Exxon Valdez Oil Spill
Long-Term Herring Research and Monitoring Program Final Report

Herring Program – Program Coordination

Exxon Valdez Oil Spill Trustee Council Project 21120111-A
Final Report

W. Scott Pegau

Prince William Sound Science Center
Box 705
Cordova, Alaska 99574

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Study History: The role of program coordination came about as a result of the Integrated Herring Restoration Program and the identified need to coordinate the herring research activities. The first integrated program was the Prince William Sound Herring Survey program (project 10100132). This was followed by the first phase of the Herring Research and Monitoring program (projects 16120111-O Coordination, and 16120111-H Outreach). This report covers the most recent five-years of coordination activities. The scope of the various projects has varied but the Coordination and Outreach components have been in all programs. The coordination efforts have also been responsible for producing a synthesis report to the *Exxon Valdez* Oil Spill Trustee Council in each phase. These synthesis reports examine different aspects of herring with a focus on the research being conducted.

Abstract: This project was responsible for the coordination of the seven research and monitoring projects within the program to ensure they would address the program's objectives. The objectives of this project were to coordinate efforts among projects, oversee a postdoctoral researcher, and provide outreach and community involvement. Coordination allowed us to conduct all research activities and collect all planned samples through the COVID-19 pandemic. This project was also responsible for developing a synthesis and ensuring all reporting deadlines were met. The synthesis examined survey design, determination of maturity, shifts in distribution and timing of spawning, movement of herring in and out of Prince William Sound, and disease factors. Two postdoctoral candidates were hired through this project. One worked with project 21120111-E (Herring Disease Program II), and the other with 21120111-C (Modeling and Stock Assessment of PWS Herring). Results of their efforts are reported in those project reports. The last objective of this project was to provide outreach. This was primarily achieved through annual updates to our website that described findings of each project. Articles in the Delta Sound Connections newsletter and presentations to various interested parties provided additional outreach to communities.

Key words: Coordination, Herring Research and Monitoring, HRM, Pacific herring, Prince William Sound

Project Data: This project did not generate any data.

Citation:

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EXECUTIVE SUMMARY

During the development of the Integrated Herring Restoration Program, the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) recognized a need for coordination of the various herring projects it was supporting. The first coordinated program was the Prince William Sound Herring Survey program which was later replaced by the Herring Research and Monitoring (HRM) program. The project described in this report was responsible for coordination and outreach. The coordination maximized shared resources and most importantly had the various research projects working together to develop connections between the projects that enhanced each effort. This project was responsible for the coordination of the seven research and monitoring projects (21160111-B Tagging, 21120111-C Modeling, 19170111-D Maturity, 21120111-E Disease, 21160111-F Surveys, 21120111-G Acoustics, and 21170115 Genetics) within the program to ensure they would address the program's goal of improving the predictive models of herring stocks through observations and research. The program objectives were to

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

The objectives of this Coordination project were to coordinate efforts among projects, oversee a postdoctoral researcher, and provide outreach.

Coordination efforts dealt with logistics, maximizing shared resources, and ensuring timely reporting. Most coordination was done by using email, but we held annual meetings with all investigators to share what was learned and look for connections between projects. Logistics became challenging during the COVID-19 pandemic when researchers were unable to travel, or personnel were limited on research cruises. We were able to conduct all planned research activities and sample collections by substituting local personnel for people who needed to travel and maximizing our available resources by collecting samples for other projects on the cruises that did occur.

This project was also responsible for developing a synthesis and ensuring all reporting deadlines were met. The synthesis (Pegau and Aderhold 2020) examined survey design, determination of maturity, shifts in distribution and timing of spawning, movement of herring in and out of Prince William Sound, and disease factors. The synthesis can be found on the EVOSTC website at https://evostc.state.ak.us/publications/science-synthesis-reports/ or through the HRM program website at https://pwssc.org/herring/.

