EVOSTC FY17-FY21 INVITATION FOR PROPOSALS
FY19 CONTINUING PROJECT PROPOSAL SUMMARY PAGE

Proposals requesting FY19 funding are due to shiway.wang@alaska.gov and elise.hsieh@alaska.gov by August 17, 2018. Please note that the information in your proposal and budget form will be used for funding review. Late proposals, revisions or corrections may not be accepted.

Project Number and Title

19120111-C

Modeling and stock assessment of Prince William Sound herring

Primary Investigator(s) and Affiliation(s)

Trevor A. Branch, Associate Professor, School of Aquatic and Fishery Sciences, University of Washington

Date Proposal Submitted

August 17, 2018

Project Abstract

Prince William Sound (PWS) herring collapsed shortly after the Exxon Valdez oil spill and has yet to recover. Here, we propose a modeling component to the long-term herring monitoring project, which has as its chief goal an understanding of the current status of PWS herring, the factors affecting its lack of recovery, and an assessment of research and fishery needs into the future. The original proposed project was expanded in FY18 with the addition of a postdoctoral fellow to investigate linkages between PWS herring recruitment to environmental forcing. Key products are the following (items 6-9 are related to the postdoctoral fellow):

1. The core product of the modeling project is the maintenance and updating of the new Bayesian age-structured assessment (BASA) model based on the ASA model used by ADF&G, including annual assessment updates of PWS herring and the revision of BASA to fit to new data sources such as the age-0 aerial survey, condition data, and updated age at maturity.
2. Adapting the BASA model to better model the disease component of natural mortality. Specifically, this would be based on new methods for detecting antibodies of viral hemorrhagic septicemia virus (VHSV) in archival and planned future collections of herring serum using a plaque neutralization assay (described by Hershberger).
3. Continued collection and expansion of catch, biomass, and recruitment time series from all herring populations around the world to place the lack of recovery of PWS herring into context given patterns of change in herring populations around the world.
4. An initial exploration of factors that may be used to predict herring recruitment, including oceanography, climate, competition, and predation.
5. A management strategy evaluation to test alternative harvest control rules for managing the fishery in the future, given realistic variability in productivity over time, and the possibility that the population has moved into a low productivity regime. Ecological, economic and social factors would be considered in the MSE.
6. Identifying relationships among oceanographic, biological, and climate data series from within PWS, the Gulf of Alaska, and the North-east Pacific that can predict PWS herring spawning, survival, and recruitment.
7. Examination of physical and ecological processes linked to PWS herring spawning, spawning survival, and survival of juvenile life stages.
8. The relative influence of physical and ecological processes on recruitment to the PWS and Sitka Sound herring populations.
9. Identifying environmental inputs for incorporation into the BASA model to improve recruitment predictions.

**The abstract should provide a brief overview of the overall goals and hypotheses of the project and provide sufficient information for a summary review as this is the text that will be used in the public work plan and may be relied upon by the PAC and other parties.*

EVOSTC Funding Requested* ***(must include 9% GA)***

FY17	FY18	FY19	FY20	FY21	TOTAL
Auth: $124,300	Auth: $288,300	$297,000	$303,300	$148,900	$1,161,900

Non-EVOSTC Funds to be used, please include source and amount per source:

FY17	FY18	FY19	FY20	FY21	TOTAL
0	0	0	0	0	0

**If the amount requested here does not match the amount on the budget form, the request on the budget form will considered to be correct.*

1. PROJECT EXECUTIVE SUMMARY

Provide a summary of the program including key hypotheses and overall goals, as submitted in your original proposal. Please include a summary and highlights since your last annual report: preliminary results with figures and tables. If there are no preliminary results to present, please explain why (i.e., lab analysis is still in progress). List any publications that have been submitted and/or accepted since you submitted your last proposal and other products in *Section 7*. Prior annual reports will be appended to remind reviewers of progress in previous years.

The herring modeling project is intended to improve predictive models of Prince William Sound herring through synthesizing the data collected by the other components of the overall herring monitoring project and hence assessing the current status of the population.

