ATTACHMENT C. Annual Program Status Summary Form (Revised 11.21.19)

1. Program Number:

20120111

2. Program Title:

Herring Research and Monitoring

3. Program Lead Name(s):

W. Scott Pegau, Prince William Sound Science Center

4. Time Period Covered by the Summary:

February 1, 2020 to January 31, 2021

5. Date of Summary:

March 2021

6. Program Website (if applicable):

https://pwssc.org/herring/

7. Overview of Work Performed during the Reporting Period:

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.

a) Progress toward addressing hypotheses and achieving goals

In addressing the first objective, the Bayesian Age Structure Analysis (BASA) model was expanded to include age-1 herring surveys. The age-1 herring index was incorporated in the past year and evaluation of the input is ongoing. The index peaked with the 2016 year class which was the largest observed joining the spawning stock; however, it is not clear that the index will be a reliable predictor of age-3 recruitment in every year. As part of the synthesis report (Pegau and Aderhold 2020), we evaluated different assumptions about maturity in the BASA model and found that none of the eleven models tested had a significant impact on biomass and recruit estimates. Therefore, we simplified the maturity schedule used by the model to increase stability.

During the past year, the model was expanded to incorporate the Viral Hemorrhagic Septicemia (VHS) prevalence and antibody data. There is the potential of novel antibody detection data (from Paul Hershberger, project 20120111-E) to better inform the severity of VHS virus (VHSV) outbreaks over time. We conducted a simulation analysis to test the accuracy and precision of estimates of annual infection rates and disease mortality from simulated antibody data. The analysis included a model of the truth that simulated more realistic disease dynamics by combining an epidemiological and an age-structured population model; and an estimation model simplified from BASA that takes antibody data as input and estimates time-and-age varying mortality due to disease. Simulations demonstrated that antibody data can provide accurate estimates of infection and mortality, whereas the current historical method of using prevalence data for VHSV in BASA results in biased estimates of biomass and recruitment. Using antibody data improves model population estimates even if other sources of natural mortality are ignored, although improvements may be small if these other sources are more substantial. A draft of this work is ready for submission once J. Trochta defends his PhD in February 2021. We continue to work closely with Dr. Hershberger to determine how best we should incorporate the antibody data before finalizing their use within BASA. The approach is also being examined for use to examine *Ichthyophonus* prevalence as well. An epidemiological model for *Ichthyophonus* infection is being developed by Dr. Groner (project 20120111-A) to understand mortality caused by that parasite.

The second objective is to provide inputs to the stock assessment model. The COVID-19 outbreak and subsequent travel and work restrictions began as we were preparing for our major sampling effort. Through rapid alterations in cruise plans, cross training of scientists in Cordova to process disease samples, and working with local fishermen to collect samples we were able to gather all of the inputs that are used by the model. This includes the collection of age-sex-length data, aerial miles-of-milt surveys, acoustic biomass surveys, the collection of disease prevalence and antibody information. All surveys and collections were successful, and results provided in the fall to the BASA model team to estimate the 2020 biomass. The unusually large 2016 year class continues to dominate the age distribution, with 79% of the fish sampled coming from this year class. There were no fish age-7 or older collected in the samples. Average size at age of age-3, -4, -5, and -6 fish increased in 2020 after a trend of declining size at age in recent years. The herring size remains well below the historical average for size at age. As the 2016 year class continued to recruit to the spawning biomass, the mile-days-milt increased to 23.7 mile days. The acoustic survey biomass estimate also increased to 18.2 MT. While Port Gravina and Canoe Pass remain active spawning areas, there was an expansion of the spawning grounds to the Port Eches area that has not been used for a considerable time. Disease prevalence remains low. The antibody presence is also low, indicating that the 2016 year class has not been affected by a VHS outbreak. The disease monitoring shows a general increase in antibody presence with increasing age.

