ATTACHMENT D **EVOSTC Annual Program Status Form**

Form Rev. 8.30.18

1. Program Number:

18120111

2. Program Title:

Herring Research and Monitoring Program

3. Program Lead Name(s):

W. Scott Pegau

4. Time Period Covered by the Summary:

1 February 2018 to 31 January 2019

5. Date of Summary:

April 2019

6. Program Website (if applicable):

http://pwssc.org/research/

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.
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.

We are addressing our first objective by expanding the age range used in the model in project 18120111-C. The model has been expanded to now incorporate data from age-0 on. We began efforts to examine the model sensitivity to various inputs and are searching for likely reasons for a recent divergence between the model population estimates and what is being observed in mile-days milt and acoustic biomass estimates. The modeling and disease research components have been working together to investigate how best to incorporate the new information on the presence of antibodies to the Viral Hemorrhagic Septicemia Virus (VHSV). The disease research work conducted in projects 18120111-A and 18120111-E have also been examining how the disease information, particularly *Ichthyophonus*, is dependent on the age of the fish and whether that information should be used to develop age-dependent mortality estimates.

The work of Dr. Hershberger (18120111-E) includes several laboratory studies designed to examine the concept of herd immunity to VHSV. This will help understand not only what the past exposure to VHSV might have been, but also help predict the potential for future VHSV outbreaks.

We completed a set of aerial surveys for forage fish, including age-1 herring in June (18120111-A). We are received a commitment for further aerial survey funding to maintain that dataset to provide a long enough time series to evaluate the value of the age-1 surveys on predicting the recruitment to the spawning stock.

The second objective was addressed through collection of age-weight-length data and aerial spawn surveys through project (18160111-F, Haught), acoustic spawning biomass surveys (18120111-G, Rand), disease prevalence measurements (18120111-E, Hershberger). Data from these projects were used as inputs to the Bayesian model of herring biomass run by Trevor Branch (18120111-C).

The age-weight-length data showed that the spawning population was made up of primarily age-4 and 3 fish, with few older age fish present. While it isn't unusual to have a large age class dominate the spawning stock, the lack of older fish in the spawning stock is unusual. There were only 4.5 mile days of spawn observed in 2018. The number of days flown was reduced, but the area covered remained large. The low number of days flown represents how short the spawn lasted. This represents a record low in mile days observed (Fig. 1). The area of spawning has contracted to a small portion of Port Gravina and Canoe Pass on Hawkins Island.

