ATTACHMENT C *EVOSTC Annual Project Report Form*

Form Rev. 9.14.17

*Please refer to the Reporting Policy for all reporting due dates and requirements.

1. Project Number: *See,* Reporting Policy at III (C) (1).

17120111-C

2. Project Title: *See,* Reporting Policy at III (C) (2).

Modeling and stock assessment of Prince William Sound herring

3. Principal Investigator(s) Names: *See*, Reporting Policy at III (C) (3).

Trevor A. Branch

4. Time Period Covered by the Report: *See,* Reporting Policy at III (C) (4).

1 February 2017 to 31 January 2018.

5. Date of Report: *See,* Reporting Policy at III (C) (5).

February 2018

6. Project Website (if applicable): *See,* Reporting Policy at III (C) (6).

http://pwssc.org/modeling-herring-population-dynamics-in-pws/

7. Summary of Work Performed: *See,* Reporting Policy at III (C) (7).

Assessment model: The main aim of the modeling project is to improve the performance of the age structure assessment (ASA) model for Prince William Sound herring. In previous years, the ASA model run by the Alaska Department of Fish & Game (ADF&G) was expanded and updated to include a Bayesian formulation which naturally weights the input data sources, and better characterizes uncertainty through estimating Bayesian posteriors, and this work was published in 2017 (Muradian et al. 2017). The Bayesian Age Structured Assessment model (BASA) has continued to evolve, now modeling ages starting at age-0 instead of age-3, and was run on the updated data age composition data through to 2017, except for the latest acoustic estimate which became available after the model was run. The BASA model continues to provide a good fit to age composition data (Figure 1), with an indication that there is a greater proportion of young fish in the population than in any year since 2007. Estimated biomass in the population displayed a slight uptick in 2017 (Figure 2) but if the acoustic survey index had been included, this would likely have led to a decline in estimated biomass.

Publication of value of past information: a manuscript describing past modeling work on the value of surveys to the current assessment has been written and is almost ready for submission.

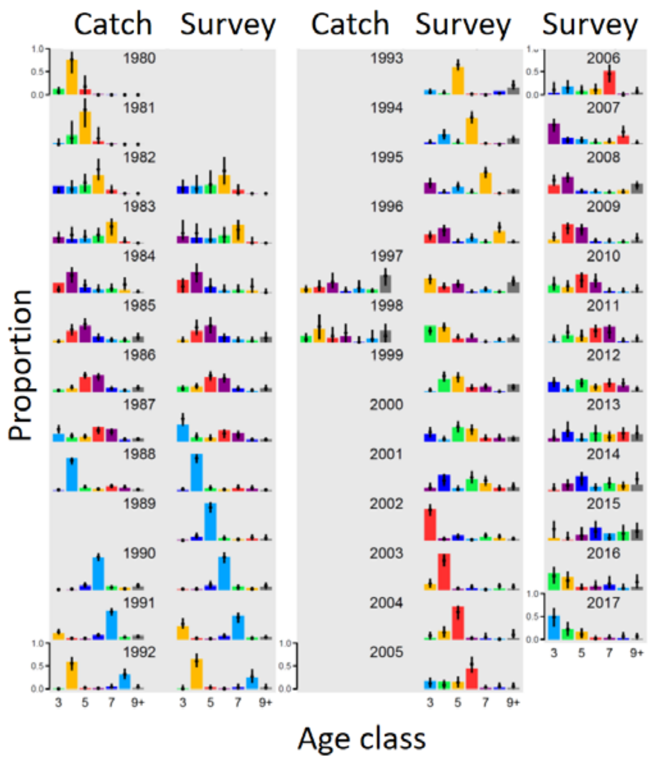

Figure 1. Fits of the BASA assessment model (points = median, lines = 95% credibility intervals) to the numbers at age data from catches and surveys (bars). Each color follows a single cohort as it ages through the fishery. Data are available only for age-3 and above.

