data.

Presentations

Bishop M.A., Branch T., Gorman K., Groner M., Haught S., Hershberger P., Pegau S., Rand P., Trochta J., and Whitehead A. 2020. PWS Herring Research, Alaska Marine Science Symposium. Poster, January. Anchorage

Bravo, E., C. Conway, P. Hershberger, J. Gregg, M. Groner. 2018. 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. Poster, October 11-13.

Cypher, A.D., P.K. Hershberger, J. Gregg, and J. Incardona. 2020. Influence of embryonic crude oil exposure in overwinter fasting and disease susceptibility in juvenile Pacific herring (*Clupea pallasii*). Alaska Marine Science Symposium. Anchorage, AK. Oral, Jan 27-31.

Cypher, A.D., P. Hershberger, N. Scholz, and J.P. Incardona. 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. Poster. January 3-7.

Gill, J.A., P. Hershberger, J. Incardona, and A. Whitehead. 2019. Interactions between oil exposure and immune function relevant for Pacific herring population collapse. Society of Environmental Toxicology and Chemistry. Toronto, Ontario, Canada. Poster, November 3-7.

Gray, B.P., M.A. Bishop, and S.P. Powers. 2020. 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. Anchorage, AK. Poster, January.

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

Hershberger, P.K., A. MacKenzie, J.L. Gregg, R. Powers, M. Purcell. 2020. Long-Term Shedding of Viral Hemorrhagic Septicemia Virus from Pacific Herring. Alaska Marine Science Symposium. Anchorage, AK. Poster, January.

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

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

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

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

McGowan, D.W., and T.A. Branch. 2019. Large multi-decadal space and time shifts in Pacific herring spawning in the Gulf of Alaska. PICES 2019 Annual Meeting, Victoria, BC, Canada. Oral presentation, October.

Mena, A.J., J. St. Ledger, A. MacKenzie, J. Gregg, M. Purcell, W. Batts, P. Hershberger, and E.E.B LaDouceur. 2020. *Ichthyophonus* sp. infection in opaleye (*Girella nigricans*). International Aquatic Animal Medicine Conference. Tampa, FL. Poster, May 16-20.

Trochta, J.T, T.A. Branch, and W.S. Pegau. 2020. Challenges to estimating maturity in stock assessment: a case study of Pacific herring in Prince William Sound, AK. SAFS Think Tank, Seattle, WA. Oral presentation, April.

Trochta, J.T, and T.A. Branch. 2020. A Bayesian Analysis of the Utility of Ecosystem Information in a Stock Assessment Model of Prince William Sound Herring. presented at Alaska Marine Science Symposium, Anchorage, AK. Oral Presentation, January.

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

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

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

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

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

Outreach

Bishop, M.A. 2017. Pacific herring: Once done spawning – Where to next? 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. 2019. Time to spawn! Delta Sound Connections. Prince William Sound Science Center.

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. Cordova, January.

Gorman, K. 2018. Reproductive maturity of Pacific herring. Delta Sound Connections. Prince William Sound Science Center.

Gorman, K. 2019. Variability in seasonal gonad development of herring. 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.

Groner, M. 2019. 'Ich-Y' diseases in Pacific herring. Delta Sound Connections. Prince William Sound Science Center.

Hershberger, H. 2017. Assessing the impacts of disease in Pacific herring. Delta Sound Connections. Prince William Sound Science Center.

Hershberger, H. 2018. Forecasting disease potential in Pacific herring. Delta Sound Connections. Prince William Sound Science Center.

Hershberger, H. 2020. Virus persists in Pacific herring. Delta Sound Connections. Prince William Sound Science Center.

Hershberger, H., T. Gill, and A. Whitehead. 2020. From oil slick to chronically sick? Delta Sound Connections. Prince William Sound Science Center.

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

Haught, S. 2018. Aerial surveys of Pacific herring. Delta Sound Connections. Prince William Sound Science Center.

Haught, S. 2019. Mile-days of milt. Delta Sound Connections. Prince William Sound Science Center.

Hoover, H. 2017, 2018, 2019, 2020. The need for Herring Research and Monitoring. Delta Sound Connections. Prince William Sound Science Center.

Hoover, H. and S. Pegau. 2020. Herring population estimates. Delta Sound Connections. Prince William Sound Science Center.

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

Pegau, S. 2019. Changes in forage fish. Delta Sound Connections. Prince William Sound Science Center.

Rand, P. 2018. The dynamics of herring and predators in Prince William Sound. Delta Sound Connections. Prince William Sound Science Center.

McGowan, D.W. 2020. Big changes in where herring spawn in Prince William Sound. Delta Sound Connections. Prince William Sound Science Center.

Trochta, J., and T. Branch. 2017. Comparing and contrasting herring collapse. Delta Sound Connections. Prince William Sound Science Center.

Trochta, J. 2019. Herring models: Why and how they are used. Delta Sound Connections. Prince William Sound Science Center.

Trochta, J. 2020. Herring in their home environment: What matters? Delta Sound Connections. Prince William Sound Science Center.

Branch continues to maintain an active science outreach program on a wide variety of fisheries-related topics on social media (Twitter, @TrevorABranch), with 12,500 followers, and 23.4 million views of his tweets since the start of the 5-year program (Feb 2017).

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.

We reached out to the Village of Tatitlek to seek a date to visit for a listening session; however, the outbreak of the Covid-10 pandemic forced us to put that visit on hold.

Dr. Groner, in collaboration with Dr. Paul Hershberger (project 20120111-D), used both *Ichthyophonus* and 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.