Background, history, and literature review (assessment model)

Muradian (2015, MS thesis) reviewed the available literature during the first five years of the long-term herring monitoring project; a brief summary is included here. PWS herring are the key forage fish species in Prince William Sound and have been harvested commercially for at least a century, with catches over 40,000 t in the 1930s (Muradian 2015). After the Exxon Valdez oil spill in 1989, which occurred during a period of high herring abundance, the herring population remained high for three years until collapsing in 1992-93 (Quinn et al. 2001). Since then, the fishery has been closed, except for a brief period during 1996-98. The fishery is managed by ADF&G which keeps the fishery closed if the pre-fishery spawning biomass is less than 22,000 short tons (19,958 mt), has the discretion to set a catch limit of 0-20% if the spawning biomass is 22,000–42,500 short tons, and opens the fishery with a catch limit of 20% of the pre-fishery spawning biomass if this is over 42,500 short tons (Muradian 2015).

The fishery was initially managed using an index of male spawning biomass until 1988 when an age-structured assessment model (the "ASA Model") was developed that fitted to catch-at-age data and mile-days-of-milt, and used egg deposition data as an absolute estimate of biomass (Funk and Sandone 1990). Later developments included the incorporation of disease data to explain the rapid declines in the population in 1992 (Marty et al. 2003, Marty et al. 2010, Quinn et al. 2001). As hydroacoustic survey biomass estimates became seen as more reliable, they too were added to the model, helping to address the conflict between the trends in mile-days-of-milt and the egg deposition data (Hulson et al. 2008); and a Ricker stock-recruit relation was added to the model to stabilize estimates of recruitment (Hulson et al. 2008). This model is the basis for the current ASA model used by ADF&G to conduct annual stock assessments, and is fit to data by minimizing sums of squares using Solver in Excel.

In the first five years of the herring monitoring program, an updated version of the ASA model was developed at the University of Washington (Muradian 2015; Muradian et al. 2017). The key new features included (1) a translation of the model into AD Model Builder (Fournier et al. 2012), (2) the use of likelihoods to allow a natural statistical weighting of data sets instead of sums of squares, (3) freely estimating recruitment in each year instead of using a Ricker stock-recruit relation, since the data did not support a Ricker model, (4) converting the model to a Bayesian model to allow statistically-based estimates of uncertainty in model parameter estimates and estimated biomass (e.g. Punt and Hilborn 1997). This Bayesian version of the ASA model (which we name "BASA") provides similar median estimates of pre-spawning biomass as the ASA model, but also reports uncertainty in model estimates, as can be seen in model fits to the survey time series (Fig 1), numbers-at-age data (Fig 2), recruitment estimates and biomass relative to management quantities (Fig 3) from the 2018 assessment based on data to the end of 2017 (John Trochta, unpublished, funded by this project). The new BASA model is the underlying basis for our proposal for the next five years of the long-term herring monitoring project.