Two postdoctoral positions were filled through this project. One worked with project 21120111-E (Herring Disease Program II), and the other with 21120111-C (Modeling and Stock Assessment of PWS Herring). These projects were designed to address the connection between herring and the environment. The disease project examined Viral Hemorrhagic Septicemia recurrence (Hershberger et al. 2021), hot spots of *Ichthyophonus* (Hershberger et al. 2019), and worked to incorporate that information into the population model (Ben-Horin et al. 2020, Cantrell et al. 2020, Trochta et al. 2022). Dr. Groner, the postdoc working with the disease project, was also able to secure outside funding to do a more detailed analysis of *Ichthyophonus* in herring. Dr. McGowan, the postdoc working with the modeling group, examined shifts in the distribution and timing of herring spawn and the factors associated with those changes (McGowan et al. 2021). The detailed results of the postdoctoral efforts are reported in their respective project reports.

The last objective of this project was to provide outreach. This was primarily achieved through annual updates to our website (https://pwssc.org/herring/) that describes findings of each project. Additional outreach was achieved through articles in the Delta Sound Connections newsletter (https://pwssc.org/education/delta-sound-connections/) and presentations to various interested parties. A Prince William Sound Herring Watch Facebook page was developed to allow us to share more rapidly the information we were learning and results of surveys. This has the additional benefit of being a location where people are willing to provide their observations as well.

INTRODUCTION

In 1993 the Pacific herring (*Clupea pallasii*) population in Prince William Sound (PWS) collapsed. Except for two years in the late 1990s the population has never recovered to a level that can sustain a fishery. Robust herring populations, suitable for exploitation by commercial fisheries, are typically sustained by periodic recruitment of strong year classes into the adult spawning population. However, until 2016, the PWS herring population has not had a strong recruitment class since the population collapse. In the *Exxon Valdez* Oil Spill (EVOS) settlement, herring were identified as an injured resource and they remain listed as an unrecovered species by the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC). Understanding why herring have not recovered in PWS requires understanding potential bottlenecks in the herring life cycle. The identification of conditions limiting herring recovery requires a series of focused process studies combined with monitoring of herring stocks and the natural conditions that affect herring survival.

In November 2006, a Herring Steering Committee was formed by the EVOSTC and tasked with developing a focused Restoration Program that identifies strategies to address recovery and restoration of herring, recognizing that activities in the program must span an ecologically relevant time frame that accounts for herring population dynamics and life history attributes. A draft Integrated Herring Restoration Program (IHRP) was completed in the fall of 2008 and was further refined in July of 2010. The main goal of the effort was to determine what, if anything, can be done to successfully recover the Pacific herring in PWS. To determine what steps could be taken, the program examined the factors limiting recovery of herring in PWS, identified and evaluated potential recovery options, and recommended courses of action for achieving restoration.

One outcome of the IHRP development was the recognition of the need to integrate the herring research projects being supported by the EVOSTC. In the past there was limited interaction between investigators working on various aspects of herring research. It was recognized that to develop a better understanding of the interactions between the many aspects of research that funding individual projects would need to give way to integrated programs that strove to have investigators interact and to synthesize the knowledge gained from projects within the program. This began with the Prince William Sound Herring Survey Program (2009-2012) and was followed by the first phase of the Herring Research and Monitoring (HRM) Program (2012-2016) and later the second phase (2017-2022). Synthesis reports have been generated by each program (Pegau 2013, HRM team 2014, Pegau and Aderhold 2020). These documents can be accessed from the herring program website (http://pwssc.org/herring/).

This project was responsible for the coordination of the seven research and monitoring projects (21160111-B Tagging, 21120111-C Modeling, 19170111-D Maturity, 21120111-E Disease, 21160111-F Surveys, 21120111-G Acoustics, and 21170115 Genetics) within the HRM program to ensure they would address the program's goal of improving the predictive models of herring stocks through observations and research. The program objectives were to

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

The projects within the program focus their efforts on PWS but use information from other regions to provide context for the findings.

OBJECTIVES

The objectives of the coordination project are as follows:

1. *Coordinate efforts among the HRM projects to achieve the program objectives, maximize shared resources, ensure timely reporting, and coordinate logistics*. Integration of the projects throughout the program is necessary to improve our scientific understanding of factors affecting herring and to maximize use of resources, such as ship time. This requires coordination among HRM researchers and the HRM, Gulf Watch Alaska (GWA), and Data Management (DM) programs.