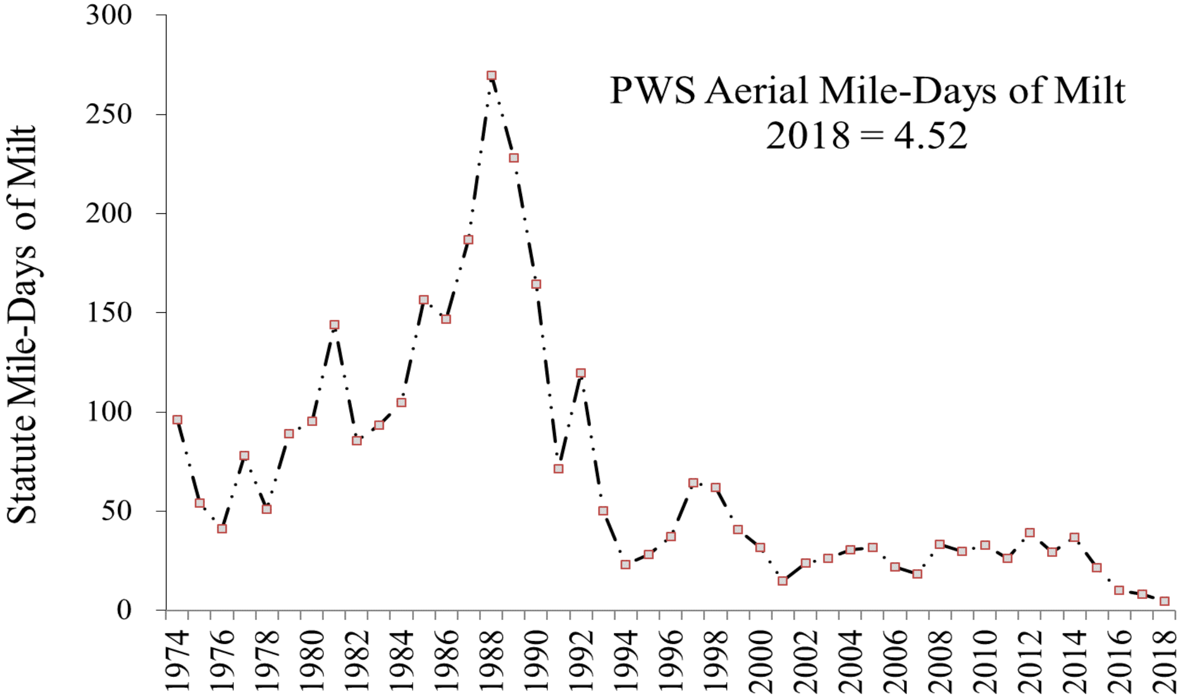

Figure 1. Mile-days-milt observed in Prince William Sound.

The acoustic surveys found a slight increase in the estimated spawning biomass in 2017 compared to 2016. The estimated spawning biomass was approximately 3,600 MT, again a near record low.

Disease prevalence measurements continue to record low levels of viral hemorrhagic septicemia (VHSV) and viral erythrocytic necrosis virus (VENV) in the spawning populations. The new approach developed in this program to detect the presence of VSHV antibodies provides a different result for the potential impact of VHSV on the PWS herring population (Fig. 2). It shows that about 8% of the herring population has been exposed to VHSV at some point in the past. The disease just not been detectable during the prevalence sampling period.

