ATTACHMENT C ***EVOSTC Annual Project Report Form***

Form Rev. 10.3.14

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

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

15120111-Q

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

PWS Herring Program: Modeling the population dynamics 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 2015 to 31 January 2016

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

15 February 2016

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

http://pwssc.org/research/fish/pacific-herring/

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

Over the past year, the first MS student employed on this grant, Melissa Muradian, graduated from the University of Washington, and the second MS student, John Trochta completed his coursework and started research on the project. The status of the four projects is as follows: (1) Bayesian model completed and submitted for publication (in review); the annual update to the Bayesian model was completed and the model revised to include ages 0-2 which were not previously included by any of the assessment models; (2) value of survey information completed in thesis format and in prep. for publication; (3) meta-analysis of herring populations is underway with data collected and preliminary analyses conducted, with completion anticipated in 2016-17; (4) examining hypotheses for the decline and lack of recovery of PWS herring has been started and a coauthored paper is in preparation looking at broader issues and will be completed in 2016-17.

Bayesian stock assessment model: the completed Bayesian stock assessment model was written up for publication and submitted to *Fisheries Research*. Reviews have been received, and are being addressed. An updated version of the model with the most recent data has been run and returns results that are consistent with the ADF&G assessment using the ASA model. The Bayesian framework employed allows for consistent weighting of different data sources and allows uncertainty to be automatically calculated from the Bayesian posteriors. This model now allows ADF&G managers, should they choose to do so, to choose management rules that directly include uncertainty in deciding on how conservative they should be in opening the herring fishery in the future. In the past six months the Bayesian model, which started at age 3 to mimic the ASA model, has been rewritten to start at age 0. This allows for the future incorporation of data such as the age-1 aerial survey, and over-winter survival estimates, in addition to other sources of data that are relevant for ages 0, 1, and 2. In addition, this revision to the model also allows a wider range of hypotheses about stock decline and recovery to be modeled and tested, which is important for the fourth part of this project.

Key results of the Bayesian model: the 2015 Bayesian model continues to provide good fits to the time series of data (Fig.1). Estimated pre-fishery biomass in 2014 was 17,000 metric tonnes (Fig. 2), just below the the threshold for opening the fishery (22,000 short tons = 19,958 mt). The 95% probability interval was 10,300-41,700 mt, and there was an estimated 80% probability of biomass being below the threshold for opening the fishery. The last year of medium recruitment was in 2002, since then, recruitment at age-3 has been between 9 and 103 million fish, compared to recruitment of 117 to 1234 million fish in every year from 1980 to 1988. Taken as a whole, the model differs little from last year's results: it confirms the ADF&G assessment that the fishery should not be reopened, and that biomass and recruitment have been low for more than a decade.