2. *Oversee a postdoctoral researcher*. To closely examine the connections between herring stocks and the physical and biological conditions requires a more focused effort than can be provided by the program coordinator. The postdoctoral researchers assisted with tying the information from the various projects together to develop greater understanding of herring in PWS. In the end, the researchers worked within a research project but conducted research that required collaboration with other projects within the program.

3. *Provide outreach and community involvement for the program*. Strong ties to Alaska Department of Fish and Game (ADF&G) and the fishing community are important for guiding program efforts, gaining new insights, and demonstrating the relevance to both the management agency and the fishing community. This requires sharing of findings and listening to community members.

METHODS

While the research is focused in PWS, the investigators involved covered a much larger area. This made face-to-face coordination more difficult. With the improvements and acceptance of telecommunication platforms it has become easier to work with investigators in other states.

To address objective one, Dr. Pegau acted as the program team leader and was responsible for ensuring a coordinated and focused research program that leverages other assets whenever possible. He was responsible for ensuring proper scientific oversight of individual projects and reporting to the EVOSTC. He led the development of annual work plans and the synthesis of findings from these programs. He coordinated the efforts of the HRM program with those of the GWA and DM programs.

Program coordination was primarily through e-mail and phone communications. Meetings of participants occurred each year with the 2020 and 2021 meetings conducted via video conferencing. While the genetics project (21120115) was originally outside of the HRM program, it was moved under the HRM program so it could benefit from the interaction with other research activities. The HRM Principal Investigator (PI) meetings were held in conjunction with the GWA PI meetings to encourage collaboration between the programs. The DM team was also invited to the HRM meetings to ensure we remained compliant with the data management policies. These meetings were vital to ensure proper communications within and among the EVOSTC sponsored programs. They also provided an opportunity for the scientific oversight group to ask questions of the investigators. The scientific oversight group followed the progress of the research and provided input on scientific quality and potential future direction. The oversight group consisted of Sherri Dressel (ADF&G), Jeep Rice (NOAA ret.), and Steve Martell (Sea State, Inc.).

Coordination between the three EVOSTC funded programs included frequent calls, emails, and regularly scheduled management meetings. Coordination between projects also took place through scheduling of vessels and personnel. This became critical during the COVID-19 pandemic when some researchers were not able to travel, and others were not able to conduct planned cruises. We were able make all our planned observations by having vessels collect samples or measurements, hiring local fishermen to collect samples, and cross-training personnel so one team could collect measurements for another. For example, Dr. Pegau was trained to collect the plasma needed for the disease monitoring. This allowed him to participate on cruises that the disease project team were unable to travel to.

Timely, quality reporting was achieved by having the PIs provide their reports to Dr. Pegau two weeks before the deadline. This allowed time for the science oversight group and an editor to review and comment on the reports before they needed to be submitted. The early delivery of the reports also allowed for the development of a program report that synthesized the information in the project reports.

The largest reporting task was the development of a synthesis report for the EVOSTC. The subject areas were determined based on questions from the EVOSTC Science Panel and a desire to have all projects contribute to the report. Most sections of the report also had input from multiple research projects. The report was presented to the EVOSTC Science Panel to garner additional feedback and to allow the Science Panel to track the progress of the program.

Objective two involved recruiting postdoctoral researchers to focus on examining the relationship between herring condition and recruitment and physical and biological oceanographic factors. This focal area was chosen because it has the greatest overlap with the other projects within the program and connects to the long-term monitoring work that has been conducted. We hired two postdoctoral researchers, one worked with the disease project and the other was with the modeling project. Both researchers worked on topics that integrated projects and EVOSTC funded programs. Because their work is so intertwined with the work conducted by their host projects, we chose to leave the details of their research in the reports of the host project.