The third objective is to examine the connection between herring condition or recruitment to physical and biological oceanographic factors. This was a focus of the modeling group. Dr. McGowan completed the analysis of multi-decadal shifts in the distribution and timing of PWS herring spawning. He is awaiting internal review of a draft manuscript that is ready for submission. His work on the shift in spawn timing and distribution was picked up by Dr. Dias who was working with Dr. Branch. The postdoctoral fellow (Beatriz dos Santos Dias) assessed which population, environmental, and climatological data are associated with PWS herring spawn timing variability. A variety of potential drivers of these timing shifts were explored: 1) population factors—aerial survey biomass index (mile-days of milt), mean age, and condition factor; 2) environmental variables—satellite derived PWS March and April sea surface temperature, PWS modeled freshwater input, winter, fall, and spring downwelling index, winter and fall meridional and zonal winds, and Gulf of Alaska fall, spring, and winter sea surface temperature; and 3) climatological variables—multivariate El Niño Southern Oscillation (ENSO) index, Pacific Decadal Oscillation (PDO), Pacific/North American teleconnection pattern (PNA), and the North Pacific Gyre Oscillation (NPGO). Spawn timing was earlier for the eastern region. Population level factors were different in each region, earlier spawning was associated with older mean age in the Western PWS, while in the Eastern portion, earlier spawning was associated with lower mile-days of milt. Earlier spawning is also related to higher modeled freshwater input. Another factor associated with years of earlier spawning is the weakening of winter meridional winds and downwelling index. The manuscript for this work is currently being drafted and will be submitted to the *Canadian Journal of Fisheries and Aquatic Sciences*.

An in-depth analysis of the potential effects of a wide variety of factors on PWS herring recruitment and mortality has been conducted as a component of John Trochta's thesis. In the latest version of these analyses, we now include more robust model selection techniques (Pareto-smoothed importance-sampled leave-one-out cross-validation, PSIS-LOO) and explore alternative assumptions about incorporating covariates (e.g., where they are fit as data). Only one covariate had widespread support across model selection criteria (3 of 4 criteria), and that was adult pink salmon numbers which were associated with higher adult herring mortality. Weaker evidence was shown for walleye pollock adult abundance reducing herring mortality, NPGO increasing mortality, humpback whales increasing mortality, juvenile hatchery pink salmon decreasing recruitment, and a 1989 regime shift decreasing recruitment. Furthermore, the BASA model may be overly permissive of a variety of hypotheses, in which the dynamics of mortality or recruitment may be partially explained by many of the factors we explored. Trochta just successfully defended his PhD and this analysis is ready for submission to a peer-reviewed journal.

Tagging efforts provide greater information about where the herring are, which allows us the opportunity to refine our understanding of the conditions the fish are experiencing. This was the last year of placing tags out and we were able to tag 235 herring in the spring of 2020. Our analysis has focused on the phenology and use of the area around the entrance arrays. The proportion of tagged herring detected at the Ocean Tracking Network entrance arrays has ranged by tag year from 0.48 (year 2017) to 0.81 (year 2019). Across all four tag years, herring were detected at Hinchinbrook Entrance more than any other array. This is not surprising given that our modeling efforts show that fish tend to migrate out from Hinchinbrook Entrance to the Gulf of Alaska during spring.

We also evaluated the amount of time tagged herring spent near the Ocean Tracking Network arrays during and after expected time of migration. Detection events were categorized into 'days' (> 23.9 hours), 'hours' (>59.9 minutes), and 'minutes.' For the 2018 tag year, the longest detection events were 8.7 days and 20.4 days for the Hinchinbrook and Montague Strait entrances, respectively. For Hinchinbrook Entrance, the most detection events occurred in May after spawning with approximately 47% of detection events being between 1 and 23 hours. At this time, about 30% of tagged herring spent more than 1 day at the Hinchinbrook array while 23% percent moved through the array within a span of minutes. There did not appear to be a pattern between the duration of detection events and fish condition, gender, or age. Detection events at Montague Strait were fewer than at Hinchinbrook during peak detection months, May and June, but occurred throughout the year. Approximately 49 and 53% of tagged herring spend more than 1 day at the Montague Strait array during May and June, respectively. This further supports our findings that adult herring spend time in Montague Strait presumably for feeding.

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

Monitoring for VHS in age-0 herring has documented several VHS epizootics that recur annually in the same geographic location. We are still trying to understand why this may occur.

