FY14 PROGRAM PROJECT
PROPOSAL FORM

Project Title: Modeling the population dynamics of Prince William Sound herring

Project Period: February 1, 2014 – January 31, 2015

Primary Investigator(s): Trevor A. Branch, University of Washington, tbranch@uw.edu, 206-221-0776

Abstract: Shortly after the Exxon Valdez oil spill, the Prince William Sound herring populations collapsed and have not yet recovered. We propose a modeling project to (1) revise and update the ASA model used to manage this population, (2) conduct simulations to test which data sources are most important in assessing the current status of this population, and (3) collect data on herring populations worldwide to find out how often these populations collapse under ordinary conditions.

Estimated Budget:
EVOSTC Funding Requested:

FY12	FY13	FY14	FY15	FY16	TOTAL
36,907	87,014	97,836	100,406	104,920	427,083

(Funding requested must include 9% GA)

Non-EVOSTC Funds to be used:

FY12	FY13	FY14	FY15	FY16	TOTAL
		0			

Date:

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I. NEED FOR THE PROJECT
A. Statement of Problem

Robust Pacific herring (*Clupea pallasii*) populations, suitable for exploitation by commercial fisheries, are typically sustained by periodic recruitment of strong year classes into the adult spawning population. However, the Prince William Sound (PWS) herring population has not had a strong recruitment class since 1989, when the Exxon Valdez Oil Spill (EVOS) occurred. In the EVOS settlement herring were identified as an injured resource and they remain listed as an unrecovered species by the EVOS Trustee Council (EVOSTC). Understanding why herring have not recovered in Prince William Sound requires understanding potential bottlenecks in the herring life cycle. The identification of the limiting conditions to herring recovery requires a series of focused process studies combined with monitoring of the natural conditions that affect herring survival.

Described here is a single project that is a part of an integrative program that will enhance the current monitoring efforts of the Alaska Department of Fish and Game (ADF&G), and examine aspects of particular life stages to allow better modeling of herring populations. **The long-term goal of the program is to improve predictive models of herring stocks through observations and research.** While we do not anticipate that there will be a major change in our modeling ability in the next five years, we expect that the combination of monitoring and focused process studies will provide incremental changes over the next twenty years and result in a much better understanding of herring populations by the end of the program.

B. Summary of Project to Date (if applicable)

All milestones have been met. A graduate student has been identified and hired, and completed most of the remaining coursework on schedule, and has translated the current Excel model of herring dynamics into AD Model Builder, ready for conversion to a Bayesian model of herring abundance. The immediate goal is a fast-running model that assesses population status of Prince William Sound herring including characterization of uncertainty in abundance.

II. PROJECT DESIGN

A. Objectives

This project is designed to complement the “PWS Herring Research and Monitoring” proposal submitted by the Prince William Sound Science Center. The objectives of that program are:

1) *Provide information to improve input to the age-structure-analysis (ASA) model, or test assumptions within the ASA model.* The ASA model is currently used by ADF&G for estimating herring biomass (Hulson et al. 2008). The proposed monitoring efforts are designed to address this objective by either expanding the data available for the existing ASA model or by providing information about factors that determine the size of recruitment events.
2) *Inform the required synthesis effort.* Proper completion of a detailed synthesis means being able to access and manipulate different sources of data and information. We are proposing projects that make data available to all researchers.
3) *Address assumptions in the current measurements.* Many of the existing studies are based on historical or logistical constraints. We are proposing research necessary to put the existing measurements into context spatially and temporally. This effort will allow the design of the most accurate and efficient monitoring program.
4) *Develop new approaches to monitoring.* With technological advances we have the potential to improve our monitoring programs so they require less effort or reduce the need to collect fish.

This modeling program addresses objectives 1, 2 and 3 by examining which data sources provide the most informative inputs to the ASA assessment model, holistically modeling the PWS herring life cycle, identifying possible issues with the assumptions of the measurement program, and examining factors that could determine future herring recruitment.