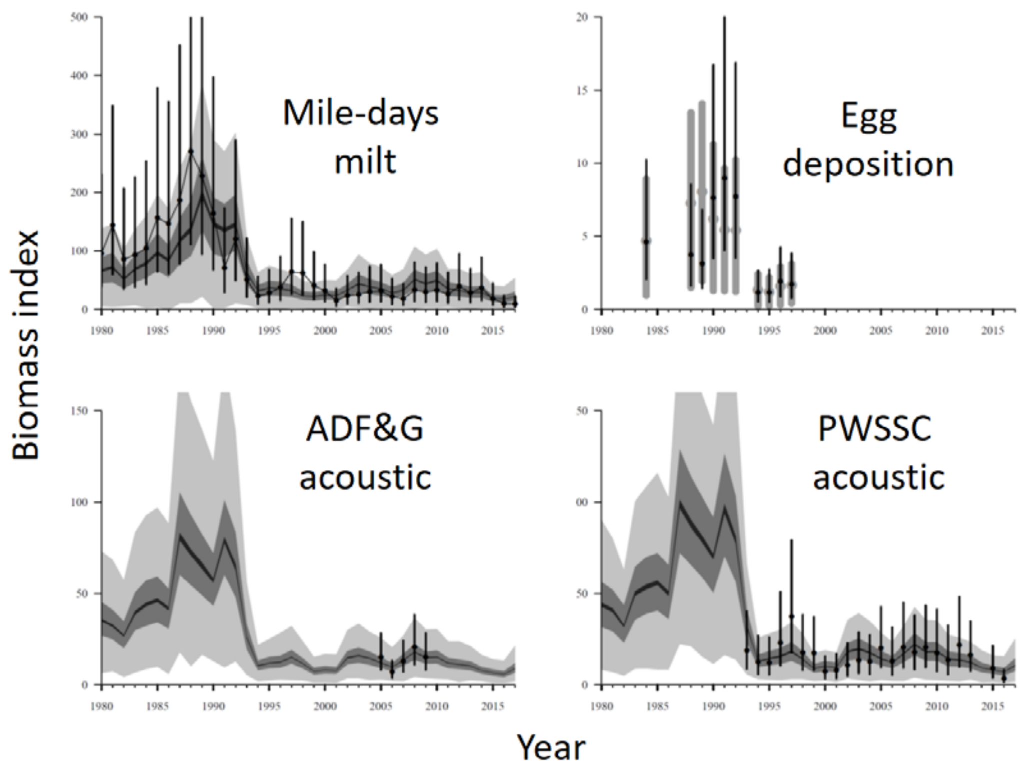

Figure 2. Estimated biomass from BASA (points and lines showing 95% credibility intervals) compared to indices of biomass in the population (shading). Although BASA predicted a slight uptick in biomass in 2017, the mile-days of milt survey declined (upper left panel), and so did the Prince William Sound Science Center (PWSSC) acoustic estimate (not available in time for model running). With the inclusion of the latter data point, predicted biomass would likely have declined, not increased.

Global herring meta-analysis: the meta-analysis placing PWS herring in a global context has been written and is ready for submission to Fish and Fisheries. The results further strengthen the idea that this population's collapse and failure to recover is highly unusual. For example, PWS herring has now spent 24 years below 30% of the average high biomass level, a longer time than all but two of the global herring stocks (Figure 3), and has also had many years of poor recruitment and much lower average recruitment than other herring stocks (Figure 4).

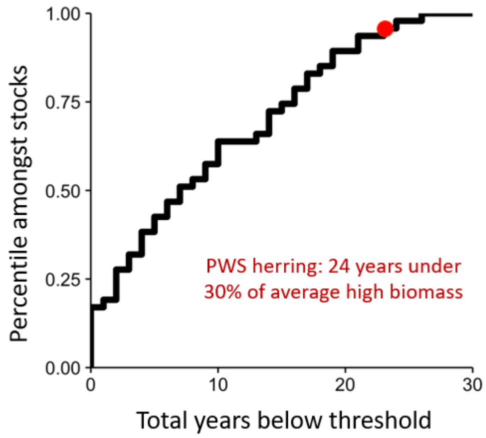

Figure 3. The red dot shows where PWS herring fall among global herring populations in terms of the duration of the current period of low biomass.