The third project objective is for outreach and community involvement. The outreach effort was focused on updating and enhancing the HRM website (http://pwssc.org/herring/). Initially, we transitioned the project descriptions to an updated version of the Prince William Sound Science Center's (PWSSC's) website. Upon completing the transition, we updated each of the active and completed projects to provide greater information about what the project had learned. Each of the active project pages was update annually to describe new lessons learned.

We watched how the distribution list for the HRM herring survey information grew and decided to set up a Prince William Sound Herring Watch Facebook page to allow information from the various projects to be shared more widely. As of 2022, there are 981 followers. This avenue provides a good means to not only share information but to also see what garners interest and provides a means for us to get observations from people out in PWS.

Beyond the website and Facebook, we have coordinated submissions of short articles on the herring research to the Delta Sound Connections newsletter. This newsletter is then distributed to various locations around PWS and serves as an informal outreach to the general public. We also generated several episodes of a podcast called Field Notes that are posted to the PWSSC website.

Much of our outreach to agencies has occurred on an informal basis with the inclusion of the ADF&G Cordova based research biologist in the program and Dr. Dressel, ADF&G's statewide herring coordinator on our scientific oversight group. We have also generated a report each year on the status of PWS herring that describes the status and trends observed in the population. This report is submitted for inclusion in The National Oceanic and Atmospheric Administration's (NOAA's) Gulf of Alaska Ecosystem Status Report.

We also provided overview presentations about the program and its findings to various organizations, such as Cordova District Fishermens' United (CDFU), Prince William Sound Regional Citizens' Advisory Council (PWSRCAC), and at the Prince William Sound Natural History Symposium.

We participated in a Chugachmuit sponsored workshop on communicating science and had an investigator participate in an outreach trip to Port Graham. Additionally, we were a keynote speaker at Chugach Regional Resources Commission (CRRC) subsistence gathering hosted online. We reached out several times to the village of Tatitlek to set up a listening session so we could learn from their observations and share our own. Unfortunately, the COVID-19 pandemic created conditions that were not favorable for people to travel into this small community. We also spent two years reaching out to the Native Village of Eyak in Cordova but were unable to establish an opportunity to meet with them. We are getting reactions and shares of our Facebook posts from people in the villages.

RESULTS

This effort resulted in a program that was able to collect and analyze all the planned data while facing the challenges associated with the COVID-19 pandemic. The first major pandemic-related shutdown occurred in mid-March 2020, just prior to the herring spawn, which caused us to scramble to rearrange the efforts on the boats that were already at sea to collect samples for the cruises that had to be canceled. We also worked with local fishermen to collect herring and bring them back to Cordova for processing.

The work of the postdoctoral researchers drew heavily from many projects within the HRM and GWA programs. The postdocs were involved in the PI meetings to provide them an avenue for connecting to the other research and monitoring efforts underway. The meetings provided the researcher with background in disease ecology to become more familiar with the age-structure-analysis (ASA) model used for population estimation, which led to better disease information being incorporated into the model and the development of a model of disease dynamics that was used to understand the potential spread of diseases. The disease project examined Viral Hemorrhagic Septicemia recurrence (Hershberger et al. 2021), hot spots of *Ichthyophonus* (Hershberger et al. 2019), and worked to incorporate that information into the population model (Ben-Horin et al. 2020, Cantrell et al. 2020, Trochta et al. 2022). Dr. Groner was also able to secure outside funding to do a more detailed analysis of *Ichthyophonus* in herring. Another researcher was combined with the researchers in the GWA program to allow them to use the environmental drivers data from GWA to examine why there may have been changes in the herring spawn locations and timing. The postdoc working with the modeling group examined shifts in the distribution and timing of herring spawn and the factors associated with those changes (McGowan et al. 2021).