The specific objectives of this project are to:

a) Determine which datasets provide the most informative information for the ASA model (objective 1).
b) Predict levels of future recruitment, and autocorrelation in recruitment, using information from other herring populations and other species of clupeids (objective 1).
c) Synthesize the data collected from the monitoring program into a holistic model of herring dynamics (objective 2), to determine which life stages the observational program should focus on (objective 3).

B. Procedural and Scientific Methods

Identify the most informative datasets: conduct a management strategy evaluation (e.g. Butterworth & Punt 1999, Sainsbury et al. 2000) to identify which types of data are most informative for the ASA model. This task will comprise developing an operating model (modeling the “truth”) to generate data types used by the ASA model (hydroacoustic survey, surveys of milt production, age composition, etc.), particularly the new time series developed as part of this program. For each model run, one type of data will be omitted, a large number of data sets will be generated (100-1000 depending on the time it takes to run the model), and the ASA model applied to the generated data to produce estimates of abundance. The estimates will then be compared to the underlying “truth” in the operating model to see how well the ASA model performs in the absence of that particular source of data. The end result will be an ordering of input data types from most to least informative, providing critical information to prioritize current and future monitoring efforts.

Predict future levels of recruitment: collate time series of herring abundance and recruitment in Pacific herring stocks, and for stocks of other clupeid species. Conduct a meta-analysis to estimate the average duration that a typical herring stock would be expected to remain at low abundance. Estimate the average level of autocorrelation in herring recruitment from other stocks, to understand how much recruitment covaries from one year to the next. Gather covariates (e.g. length, trophic level, price, latitude, sea surface temperature) to understand which factors influence recruitment in clupeid populations. Much of the data for this task has already been completed in the RAM Legacy stock assessment database (e.g. Branch et al. 2010, 2011, Ricard et al. submitted), but more stocks will be added for the analysis.

Create holistic model of herring dynamics: develop a life stage model to synthesize data from each aspect of the monitoring program, to understand which age groups and sources of mortality are most likely to explain the decline in the abundance of PWS herring. The model will be age-based and include separate terms for each component of mortality. The model will be fitted to time series of abundance at each life history stage and time series of disease prevalence.

These tasks will be conducted on computers by University of Washington students and faculty, who have access to a wide range of in-house fisheries modeling expertise (e.g. faculty members Ray Hilborn, André Punt, Tim Essington). This will allow us to examine statistical modeling, process based modeling, and ecosystem modeling approaches in choosing the best approach for each objective.

C. Data Analysis and Statistical Methods

By working with a well-established measurement program we foresee being able to learn about previous work and have access to historical data more rapidly than if this was a stand-alone project. Thus there will be no need to collect data or analyze data separately from the ongoing efforts of the monitoring program. The only data collection will involve gathering time series of abundance and recruitment for clupeid stocks as described above.

Computer models will be written in a combination of R, a high level language such as C++ or Fortran, and AD Model Builder (ADMB Project 2010) software which can rapidly and efficiently fit models to data.

D. Description of Study Area

The study area includes all of Prince William Sound (N, E, S, and W boundaries of respectively, ~ 61, -145.5. 60, and -149°). However, most of the projects will focus on the four bays (Zaikof, Whale, Eaglek, and Simpson) that were extensively studied during the Sound Ecosystem Assessment study and PWS Herring Survey program (Figure 2). This allows the work to build upon the historical research completed in those bays. These bays also cover four different quadrants of the Sound. We anticipate a potential build out to include other bays or contraction based on the results from the synthesis. As part of the synthesis effort we will be reviewing the question "What is the appropriate sampling distribution?" as applied to the questions of juvenile herring condition and providing an index of juvenile abundance.