Transmission of *Ichthyophonus* in clupeid hosts has been a subject of speculation since the earliest reported epizootics, but neither the mode of infection in herring, nor the life cycle of *Ichthyophonus* are adequately described. Several oceanic conditions were simulated to see if water-borne transmission could be observed. There is no evidence of water-borne transmission, suggesting there is an intermediary involved in the transmission of the parasite. We are examining the potential for transmission through consumption of pollock eggs.

With additional support from the North Pacific Research Board, Dr. Groner has been able to examine the temporal changes in *Ichthyophonus* in PWS and Sitka Sound. The patterns of infection prevalence across time and age are distinctly different between the two locations. Since *Ichthyophonus* is incurable we surmise that a decrease in *Ichthyophonus* prevalence with age signals an increase in mortality caused by the parasite. A model has been developed to quantify mortality due to *Ichthyophonus* infection. The desire is to determine appropriate parameterization for *Ichthyophonus* caused mortality in the population model.

This year saw progress in extending work on our large multi-dose oil and pathogen exposure experiments. We detected population differences in sensitivity to the cardiotoxic effects of oil exposure; the PWS population was most sensitive (compared to Sitka Sound and Puget Sound populations) to cardiac developmental impairment caused by oiling. Animal experiments over the past three years have surprised us, insofar as results have indicated that exposure to oil during embryogenesis does not seem to sensitize animals to pathogen challenge during later life. This could be because 1) oil exposure during early development does not perturb immune development/function, 2) early-life exposure to oil does perturb immune development/function but our doses were too low, or 3) early-life exposure to oil does perturb immune development/function but we have not yet exposed developing animals to oil at the effective developmental stage. To test the third hypothesis, we exposed herring at the larval stage when the immune function is being developed. Subsequent virus challenge experiments showed a surprising result, where oil-exposed animals had reduced sensitivity to virus-induced mortality. Though the effect oil early life oil exposure was opposite to that expected, these data show that early life exposure to oil does affect the developing immune system, and that this effect persists until post-metamorphosis.

An extension of virus challenge experiments included an additional bacterial challenge experiment. Our goal was to test whether embryonic oiling sensitizes animals to bacterial pathogens, and whether responses to bacterial pathogens differs between populations. We found that oil exposure during embryogenesis caused those fish as juveniles to be slightly more sensitive to *Ichthyophonus* challenge than fish not exposed to oil in early life.

Our fourth objective is to develop new approaches to monitoring the population. This year we worked with the Alaska Ocean Observing System and researchers at the University of Alaska to install a receiver on a glider. The glider was deployed in December 2020 and is currently still operating. We have located some of the tagged herring and, just as important, we are discovering locations of tags that were extruded from herring.

We continue to conduct research into other pathogens that affect herring and are expected to be responsible for significant mortality in the population. A long-term experiment for the detection of antibodies to VHS virus was concluded after three years. After three years, approximately 50% of the fish remained seropositive to the presence of the VHSV antibodies. Results are preliminary because the measurements were made using the older technique that is less sensitive than the one currently in use. Final numbers and analysis will be completed next year.

We expanded the genome sequencing using longer-read technologies to improve the final genome product. After preliminary analysis we determined that additional read data were required for the genome assembly, but this effort has been slowed because of the COVID-19 pandemic, since the University of California Davis Genome Center is occupied with virus testing/surveillance.

The population genomic work was put on pause for nearly a year because postdoctoral research associate Elias Oziolor accepted a career position elsewhere. It took some time to recruit a new postdoc to take over the population genomics work. I am very pleased to report that we have recruited Dr. Joseph McGirr who started working in the Whitehead lab in June 2020. In the past few months, he has familiarized himself with the massive population genomics dataset collected by Elias. He has generated summary statistics for each population and characterized population structure using genome-wide genetic variation data. This analysis so far shows structure across geographic regions. The important fine-scale analyses of geographic and temporal patterns between and within populations, especially Alaskan populations, are ongoing. We are now modifying our code to incorporate estimates of generation time and mutation rate in order to finalize analyses.

b) Highlights and noteworthy issues

A model for mortality caused by the VHSV has been developed and incorporated into the BASA model. This has been a long-term objective of the program since it was clear that VHSV infection prevalence was not the appropriate metric to estimate mortality by the virus.