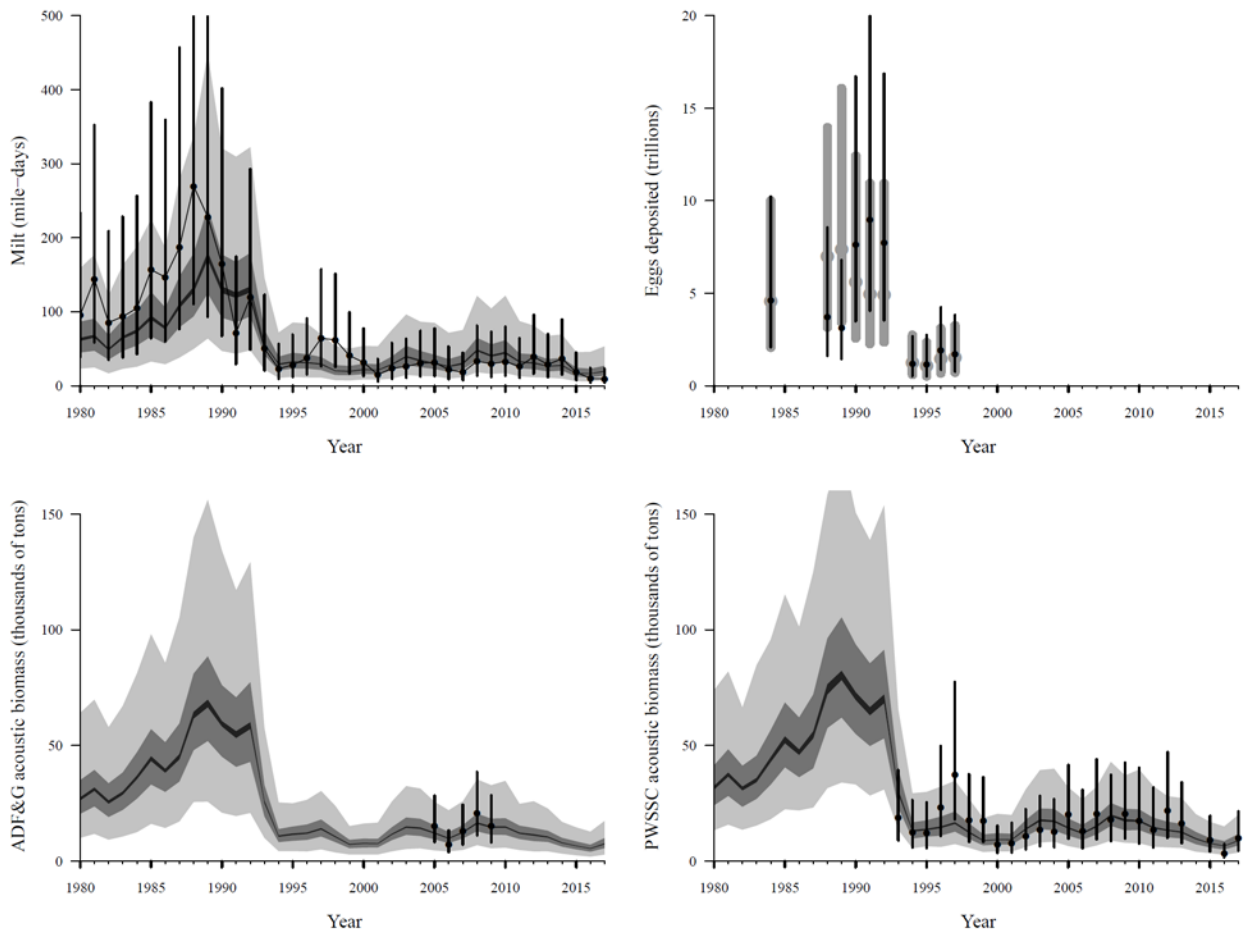

Figure 1. The 2017 Bayesian age-structured assessment (BASA) model estimates of Prince William Sound herring biomass fitted to the four main time series of biomass. Shaded polygons are the model-estimated posterior predictive intervals: 5th percentiles (black), 50th percentiles (dark gray) and 95% percentiles (light gray). Solid circles are the median of the data, and lines are the 95th percentiles including additional variance estimated by the model. Source: John Trochta, using the model described in Muradian (2015).