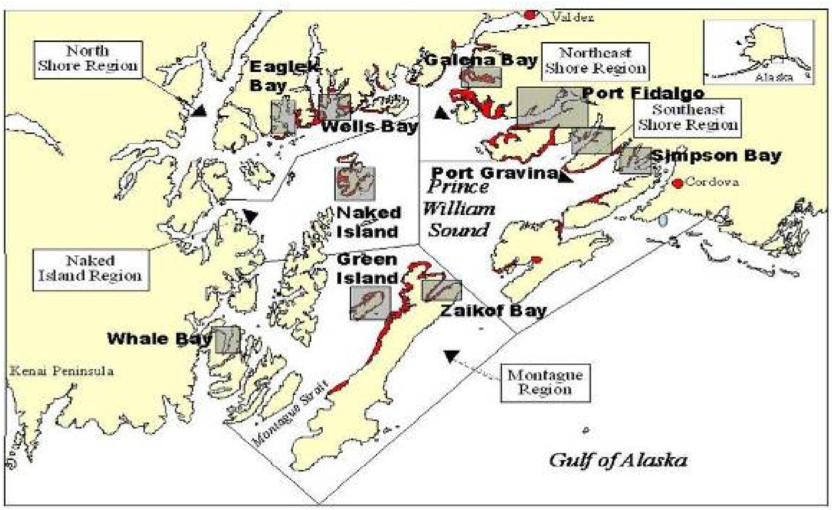

Figure 2. PWS study area, including the four SEA bays (Whale, Zaikof, Eaglek, and Simpson, as well as other bays historically important for juvenile herring.

E. Coordination and Collaboration with the Program

This proposal is structured to be part of a collaborative programmatic effort being led by the Prince William Sound Science Center. Program coordination will primarily be through e-mail and phone communications. Annual meetings are planned in Cordova, tentatively in May, for all investigators to share information between themselves and with the community. These in-person meetings are vital to ensure proper communication among programs.

Dr. Pegau will act as the program team leader and be responsible for ensuring a coordinated and focused research program that leverages other assets whenever possible. He will be responsible for ensuring proper scientific oversight of individual projects and reporting to the EVOSTC. He will lead the development of annual work plans and the synthesis of findings from these programs. He will be responsible for coordinating the efforts of the herring research program with those of the Long-term Monitoring program.

There will be annual Principal Investigator meetings in Cordova each year to provide updates to the oversight panel, improve coordination between projects, and provide outreach and public input opportunities. This meeting will be in the spring so that there is opportunity to provide input on the development of the next year's work plan. In an effort to be proactive in the scientific oversight we sought input on the development of this proposal from ADF&G, NOAA, Cordova District Fishermens United (CDFU), and others. Team development and input on research direction was also sought at the 2011 Alaska Marine Science Symposium.

The wide array of projects that make up this program required careful integration to ensure the maximum collaboration between projects. Not all observation projects are directly connected to each other, but are connected through the objectives of the program. The full benefits of the linkages will be seen at the points where synthesis efforts occur. As the modeling component to this program the proposed project is one of the main tools for synthesizing the different observation program. It is designed to utilize data from the observation programs and help guide future sampling efforts to maximize the likelihood of achieving the program objectives.

Direct overlap between observation projects occurs in the area of logistics. We intend to have the acoustic surveys, direct capture, and non-lethal collection components sharing a vessel. The direct capture and non-lethal collection are intended to provide validation to the acoustics. The direct capture component will be responsible for providing fish to the RNA condition, energetic condition, disease research, fatty acid indicators, and genetic stock indicator projects. Another direct project overlap occurs between the herring scale analysis and primiparous herring projects, which will share growth information as determined from the scales. The combined efforts will lead to a greater number of scales becoming digitized and improving the statistics for both projects. All projects will also interact with the data management efforts to ensure the data is properly archived and maintained.

Indirect project overlap occurs between projects through the scheduling. Projects like the genetic stock indicators are pushed back in the cycle to ensure that the methodologies used by the direct capture program are mature enough to ensure collection of the required samples. Non-lethal collection is also later in the program to ensure new direct capture techniques are fully tested. Fish collected from the RNA and energetics intensive studies will also be used by the fatty acid indicator project. The acoustic tagging project is early in the program to take advantage of the acoustic receiver array that is in place and has a limited life span. Some projects like the disease research component also start later in the program because of coordination with the existing herring monitoring program. We worked hard to ensure that there isn't duplication between the proposed program and the existing program. One apparent exception is the RNA and energetic condition intensives. By moving these projects early in the program we intend to fill what is seen as a major gap in the existing program and hopefully more quickly resolve the information value that each project provides.

