ATTACHMENT C EVOSTC Annual Project Report Form

Form Rev. 8.30.18

1. Program Number:

18120111-A

2. Project Title:

Herring Program – Program Coordination

3. Principal Investigator(s) Names:

W. Scott Pegau

4. Time Period Covered by the Report:

February 1, 2018-January 31, 2019

5. Date of Report:

April 2019

6. Project Website (if applicable):

http://pwssc.org/research/

7. Summary of Work Performed:

The work described here is intended to provide coordination of the Herring Research and Monitoring (HRM) program. In addition to the coordination efforts, it includes a postdoctoral researcher to analyze the relationships between herring diseases and physical and biological oceanographic conditions. Furthermore, it covers the community involvement and outreach activities of the program. The goal of the project is to provide coordination within the HRM program and with the Gulf Watch Alaska (GWA) and Data Management (DM) programs. The objectives of the project are:

1. *Coordinate efforts among the HRM projects to achieve the program objectives, maximize shared resources, ensure timely reporting, and coordinate logistics.*
2. *Provide outreach and community involvement for the program.*
3. *Oversee a postdoctoral researcher.*

The proposed approach follows that used during the Prince William Sound Herring Survey and initial HRM programs. Coordination is primarily through e-mail and teleconference. The management team of GWA and the lead of DM are included in the emails to HRM principal investigators (PIs) to ensure they are aware of our activities. We also have joint PI meetings and community involvement activities. The focus of the HRM PI meeting is in sharing findings and spending time coordinating between projects.

Coordination effort

Reports and proposals have been submitted to the National Oceanic and Atmospheric Administration (NOAA) and the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) on time. Reports and proposals are being requested from the PIs earlier than they have in the past to allow the HRM Science Oversight Group additional time to comment on them before submission. We are also implementing additional internal review of the grammar and formatting of the materials being submitted.

The annual PI meeting was held in Anchorage in November in conjunction with the GWA PI meeting. PIs, including the post-doc in this project and the one in the modeling project presented on the progress of their projects. We also invited Dr. Whitehead, who has an EVOSTC lingering oil research project on herring that we incorporated into the HRM program in August, to attend the PI meeting. The meeting was open, and we had a couple of members of the public take advantage of the opportunity to follow our work. We also had the DM program present and work with the PIs. During this meeting we outlined the effort for the upcoming synthesis effort. The following day the HRM PIs joined the GWA PIs to provide coordination among projects from the two programs.

Outreach effort

Outreach efforts are focused on providing up-to-date information on the projects and their findings. Community involvement includes regular communications with stakeholders. In the past year we worked with the GWA program to have listening sessions in Kachemak Bay communities. Dr. Groner participated in the Port Graham listening session and Hayley Hoover participated in the Chugachmiut meeting with elders held in Homer. Scott Pegau met with the herring division of the Cordova District Fishermen United (CDFU) and Alaska Department of Fish and Game (ADF&G). These meetings facilitate the exchange of information across stakeholder groups. In this way we can ensure that all available findings and observations are recorded. In addition, Stormy Haught presented his findings at the Cordova Community Lecture Series hosted by Prince William Sound Science Center (PWSSC) staff.

Keeping the HRM section of the PWSSC website up to date has been a key objective. This last year we updated the HRM program website with new findings from projects that continued from the previous five-year period and to added summary pages for research new to the program during the current five-year period. Additionally, a Field Notes page was developed. Field Notes is a podcast describing the work of the HRM program. The podcast had previously only been available on each PIs summary page and shared with the local public radio station. With the development of the new page, all episodes are centrally located for ease of listening. We also contributed four articles to the Delta Sound Connections publication in an HRM spread updating the spill-affected communities on the year's findings. Delta Sound Connections is a newspaper produced annually by the PWSSC and distributed widely throughout Prince William Sound and the Copper River Delta (e.g., state ferries, Ted Stevens Anchorage International airport, Mudhole Smith airport in Cordova, Begich Boggs Visitor Center at Portage Glacier, and a variety of sites in Girdwood, Glenallen, Copper Center, and Valdez).