Figure 4. Distribution of recruitment relative to the average maximum, and number of years of low recruitment, showing how PWS herring is, again, anomalous.

Factors associated with low biomass: preliminary analyses of the global meta-analysis have found that low biomass is usually associated with low catches (because management closes herring fisheries), but is also more common when variability is high in both sea surface temperature and sea surface height anomalies. These results are still preliminary and may change.

Incorporating VHSV antibody data into the model: one currently poorly-modeled component of BASA is the incorporation of disease data. New antibody detection methods from project 17120111-E promise to provide a much more realistic estimate of the natural mortality due to disease. In brief, herring appear to retain antibodies to the virus VHSV, and thus if a disease outbreak hits the population, all individuals will be exposed and harbor antibodies at a proportion related to the prevalence of the disease outbreak. New recruits will not have antibodies, and thus an age-specific antibody prevalence can be used to estimate the ages affected by VHSV, and the prevalence of VHSV in the population. An initial simulation study (Figure 4) demonstrated that it is possible to estimate VHSV prevalence by year and age from the antibody data, and thus the utility of including this component and the data in the BASA model. Antibody data are expected to become available in 2018.

		Age of herring									
Year	Disease	0	1	2	3	4	5	6	7	8	9+
2005	0.9	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
2006	0	0.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
2007	0	0.00	0.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
2008	0	0.00	0.00	0.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90
2009	0	0.00	0.00	0.00	0.00	0.90	0.90	0.90	0.90	0.90	0.90
2010	0.2	0.20	0.20	0.20	0.20	0.20	0.92	0.92	0.92	0.92	0.92
2011	0.5	0.50	0.60	0.60	0.60	0.60	0.60	0.96	0.96	0.96	0.96
2012	0	0.00	0.50	0.60	0.60	0.60	0.60	0.60	0.96	0.96	0.96
2013	0	0.00	0.00	0.50	0.60	0.60	0.60	0.60	0.60	0.96	0.96
2014	0.2	0.20	0.20	0.20	0.60	0.68	0.68	0.68	0.68	0.68	0.97
2015	0.1	0.10	0.28	0.28	0.28	0.64	0.71	0.71	0.71	0.71	0.71
2016	0.2	0.20	0.28	0.42	0.42	0.42	0.71	0.77	0.77	0.77	0.77

Figure 4. Simulated antibody prevalence if the background mortality from non-VSHV causes is $M = 0.2$, mortality from VHSV is $M_d = 0.6$, and there were disease outbreaks affecting 90% of the population in 2005, 20% in 2010, 50% in 2011, 20% in 2014, 10% in 2015, and 20% in 2016. A simple model fitted to these data was able to perfectly estimate VSHV annual prevalence and mortality from VHSV, demonstrating the utility of including this modeling component and the VHSV data in the BASA stock assessment model.

Unanticipated delay: John Trochta, the principal graduate student working on the herring modeling, was awarded a Bonderman Travel Fellowship, which requires an eight month leave of absence from the project (October 2017 to April 2018). Another student Stephanie Thurner is taking on the modeling component, but it is expected that progress will be slower during this period until John Trochta returns.

8. Coordination/Collaboration: *See*, Reporting Policy at III (C) (8).

(1) Within the Program: close collaboration and coordination with the components of the HRM program are an integral part of the modeling project, including assumptions going into the model, data collection (milt survey, acoustic survey, numbers at age, age at maturity, and other data). In addition, the development of the antibody data involves working closely with the disease component of the project.

(2) Across Programs

(a) Gulf Watch Alaska: the new postdoc David McGowan will start work in February 2018, and will be coordinating with GWA and the HRM program on a three broad-scale integrative project to predict herring recruitment and holistically combine all elements of the HRM and GWA programs.