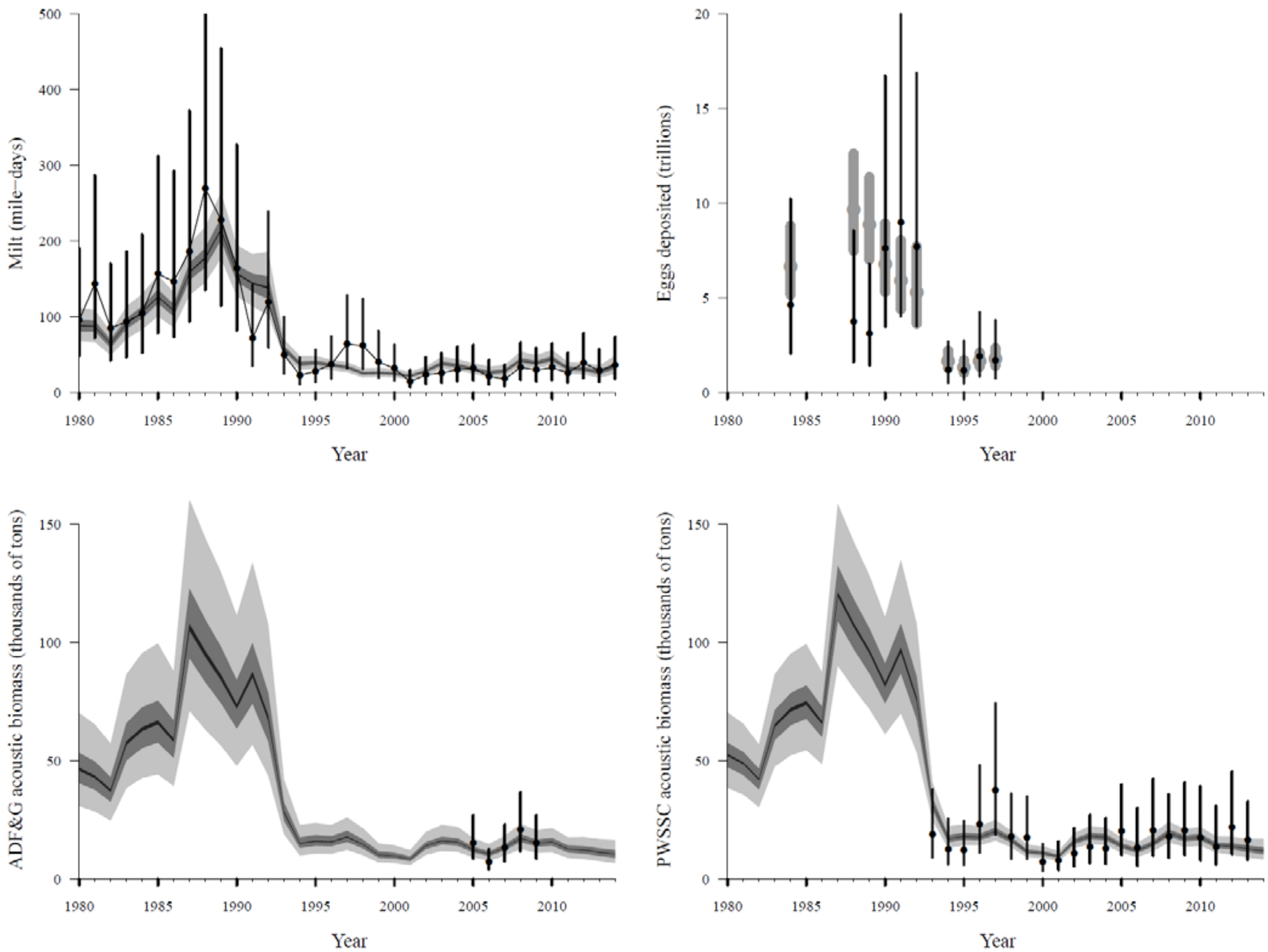

Fig. 1. Model estimates fitted to the four time series of abundance estimates (1980–2012): (A) mile-days of milt, (B) egg deposition surveys, (C) ADF&G hydroacoustic estimates, and (D) PWSSC hydroacoustic estimates. The solid circles and lines represent the mean and 95% confidence intervals of the data (plus additional variance estimated by the model); the shaded polygons represent the respective posterior intervals (light gray = 95% interval, darker gray = 50% interval, black = 5% interval). Source: J. Trochta.