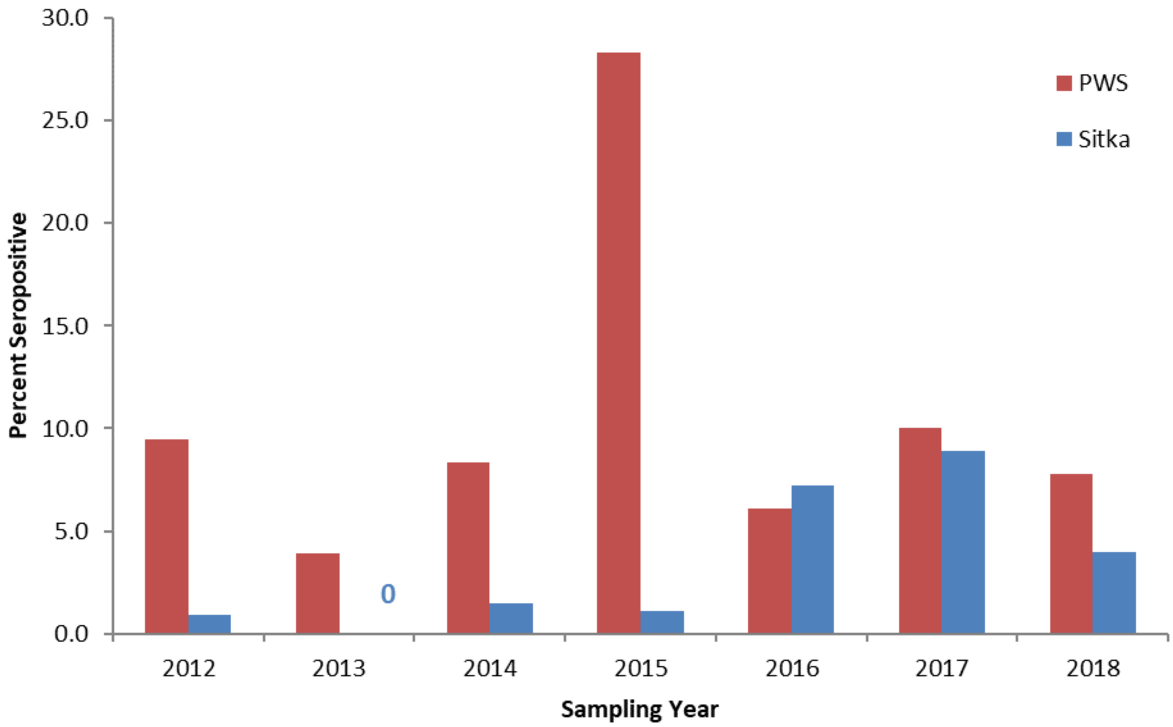

Figure 2. The presence of VHSV antibodies in herring collected in PWS and Sitka.

The data was used as inputs to the Bayesian Age-Structure-Analysis (BASA) model to estimate the total population. The BASA model continues to provide a good fit to age composition data, with an indication that there continues to be more young fish in the population than in any years since 2007. Estimated biomass in the population continued to be at record low levels (9,430 t, 95% CI 5,860-15,630t), even though the model displays an apparent upward bias in biomass in the most recent year, with estimated biomass considerably above the mile-days of milt, and somewhat above the acoustic estimate.

Many of the projects addressed our third objective. The modeling effort (18120111-C) continues to examine the characteristics of the PWS herring population compared to others around the globe. The focus was on recruitment this past year and we found that the magnitude and duration of the low recruitment levels currently observed are highly unusual (Fig. 3).

The model was used to examine potential relationships to 21 environmental time series (Fig. 4). The preliminary analysis examines the relationship between these environmental time series and the herring mortality and recruitment. Mortality was examined in four time bins (1980-1999, 198002012, 1993-2012, and 2000-2012). Adult mortality was most closely associated with walleye pollock numbers and winter North Pacific gyre oscillation, while walleye pollock (age-1), juvenile hatchery pink salmon, and a regime shift are most closely associated with herring recruitment (Fig. 5).

Figure 3. Average Prince William Sound herring recruitment, standardized to the maximum, is much lower than all other herring populations except one, and the number of years of poor recruitment (right panel) is the second highest in the collected data set.