The 2016 year class of herring that began recruiting to the spawning stock in 2019 appears to be the largest year class on record across the Gulf of Alaska. The age-1 index and age-structure data from 2020 suggests that the next few year classes should be expected to be moderate or small in size, resulting in a decline in the expected population over the next couple of years.

We feel it is noteworthy to stress that we were able to collect all of the samples and tag the planned number of herring. The travel and work restrictions associated with the COVID-19 outbreak occurred as one vessel had left, one was loading, and the third cruise was being prepared. By projects supporting each other and being flexible in who would go to sea we were able to complete our work. We were able to work with local fishermen to collect the age-structure and disease samples that normally would have been collected by the one cruise that did not occur.

c) Efforts to achieve community involvement/traditional ecological knowledge and resource management application

This past year we continued to work with Dr. Sherri Dressel of Alaska Department of Fish and Game (ADF&G) to exchange information that is of value to resource management. We also contributed a status of PWS herring to the National Oceanic and Atmospheric Administration's (NOAA's) Ecosystem Status Report for the Gulf of Alaska that is provided to the North Pacific Fishery Management Council.

We reached out to the president of the Tatitlek Village Council prior to the COVID-19 outbreak but with the pandemic we were unable to schedule a listening session with them. This winter we reached out again and also reached out to the Native Village of Eyak to begin information exchanges.

d) Problems and unusual developments

Dr. Whitehead's project (19170115) genome sequencing component was the one aspect of the program that experienced delays due to COVID-19. The lab used for the sequencing was busy processing COVID-19 samples and had to put the herring work on hold because health mandates restricted access to the lab.

e) Other significant information

We have begun to examine our spring sampling procedures to create plans to ensure samples can be collected if COVID-19 restrictions prevent planned sampling.

8. Coordination/Collaboration:

A. Projects Within a Trustee Council-funded program

1. Within the Program

Coordination is primarily through email and the annual principal investigators (PI) meeting. Work with projects includes ensuring reporting is completed promptly and assisting the coordination of sampling logistics. Dr. Pegau works with individual projects to ensure the collection of samples and as a source of information about existing data and results. This year all PIs worked together on a synthesis report that was provided to the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) office. This past year, because of COVID-19 state and federally mandated health restrictions, there was additional coordination needed to ensure all samples were collected and processed. Through the cooperation of all the projects we were successful in conducting all planned work.

2. Across Programs

a. Gulf Watch Alaska

Dr. Pegau serves as the primary contact for the HRM program with the Gulf Watch Alaska (GWA) program. Coordination includes having the leads to all the programs on the HRM mailing list, so everyone is aware of any information going out to the HRM PIs. He also works with the leads to address specific topics of joint interest, such as reporting. The HRM and GWA PI meetings are held together to allow for greater exchange of information. Individual projects, particularly the modeling project and the work of Dr. Dias, are working with the GWA program to obtain the necessary time series to conduct the analysis examining the relationship between herring and other environmental factors.

b. Data Management

Dr. Pegau serves as the primary contact for the HRM program with the data management (DM) program. The DM program is in contact with individual projects to ensure timely submission of data.

B. Projects not Within a Trustee Council-funded program

None

C. With Trustee or Management Agencies

Sherri Dressel of ADF&G is on the HRM scientific oversight group. Sherri, along with Stormy Haught of the Cordova office of ADF&G, are the primary contact points between the HRM program and the Trustee Agency with oversight of herring in PWS. The monitoring work of the HRM program provides the data necessary for ADF&G to monitor the Pacific herring population in PWS and determine if the population is at a fishable threshold. The exchange of information with ADF&G is important for being able to track similar research efforts ongoing at ADF&G and in the HRM program.

Drs. Groner and Hershberger have partnered with ADF&G in Sitka to assess whether temporal changes in the severity of *Ichthyophonus* infections may be responsible for recent declines in the spawning herring biomass and age structure. Data and archived samples from the past 10 years of this EVOSTC-funded project were leveraged to obtain supplemental funding from the North Pacific Research Board (# 1807: *Ichthyophonus* in Pacific Herring).

A status of PWS herring was provided to the NOAA for incorporation into their Gulf of Alaska Ecosystem Considerations report, which is reviewed by the North Pacific Fisheries Management Council.