Research effort

The coordination project has limited research responsibilities. Most of the research is being conducted by the postdoctoral researcher is being supervised by Dr. Pegau. Research conducted by Dr. Groner has been focused on three topics. First is experimentally quantifying the relationship between *Ichthyophonus* sp. pathogen load and mortality by using specific pathogen-free herring at the U. S. Geological Survey Marrowstone Laboratory. Replicate tanks (3) of herring were exposed to *Ichthyophonus* via consumption of offal from ground-up infected conspecifics. Mortality, infection status, size and cardiac tissue samples were collected from all tanks. Pathogen load will be quantified in moribund, dead and subsamples of live fish by through quantitative image analysis of histologically sectioned cardiac tissue. A pilot experiment was completed with age-1 herring and a second experiment with age-4 herring was just completed. Due to unexpected mortality with the age-1 herring experiment, this will be repeated in spring 2019. These experiments will be used to estimate the probability of mortality as a function of infection intensity. These probabilities will inform estimates of mortality due to *Ichthyophoniasis* in both Sitka Sound and Prince William Sound between 2009 and 2019 (described below).

Estimates of mortality due to ichthyophoniasis will be based on infection loads from historical samples of herring hearts in Sitka Sound and Prince William Sound from 2009 to 2019 (180 hearts/ site/ year). While pathogen presence/absence has been measured on these samples, further examination of infection intensity (# parasites/ area) will allow us to determine if there has been an increase in mortality associated with higher intensity *Ichthyophonus* infections. This work is motivated by shifting patterns in disease prevalence across age (as a proxy for size) and an increase in gross observations of severely diseased herring particularly in Sitka Sound after 2013. Quantitative estimates of survival as a function of infection intensity can be made using the likelihood method outlined in Wilber et al. (2016). Briefly, the probability of survival for a host with *x* number of parasites or pathogens can be determined using standard rules of conditional probability:

$$P(x|survival) = \frac{h(survival;x,\theta)*g(x,\varphi)}{\sum_{x=0}^{\infty} h(survival;x,\theta)*g(x,\varphi)} \qquad \text{(eq. 1)}$$

In this equation (eq. 1), $h(survival; x, \theta)$ is the probability of having *x* parasites, conditional on host survival, and $g(x, \varphi)$ is the pre-mortality distribution of parasites among hosts. The pre-mortality distribution is typically assumed to be a negative binomial, but other distributions are possible. This distribution can be determined empirically from our data (though we suspect it will take a negative binomial distribution). Using the probability distribution in equation 1, the parameters θ and φ that maximize the likelihood of the data can be determined. Code for fitting estimating θ and φ from empirical data is available at: (https://github.com/mqwilber/parasite_mortality). Comparisons will be made to determine how if probabilities calculated with this method agree with those determined experimentally using *Ichthyophonus* challenge experiments (described above). Ultimately, these probabilities will feed into population models for Sitka and Prince William Sound. Disease prevalence for different age classes will be calculated using an age-length key and empirically sampled values from our collections. Mortality due to disease from our calculations will be applied to these age classes in yearly time steps to determine if the mortality can account for changes in disease prevalence and cohort size over time and across cohorts.

Progress on this project has been good. In addition to completing two experiments, we have finished processing, sectioning, and staining all of the hearts collected to date (Fig. 1, samples from 2009 to 2018) onto slides and have begun imaging these samples for quantification of lesions. This work has been facilitated by a North Pacific Research Board (NPRB) grant awarded to Groner and Hershberger that allowed us to hire a technician (through U.S. Geological Survey (USGS) Western Fisheries Research Center) in summer 2018. This intern, Eliana Bravo-Mendosa, was very productive and plans to return for the summer of 2019.

The second ongoing experiment is investigating interactions between age and susceptibility to viral erythrocytic necrosis (VEN) in herring. Replicate tanks (3) of mixed aged herring (age-0, 1, 2, or 4) were exposed to erythrocytic necrosis virus (ENV) or a control (phosphate buffered saline). Herring were tagged with elastomer tags to identify them to age cohort. Mortality was monitored for two months; kidneys were collected from all mortalities and subsamples from the end of the study. ENV was detected in all groups by qPCR, including negative controls. This observation of pervasive ENV has also been observed in prior controlled experiments, suggesting the possibility that this putative iridovirus may be vertically transferred (i.e. from parent to offspring). Future studies will further investigate this possibility.

