***Exxon Valdez* Oil Spill Trustee Council**

Long-Term Research and Monitoring, Mariculture, Education and Outreach

Annual Project Reporting Form

Project Number: 23120111-C

Project Title: Modeling and stock assessment of PWS herring

Principal Investigator: Trevor A. Branch, University of Washington

Reporting Period: February 1, 2023 – January 31, 2024

Submission Date: March 1, 2024

Project Website: https://gulfwatchalaska.org/

Please check all the boxes that apply to the current reporting period.

☒ **Project progress is on schedule.**

☐ **Project progress is delayed.**

☒ **Budget reallocation request.**

A reallocation was approved as follows: $3,248 from commodities and $1,802 from indirect costs, in the FY22 budget to $5,050 in equipment.

☒ **Personnel changes.**

Graduate student Joshua Zahner has completed his M.S. and graduated. I have recruited two new graduate students, one who will remain working at Alaska Department of Fish and Game, who will start in September 2024, but neither appointment is finalized yet.

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1. Summary of Work Performed:

During this year, Goals 1-4 of the original eight proposed goals of the project were completed, as detailed below.

Goal 1: conduct annual stock assessments of Prince William Sound herring using the Bayesian age-structured assessment model (BASA):

The stock assessment of the 2023 season was completed early in December 2023 (Zahner and Branch 2023), just ahead of Zahner graduating from the University of Washington. The assessment shows a slight improvement in spawning biomass to a median of 27,050 metric tons (t), above the management threshold for fishery reopening (19,958 t), albeit with an 11% probability of being below the threshold (Fig. 1). Estimated biomass is the highest since 1993, driven by relatively strong 2020- and 2021-year classes and continued presence of the strong

2016 cohort (Fig. 2). The Shannon-Wiener evenness index is added to the age composition plot (Fig. 1) showing that the 2022-23 biomass is more evenly distributed among age classes (0.71 and 0.70) than during 2019-21 (0.43-0.53) when the 2016-year class dominated. Another diagnostic added this year was to include a retrospective analysis involving sequentially removing one year of data and repeating the assessment, which showed no patterns of bias in the assessment (Fig. 3).

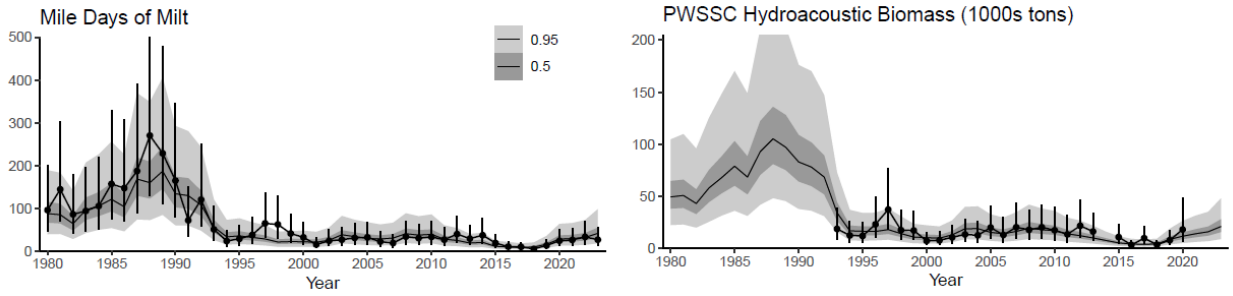

Figure 1. Estimated spawning biomass of Prince William Sound herring from the Bayesian age-structured assessment (BASA) model fitted to the aerial mile-days-of-milt survey and the long-term Prince William Sound Science Center (PWSSC) hydroacoustic survey that ended in 2020.

Goal 2: Review best practices globally for managing highly variable fish populations:

During this period, we conducted a global review of harvest control rules used to manage marine fisheries, focusing on rules used in six major regions of the world including the USA and Canada. This is included as a chapter in the MS thesis (Zahner 2023), and a publication has been prepared for submission to *Fish and Fisheries* and awaiting only feedback from coauthors before submission (Zahner et al. in prep.). The review showed that best practices for harvest control rules of data-rich fisheries, such as Prince William Sound herring, are to use threshold-based rules to manage them, where harvest rates are reduced below specific thresholds (Fig. 4, Zahner 2023). Thus, one major conclusion is that the default harvest control rule used in managing Prince William Sound herring follows global best practices.