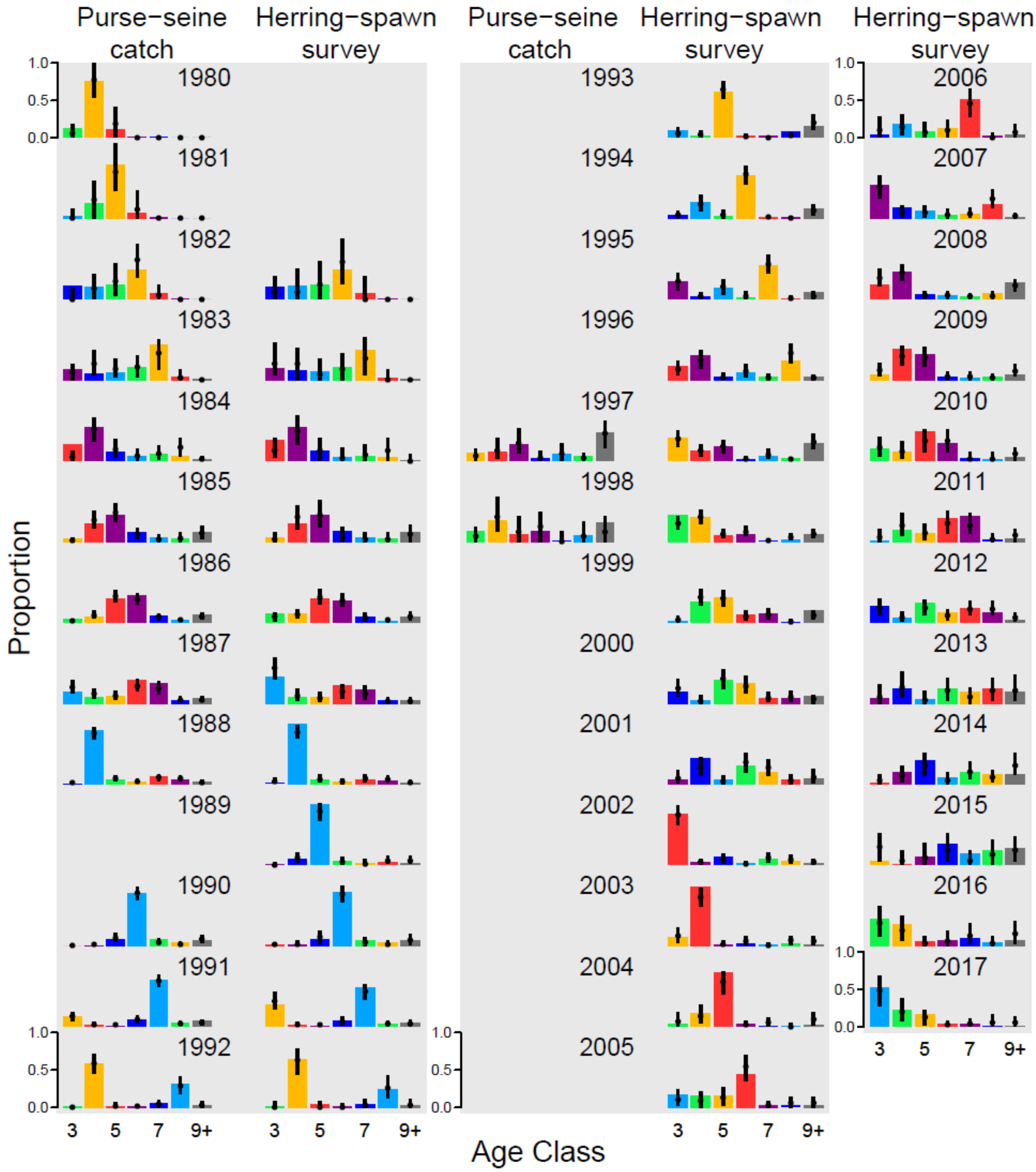

Figure 2. The 2017 Bayesian age-structured assessment (BASA) model fits to the age composition data from purse-seine catches and from the ADF&G herring-spawn survey. Colors track individual cohorts over time, while points and lines indicate the model posterior median and 95% posterior intervals. Source: John Trochta, using the model described in Muradian (2015).

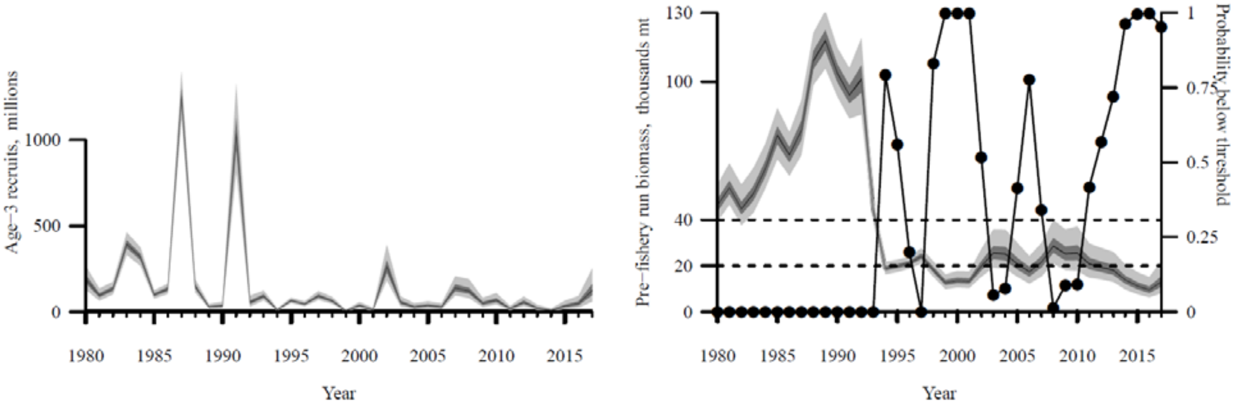

Figure 3. Estimates of age-3 recruitment (left) and the probability that biomass falls below the management threshold of 22,000 short tons in each year (points, right) from the 2017 BASA model. Source: John Trochta.