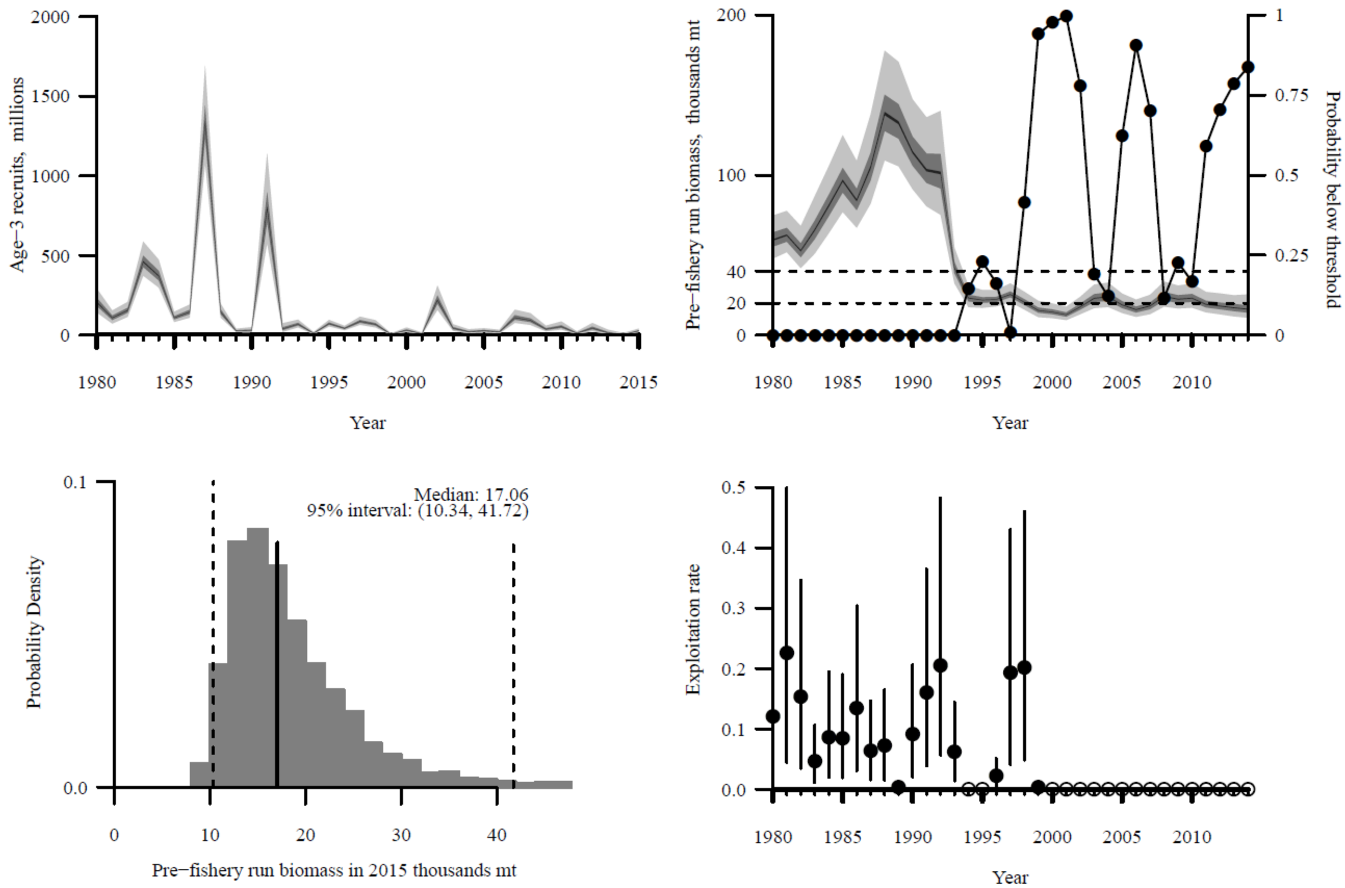

Fig. 2. (A) estimated recruitment at age-3 (posterior intervals; light gray = 95% interval, darker gray = 50% interval, black = 5% interval), (B) estimated pre-fishery biomass (posterior intervals; light gray = 95% interval, darker gray = 50% interval, black = 5% interval) and the probability that pre-fishery biomass is below the lower regulatory threshold (LRT) of 22,000 short tons (19,958 mt) (connected black points) with the upper regulatory threshold (URT: 42,500 short tons ≈ 38,555 mt) shown for reference, (C) posterior distribution of estimated pre-fishery biomass for 2013 with the 95% credible interval (light grey) and the median (black) shown, and (D) posterior median exploitation rates (black points) with 95% posterior intervals (segments) – open points show fishery closures. Source: J. Trochta.

Value of surveys: the Bayesian model was used to determine with surveys in the past were most valuable in obtaining precise estimates of abundance. The model is run with multiple iterations (in each iteration a different set of data are simulated and then fit with the model), for six scenarios. In the base scenario, all data are included in the assessment, while for the other scenarios, data from a particular survey or method of data collection are omitted. The results are reported in the MS thesis of Melissa Muradian, University of Washington, and are being prepared for submission to ICES Journal of Marine Science. The analysis shows, as, expected, that excluding data results in broader uncertainty intervals and greater bias in the abundance estimates. Quoting from the thesis results (Muradian 2015), the trade-off between survey cost and precision and bias revealed that the disease survey (which is relatively cheap and collects an index of additional mortality due to disease) and the egg-deposition diver survey (which is relatively expensive and collects an absolute index of abundance) were the most valuable sampling programs in the past. For $10,000 a year the disease survey reduces bias and imprecision in the forecast by 34% on average, increases model reliability by 22%, and decreases by 31% the probability of a false management conclusion when regulating the fishery. For $350,000 a year the diver survey reduces bias and imprecision in the forecast by 12% on average, increases model reliability by 6%, and decreases the probability of a false management conclusion by 23% (Fig. 3).