9. Information and Data Transfer:

A. Publications Produced During the Reporting Period

1. Peer-reviewed Publications

Ben-Horin, T., G. Bidegain, G. de Leo, M.L. Groner, E.E. Hofmann, H. McCallum, and E.N. Powell. 2020. Chapter 13. Modeling and forecasting disease dynamics in the sea. In DC Behringer, BR Silliman, KD Lafferty (Eds.), Marine disease ecology. Oxford, England: Oxford University Press.

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

Burge, C.A., and P.K. Hershberger. 2020. Chapter 5: Climate change can drive marine diseases. pp. 83-94 *In:* Marine Disease Ecology. and Donald C. Behringer, Brian R. Silliman, and Kevin 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 parasite dispersal in marine ecosystems. Trends in Parasitology 36:239-249.

Chong, L., T.K. Mildenberger, M.B. Rudd, M.H. Taylor, J.M. Cope, T.A. Branch, M. Wolff, and M. Stäbler. 2020. Performance evaluation of data-limited, length-based stock assessment methods. ICES Journal of Marine Science 77:97-108.

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

Hershberger, P.K., M. Stinson, B. Hall, J.L. Gregg, A.M. MacKenzie, J.R. Winton. 2020. Pacific herring are not susceptible to vibriosis under laboratory conditions. Journal of Fish Diseases 43:1607-1609.

Hilborn, R., R.O. Amoroso, C.M. Anderson, J.K. Baum, T.A. Branch, C. Costello, C.L. de Moor, A. Faraj, D. Hively, O.P. Jensen, H. Kurota, L.R. Little, P. Mace, T. McClanahan, M.C. Melnychuk, C. Minto, G.C. Osio, A.M. Parma, M. Pons, S. Segurado, C.S. Szuwalski, J.R. Wilson, and Y. Ye. 2020. Effective fisheries management instrumental in improving fish stock status. Proceedings of the National Academy of Sciences U.S.A. 117:2218-2224.

LaDouceur, E.E.B., J. St Leger, A. Mena, A. MacKenzie, J. Gregg, M. Purcell, W. Batts, P. Hershberger. 2020. *Ichthyophonus* infection in Opaleye (*Girella nigricans*). Veterinary Pathology 57:316-320.

Trochta, J.T., T.A. Branch, A.O. Shelton, and D.E. Hay. 2020. The highs and lows of herring: A meta-analysis of patterns and factors in herring collapse and recovery. Fish and Fisheries 21:639-662.

White, E.R., H.E. Froehlich, J.A. Gephart, R.S. Cottrell, T.A. Branch, R.A. Bejarano, and J.K. Baum. 2020. Early effects of COVID-19 on US fisheries and seafood consumption. Fish and Fisheries 22:232-239.

2. Reports

Pegau. W.S. 2020. Herring Research and Monitoring. FY19 annual report to the *Exxon Valdez* Oil Spill Trustee Council, project 19120114-D. *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Pegau, W. S, and D. R. Aderhold, editors. 2020. Herring Research and Monitoring Science Synthesis. Herring Research and Monitoring Synthesis Report, (*Exxon Valdez* Oil Spill Trustee Council Program 19120111). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Pegau, W.S., J. Trochta, and S. Haught. 2020. Prince William Sound Herring. In Ferriss, B., and S. Zador (Eds.) Ecosystem Status Report 2020 Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK.

Shepherd, C.S., and S. Haught. 2019. Pacific herring aerial surveys and age, sex, and size processing in the Prince William Sound Area, 2018–2021. Alaska Department of Fish and Game, Regional Operational Plan ROP.CF.2A.2019.05, Cordova.

3. Popular articles

Dias, B.S. 2021. About time. *Delta Sound Connections*. Prince William Sound Science Center.

Hoover, H. 2020. Herring Research and Monitoring. *Delta Sound Connections*. Prince William Sound Science Center (https://pwssc.org/wp-content/uploads/2020/07/DSC-2020-web.pdf).

McGowan, D.W. 2020. Big changes in where herring spawn in Prince William Sound. *Delta Sound Connections*. Prince William Sound Science Center (https://pwssc.org/wp-content/uploads/2020/07/DSC-2020-web.pdf).