A novel modeling approach has been initiated to parameterize the factors influencing VHS in Pacific herring. For this effort, Groner is using existing data from VHS infection trials conducted by Paul Hershberger (and described in his current annual report) to parameterize mathematical models of VHS dynamics in herring populations. The model will be a deterministic Susceptible-Exposed-Infected-Resistant (S-E-I-R) model, which will allow investigation of the role of herd immunity in dampening disease prevalence. Because parameters will be derived from lab experiments, these models will be conceptual in nature (as opposed to modeling distinct geographic areas) and will provide the first disease models of VHS in Pacific herring.

Sensitivity analyses of model parameters can be used to identify processes that have the most influence on outbreak dynamics. Two timeframes will be used in these models: across weeks and across years. Within schools, VHS outbreaks occur on the order of weeks, with mortality tapering after 3-4 weeks. Impacts of recruitment and herd immunity (i.e., a dampening of a disease epidemic due to a high number of resistant individuals in a population) will impact disease dynamics across years. An initial paper describing the model structure and parameterization is in development and with a submission goal of September 2019. A second paper exploring herd immunity across years is anticipated for September 2020.

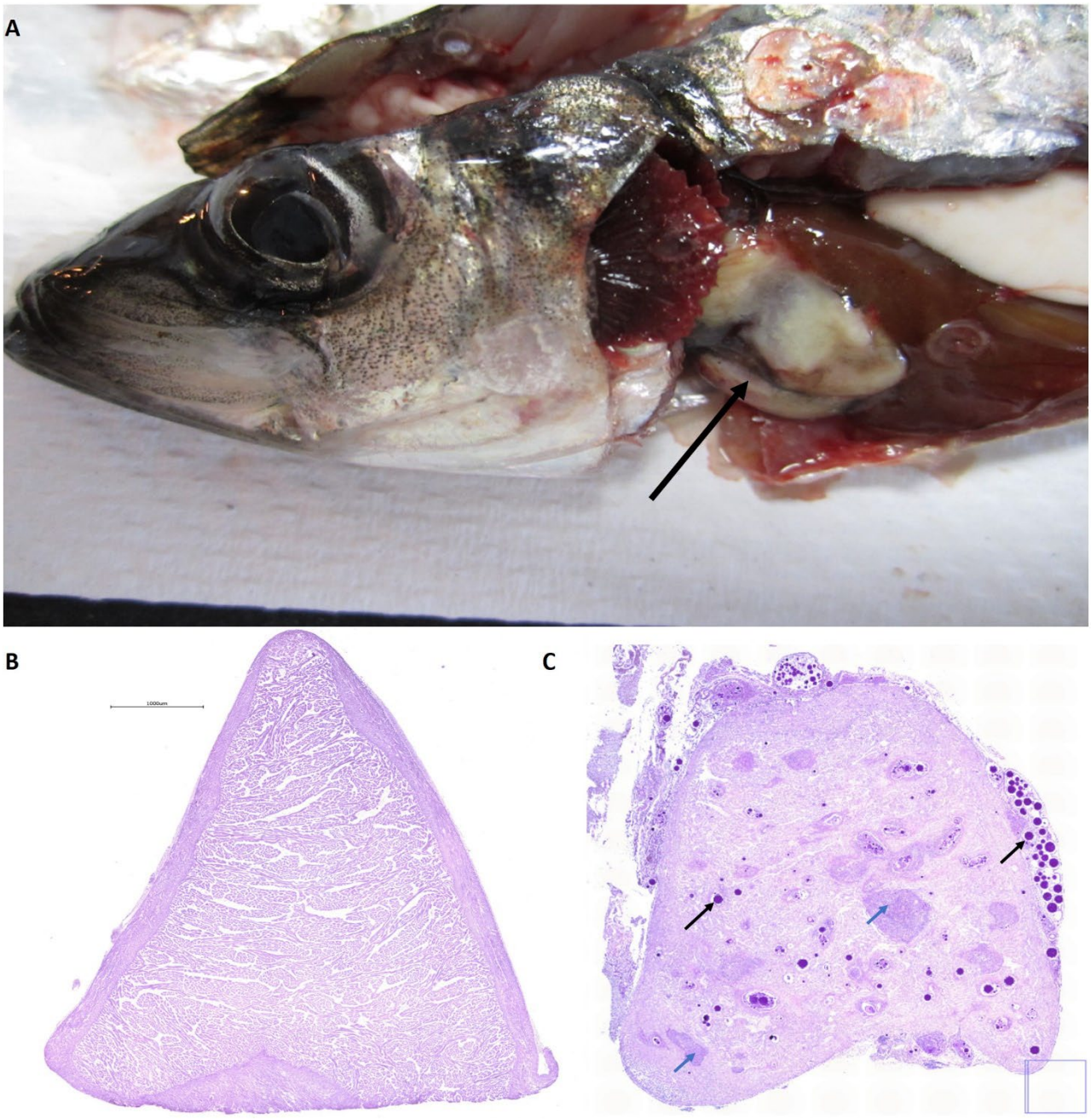

Figure 1. Hearts heavily infected with *Ichthyophonus* sp. can appear white instead of dark red (arrow) (A). Histological sections of a healthy herring ventricle (B) next to an infected ventricle (C). On the infected ventricle, the dark purple circles (black arrows) indicate *Ichthyophonus* sp. schizonts. Granulomas of darker staining tissue surround some of the schizonts (blue arrows).