Coordination with the EVOSTC Long-term Monitoring program is critical to the success of the herring program. The ability to develop a predictive tool using the juvenile condition component requires an understanding of when feeding may occur and hence the need to coordinate with the oceanographic monitoring component. Predation by whales, fish, and birds are also considered potential factors inhibiting the recovery of herring. In that regard we will be looking to the monitoring program for information on the changes in the predator population base. That information will be critical if the herring program chooses to focus on predation during future efforts. The forage fish component and our efforts to develop an index of juvenile herring populations must inform each other. We expect that our hydroacoustic surveys and direct capture efforts will help provide measures of total fish biomass as well as forage fish populations. We will also work together to identify historical data that both programs would benefit from as part of the data management efforts. Throughout the proposal writing effort, the herring and long-term monitoring efforts led by Kris Holderied have been working together to identify how the two programs can inform and complement each other.

Other important programs for coordinating with are the existing PWS herring survey program and existing ADF&G herring research. This program has been developed with input from both of these programs and the focus of this proposal is extending the interpretation of the data from those two programs. The Herring Survey program will still be operating in FY12 and FY13. There are field observations scheduled in FY12 and in FY13 funds are strictly for analysis and report writing. Included in the report writing is a synthesis of previous and current research. This report will be finished in FY13 and be the basis for the synthesis required under this request for proposals.

III. CV's/RESUMES

Biographical sketch

Trevor A. Branch, tbranch@uw.edu

Professional preparation

University of Cape Town	Zoology, Computer Science	B.Sc. 1994
University of Cape Town	Zoology	B.Sc.(Hons) 1995
University of Cape Town	Conservation Biology	M.Sc. 1998
University of Washington	Aquatic and Fishery Sciences	Ph.D. 2004

Appointments

2010–present	Assistant Professor, School of Aquatic and Fishery Sciences, Univ. of Washington
2006–2010	Research Scientist, School of Aquatic and Fishery Sciences, Univ. of Washington
2005–2006	Research Scientist, Marine Resource Assessment and Management Group, Department of Mathematics and Applied Mathematics, University of Cape Town
2000–2004	Research Assistant, School of Aquatic and Fishery Sciences, Univ. of Washington
1999–2000	Research Assistant, Marine Resource Assessment and Management Group, Department of Mathematics and Applied Mathematics, University of Cape Town
1998–2000	Consultant, Marine Resources Assessment Group, London (MRAG, Ltd)
1995–1998	Research Assistant, Marine Resource Assessment and Management Group, Department of Mathematics and Applied Mathematics, University of Cape Town

Products

Five scientific papers closely related the proposed project:

Branch TA, Watson R, Fulton EA, Jennings S, McGilliard CR, Pablico GT, Ricard D, Tracey SR (2010) The trophic fingerprint of marine fisheries. Nature 468:431-435

Sethi SA, Branch TA, Watson R (2010) Fishery development patterns are driven by profit but not trophic level. Proc Natl Acad Sci USA 107:12163-12167

Branch TA, Jensen OP, Ricard D, Ye Y, Hilborn R (2011) Contrasting global trends in marine fishery status obtained from catches and from stock assessments. Cons Biol 25:777-786

Worm B, Branch TA (2012) The future of fish. Trends Ecol Evol 27:594-599

Worm B, Hilborn R, Baum JK, Branch TA, Collie JS, Costello C, Fogarty MJ, Fulton EA, Hutchings JA, Jennings S, Jensen OP, Lotze HK, Mace PM, McClanahan TR, Minto C, Palumbi SR, Parma AM, Ricard D, Rosenberg AA, Watson R, Zeller D (2009) Rebuilding global fisheries. Science 325:578-585

Five other significant scientific papers (n = 53):

Branch TA, Lobo AS, Purcell SW (2013) Opportunistic exploitation: an overlooked pathway to extinction. Trends Ecol Evol 28:409-413

Branch TA, DeJoseph BM, Ray LJ, Wagner CA (2013) Impacts of ocean acidification on marine seafood. Trends Ecol Evol 28:178-186

Branch TA and 42 coauthors (2007) Past and present distribution, densities and movements of blue whales *Balaenoptera musculus* in the Southern Hemisphere and northern Indian Ocean. Mammal Rev 37:116-175