Background, history, and literature review (postdoctoral project – David McGowan)

Hypotheses vary on the primary causes of the herring population collapse (Hulson et al., 2008; Pearson et al., 2012; Thorne and Thomas, 2008) and continued low population size and poor recruitment (Deriso et al., 2008; Pearson et al., 2012; Ward et al., 2017). High recruitment is needed for the population to recover to pre-1993 abundance. The PWS herring population has not experienced any high recruitment events during the last three decades (Muradian et al., 2017), creating uncertainty as to which environmental conditions will be favorable to the population's long-term recovery.

While the PWS herring population has not had a strong year class since 1988, it is possible to gain insight from high recruitment events that have occurred in other local herring and groundfish populations that historically had synchronized recruitment with the PWS population. From 1978-1993, recruitment in the Sitka Sound herring population, along with other smaller populations within Southeast Alaska (SEAK), was closely related to PWS herring recruitment (Williams and Quinn, 2000). Similarly, recruits-per-spawner estimates for PWS herring were positively related to walleye pollock (*Gadus chalcogrammus*) young-of-year abundance in the GOA from 1980 to 2009 (Sewall et al., 2017). Since 1993, both the Sitka herring and GOA pollock populations have had multiple strong year classes, most recently in 2012 (Dorn et al., 2015; Hebert, 2016).

Given that herring and pollock typically recruit to their populations at age-3 and age-5, respectively, observed synchrony in recruitment success among these populations indicates that large-scale oceanographic processes operating across the GOA and Northeast Pacific are potentially influencing spawning and/or survival through the critical first year of life. Although the 2012 year class did not result in high recruitment to the PWS herring population (Haught et al. 2017; Muradian et al. 2017), there is evidence that the 2012 cohort initially experienced relatively high survival through the first year. The PWS juvenile herring aerial survey estimated that the relative abundance of age-1 fish in June 2013 was the highest among all surveyed years (1996-99, 2010-2016) (M. Arimitsu pers. comm.). This suggests that conditions in 2012 across the GOA and within PWS were favorable to spawning and survival through the first year of life for both herring and pollock, but that age-1 and age-2 herring in PWS incurred higher mortality within PWS between summer 2013 and spring 2015 that resulted in low recruitment as age-3 fish. Potential sources of mortality in the second and third years of life that would suppress herring recruitment following successful spawning and relatively high first-year survival include insufficient prey, disease (Hershberger et al. 2016; Kocan et al. 1997), and predation by marine mammals (Moran et al. in press), seabirds (Bishop et al. 2015), adult salmon (Sturdevant et al. 2013), and groundfish (Pegau 2013).

Most oceanographic and biological time series available from ongoing PWS monitoring efforts are relatively short in duration (< 10 years), preventing direct comparison with herring abundance and condition before the population crash. Strong connectivity between PWS and the northern GOA shelf (Halverson et al., 2013; Kline, 1999; Musgrave et al., 2013; Wang et al., 2001) indicates that climate and oceanographic drivers operating across the GOA and Northeast Pacific influence physical and biological conditions within PWS. This includes water column properties and circulation patterns (Halverson et al., 2013; Musgrave et al., 2013; Wang et al., 2001), the timing and magnitude of spring blooms (Eslinger et al., 2001), and zooplankton biomass and community composition (Cooney et al., 2001; Coyle and Pinchuk, 2003). Integrating longer time series from the GOA and Northeast Pacific (cf. NPFMC, 2016) may be used to infer conditions within PWS that influence the abundance, growth, and condition of PWS herring (e.g. Batten et al., 2016). Similarly, comparative studies between the PWS and Sitka herring populations may provide insight as to large-scale processes that favor spawning, as well as local processes whose impact on mortality varies between populations (e.g. Moran et al., In press).

The Herring Research and Monitoring (HRM) program has hypothesized that herring recruitment is driven by bottom up forcing, while mortality (i.e. the population level) is primarily determined by disease and predation (HRM proposal to EVOSTC FY17-FY21). Based on the recent observations from the 2012 year class and recognized bio-physical connectivity between PWS and the GOA, I expand upon the HRM hypothesis and propose that spawning and survival of herring during their first year of life is determined by bottom up processes that operate across the northern Gulf of Alaska (GOA) and broader Northeast Pacific, as seen for herring in the North Sea (Gröger et al. 2004), while survival of juvenile fish after their first winter is determined by local ecological processes within PWS.