The synthesis (Pegau and Aderhold 2020) was the largest collaborative effort conducted by the program. This synthesis was meant to complement the previous synthesis efforts (Norcross et al. 2001, Pegau 2013, Herring Research and Monitoring Team 2014) by focusing on different aspects of the herring research. The synthesis begins with a discussion of the survey designs used within the HRM program and then examines research on maturity, spawn timing, movement, and disease. The executive summary of the synthesis is as follows:

> This synthesis of research topics related to Pacific herring (*Clupea pallasii*) is meant to build upon earlier syntheses (Norcross et al. 2001, Pegau 2013, Herring Research and Monitoring Team 2014). The report includes sections that describe the survey designs used and research on maturity, spawn timing, movement, and disease. This selection allows the description of information from all the components of the Herring Research and Monitoring (HRM) program. There are significant differences in the development of each of the topics that leads to differences in the style of presentation. For instance, the research on spawn patterns is nearly ready to be submitted as a manuscript, whereas the work on herring movement is still in the early stages. The work presented in each section is not necessarily limited to results of *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) funded research. We incorporate other findings where appropriate.
>
> The chapter on survey designs describes efforts used in the recent past or are ongoing. We do not cover how surveys that have been discontinued were conducted. Data from the surveys are used in the Age-Structure-Analysis (ASA) model to estimate the Prince William Sound (PWS) herring population. These surveys include the aerial spawn surveys, acoustic surveys, and age-sex-size (ASL) sampling. We discuss supplemental spawn detection efforts the HRM program has tried and describe the aerial forage fish surveys that are conducted in collaboration with the Gulf Watch Alaska (GWA) forage fish program.
>
> The aerial milt surveys provide the mile-days of milt index, which is the longest running and most consistent time series of herring abundance in

PWS. As such, it is critical to maintain this index to provide necessary inputs to the assessment models. The acoustic surveys provide an independent index that measures a similar portion of the herring population. The combination of the aerial milt surveys and acoustics provides an indication if one survey has unusual values. The ASL sampling efforts inform nearly every other project in the HRM program by providing age composition and weight at age for the ASA models, estimating target strength for the acoustic survey estimates of biomass, providing vessel support for spring acoustic surveys and disease sampling, and assisting with the collection efforts for tagging and maturity studies.

Because aerial milt surveys do not include areas outside of PWS and are limited by weather, we tested the deployment of people and cameras to remote spawning locations. Neither of those approaches proved to be practical for monitoring for spawn. The use of visible remote sensing works when the skies are clear. Newer satellites with very high resolution are the most appropriate for detecting spawning events.

The forage fish surveys have been conducted since 2010 and provide information on a few different forage fish including herring. We are in the process of determining if the number of schools of age-1 herring can be used to predict the size of recruitment to the spawning stock at age-3. The aerial forage fish surveys work with the GWA forage fish project to provide an indication of the forage fish distribution in waters too shallow for that program to survey. In turn, the GWA forage fish project provides validation observations of the species identification from the aerial surveys.

In the second chapter we examine the maturity of herring. The term maturity is currently used in two manners. The first is that the herring are mature enough to spawn. The second is used in the model in that the fish are available to the ASL sampling. The percent of mature (available) herring at each age is estimated by the ASA model; however, there are no independent checks of the results. A maturity function in the ASA model uses the maturity estimates to then determine the total herring population in PWS. From the ASL data we determined that not all herring in the pre-spawning aggregations are likely to spawn. By using some crude assumptions, we estimated the percentage of the herring population not observed in the ASL samples and roughly estimated the mortality over time. These estimates are in good agreement with the maturity estimates from the ASA model.

Scale growth is examined to determine whether bimodal growth distributions occur that are hypothesized to be a result of fish not spawning able to put greater energy into growth than those that are preparing to spawn. The scale growth of four cohorts (1984, 1988, 1999, 2005) were examined to see if there is evidence of bimodal growth in male and female herring. The cohorts were chosen to include two from each time block that the ASA model currently uses. Preliminary results demonstrate that both male and female herring show indications of bimodal growth in the scale records that is most evident at the older ages (age-5 and age-6). Fewer scales were imaged at these older age classes and more scales will need to be imaged before making conclusions.