Branch TA, Hilborn R, Haynie AC, Fay G, Flynn L, Griffiths J, Marshall KN, Randall JK, Scheuerell JM, Ward EJ, Young M (2006) Fleet dynamics and fishermen behavior: lessons for fisheries managers. Can J Fish Aquat Sci 63:1647-1668

Hilborn R, Branch TA (2013) Does catch reflect abundance? No, it is misleading. Nature 494:303-306

Synergistic activities

1. Outstanding Researcher award for the College of the Environment, University of Washington, 2013. For "research or scholarship contributed within the past two years that has been or has the potential to be widely recognized by peers and whose achievements have had or may have a substantial impact of the profession, on research or the performance of others, or on society as a whole."
2. Ecological Society of America "2011 Sustainability Science Award" for the paper Worm et al. (2009) "Rebuilding Global Fisheries" published in Science. For "the peer reviewed paper published in the past

five years that makes the greatest contribution to the emerging science of ecosystem and regional sustainability through the integration of ecological and social sciences."

3. Aldo Leopold Fellow, 2013, training mid-career researchers in "translating their knowledge to action and for catalyzing change to address the world's most pressing environmental and sustainability challenges."
4. Editor, Animal Conservation, 2012-present.
5. Reviewer for 32 journals including Science, Nature, Proceedings of the National Academy of Sciences USA, Ecology Letters, Ecology, Proceedings of the Royal Society B, Biology Letters, Canadian Journal of Fisheries and Aquatic Sciences, Marine Ecology Progress Series, Fisheries Research, ICES Journal of Marine Science, and Fish and Fisheries.

Collaborators and co-editors in the last 48 months (*n* = 117)
Acevedo-Whitehouse, K (UK), Agnew, D (UK), Alagiyawadu, A (Sri Lanka), Altweg, R (South Africa), A'mar, ZT (NOAA), Anderson, RC (Maldives), Anderson, SC (Simon Fraser Univ), Ashe, E (UK), Austin, J (Univ Florida), Baker, CS (Oregon State Univ), Baker, MR (UW), Baldwin, R (Oman), Banobi, J (UW), Baum, JK (Univ Victoria, Canada), Bianci, PL (UC Santa Barbara), Bravington, M (Australia), Clarke, E (NOAA), Clark, S (Sea World), Collie, JS (Univ Rhode Island), Cope, JM (NOAA), Cornejo-Donoso, J (Chile), Costello, C (UC Santa Barbara), DaVolls, L (UK), Defeo, O (Uruguay), deJoseph, B (UW), Dziak, RP (NOAA), Essington, TE (UW), Evans, DM (UK), Findlay, KP (South Africa), Fogarty, MJ (NOAA), Froese, R (Germany), Fulton, EA (Australia), Garner, TWJ (UK), Gedamke, J (NOAA), Gompper, ME (Univ Missouri), Gordon, IJ (UK), Guinet, C (France), Guttierrez, NL (UK), Haynie, AC (NOAA), Hammond, P (UK), Hancock-Hanser, B (NOAA), Hedley, S (UK), Heppell, SS (Oregon State Univ), Hilborn, R (UW), Hively, DJ (UW), Hoggarth, DD (UK), Hollowed, A (NOAA), Holtgrieve, GW (UW), Hoyt, E (UK), Hutchings, JA (Dalhousie Univ), Jackson, JA (Oregon State Univ), Jennings, S (UK), Jensen, OP (Rutgers Univ), Johnson, JA (Univ N Texas), Karachle, PK (Greece), Kato, H (Japan), Katzner, TE (W Virginia Univ), Kendall, NW (UW), Krkosek, M (New Zealand), Larsen, A (UC Santa Barbara), LeDuc, RL (NOAA), Link, JS (NOAA), Lobo, AS (India), Lotze, HK (Dalhousie Univ), Mace, PM (New Zealand), Marsac, F (South Africa), Martell, SJD (Int Pac Halibut Comm), McClanahan, TR (Kenya), McGilliard, CR (UW), Melnychuk, MC (UW), Mikhalev, Y (Ukraine), Minto, C (Ireland), Ninnes, C (UK), Noren, DP (NOAA), Pablico, GT (Philippines), Palomares, MLD (Univ British Columbia), Palumbi, SR (Stanford Univ), Parma, AM (Argentina), Pettorelli, N (UK), Pope, JG (UK), Purcell, SW (Australia), Proelß, A (Germany), Quaas, M (Germany), Quinn, TP (UW), Ranjan, R (India), Rantanen, E (UK), Ray, L (UW), Ricard, D (Dalhousie Univ), Rosen, D (Univ British Columbia), Rosenberg, AA (Univ New Hampshire), Royer, J-Y (France), Sainsbury, K (Australia), Samaran, F (France), Schindler, DE (UW), Selden, RL (UC Santa Barbara), Sethi, SA (UW), Sistla, S (UC Santa Barbara), Smith, ADM (Australia), Sremba, A (Oregon State Univ), Stafford, KM (UW), Stern-Pirlot, A (UK), Stewart, IJ (NOAA), Teck, SJ (UC Santa Barbara), Thorson, JT (UW), Tracey, SR (Australia), Valencia, SR (UC Santa Barbara), Visser, IN (New Zealand), Wagner, C (UW), Watson, R (Australia), Williams, NE (Australia), Williams, RS (Canada), Winship, A (Dalhousie Univ), Worm, B (Dalhousie Univ), Ye, Y (Italy), Zeller, D (Univ British Columbia), Zerbini, AN (Cascadia Research), Zimmermann, C (Germany)