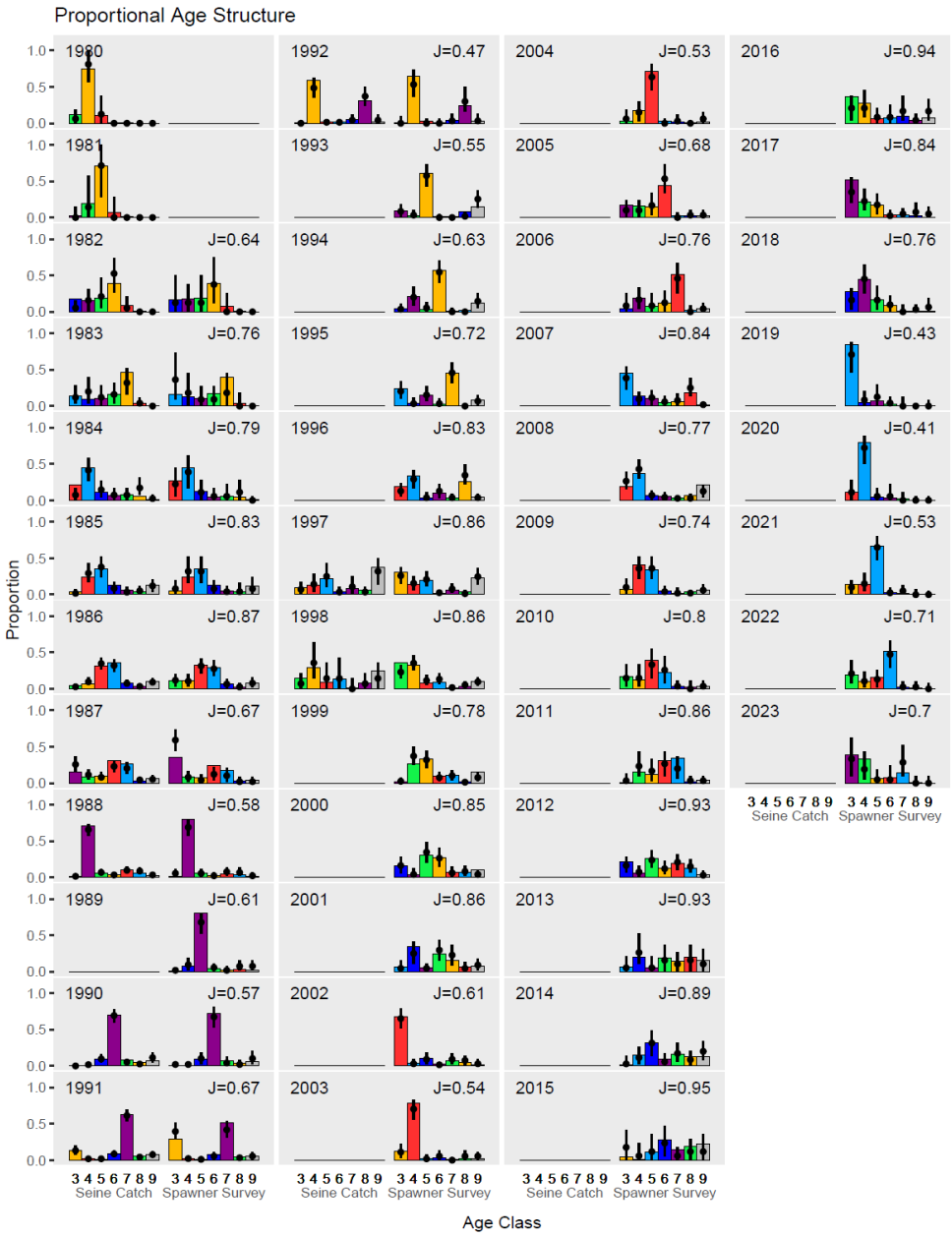

Figure 2. Model fits (circle and lines) to the fishery age composition data (left column) and survey age composition data (right column), 1980-2023. In each panel the "J" value is the evenness of the age composition, which is close to 1 when fish are evenly distributed among the age groups, and close to zero when a single age class dominates.