Dr. McGowan began in the 1st quarter of FY18. Progress to date has entailed conducting a literature review to become familiarized with historical herring- and oceanographic-related work conducted in PWS and the broader NE Pacific, and to explore analytic approaches that may be applicable to the project objectives. The literature review has led to the ongoing identification of available data from historical and current EVOS-funded studies, ADF&G, NOAA, and other sources. These include atmospheric and oceanographic data series from field sampling, remote sensors, and models for the GOA shelf and PWS; fisheries dependent and independent data from aerial, trawl, and acoustic surveys conducted in inshore and offshore waters between Kodiak and Southeast Alaska; diet and bioenergetic data; and predator distributions and diet data. Dr. McGowan has also been reaching out to other scientists in the region that are conducting research related to herring and other forage species in the NE Pacific to gain background on PWS and other herring populations in the GOA and develop potential collaborations.

Summary of project

Modeling: over the next five years, the BASA model will be revised and updated to provide an annual stock assessment of PWS herring to complement the ADF&G herring assessment. Updates will include model fits to new data sources and a more realistic disease component. We will continue the expansion of the database of herring abundance catch, and recruitment time series to place PWS in context of global trends in herring stocks. We will examine environmental factors that might predict herring recruitment. Finally, we will conduct management strategy evaluations to test alternative harvest control rules for managing the fishery; and evaluate which future data sources will be the most cost-effective at improving the accuracy of the BASA model.

Postdoctoral project: this three-year study will examine linkages between physical and ecological processes to PWS herring recruitment. Spatiotemporal models and time series analysis techniques will quantify the influence of environmental covariates on herring spawning, survival during juvenile stages, and recruitment. The model will be based on oceanographic, biological, and climate data series that represent environmental conditions across a range of spatial scales from within PWS to the Northeast Pacific basin. Significant environmental covariates linked to PWS herring recruitment will be included in the BASA model to improve the accuracy of recruitment predictions.

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2. PROJECT STATUS OF SCHEDULED ACCOMPLISHMENTS

A. Project Milestones and Tasks

Milestones are annual steps to meet overall project objectives. For each milestone listed, specify the status (completed, not completed) when each was completed and if they are on schedule, as submitted in your most current proposal.

Tasks are annual steps to meet milestones. Specify, by each quarter of each fiscal year, when critical tasks (for example, sample collection, data analysis, manuscript submittal, etc.) were and will be completed.

Please identify any substantive changes and the reason for the changes. *Reviewers will use this information in conjunction with annual program reports to assess whether the program is meeting its objectives and is suitable for continued funding.*

B. Explanation for not completing any planned milestones and tasks

Please identify any substantive changes and the reason for the changes. If tasks were not completed as scheduled or delayed, please explain why and the anticipated completion date.

C. Justification for new milestones and tasks

Please identify any new milestones and tasks and the reason why they have been added.

A. Project Milestones and Tasks

Project milestone and task progress by fiscal year and quarter, beginning February 1, 2017. Yellow highlight indicates proposed fiscal year Work Plan. Additional milestones and tasks may be added. C = completed, X = not completed or planned. Fiscal Year Quarters: 1= Feb. 1-April 30; 2= May 1-July 31; 3= Aug. 1-Oct. 31;

4= Nov. 1-Jan 31.

	FY17				FY18				FY19				FY20				FY21			
Milestone/Task	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Personnel																				
Identify graduate student	C																			
Data and BASA model																				
Simulation study completed on feasibility of estimating annual VHSV infection rate from antibodies in serum				C																
Obtain antibody data from herring serum 2012-17 for inclusion in model							C													
Preliminary examinations of environmental factors affecting recruitment										X										
Preliminary analysis of harvest control rules																		X		
Submit model results and code to Workspace and ADFG				C				X				X				X				X
Update on global herring meta-analysis and relevance to PWS herring												X								
Update BASA model with antibody disease component									X											
Annual assessment update from BASA model					C				X				X				X			
Post-doc																				
Obtain oceanographic, biological, and climate data							X													
Preliminary analysis relating PWS data series to longer time series from the Gulf of Alaska and NE Pacific								X												
Analysis of environmental linkages to PWS spawning									X											
Analysis of environmental linkages to survival of age-1 and -2 PWS herring											X									
Analysis of environmental linkages to recruitment to PWS and Sitka populations														X						
Identify environmental factors to facilitate expansion of BASA model														X						
Reporting																				
Annual reports				C				C				X				X				
FY work plan (DPD)				C				C												
Draft FY17-21 Final Report																				X
Meetings & Conferences																				
Annual PI meeting				C				C				X				X				X
AMSS (post-doc)								X				X				X				
Publications																				
Submit paper on antibody disease component										X										