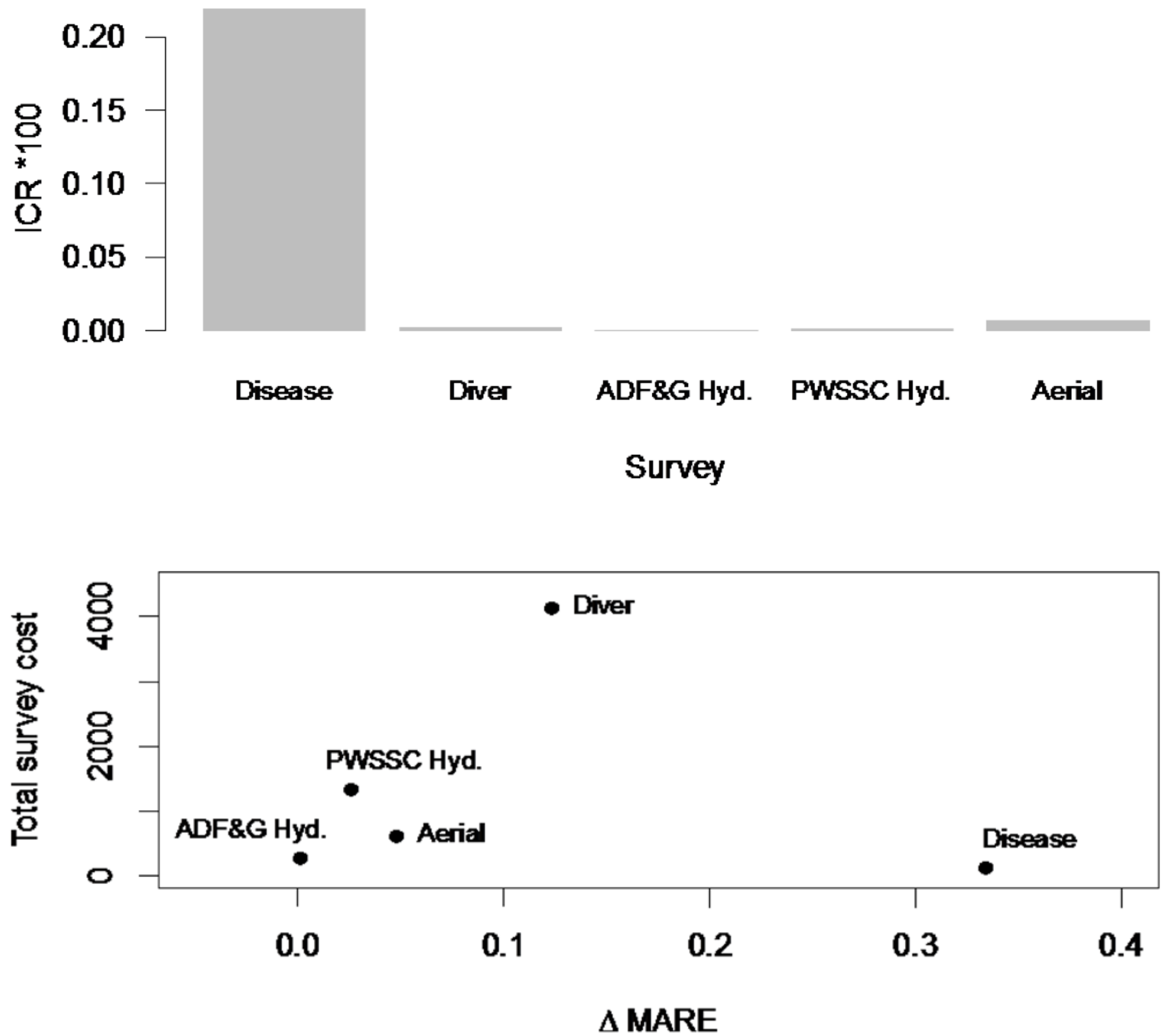

Fig. 3. The top panel shows the information to cost ratio (ICR) for each survey relating to the estimate of the forecast biomass in 2013. The bottom panel shows the estimated total cost of each survey program compared to the improvement in median absolute relative error (MARE) in the forecast biomass due to the addition of that survey's data.