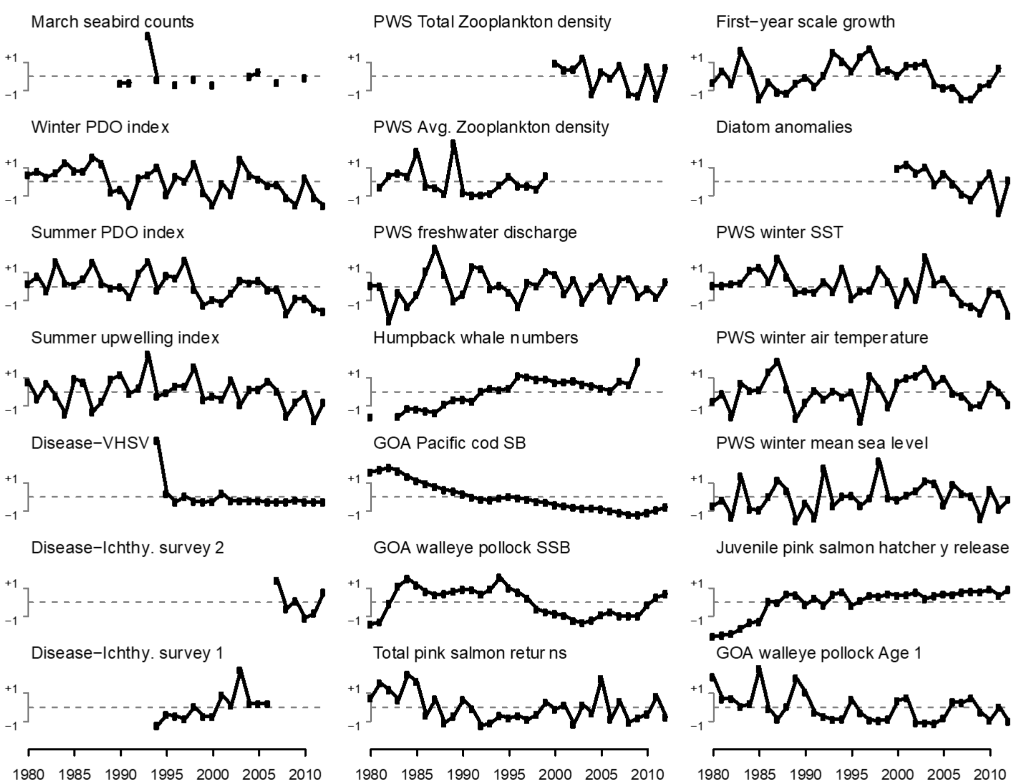

Figure 4. Time series used to examine the relationship between PWS herring mortality and recruitment to environmental variables.

Individual models with mortality covariates	DIC	WAIC	$D_{\infty\|SEL}$
null model (no covariates)	268.9	223.3	87.4
Freshwater discharge (Age 0)	269.8	223.5	87.0
Walleye pollock Age 1 (Age 0)	268.9	223.4	86.8
Winter air temperature (Age 0)	269.3	223.3	87.0
Winter mean sea level (Age 0)	268.5	223.6	86.7
Winter SST (Age 0)	269.4	223.7	86.8
Hatchery juvenile pink salmon (Age 0)	268.9	223.8	86.7
Freshwater discharge (Age 1)	269.4	223.7	87.2
Humpback whale numbers (Age 1-2)	267.4	224.1	86.6
Total pink salmon returns (Ages 1-2)	267.7	223.9	86.5
Disease-Ich. hof. & VHS virus (Ages 3+)	267.0	222.4	85.2
Arrowtooth flounder spawning biomass (Ages 3+)	269.3	224.7	86.6
Pacific cod spawning biomass (Ages 3+)	258.1	213.9	86.2
Walleye pollock spawning biomass (Ages 3+)	246.7	202.0	84.6
Summer NPGO index (Ages 3+)	256.1	208.7	84.5
Summer PDO index (Ages 3+)	261.2	216.3	86.8
Summer upwelling index (Ages 3+)	272.5	227.9	86.7
Total pink salmon returns (Ages 3+)	270.7	225.8	87.1
Winter NPGO index (Ages 3+)	251.6	204.9	81.1
Winter PDO index (Ages 3+)	271.4	226.8	87.4

Individual models with recruitment covariates	DIC	WAIC	$D_{\infty\|SEL}$
1989 pulse/recovery	269.7	224.4	87.7
1989 regime shift	255.5	222.7	86.8
1980s trending shift	256.0	223.6	86.6
Walleye pollock Age 1	244.0	221.4	87.5
Hatchery juvenile pink salmon	256.8	222.5	87.2
Spring air temp	269.7	223.8	87.1
Spring mean sea level	268.6	222.9	87.0
Winter mean sea level	264.6	223.9	86.7

Lower values of each criterion imply better models/important factors and have darker cells. The best performing model for each criterion (i.e. the minimum) has a white value.

Figure 5. Covariates examined for adult mortality (left) and recruitment (right) in the BASA model.

Dr. McGowan was selected as the postdoctoral researcher with the modeling project has begun examining the semi-spatial recruitment patterns. This includes examining the temporal patterns of spawn timing and location.

Dr. Maya Groner is working with Dr. Hershberger and supervised by Dr. Pegau (18120111-A) began work examining the interaction of age with the susceptibility to Viral Erythrocytic Necrosis. Unfortunately, we have not been able to isolate an appropriate control population for laboratory experiments so that work has been ended. She has shifted to focusing on how to model VHSV using existing infection trial information. This provides a numerical framework to examine herd immunity and improve how the disease information might be used in the BASA model.