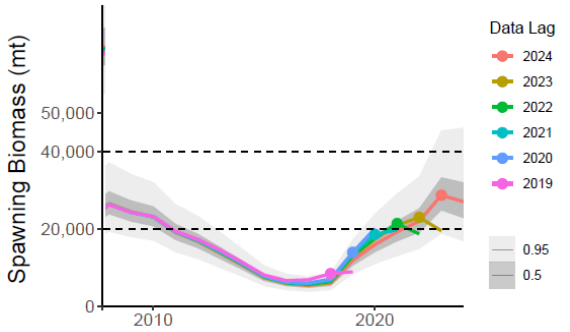

Figure 3. Results of retrospective analysis, showing no substantial bias in model predictions over time. Each color represents an assessment run with data from 1980-2023 (prediction to 2024), from 1980-2022, from 1980-2021, etc.

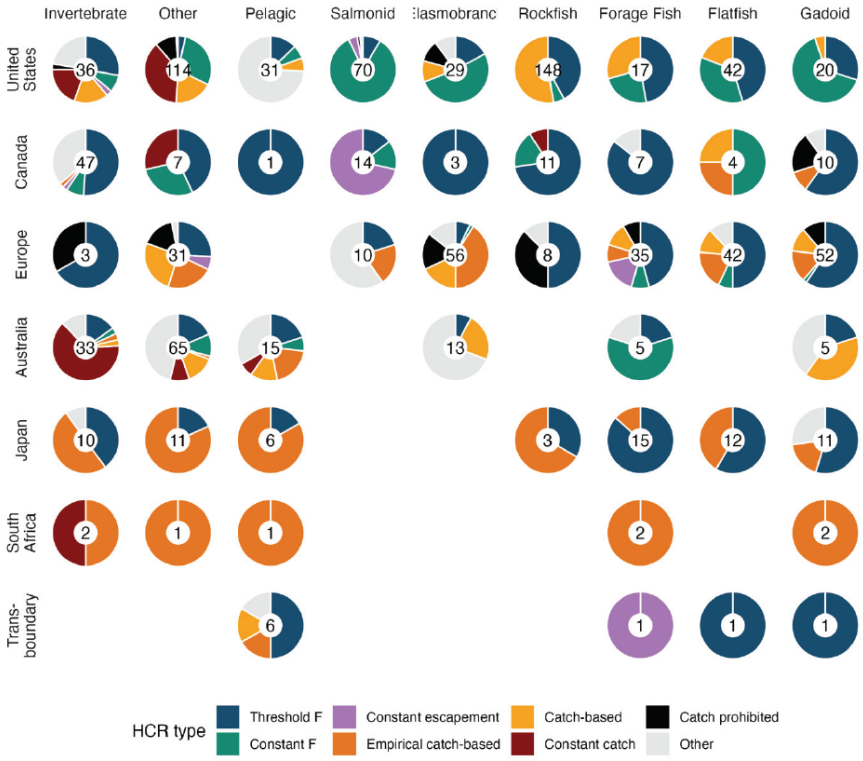

Figure 4. Types of harvest control rules used in different regions of the world and on different types of species including forage fish (e.g., herring), showing how threshold rules such as the current rule used to manage Prince William Sound herring, are widely used.

Goal 3: Create an MSE framework for Prince William Sound herring:

The framework for management strategy evaluations (MSEs) was developed as part of J. Zahner's MS thesis (Zahner 2023) and is prepared for use in addressing the original Goals 4-6 of this proposal.

Goal 4: Evaluate alternative harvest control rules for setting herring catches:

The MSE framework in Goal 3 was used to conduct this evaluation, which used the global analysis of harvest control rules (Zahner 2023) and a meeting of Alaskan herring managers and interested parties to select a suite of rules to evaluate. The MSE framework models the true state of the herring population, at each annual modeling step this simulates data that would be collected in the actual fisheries, applies the assessment model (BASA) to assess the state of the stock, and then uses the results of the assessment to feed into a harvest control rule that sets of the catch for the following simulated year, and this process repeats over many years, and is repeated 150 times for each evaluated harvest control rule. The rules evaluated included a series of threshold rules (since these were considered best practice in the global review for data rich fisheries): the default harvest control rule, one with a lower threshold and higher threshold to open the fishery, one with a lower harvest rate and a higher harvest rate; plus additional rules that modify the threshold rules to take into account evenness of cohorts (fishing less when the population is dominated by a single cohort), and size of fish (fishing more when the population includes more large fish, which are more valuable). In the future projections for testing the rules, continuing the current state of the population would have been uninteresting since the fishery would remain closed for most rules given a continued low biomass state as has been the case since the 1990s (Fig. 1). Therefore, the rules were tested with future projections assuming an elevated level of average recruitment for 15 years, initiating an increase in biomass over that time period, followed by a return to more recent recruitment conditions, and a corresponding decline in biomass towards more recent levels (Fig. 5). Thus, the harvest control rules are tested both in how they respond to increased biomass, and to a decline in biomass.

The results showed that the default rule, the rule with a lower threshold for reopening the fishery, and the evenness rule performed the best (Fig. 6), based on a balance between catch levels, probability of low biomass, and low inter-annual variability in catches (Fig. 7). The resulting piece of research is included as a chapter in the MS thesis of Zahner (2023) and published in ICES Journal of Marine Science (Zahner and Branch 2024).

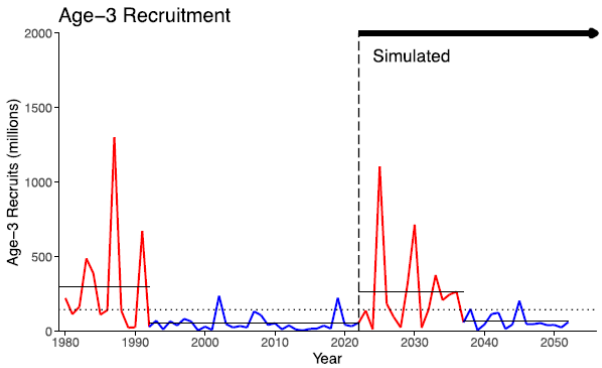

Figure 5. One iteration of the simulation scenarios used to test the harvest control rules, which simulated 15 years of future high recruitment followed by 15 years of low recruitment similar to that seen in recent years (Zahner and Branch 2024).