Meta-analysis of herring populations: in this project we address whether it is an unusually long period of time over which PWS herring have collapsed and failed to recover, compared to other herring populations. We have now compiled spawning biomass time series for 32 herring populations, catches for 48 populations, and time series of recruitment for 39 populations (Fig. 4). Initial analyses suggest that there are many herring populations that are at low levels in recent years, suggesting a global trend towards decline, and that while the long period of time PWS herring has spent at low levels is unusual, it is not unique. A predictive model is being developed that takes into account other factors that might influence collapses and recovery, to make a quantitative prediction relevant to PWS herring.

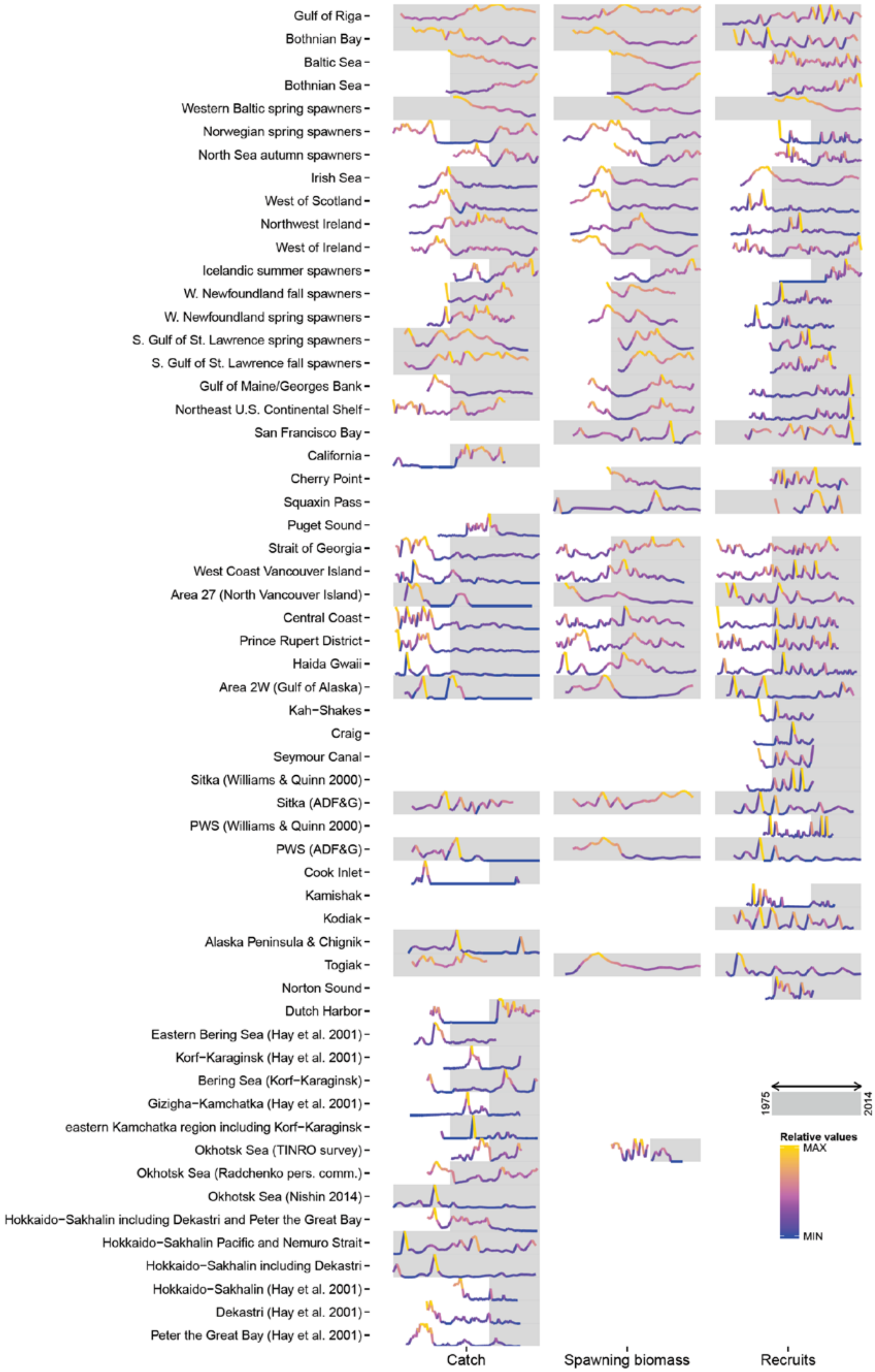

Fig. 4. Time series for catch, spawning biomass, and recruitment that have been collated for the meta-analysis of herring collapse and recovery. Gray shading represents the time period 1975-2014, thus sections with a short gray bar represent very long time series of data. Blue color shows low values and yellow high values within each time series.

Alternative hypotheses for PWS herring decline: work on this section of the project is scheduled for 2016-17, although the assessment model has been rewritten to allow for hypotheses affecting ages 0-2 to be modelled. This will assist in modeling hypotheses about over-winter survival, and correlates between environmental covariates and subsequent recruitment. In addition, this will allow for explicit fitting to the new time series of aerial surveys of juvenile herring conducted by Scott Pegau.

Personnel: Melissa Muradian defended her MS in 2015. John Trochta joined the project and is working on annual updates to the Bayesian stock assessment, the herring meta-analysis, and in examining hypotheses for the decline of PWS herring.

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

Close coordination with Steven Moffitt of ADF&G to include the data collected by ADF&G for the ASA Model, sharing of model code and results of the Bayesian model.

Coordination with Scott Pegau for data interpretation and oceanographic hypotheses.

Close coordination with Moffitt and Paul Hershberger to revise the indices of disease incorporated in the model.

It is intended that John Trochta will participate in the hydroacoustic surveys.