(c) Data Management: data and model outputs are being uploaded as they become available to the AOOS Data Portal.

(3) With Trustee or Management Agencies: coordination with ADF&G herring scientists is required for data inputs collected by ADF&G.

9. Information and Data Transfer: *See,* Reporting Policy at III (C) (9).

a) publications produced during the reporting period;

Directly related publications

Muradian ML, Branch TA, Moffitt SD, Hulson P-JF (2017) Bayesian stock assessment of Pacific herring in Prince William Sound, Alaska. PLoS One 12:e0172153

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

Three more publications are in preparation.

Partially related publications

Anderson SC, Branch TA, Cooper AB, Dulvy NK (2017) Black-swan events in animal populations. Proceedings of the National Academy of Sciences USA 114:3252-3257

Barnett LAK, Branch TA, Ranasinghe RA, Essington TE (2017) Old-growth fishes become scarce under fishing. Current Biology 27:2843-2848

Rudd MB, Branch TA (2017) Does unreported catch lead to overfishing? Fish and Fisheries 18:313-323

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

b) dates and locations of any conference or workshop presentations where EVOSTC-funded work was presented.

Trochta, J. & Branch T.A. 2017 Insights into the dynamics of Atlantic and Pacific herring following population collapse. Alaska Marine Science Symposium. Anchorage, Alaska. 23-27 January 2017.

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

Science Panel Comments and Responses on Revised FY17-21 Proposal, September 2016

The original proposal, and the revision, was very well presented. The Panel appreciates the feedback from the PI on our concerns and the removal of some aspects of the proposal as suggested by the Panel. We understand the PI's justification to retain other aspects.

PI response: NA

Science Panel Comments and Responses on Revised FY18 Proposal, September 2017

The Panel is pleased to see the data presented and supports the elimination of the Ricker SRR. The Panel has some suggestions in regards to the model:

The BASA is a logical extension of the preceding ASA assessment model for PWS herring, and may be of use to fishery managers as a model intended to determine such quantities as the stock abundance relative to the stock size threshold for opening a fishery. Some aspects of the BASA model pose difficulties for the examination of environmental relationships. The Panel does not consider the present BASA to be an adequate operating model for purposes of Management Strategy Evaluation (MSE). EVOSTC research needs would be better met by implementing the following changes to the BASA model to aid in identifying critical population processes and environmental influences on PWS herring:

A. Extend the time series as early a date as possible (previous assessments go back to 1925). This will greatly increase the statistical power for examining environmental influences. The present BASA model begins in 1980, reducing the length of the time series.

PI Response (10/11/2017)

It is our indeed our intent to extend the time series of the BASA model further back in time than the current ASA model used by ADF&G for stock assessments. At present, both BASA and ASA start in 1980, because this marks the start of indices of abundance for this population. In the absence of biomass indices prior to 1980, annual stock assessment estimates of recruitment and biomass will be far more uncertain and less useful in examining the influence of environmental processes. However, prior to 1980, there are data on total catch, proportion at age in catch, and length at age are available (e.g. Reid 1971). It should be noted that while much more uncertain estimates of biomass and recruitment can be obtained prior to 1980, this is not true of most of the time series of explanatory factors, many of which rely on time series of data started under the EVOSTC program, or on satellite imagery. Indeed, there are far fewer explanatory variables extending back in time beyond 1980 that could be used in the analysis, reducing the usefulness of this exercise.

B. Allow the background natural mortality rate to vary in time and estimate it. An example methodology is provided by the Canadian herring assessments (DFO 2015). This should increase accuracy of recruitment estimates and allow additional insight into possible alternative population states. This also will examination of the influence of top-down drivers (predation) and comparison with trends in predator abundance.