A suite of eleven model runs were used to examine the question of sensitivity of the model to different assumptions about maturity and availability. The eleven model runs were meant to bound the likely range of scenarios. The model runs were also used to examine if the maturity function should be calculated in two separate time blocks. We found that the estimated biomass is not sensitive to the range of maturity scenarios. There is no value to the model in trying to separate mature and immature fish in the ASL samples. While estimating the maturity function for two time-blocks using the ASA model provides different parameters for each time block, we did not find evidence in the residuals of a change in the maturity schedule over time. Therefore, we recommend estimating a single set of maturity parameters for the entire dataset.

The third chapter examines how spawning events have changed in space and time. The location and time of spawning plays a critical role in the survival of pelagic fish during early life stages that subsequently affects recruitment to the population. This chapter examines whether changes in spawning patterns from 1973 to 2019 provide insights on factors that are inhibiting recruitment of Pacific herring to the PWS population. Our findings show substantial changes in spatial and temporal patterns of herring spawning in PWS over the past four decades, and that these changes are likely contributing to the population's lack of recovery. We attribute major shifts in spawning distributions to changes in population demographics and fishery-related effects on local spawning aggregations. In addition, major shifts in spawn timing have coincided with large-scale changes in ocean temperatures, indicating the population is also responding to external perturbations in their environment. The current state of the population (i.e., low abundance, spatially constrained spawning habitat, and lack of a broad age structure that extends the spawning period) suggests its potential for reproductive success is greatly reduced.

The movement of herring in and out of PWS is examined in the fourth chapter. Herring are tagged with acoustic tags during the spawning period. These tags can then be detected by acoustic receivers in the entrances, near the spawning grounds, and at locations within PWS that we expect fish may pass. The tagging effort builds upon a 2013 pilot project that established that after spawning, a majority of adult acoustic-tagged Pacific herring moved from the spawning grounds in PWS, where spawning ground acoustic arrays were located, to the entrances to the Gulf of Alaska (GOA), where the Ocean Tracking Network acoustic arrays were located.

In this effort, we analyzed herring movements over a two-year period (April 2017 through March 2019) based on herring tagged in PWS during 2017 and 2018. We modeled movement probabilities between PWS and the GOA. At both Hinchinbrook Entrance and Montague Strait, herring were more likely to migrate from PWS to GOA during the spring/summer season, while during the fall/winter season herring were more likely to migrate from GOA to PWS. At the Southwest Passages, similar patterns were not observed, suggesting that the migration pathways run primarily through Hinchinbrook Entrance and Montague Strait. We found that some fish mingle around the entrance arrays, in particular those in the Southwest Passages. We found that during spring/summer season, heavier herring were more likely to move to the entrance arrays. Smaller herring were more likely to overwinter near the spawning grounds.

The final chapter examines two common pathogens affecting herring populations, Viral Hemorrhagic Septicemia (VHS) virus and *Ichthyophonus*. It is now known that VHS virus (Genogroup IVa) is highly virulent to many species of marine fishes and it periodically causes epizootics and resulting fish kills throughout the Pacific Northwest. Efforts within the Herring Disease project have identified a series of guiding principles that govern the epizootiology of VHS virus: 1) Pacific herring are highly susceptible to VHS, 2) Pacific herring are super-shedders of VHS virus, 3) Pacific herring are a natural reservoir for VHS virus, 4) Co-factors influence the potential for VHS epizootics, and 5) Acquired resistance is a critical determinant of VHS potential.

Information from these newly articulated principles can be integrated into tools capable of assessing prior population-level impacts and forecasting future disease risk. In this context, Principle #5 is the most informative, as the immune status of individuals and populations supersedes all the principles. For example, a population of immune individuals will not experience an epizootic, even if all other disease co-factors occur simultaneously (i.e., exposure to virus, cool temperatures, elevated infection pressures, etc.). Further, with annual immunological monitoring of herring population across year classes, we can deduce if, and when, epizootics occurred. This deduced exposure history can then be paired with population assessments to assess whether the epizootic was associated with a concomitant reduction in biomass or abundance.