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

Pegau, S. 2020. Population Estimates. *Delta Sound Connections*. Prince William Sound Science Center (https://pwssc.org/wp-content/uploads/2020/07/DSC-2020-web.pdf).

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

1. Conferences and Workshops

Groner, M.L., E. Bravo-Mendosa, C. Conway, J. Gregg, A. Mackenzie, and P. Hershberger. 2021. Epidemiology of Ichthyophoniasis in Pacific herring in Sitka Sound and Prince William Sound from 2007-2018. Oral Presentation. Alaska Marine Science Symposium, January.

Dias, B.S., D.W. McGowan, R. Campbell, and T.A. Branch. 2020 What affects spawning phenology of herring (*Clupea pallasii*) in Prince William Sound? Oral presentation. Alaska Marine Science Symposium, January.

Dias, B.S., D.W. McGowan, and T.A. Branch. 2020 Influence of environmental and population factors on herring spawn timing in Prince William Sound. Oral presentation. PICES Workshop VW6.

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

Trochta, J.T., M.L Groner, P.K. Hershberger, and T.A. Branch. 2021. Using antibody data to quantify disease impacts in fisheries stock assessment. Oral presentation. Alaska Marine Science Symposium, Anchorage, January.

Trochta, J.T., M.L. Groner, P.K. Hershberger, and T.A. Branch. 2020. Using antibody data to improve estimates of natural mortality in fisheries stock assessment. Invited talk. Quantitative seminar. School of Aquatic and Fisheries Science, Seattle, WA.

Trochta, J.T. 2020. The rise of Bayesian: A stock assessment story. Invited talk. American Fisheries Society 150th Annual Meeting, Virtual.

Trochta, J.T., and T.A. Branch. 2020. Challenges to estimating maturity in stock assessment: a case study of Pacific herring in Prince William Sound, AK. Invited talk. Think Tank Seminar Series. School of Aquatic and Fisheries Science, Seattle, WA.

Trochta, J.T., and T.A. Branch. 2020. Hard of herring: Detecting effects on herring survival from a noisy environment in the Gulf of Alaska. Invited talk. Alaska Department of Fish and Game, Juneau, AK.

2. Public presentations

Groner, M.L. 2020. Lobsters in a pinch and other tails of disease in fished populations. School of Aquatic Fisheries Sciences. University of Washington, USA.

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

A PWS herring contribution to the NOAA Ecosystem Status Report for the Gulf of Alaska.

Stock assessment of PWS herring for 2020.

All project websites were updated to include current results.

Data and information products developed during the reporting period include: 2020 individual aerial survey maps (distributed to HRM participants, other herring researchers, and a variety of stakeholders within 24hrs of survey), 2008-2020 aerial herring biomass observations shapefiles, 1973-2020 aerial herring spawn observations shapefiles, 1997-2020 herring aerial survey routes shapefiles, 2008-2020 aerial survey marine bird observations shapefiles, 2008-2020 aerial survey marine mammal observations shapefiles, 2008-2020 aerial survey sea lion observations shapefiles, age-sex-length database updated through 2020, and age structure and size at age summaries by sample and overall (pooled).

Population genomics data collection is complete. Raw sequence read data has been uploaded for long-term archive at National Center for Biotechnology Information, as per common practice in our field. Data have not yet been publicly released – we will keep data under embargo until our analyses are complete, at which time we will provide links to the data to be posted on the Gulf of Alaska Data Portal. We have started archiving our population genomics bioinformatics analysis scripts in GitHub. When script archives are completed following our analysis, we will provide links through the Gulf of Alaska Data Portal.

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

2020 aerial forage fish survey data.

Datasets and relevant code for projects conducted by Maya Groner on *Ichthyophonus* in herring will be uploaded by Feb 28, 2021.

Pathogen survey data from PWS and Sitka Sound.