Inclusion of weight-at-age, sex ratios, hydroacoustic surveys (ADF&G and PWSSC), mile-days of milt survey, spawner-egg survey, and other data collected during the herring program, involving too many people to name individually.

Regular PI meetings, including at the AMSS meeting.

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

Theses/dissertations: Muradian, M. L. 2015. Modeling the population dynamics of herring in the Prince William Sound, Alaska. MS thesis, School of Aquatic and Fishery Sciences, University of Washington, Seattle.

Popular articles: by Melissa Muradian for Delta Sound Connections in 2014: "Herring: How much information does a population model need?"

Peer-reviewed publications coauthored by PI Branch, or graduate students Muradian and Trochta on broader issues related to recruitment, fisheries status, or fisheries stock assessment simulation methods, although none focused solely on Prince William Sound herring:

Branch, T. A. 2015. Fishing impacts on food webs: multiple working hypotheses. Fisheries 40:373-375

Hilborn, R., D. J. Hively, O. P. Jensen, and T. A. Branch*. 2014. The dynamics of fish populations at low abundance and prospects for rebuilding and recovery. ICES Journal of Marine Science 71:2141-2151.

Hurtado-Ferro, F., C. S. Szuwalski, J. L. Valero, S. C. Anderson, C. J. Cunningham, K. F. Johnson, R. Licandeo, C. R. McGilliard, C. C. Monnahan, M. L. Muradian*, K. Ono, K. A. Vert-Pre, A. R. Whitten, and A. E. Punt. 2015. Looking in the rear-view mirror: bias and retrospective patterns in integrated, age-structured stock assessment models. ICES Journal of Marine Science 72:99-110.

Johnson, K. F., C. C. Monnahan, C. R. McGilliard, K. A. Vert-pre, S. C. Anderson, C. J. Cunningham, F. Hurtado-Ferro, R. R. Licandeo, M. L. Muradian*, K. Ono, C. S. Szuwalski, J. L. Valero, A. R. Whitten, and A. E. Punt. 2015. Time-varying natural mortality in fisheries stock assessment models: identifying a default approach. ICES Journal of Marine Science 72:137-150.

Ono, K., R. Licandeo, M. L. Muradian*, C. J. Cunningham, S. C. Anderson, F. Hurtado-Ferro, K. F. Johnson, C. R. McGilliard, C. C. Monnahan, C. S. Szuwalski, J. Valero, K. A. Vert-Pre, A. R. Whitten, and A. E. Punt. 2015. The importance of length and age composition data in statistical age-structured models for marine species. ICES Journal of Marine Science 72: 31-43.