In addition, Dr. Groner has participated in several publications that are tangentially related to this project, including collaborations on (1) a book chapter on marine disease modeling and (2) a manuscript reviewing how management of marine resources (i.e., fisheries, marine protected areas, and rehabilitation) can indirectly alter host-pathogen interactions. The book chapter will be published in a textbook on marine diseases. Dr. Groner's contribution is focused on how to infer epidemiological processes by examining and modeling distributions of parasites within hosts. The theory in this chapter underlies her current work being applied to quantifying and interpreting *Ichthyophonus* intensities in herring hearts. The manuscript uses several examples of Pacific herring diseases to illustrate how fishing practices may alter diseases processes, including size-selective harvests that may inadvertently target herring infected with *Ichthyophonus* and the spawn-on-kelp fishery which has been associated with shedding of VHS. Both publications are targeted for summer 2019.

Additional work conducted by Dr. Pegau over the last year includes conducting aerial surveys for forage fish in Prince William Sound. The aerial surveys found a moderate number of forage fish schools (most identified as age-1 herring) during June (Fig. 2). For the first time in a few years we saw a number of schools that we identified as capelin (Fig. 3). Data from these surveys will be used by the modeling project to determine if the aerial survey can improve the estimate of the age-3 herring joining the spawning population. We obtained funding for additional aerial surveys from the Prince William Sound Regional Citizens' Advisory Council and will be coordinating with boat surveys to be conducted as part of the GWA program.