Ichthyophonus is perhaps the most ecologically and economically significant pathogen of wild marine fishes throughout the world, based on its low host specificity, broad geographic range, and recurring association with epizootics that result in massive fish kills and population-level impacts. Natural route(s) of *Ichthyophonus* transmission in Pacific herring remain unresolved and laboratory studies have been largely unsuccessful at demonstrating transmission by host cohabitation, immersion in parasite isolates, or feeding with infected tissues or isolates. Over broad spatial and

> temporal scales, the prevalence of *Ichthyophonus* infections typically increases with herring size and age. This zoographic pattern is consistent with that of a chronic infection that accumulates in a population via recurring exposures throughout the lifetime of the host. Although *Ichthyophonus* typically persists in Pacific herring at chronic levels that accumulate in populations over time, several lines of evidence indicate that the parasite may periodically contribute to negative impacts on Pacific herring population dynamics. Investigations are currently underway to understand when the typical chronic *Ichthyophonus* infections shift to a more acute form that leads to mortality.

Since the synthesis was developed early in the program, the reports from individual projects will provide updated and more detailed findings.

Outreach activities resulted in maintaining the nine web pages associated with the HRM program, reaching 981 followers on Facebook, 28 Delta Sound Connection articles (distribution ~3,500 annually), 9 Field Notes podcasts, 7 program overview presentations to various groups, and 4 submissions to the NOAA Ecosystem Status report.

DISCUSSION

The most significant results from this effort were the collection of all planned data during the pandemic, the development of the synthesis, and the postdoctoral research projects. All these tasks required considerable coordination. The data collection in the projects required the projects to find ways to accommodate the research needs of other projects, cross-training to collect information for others, and working with the local communities to collect samples for projects that couldn't send personnel or vessels out into the field during the pandemic. The collection of these samples is not only important in maintaining the long-term record, but the data are also needed for the ASA model to estimate the herring biomass. The 2016 herring year class that began recruiting to the spawning stock in 2019 was one of the strongest year classes throughout the Gulf of Alaska. Our efforts to continue sampling allowed us to get the necessary information to understand this first strong recruit class since 1999. Understanding the formation of strong recruit classes is fundamental to understanding how herring populations recover.

The synthesis is the report in which various projects looked at not only the information their project was collecting but the works of the other projects to address particular topics. The synthesis pulls together the knowledge provided in various research papers to help develop an understanding of herring and herring recovery.

Like the synthesis effort, the postdoctoral research projects required collaboration across projects. This led to not only incorporating additional disease information into the ASA model, but also modeled disease dynamics to better understand how diseases spread through a population. Understanding the factors associated with changes in herring spawn patterns required working with researchers in the GWA program to examine how predators (Pelagic Component) and oceanographic conditions (Environmental Drivers Component) were related to herring. The modeling effort also examined how those factors affected recruitment and mortality.

The efforts to ensuring sharing of information between programs generated connections between the programs that expanded the approach used by projects. Timely reporting and the review of those reports helped to ensure quality products were provided to the EVOSTC.

Our outreach met the EVOSTC requirement of maintaining a website and was able to do more to improve the flow of information to community members and agency personnel. We were able to go above the programmatic requirements requested by the EVOSTC and create avenues for outreach to general audiences through Delta Sound Connections articles, Field Notes podcasts, and presentations, such as those at the PWS Natural History Symposium and PWSRCAC Science Night. Presentations to CDFU provide an opportunity for exchange of information with the fishing community. The CRRC workshop and subsequent outreach trip to Port Graham provided the opportunity to exchange information with the native communities.

CONCLUSIONS

This project was not designed to be an independent research project but instead to enhance the existing projects by facilitating collaboration and ensuring quality through review of the work by the scientific oversight group and review of reports. It is the project that sees all the work being conducted by the various projects within the program and within the GWA and DM programs so it positioned to encourage connections when appropriate. Being connected to all the projects also makes outreach easier since it takes a holistic view of the program. Not being a specialist in a research field also makes it easier for us to condense the research findings and communicate them in a manner that a broader audience can understand.

ACKNOWLEDGEMENTS

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These findings and conclusions presented by the author(s) are their own and do not necessarily reflect the views or position of the *Exxon Valdez* Oil Spill Trustee Council.

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