Our tagging project (Bishop 18160111-B) addresses both our third and fourth goal. We need to understand where the herring are through the year to connect them with the appropriate environmental conditions. Therefore, the tagging helps guide our efforts to connect the PWS herring population to environmental variables.

At the beginning of this project year we uploaded the data from the acoustic array to determine movement of the 124 fish that had been tagged the previous spring. In all, 47.6% (n-59) of the fish tagged in 2017 were detected at the receiver arrays located at the entrances to the Gulf of Alaska (GoA). A likelihood ratio test was conducted to determine if there were factors that made a fish more likely to be detected at those arrays and fish with heavier weight at tagging and males were found to be significantly more likely to be detected at the arrays at the entrances to GoA. Of the 59 fish detected at the entrances 10 were later detected near one of the two arrays near the spawning grounds the following spring.

In April 2018 an additional 202 fish were tagged (83 near Gravina and 119 near Canoe Pass). Over 90% of the herring tagged at Port Gravina were subsequently detected at a nearby receiver array. The release site near Canoe Pass was not as close to the nearest receivers and a lower percentage (66%) were detected. We documented movement of the herring between the two spawning areas with 22 fish tagged at each location were later detected at the other spawning area. A partial upload from the receivers at the entrances showed the detection of 129 of the herring tagged in 2018.

Additional receivers were deployed in Prince William Sound to provide more information about movement within the Sound.

The herring maturity project collected herring at several times through the year. We were much more successful in capturing fish in the summer months due to shifting our methods and help from the salmon fishing fleet. We examined the gonad somatic index (GSI) and Hjort index as indications of the maturation process. The existing data allowed us to examine the seasonal maturation process (Fig. 6).

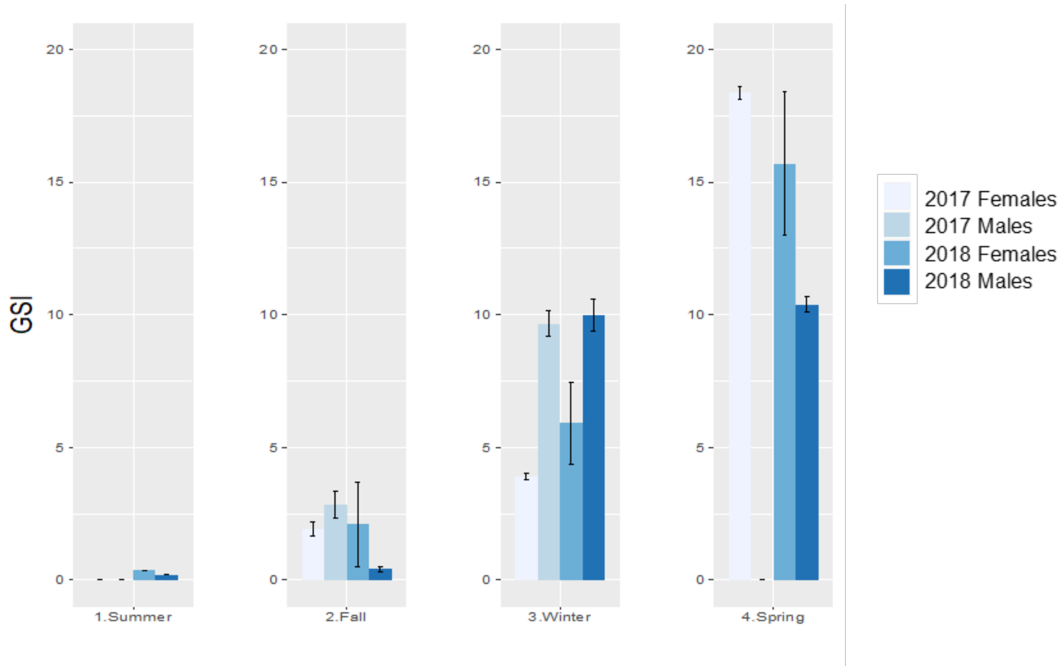

Figure 6. Variability in the gonad somatic index (%) of Pacific herring caught in Prince William Sound during the summer (July), fall (September), early winter (November), and spring (April). Data was not collected for males in the spring of 2017.