A tagging log with accompanying age, sex, and length of each herring tagged along with a unique tag ID number. These data were recorded in April 2020 and have been uploaded to the Research Workspace. https://workspace.aoos.org/files/7835346/2017 to 2020 herring tag data for workspace - master list .xlsx

Detection data have 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

2022. [herring_detections_2017 to fall 2020_adc csv w mab corrections.csv | Research Workspace (aoos.org)]

Data sets and associated metadata that have been uploaded to the Gulf of Alaska Data Portal include: 2020 aerial survey maps, 2008-2020 aerial herring biomass observations shapefiles, 1973-2020 aerial herring spawn observations shapefiles, 1997-2020 herring aerial survey routes shapefiles, 2008-2020 aerial survey marine bird observations shapefiles, 2008-2020 aerial survey marine mammal observations shapefiles, 2008-2020 aerial survey sea lion observations, 2014-2020 herring age-sex-length data.

Raw acoustic data from the spring 2020 survey were uploaded to the Gulf of Alaska Data Portal on 8 July 2020. Intermediary acoustic summary files were uploaded on 9 February 2021, and the final biomass estimate was added to the time series and made public on 9 February 2021. Preliminary acoustic biomass estimates were shared with HRM PIs during the November 2020 PI meeting during a presentation.

Uploaded the most recent version of the BASA model and results using 2020 data. Metadata on the workspace summarizes the data sets and how to run the model, while detailed instructions and descriptions are contained within READ_ME files and line comments within the code. The upload includes: AD Model Builder files to run model, R code to pre-process data for model & post-process model output, figures, and tables of key model output (fits to data, estimates of biomass and recruitment, parameter estimates), and raw model output (read in by R code to produce figures and tables).

10. Response to EVOSTC Review, Recommendations and Comments:

EVOSTC Science Panel Comment (FY21). The SP appreciates creativity of PIs in the herring program to find ways to collect field data during the Covid pandemic. We may see more of the same pandemic-related restrictions on field work and access to labs, which will require alternative plans that were not stated in the program and project proposals. Each project should address the following questions. What are the program and project contingency plans for FY21 in regard to accomplishing goals and field activities? The SP understands that it may be challenging to develop extensive and detailed contingency plans for the future, but some planning is required. Will any unused funds for FY21 be repurposed for additional lab and/or data analyses? Or will they be requested to rollover to FY22 (pending proposal approval)? The SP noted that community outreach was postponed owing to safety concerns. However, as with the GWA program, the SP agrees with the Science Director's recommendation of finding internet-based solutions to community outreach. Issues related to the pandemic are likely to persist in 2021, too. Additionally, GWA monitors conditions for herring growth and recruitment, but the SP feels that the connection with the HRM program can be strengthened.

Response (FY21): We feel that our ability to adjust sampling efforts to cover all sampling requirements in 2020 shows the connectivity between our projects and how each person is willing to help out the other projects. This resilience helps us to adjust to contingencies such as the COVID-19 pandemic. Short descriptions of the primary sampling contingencies follow.

Mile-days-spawn measurements could be obtained by contracting aircraft operators to collect video with date and location stamps. We currently use this equipment to provide backup to the observers. Age structure analysis and disease prevalence samples could be obtained through contracting with fishermen to capture herring using cast nets and jigs as we did in 2020. People in Cordova could be trained to collect samples for the disease project. Training materials were developed to provide the necessary information for the collection of disease prevalence samples. The equipment for the acoustic surveys is in Cordova and can be deployed by researchers that live there. The captain of the Auklet is very familiar with the sampling protocol and can assist if necessary. The tagging project can turn over the data uploading to the charter vessel captain who has been trained in its use. He is a former researcher at Prince William Sound Science Center and has extensive experience with the equipment. Since no tagging is to occur in 2021, personnel with the tagging project can help cover projects that are unable to travel or short staff.

The postdoctoral researcher working with Dr. Branch is focused on connecting the data collected in the Gulf Watch Alaska program to information from the Herring Research and Monitoring Program. Outside of the postdoc's efforts, there are currently at least three manuscripts in progress that examine connections between herring growth or biomass with environmental conditions. Two are led by investigators in the GWA and one by the HRM coordination project.

EVOSTC Science Coordinator Comment (FY21). Overall, the program is completing tasks on time. The COVID-19 pandemic caused travel and work restrictions but Dr. Pegau was able to coordinate with other field programs and the local community to collect samples for projects that were not able to conduct their regular sampling. Dr. Pegau's efforts are recognized and appreciated. The pandemic has also put outreach visits on hold. Many businesses and communities are moving toward video conferencing platforms to hold virtual events online - could this be an alternative way to effectively conduct outreach activities such as a community listening session? I understand that face-to-face meetings can be more effective and meaningful depending on the topics and participants, but this may be a way to sustain connections with communities, and this is also assuming that participants have access to video conferencing capabilities. The program is requesting additional funding for one existing project (see project A for details). The budget for the Herring Maturity Project was ended at the end of FY19 which has led to a $173,300 reduction in FY21 requested funding for the program.