Submit paper on factors predicting herring recruitment (if study is conclusive)														X						
Submit paper on harvest control rules suitable for managing herring																				X
Submit paper on environmental linkages to PWS spawning										X										
Submit paper on environmental linkages to survival of juvenile herring												X								
Submit paper on environmental linkages to herring recruitment															X					
New Milestone																				
New task																				

B. Explanation for not completing any planned milestones and tasks

Progress on the modeling component has met planned milestones, but nevertheless is slower than anticipated. The primary graduate student on the project (John Trochta) was awarded a prestigious Bonderman Fellowship which involved taking a leave of absence from the project October 2017 to June 2018. Less progress than expected was made during his absence despite temporarily funding another graduate student.

C. Justification for new milestones and tasks

Milestones and tasks listed under “Post-doc” were previously reported in the appendix of the FY18 proposal.

3. PROJECT COORDINATION AND COLLABORATION

A. Within an EVOTC-Funded Program

Provide a list and clearly describe the functional and operational relationships with any EVOSTC-funded Program (Herring Research and Monitoring, Long-Term Research and Monitoring or Data Management Programs). This includes any coordination that has taken or will take place and what form the coordination will take (shared field sites or researchers, research platforms, sample collection, data management, equipment purchases, etc.).

B. With Other EVOSTC-funded Projects

Indicate how your proposed project relates to, complements or includes collaborative efforts with other proposed or existing projects funded by the EVOSTC that are not part of a EVOSTC-funded program.

C. With Trustee or Management Agencies

Please discuss if there are any areas which may support EVOSTC trust or other agency work or which have received EVOSTC trust or other agency feedback or direction, including the contact name of the agency staff. Please include specific information as to how the subject area may assist EVOSTC trust or other agency work. If the proposed project requires or includes collaboration with other agencies, organizations or scientists to accomplish the work, such arrangements should be fully explained and the names of agency or organization representatives involved in the project should be provided. If your proposal is in conflict with another project, note this and explain why.

Detailed coordination is outlined in the overall project proposal. A few highlights are listed below.

Within the Program: coordination takes place through regular data transfer, emails, phone calls, and two in-person meetings per year. Each of the components of the herring plan has a close connection to the model, from the acoustic survey, to the disease work, to aerial surveys, and assessment of age at maturity.

With other EVOSTC-funded programs and projects: model inputs for oceanographic and predator data (humpback whales, etc.) will come through collaboration with the Gulf Watch program.
With Trustee or Management Agencies: input data for the assessment model (ADF&G survey, age composition, weight at age, etc.) comes from ADF&G, which requires close coordination to understand how the data were collected and how they should be used in the model. Results are transmitted to lead ADF&G scientists (Sherri Dressel) for comments and review.
With Native and Local Communities: no direct involvement is planned at this point.

4. PROJECT DESIGN

A. Overall Project Objectives

Identify the overall project objectives for your project as submitted in your original proposal.

B. Changes to Project Design and Objectives

If the project design and objectives have changed from your original proposal, please identify any substantive changes and the reason for the changes. Please include the revised objectives in this section. Include any information on problems encountered with the research or methods, if any. This may include logistic or weather challenges, budget problems, personnel issues, etc. Please also include information as to how any problem has been or will be resolved. This may also include new insights or hypotheses that develop and prompt adjustment to the project.

The two primary objectives are to conduct annual stock assessment for Prince William Sound herring, and to work on including the new antibody data from herring serum, which will tell us what percent of the herring at each age have been exposed to viral hemorrhagic septicemia virus (VHSV) disease in each year in the past. Work will continue on the global herring meta-analysis to provide informative Bayesian priors for the assessment, and to explore factors used to predict herring recruitment.

To examine linkages between physical and ecological processes to PWS herring recruitment, the following objectives will be completed:

1. Measure coherence between PWS data series and related time series from the GOA and Northeast Pacific with greater spatial and temporal coverage to identify oceanographic, biological, and climate covariates that can be used in subsequent analyses as potential predictors of PWS herring spawning, survival, and recruitment,
2. Identify physical and/or ecological processes linked to PWS herring spawning,
3. Identify physical and/or ecological processes linked to survival of age-1 PWS herring,
4. Identify physical and/or ecological processes linked to survival of age-2 PWS herring,
5. Quantify the influence of environmental factors linked to PWS herring spawning and/or juvenile survival on recruitment to PWS and Sitka Sound herring populations,
6. Provide environmental factors linked to PWS herring spawning and/or juvenile survival to the modeling and stock assessment project to assess if expanding the BASA model to include these environmental inputs improves the accuracy of the recruitment predictions.