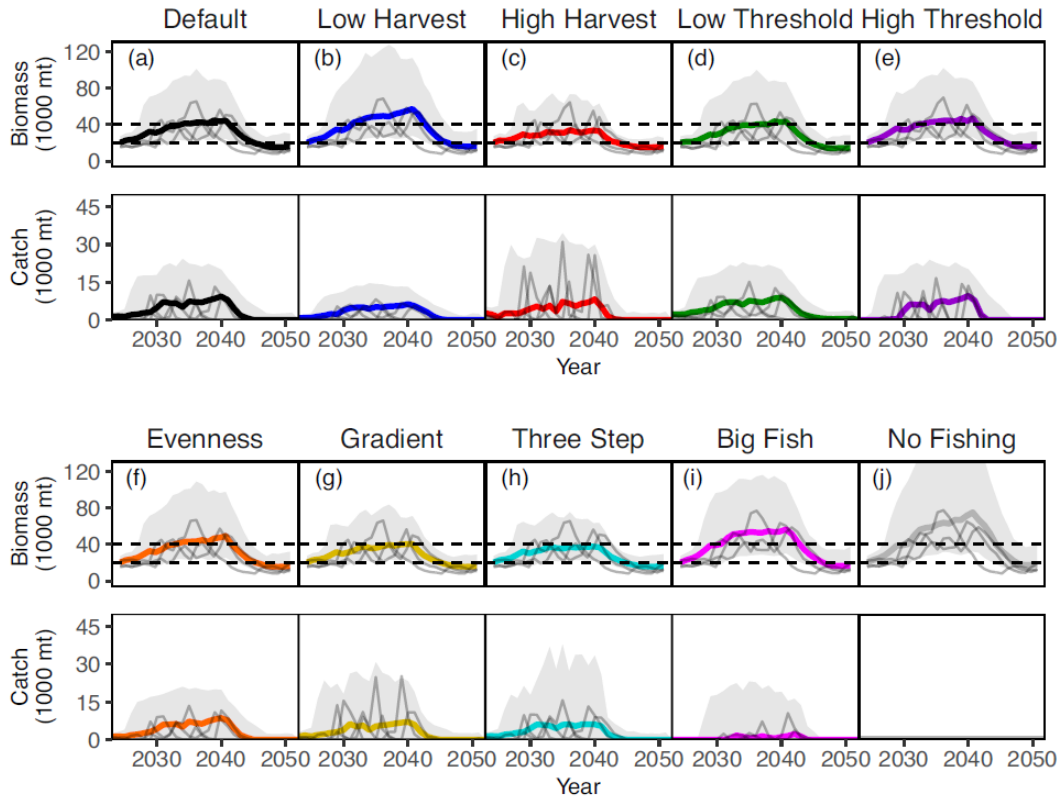

Figure 6. Predicted biomass and catch levels under each of the ten harvest control rules tested. The thick line is the median, the shading is the 80th percentiles, and individual gray lines show 5 randomly selected trajectories for individual simulations (Zahner and Branch 2024).

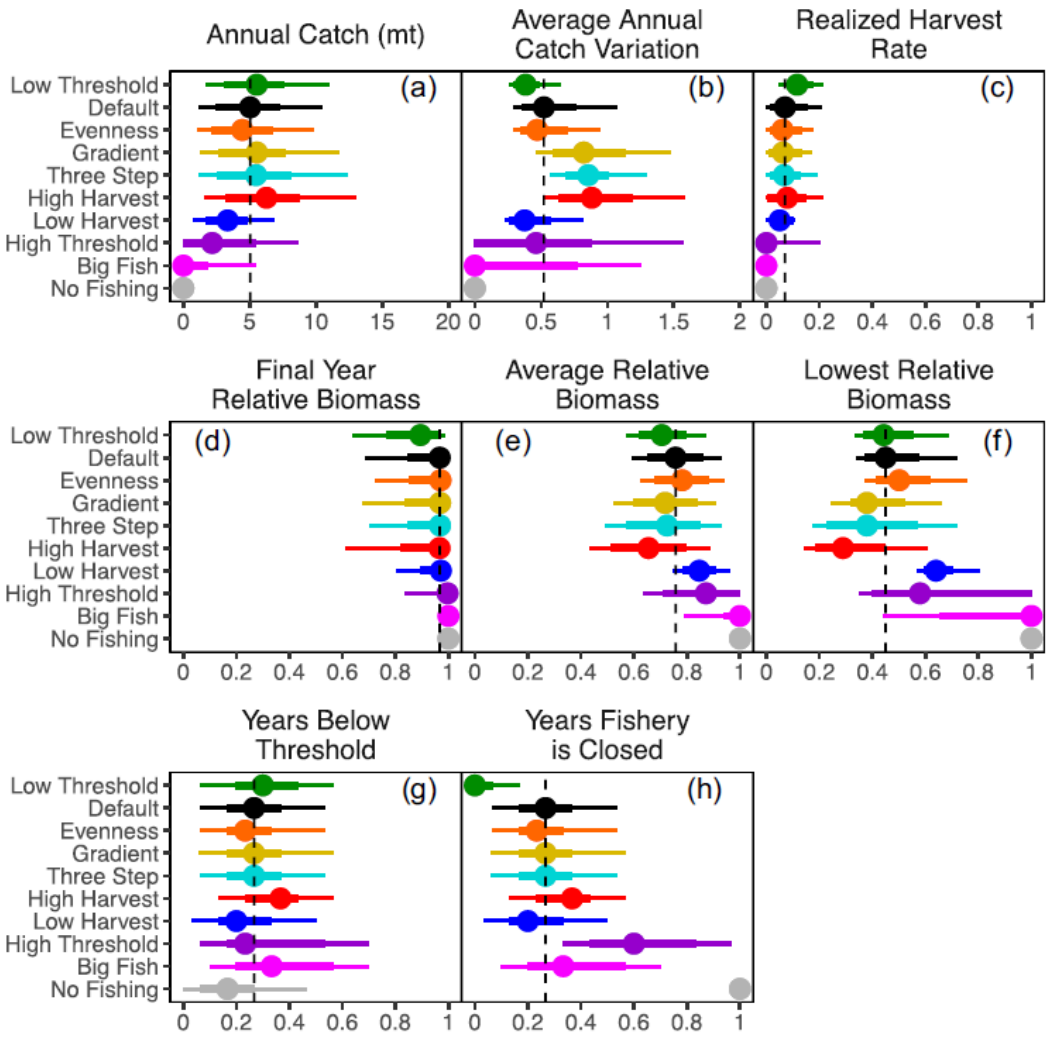

Figure 7. Performance of the 10 harvest control rules in terms of a variety of metrics measuring catch, biomass, and variability in catch (Zahner and Branch 2024).