Graduate advisors and postdoctoral sponsors: Douglas S. Butterworth, University of Cape Town (M.Sc.); John G. Field, University of Cape Town (M.Sc.); Ray Hilborn, University of Washington (Ph.D.)

Thesis advisor and postgraduate-scholar sponsor (last five years): Cole Monnahan (MS, UW), Melissa Muradian (MS, UW), Peter Kuriyama (MS, UW). Total graduate students: 3. Postdoctoral: 0.

IV. SCHEDULE

A. Project Milestones

All projects will be conducted simultaneously and are interlinked. The dates given are the expected dates of submission of scientific papers, but preliminary results will be used to improve the monitoring efforts as they are generated.

Objective 1. Create life history model of herring dynamics.
To be met by September 2014

Objective 2. Identify the most informative datasets using management strategy evaluation.
To be met by September 2015

Objective 3. Predict future levels of recruitment from other herring and clupeid stocks.
To be met by September 2016

B. Measurable Project Tasks

FY14, 2nd quarter
January Annual Marine Science Symposium, Anchorage
March Draft manuscript: life history model of herring dynamics

FY14, 3rd quarter
May Annual Cordova meeting with broader project PIs
June Student completes all required coursework and milestones

FY14, 4th quarter
August Annual report
September Manuscript submission: life history model of herring dynamics

FY15, 1st quarter (October 1, 2014-December 31, 2014)
December Finalize gathering of time series of abundance and recruitment for herring stocks and other clupeids

References

Branch, T. A., R. Watson, E. A. Fulton, S. Jennings, C. R. McGilliard, G. T. Pablico, D. Ricard, and S. R. Tracey. 2010. The trophic fingerprint of marine fisheries. Nature 468:431-435.

Branch, T. A., O. P. Jensen, D. Ricard, Y. Ye, and R. Hilborn. 2011. Contrasting global trends in marine fishery status obtained from catches and from stock assessments. Conservation Biology doi: 10.1111/j.1523-1739.2011.01687.x.

Butterworth, D. S. and A. E. Punt. 1999. Experiences in the evaluation and implementation of management procedures. ICES Journal of Marine Science 56:985-998.

Ricard, D., C. Minto, J. K. Baum, and O. P. Jensen. Submitted. RAM Legacy: a new global stock assessment database for exploited marine species. Fish and Fisheries.

Sainsbury, K. J., A. E. Punt, and A. D. M. Smith. 2000. Design of operational management strategies for achieving fishery ecosystem objectives. ICES Journal of Marine Science 57:731-741.

V. BUDGET
Budget Form (Attached)