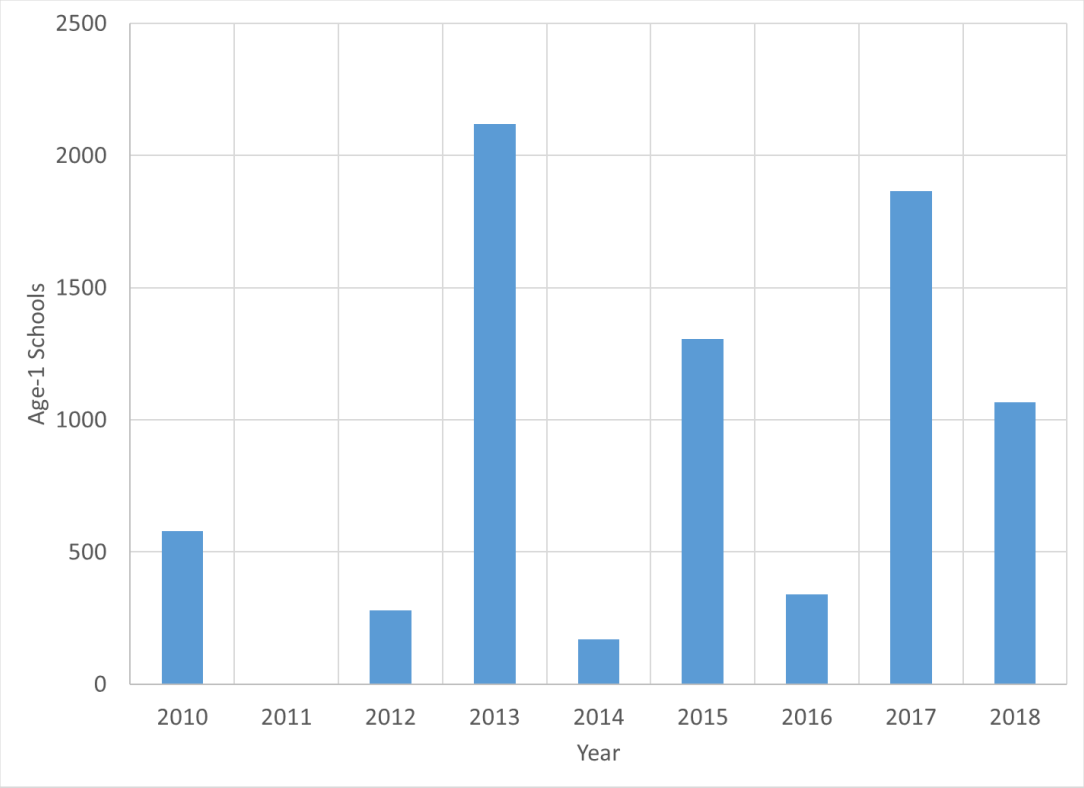

Figure 2. Number of schools of fish identified as age-1 herring during June aerial surveys.

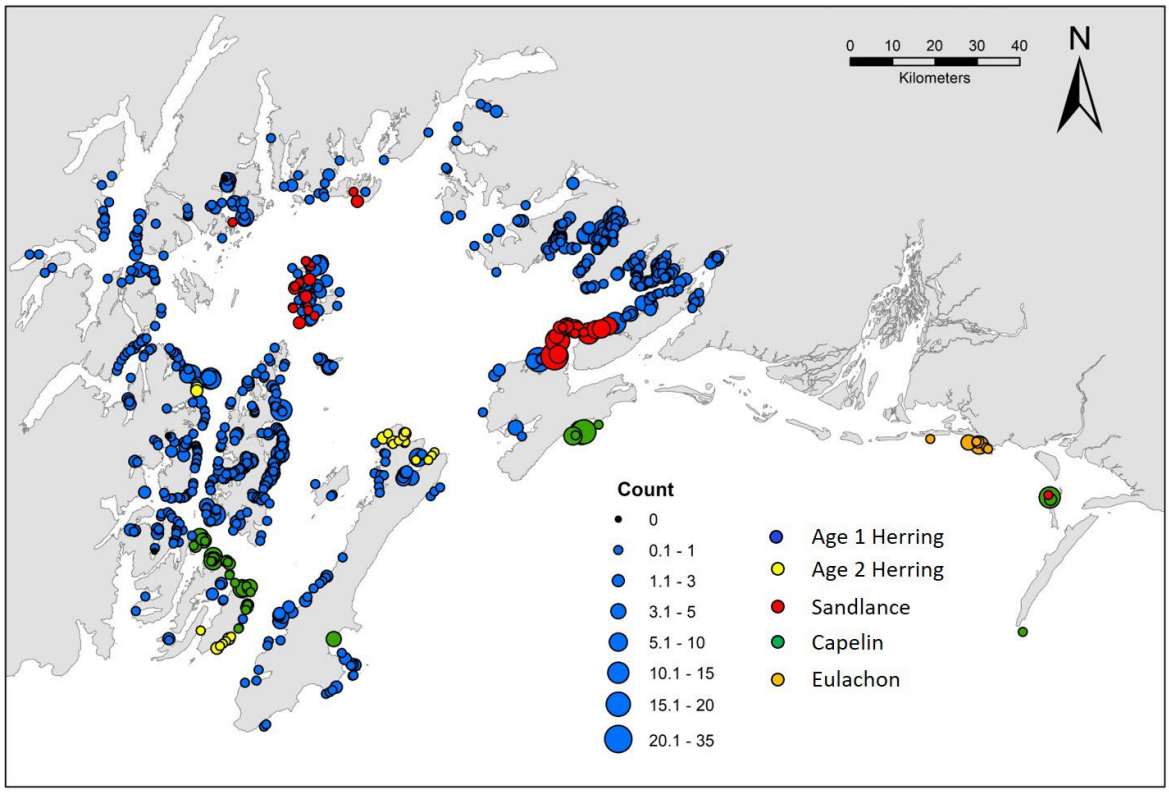

Figure 3. Map of forage fish schools observed in June 2018.