PI Response (10/11/2017)

The Canadian herring assessments (DFO 2015) differ from BASA in two key ways: (1) they estimate varying natural mortality constrains by a random walk with autocorrelation, such that natural mortality cannot vary much from year to year; and (2) they do not estimate additional mortality from disease. There is considerable debate in the stock assessment literature about whether natural mortality can be estimated, since it changes with estimates of recruitment and selectivity. Indeed, in the DFO models, there are unrealistically large changes in natural mortality over time from 0.15 to 1.2 (Figure 5, DFO 2015). Setting that technical issue aside, allowing time-varying natural mortality in BASA would remove the ability to estimate additional mortality from disease, since any signal in natural mortality would be soaked up by time-varying natural mortality. This would compromise goal 2 of the project: the inclusion of new antibody data for VHSV into BASA. It is therefore premature to alter the structure of BASA at this time.

C. Consider constructing a similar BASA model for the Sitka fishery. To the extent that Sitka shares previously-identified large-scale environmental influences with PWS (Williams & Quinn 2000), combined models will increase statistical power. Conversely, if this pattern of correlation no longer applies in recent years, comparing models should help isolate the important differences or changes in the PWS system relative to Sitka. A long-term Sitka assessment may possibly allow the time-series gap in PWS assessments (no assessments 1957-1971) to be filled on the basis of correlated recruitment patterns.

PI Response (10/11/2017)

This would be a very interesting addition, especially if the correlations in recruitment for Sitka, Seymour Canal, and Kah-Shakes have continued beyond the 1993 end point in Williams & Quinn (2000). Indeed the herring meta-analysis (in prep.) from the 2011-2016 program examines factors that might explain recruitment in all herring populations worldwide. A new model for Sitka is beyond the scope of our proposal, and would require substantial additional work, but if additional funds are available to support this expansion, we would gladly construct another BASA-type model for Sitka.

The Panel strongly encourages addressing items A and B before the use of the BASA model for analysis of environmental influences and to take into consideration item C, even though it is not within the scope of the proposal the additional model will add to the already high quality of this project. The Panel also noted the merits of conducting sensitivity analyses to evaluate the importance of errors in assumptions or parameters, such as natural mortality, on model performance. Together with Items A and B, this would help to determine when the model is ready for MSE.

PI Response (10/11/2017)

Sensitivity tests for model parameters are an integral part of the model assessment process for BASA. For instance, Muradian et al. (2017) reran the model with natural mortality of 0.15 and 0.35 in addition to the base value of 0.25 (excluding disease mortality), and also examined retrospective runs to test for bias in recent years.

The Panel whole-heartedly supports the request to use the CPPG funding (total $150K) toward 1.5 years of salary for another postdoc (David McGowan) to conduct synthesis work via modeling project with Trevor Branch. However, herring program needs to request an additional $150K for the remaining 1.5 years (part of FY19 and

FY20) needed to create a three-year synthesis, which would provide the minimum time needed for achieve appropriate synthesis.

PI Response (10/11/2017)

We are excited to start work with David McGowan.

References:

DFO 2015. Stock assessment and management advice for BC Pacific herring: 2015 status and 2016 forecast. Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Pacific Region, Science Response 2015/038.

Williams, E. H., Quinn, T. H. 2000. Pacific herring, Clupea pallasi, recruitment in the Bering Sea and north-east Pacific Ocean, I: relationships among different populations. Fish. Oceanogr. 9:285-299.

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

***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	$ 43.1
Travel	$6.4	$13.7	$12.1	$9.3	$6.9	$48.4	$ 4.5
Contractual	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$ 17.8
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	$ 26.5
SUBTOTAL	$114.0	$264.5	$272.5	$278.3	$136.6	$1,065.9	$91.9
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	

COMMENTS:
This summary page provides an five-year overview of proposed project funding and actual cumulative spending. The column titled 'Actual Cumulative' must be updated each fiscal year as part of the annual reporting requirements. Provide information on the total amount actually spent for all completed years of the project. On the Project Annual Report Form, if any line item exceeds a 10% deviation from the originally-proposed amount; provide detail regarding the reason for the deviation.

The numbers presented here reflect what has been billed to PWSSC and may be below actual spending at the end of the year.

We appreciate your prompt submission
and thank you for your participation.