The histology information from samples collected in November 2017 showed did not show the presence of post ovulatory follicles. We are awaiting the histological results for the fish captured in July 2018 to determine if we can detect the post ovulatory follicles and if there is a mixture of post spawning and immature fish.

Preliminary analysis of the ADF&G age-structure database showed that not all age-3 fish could be accounted for in the seine or cast net samples. Some immature fish are observed in the seine samples and must be removed to get agreement in the age structure between seine and cast net samples. This indicates that a small percentage of immature fish are in the pre-spawn schools.

b) Highlights and noteworthy issues

Indications are that the spawning biomass has reached a new record low in Prince William Sound. There is some disagreement between the model and the indices used by the model.

All of our efforts indicated that the herring population is dominated by young fish with relatively few older fish. This happens when there are large recruitment events, but the numbers of age-4 fish in 2018 were not that unusual. Instead the lack of older herring made the age-4 fish a large percentage of the population.

The relationship between recruitment and age-1 walleye pollock was expected from previous work. The relationship between mortality and the pollock spawning stock and winter NPGO index have not been reported before.

We were able to deploy additional acoustic receivers that will give us more information about the movement of herring within Prince William Sound and the direction of travel at the entrances.

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

The Alaska Department of Fish and Game statewide herring coordinator serves on the HRM science oversight group and participated in the HRM PI meeting, so she was able to directly interact with all of the researchers in the HRM program. The local ADF&G fisheries biologist with responsibilities relating to herring is also a member of the HRM program and therefore directly connected to the various projects.

Dr. Groner participated in the Port Graham listening session and Hayley Hoover participated in the Chugachmiut meeting with elders held in Homer.

d) Problems and unusual developments

Some of the modeling work was delayed because the student working with the model received a prestigious travel award.

We continue to have biofouling issues with older acoustic receivers but have deployed additional receivers to maintain coverage while we try to retrieve the initial receivers.

e) Other significant information

We received funds to conduct an additional year of aerial surveys to lengthen the record of age-1 herring observations.

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. Dr. Pegau works with individual projects to ensure the collection of samples and as a source of information about existing data and results.

2. Across Programs

a. Gulf Watch Alaska

Dr. Pegau serves as the primary contact for the HRM program with the 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 Principal Investigator meetings are held together to allow for greater exchange of information. Individual projects, particularly the modeling project, is 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. Herring Research and Monitoring

N/A

c. Data Management

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

d. Lingering Oil

We began the process of incorporating the one existing lingering oil project (18170115 Whitehead) into the HRM program. The full inclusion of that project will be completed in 2019.

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: *See,* Reporting Policy at III (D) (9).

A. Publications Produced During the Reporting Period

Bishop, M.A., and J.H. Eiler. 2018. Migration patterns of post-spawning Pacific herring in a subarctic sound. *Deep-Sea Research Part II.* 147: 108-115. https://doi.org/10.1016/j.dsr2.2017.04.016

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

Hershberger, P.K., J.L. Gregg, C. Dykstra. 2018. High-prevalence and low-intensity *Ichthyophonus* infections in Pacific Halibut (*Hippoglossus stenolepis*). Journal of Aquatic Animal Health 30:13-19.

Lewandoski, S., and M.A. Bishop. 2018. Distribution of juvenile Pacific herring relative to environmental and geospatial factors in Prince William Sound, Alaska. *Deep Sea Research II.* 147:98-107. http://dx.doi.org/10.1016/j.dsr2.2017.08.002

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

Rand, P.S. 2018. Pacific herring response to surface predators in Prince William Sound, Alaska, USA. Marine Ecology Progress Series 600:239-244.