8. Coordination/Collaboration:

A. Projects Within a Trustee Council-funded program

1. Within the Program

This project works with all projects within the HRM program. Coordination is primarily through email and the annual PI meeting. Work with projects includes ensuring reporting is completed promptly and assisting the coordination of sampling logistics. I work with individual projects to facilitate coordination of the collection of samples needed and as a source of information about existing data and results.

2. Across Programs

Pegau serves as the primary contact for the HRM program with the GWA and DM programs. 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. During this year we also began the process of incorporating Dr. Whitehead's lingering oil project into the HRM program

B. Projects not Within a Trustee Council-funded program

We did not coordinate with projects outside of the Trustee Council-funded programs.

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 Prince William Sound. The monitoring work of the HRM program provides the data necessary for ADF&G to monitor the Pacific herring population in Prince William Sound

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 EVOS-funded project were leveraged to obtain supplemental funding from the NPRB (# 1807: *Ichthyophonus* in Pacific Herring).

A status of Prince William Sound herring was provided to 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

These publications are *in prep*

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

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

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

Groner, M. L. 2018. Managing disease in fished populations. University of Prince Edward Island, Charlottetown, PE, Canada.

Groner, M. L. 2018 Managing marine diseases. PISCO Marine disease summit. Portland, Oregon, USA.

Bravo, E., Conway, C., Hershberger, P., Gregg, J., Groner, M. 2018. Do histological analyses of herring infected with *Ichthyophonus* sp. suggest a shift from endemic to epidemic disease? SACNAS The National Diversity in STEM conference. San Antonio, TX, USA.

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

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

Aerial surveys of forage fish in June provided data on the location of forage fish schools, their size, and species. This includes age-1 and age-2+ herring, sand lance, eulachon, and capelin. One-page project descriptions of active projects were generated as handout of the information available on the web.

Pegau, W. S., Trocta, J., Haught, S. *Prince William Sound Herring* a status report for incorporation into NOAA's Alaska Marine Ecosystem Status Reports.

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

Aerial surveys of forage fish provided data on the location of forage fish schools, their size, and species.

10. Response to EVOSTC Review, Recommendations and Comments:

Science Panel Comments: The Panel appreciates Scott's hard work and effort in the coordination of the Herring Research Monitoring Program. We were pleased to hear that PIs are compliant and rapidly uploading

their data to the data portal. The panel is especially pleased to see Scott's involvement in promoting the inclusion of a postdoc in the Herring Program.

No response was required.

11. Budget:

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

Budget Category:	Proposed FY 17	Proposed FY 18	Proposed FY 19	Proposed FY 20	Proposed FY 21	TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	$57.0	$153.3	$177.4	$161.9	$51.7	$601.2	$ 168.0
Travel	$6.4	$9.9	$6.4	$6.4	$6.4	$35.5	$ 19.8
Contractual	$24.7	$26.0	$26.2	$11.0	$4.4	$92.3	$ 63.7
Commodities	$3.8	$1.5	$3.5	$1.4	$1.5	$11.7	$ 2.2
Equipment	$0.0	$0.0	$0.0	$0.0	$19.8	$19.8	
Indirect Costs (*will vary by proposer*)	$35.1	$57.20	$64.0	$54.2	$19.2	$229.7	$ 83.6
SUBTOTAL	$127.0	$247.8	$277.5	$234.9	$103.0	$990.2	$337.3
General Administration (9% of subtotal)	$11.4	$22.3	$25.0	$21.1	$9.3	$89.1	N/A
PROJECT TOTAL	$138.4	$270.2	$302.5	$256.1	$112.3	$1,079.3	
Other Resources (Cost Share Funds)	$26.0	$26.6	$27.2	$28.0	$28.3	$136.1	

We are slightly behind in spending on Personnel and a bit over on Contractual. The excess Personnel funds cover the cost of the excess contractual.