Response (FY21): Our outreach coordinator will work with the native village of Tatitlek to determine appropriate methods of outreach. We will determine if the communication infrastructure and cultural norms in the village are suitable for a virtual listening session. Our existing connection with the village allows for sharing of information during the herring spawn season and we hope that we can build upon that connection.

EVOSTC Science Panel Comment (FY20). The productivity of this program is quite high and the Panel commends the PIs for this. The Science Panel also appreciates the inclusion of postdocs, as well as undergraduate and graduate students, on herring techniques ranging from molecular, disease, to population approaches. For future proposals, please separate out peer-reviewed publications from agency and data reports and include subheading of published, in prep, in review if necessary. We would also like to see more interpretation and discussion of data and figures presented in the proposals; this is included in some of the proposals such as in project 20170111-B. The Panel is not looking for new or additional analyses in the proposals. We are looking for context and some interpretation to allow us to evaluate the proposal.

Response (FY20). Thank you for the guidance.

EVOSTC Science Panel Comment (FY20). The Science Panel had some concern that survey efforts, though laudable, might miss significant amounts of herring in PWS. Herring are notorious for shifting spawning locations by tens or hundreds of kilometers over time. A discussion with herring program lead Pegau indicated that extra efforts have been taken through opportunistic and other sampling to explore the possibility that herring occur in significant quantities in other portions of PWS. Pegau noted that aerial surveys are quite extensive, much larger than the acoustic surveys. For example, ADFG flies over Kayak Island, but this area is not included in the PWS management area. It would be helpful if these non-Program efforts could be briefly described in future proposals and annual reports to provide context. It seems that the herring spawning at Kayak Island should be considered part of the PWS herring metapopulation.

Response (updated response). The COVID-19 outbreak limited the amount of additional work that we were able to accomplish this past year. There were a couple of flights to Kayak Island, but satellite imagery showed that not all spawn that occurred there was surveyed. We have tried several approaches to document the spawn at Kayak Island and none have proven practical. We agree that all the evidence suggests that the Kayak Island spawning population and the PWS spawning population are connected. Without the ability to reliably survey spawn at Kayak Island it is not possible to include fish that spawn there in the population estimate. We also are concerned that adding additional spawning grounds when there has not been consistent historical survey effort will artificially inflate the population estimate. How to best treat the Kayak Island spawning area remains a very active discussion topic within the HRM program.

11. Budget:

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	$905.2	$710.5	$4,097.6	$3,105.9
Travel	$37.1	$49.1	$45.4	$43.4	$39.8	$214.7	$119.0
Contractual	$198.7	$221.9	$218.7	$166.7	$140.9	$946.9	$462.0
Commodities	$247.0	$261.3	$159.0	$194.9	$99.0	$961.2	$770.2
Equipment	$5.9	$0.0	$50.3	$0.0	$72.0	$128.2	$76.8
Indirect Costs (*will vary by proposer*)	$200.1	$276.5	$397.3	$357.0	$222.3	$1,453.1	$1,240.9
SUBTOTAL	$1,280.9	$1,737.1	$1,832.0	$1,667.2	$1,284.4	$7,801.6	$5,774.8
General Administration (9% of subtotal)	$115.3	$156.3	$164.9	$150.0	$115.5	$702.1	
PROJECT TOTAL	$1,396.2	$1,893.4	$1,996.9	$1,817.2	$1,400.0	$8,503.6	
Other Resources (Cost Share Funds)	$157.2	$159.7	$203.2	$225.2	$149.4	$894.7	N/A

LITERATURE CITED

Pegau, W. S, and D. R. Aderhold, editors. 2020. Herring Research and Monitoring Science Synthesis. Herring Research and Monitoring Synthesis Report, (*Exxon Valdez* Oil Spill Trustee Council Program 19120111). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.