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

Vega, S. L., C. W. Russell, J. Botz, and S. Haught. (in Press). 2017 Prince William Sound area finfish management report. Alaska Department of Fish and Game, Fishery Management Report No. XX-XX, Anchorage.

Vega, S. L., C. W. Russell, J. Botz, and S. Haught. (In Prep). 2018 Prince William Sound area finfish management report. Alaska Department of Fish and Game, Fishery Management Report No. XX-XX, Anchorage.

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

Bishop, M.A. Annual herring migration cycle. Herring Research and Monitoring and Gulf Watch Alaska joint Principal Investigators annual meeting, November 2018. Anchorage.

Bishop, M.A., and B. Gray. How to tag a herring and where do they go afterwards? PWS Science Center Tuesday night lecture series. January 2019. Cordova.

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.

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

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.

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.

Hershberger, P. December 6, 2018. Causes of Pacific Herring Mortality: A Disease Perspective Prince William Sound Regional Citizens Advisory Council, Annual Science Night.

Hershberger, P. May 24, 2018. The Ecology of Disease in Marine Fishes: Insights from Pacific Herring. NOAA – Northwest Fisheries Science Center, Monster Seminar Jam

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

Trochta, J. T., A. MacCall, D. McGowan, T. A. Branch. 2019. Incorporating spawn surveys in a semi-spatial stock-recruitment model. Center for the Advancement of Population Assessment Methodology (CAPAM) conference on Spatial Stock Assessment Models, La Jolla. Oral presentation, 1-5 October 2018.

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

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

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

The modeling project provided a stock assessment of Prince William Sound herring for 2018.

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

All projects have uploaded their data to the data portal.

10. Response to EVOSTC Review, Recommendations and Comments: *See,* Reporting Policy at III (D) (10).

Science Panel Comments

Overall, the Panel is pleased with the Program's progress. The Panel strongly recommends that all proposals include hypotheses, highlights and figures reflecting progress made during the previous year(s), as did PIs for two of the proposals (18120111-C Branch and 18120111-E Hershberger/Purcell). The LTM proposal provide good examples of what the Panel is looking for, as they nicely addressed our previous request for this information. They also included a list of publications and datasets uploaded during the previous year, which we endorse and recommend that all proposals now include. This information is very helpful to determine whether changes are warranted in study plans for the upcoming year. Toward this end, improvements to the proposal forms will help. The Panel supports Scott's request to hire Maya Groner for the Post-doc position.

Response

Hopefully the Science Panel found that more detail was found in the FY19 proposals. That instruction was sent to the investigators and the proposal form was modified by EVOSTC staff to emphasize these points.

11. Budget: ***See,*** **Reporting Policy at III (D) (11).**

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

Budget Category:	Proposed FY 17	Proposed FY 18	Proposed FY 19	Proposed FY 20	Proposed FY 21	TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	$515.1	$741.7	$961.4	$962.0	$589.4	$3,769.6	$1,082.4
Travel	$37.1	$47.9	$45.4	$42.5	$39.0	$211.9	$53.1
Contractual	$198.7	$221.9	$218.7	$156.1	$144.0	$939.4	$246.9
Commodities	$192.6	$160.6	$159.0	$97.7	$98.8	$708.7	$266.5
Equipment	$5.9	$0.0	$50.3	$0.0	$44.9	$101.1	$32.0
Indirect Costs (*will vary by proposer*)	$200.1	$276.5	$397.3	$341.4	$186.3	$1,401.5	$381.2
SUBTOTAL	$1,149.5	$1,448.5	$1,832.0	$1,599.7	$1,102.4	$7,132.1	$2,062.1
General Administration (9% of subtotal)	$103.5	$130.4	$164.9	$144.0	$99.2	$641.9	
PROJECT TOTAL	$1,252.9	$1,578.8	$1,996.9	$1,743.7	$1,201.6	$7,774.0	
Other Resources (Cost Share Funds)	$157.2	$159.7	$160.7	$162.7	$149.7	$790.0	N/A