Stachura, M. M., T. E. Essington, N. J. Mantua, A. B. Hollowed, M. A. Haltuch, P. D. Spencer, T. A. Branch*, and M. J. Doyle. 2014. Linking Northeast Pacific recruitment synchrony to environmental variability. Fisheries Oceanography 23:389-408

Stawitz, C. C., T. E. Essington, T. A. Branch, M. A. Haltuch, A. B. Hollowed, and P. D. Spencer. 2015. A state-space approach for detecting growth variation and application to North Pacific groundfish. Canadian Journal of Fisheries and Aquatic Sciences 72:1316-1328.

Szuwalski, C. S., K. A. Vert-pre, A. E. Punt, T. A. Branch, and R. Hilborn. 2015. Examining common assumptions about recruitment: a meta-analysis of recruitment dynamics for worldwide marine fisheries. Fish and Fisheries 16:633-648

Publications in review: Muradian, M. L., Branch, T. A., Moffitt, S. D., and Hulson, P-J. F. Bayesian stock assessment of Prince William Sound herring, Alaska. Fisheries Research.

Publications in prep: Ward, E. J., Adkinson, M., Couture, J., Dressel, S., Litzow, M., Moffitt, S., Neher, T. H., Trochta, J., and Brenner, R. (in prep.). Evaluating signals of climates, oil spill impacts, and interspecific interactions on salmon and herring populations in Prince William Sound, Alaska.

Muradian, M. L., Branch, T. A., and Punt, A. E. (in prep.) A framework for assessing which sampling programs provide the best trade-off between accuracy and cost of data in stock assessments. ICES Journal of Marine Science.

Presentations: Trochta, J. 2015. The Highs and Lows of Herring: Characteristics of Collapse and Recovery.Poster, Alaska Marine Science Symposium, Anchorage, AK, January 25-29, 2015

Trochta, J. 2015 Transitioning toward a Bayesian assessment model of the Pacific herring in Prince William Sound, Alaska. Talk, Ocean Modeling Forum-Pacific Herring Summit, Richmond, BC, June 8-10, 2015

Data transfer: The current code for the Bayesian model is available for review and use by ADF&G, and final data inputs and AD Model Builder code have been uploaded to the herring portion of the Ocean Workspace, together with the MS thesis of Melissa Muradian.

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

Review requests were in line with what is being accomplished on this program, which was rated as the top priority for funding in the next five-year cycle for PWS herring.

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

Budget Category:	Proposed FY 12	Proposed FY 13	Proposed FY 14	Proposed FY 15	Proposed FY 16	TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	$20,734.0	$34,445.7	$35,823.5	$37,256.4	$38,746.7	$167,006.3	$ 126,621
Travel	$982.0	$3,636.0	$8,194.0	$7,812.0	$8,508.0	$29,132.0	$ 15,005
Contractual	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$ 35,136
Commodities	$200.0	$16,884.0	$20,552.4	$21,286.5	$22,050.0	$80,972.9	$ 1,072
Equipment	$0.0	$4,000.0	$0.0	$0.0	$0.0	$4,000.0	$ 7,470
Indirect Costs (*will vary by proposer*)	$11,944	$20,863	$25,188	$25,761	$26,952	$110,708.0	$ 72,388
SUBTOTAL	$33,860.0	$79,828.7	$89,757.9	$92,115.9	$96,256.7	$391,819.2	$257,692.0
General Administration (9% of	$3,047.4	$7,184.6	$8,078.2	$8,290.4	$8,663.1	$35,263.7	
PROJECT TOTAL	$36,907.4	$87,013.3	$97,836.1	$100,406.4	$104,919.8	$427,082.9	
Other Resources (Cost Share Funds)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	

Spending on this budget has been close to budgeted amounts for salary, tuition, and travel. The difference in contractual and commodities is due to how the various organizations budget tuition.

In addition to the expenses charged against the budget, in 2014-15 the current graduate student Melissa Muradian and new graduate student John Trochta have overlapped for two quarters while Muradian was finishing. In the original project it was envisaged that a single PhD student would complete the entire project. As a result, salary and tuition for Muradian came from her being a Teaching Assistant for a course Oct-Dec

2014, and she was funded as a Research Assistant on the PI’s own funds Jan-March 2015. These expenses were not charged to the EVOSTC grant.

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