This study is designed to synthesize available data series collected over the past four decades to improve our understanding of how environmental variability has influenced, and potentially suppressed, PWS herring recruitment and population size. It builds upon decades of research and monitoring following the EVOS: this includes recent efforts by Batten et al. (2016) to examine the relationship between temperature and prey availability to PWS herring first year growth, and by Sewall et al. (2017) and Ward et al. (2017) to identify environmental and anthropogenic connections to PWS herring recruitment. By examining the influence of environmental factors related to bottom up and top down forcing on herring during subsequent life stages that ultimately determine recruitment success, this study is designed to shed light on stage-specific bottlenecks that are potentially constraining recovery of PWS herring.

Final products from this project are expected to result in 3-4 scientific papers describing results for Objectives 2-5 (results from Obj. 3 and 4 will be submitted as either 1 joint paper or 2 separate papers). In addition, relationships identified by Obj. 1 are expected to support other HRM and Gulf Watch Alaska projects by identifying new environmental covariates relevant to their respective analyses.

Changes to project design: the graduate student, John Trochta, has obtained a bypass from his MS to a Ph.D. degree and continues to work on the project after returning from a leave of absence due to receiving the Bondermann Travel Fellowship. A new MS student, Stephanie Thurner, acted as caretaker of the stock assessment portion of the project during his absence, but progress was slowed.

5. PROJECT PERSONNEL – CHANGES AND UPDATES

If there are any staffing changes to Primary Investigators or other senior personnel please provide CV's for any new personnel and describe their role on the project.

The postdoctoral fellow, David McGowan, began in the 1st quarter of FY18.

6. PROJECT BUDGET FOR FY19

A. Budget Forms (Attached)

Provide completed budget forms.

B. Changes from Original Proposal

If your FY19 funding request differs from your original proposal, provide a detailed list of the changes and discuss the reason for each change.

C. Sources of Additional Funding

Identify non-EVOSTC funds or in-kind contributions used as cost-share for the work in this proposal. List the amount of funds, the source of funds, and the purpose for which the funds will be used. Do not include funds that are not directly and specifically related to the work being proposed in this proposal.

A. Budget Forms:

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	$48.7	$138.2	$144.3	$152.4	$64.8	$548.4	
Travel	$6.4	$13.7	$12.1	$9.3	$6.9	$48.4	
Contractual	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	
Commodities	$25.1	$25.7	$26.1	$25.0	$24.2	$126.1	
Equipment	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	
Indirect Costs (*will vary by proposer*)	$33.8	$86.9	$90.0	$91.6	$40.7	$343.0	
SUBTOTAL	$114.0	$264.5	$272.5	$278.3	$136.6	$1,065.9	
General Administration (9% of subtotal)	$10.3	$23.8	$24.5	$25.0	$12.3	$95.9	N/A
PROJECT TOTAL	$124.3	$288.3	$297.0	$303.3	$148.9	$1,161.9	
Other Resources (Cost Share Funds)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	

B. Changes from original proposal: none

C. Additional funding: none.

7. FY18 PUBLICATIONS AND PRODUCTS

Products include publications (include *in prep* and *in review*), published and updated datasets, presentations, and outreach during FY18.

Published papers

Ward EJ, Adkison M, Couture J, Dressel SC, Litzow MA, Moffitt S, Hoem Neher T, Trochta J, Brenner R (2017) Evaluating signals of oil spill impacts, climate, and species interactions in Pacific herring and Pacific salmon populations in Prince William Sound and Copper River, Alaska. PLoS One 12:e0172898

Trochta JT, Pons M, Rudd MB, Krigbaum M, Tanz A, Hilborn R (2018) Ecosystem-based fisheries management: Perception on definitions, implementations, and aspirations. PLoS One 13:e0190467

Ready for submission (awaiting ADF&G feedback)

Trochta JT, Branch TA, Shelton AO, Hay DE (in prep) The highs and lows of herring: A meta-analysis of patterns in herring collapse and recovery. ICES Journal of Marine Science