Progress relative to goals, and deviations from plans:

Excellent progress was made in completing four of the ten goals in the second year of the planned ten-year proposal, including the MSE framework that will be used in two future goals (value of surveys, and robustness of the assessment model to biased parameter values). However, with the graduation of J. Zahner, there will be a slowdown in future work until October 2024 when two new PhD students are anticipated to join the project, one funded partly by the Alaska Department of Fish and Game (ADF&G) employment, and one funded partly by fellowships from the University of Washington.

Literature Cited:

Zahner, J. A. 2023. Operational harvest control rules and their application to a recovering forage fish stock. M.S. thesis, School of Aquatic and Fishery Sciences, University of Washington.

Zahner, J., and T. A. Branch. 2023. 2023 Bayesian age-structure stock assessment (BASA) results for Prince William Sound (PWS) herring. University of Washington.

Zahner, J. A., and T. A. Branch. 2024. Management strategy evaluation of harvest control rules for Pacific herring in Prince William Sound, Alaska. ICES Journal of Marine Science https://doi.org/10.1093/icesjms/fsad199.

Zahner, J. A., T. A. Branch, and C. M. Free, et al. In prep. Trends in operational harvest control rules for marine fisheries. Fish and Fisheries.

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2. Products:

Peer-reviewed publications:

Zahner, J. A., and T. A. Branch. 2024. Management strategy evaluation of harvest control rules for Pacific herring in Prince William Sound, Alaska. ICES Journal of Marine Science https://doi.org/10.1093/icesjms/fsad199.

Zahner, J. A., T. A. Branch, C. M. Free, et al. In prep. Trends in operational harvest control rules for marine fisheries. Fish and Fisheries.

Reports:

Zahner, J., and T. A. Branch. 2023. 2023 Bayesian age-structure stock assessment (BASA) results for Prince William Sound (PWS) herring. University of Washington.

Popular articles:

No new contributions for this reporting period.

Conferences and workshops:

No new contributions for this reporting period.

Public presentations:

No new contributions for this reporting period.

Data and/or information products developed during the reporting period:

No new contributions for this reporting period.

Data sets and associated metadata:

Branch, T., and J. Zahner. 2023. Bayesian age-structured-analysis (ASA) model and results for herring population dynamics in Prince William Sound, EVOS herring program. Gulf of Alaska Data Portal: https://gulf-of-alaska.portal.aoos.org/#metadata/4aaecfe2-de4b-4b6b-ba8e-bb715d26c6f1/project/folder_metadata/41873621.

Additional Products not listed above:

Zahner, J. A. 2023. Operational harvest control rules and their application to a recovering forage fish stock. M.S. thesis, School of Aquatic and Fishery Sciences, University of Washington.

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3. Coordination and Collaboration:

The Alaska SeaLife Center or Prince William Sound Science Center

Extensive collaboration with personnel at the Prince William Sound Science Center, regarding historical hydroacoustic surveys of herring biomass, interpretation of stock assessment results, modeling ideas, and use of age-1 aerial survey for herring schools.

EVOSTC Long-Term Research and Monitoring Projects

This project is part of the Gulf Watch Alaska Long-Term Research and Monitoring program, within the Herring Research and Monitoring (HRM) component. This project collaborates with other HRM component project, including extensive use of herring disease modeling projects in the stock assessment model, estimation of hydroacoustic surveys for herring biomass, ageing projects, herring maturity project, herring movement project, age-1 aerial surveys and more. In essence, every herring project and other broader ecosystem project that have gathered long-term data.

EVOSTC Mariculture Projects

None.

EVOSTC Education and Outreach Projects

In most years we provide articles for *Delta Sound Connections* (although not this year). In addition, the principal investigator (PI) actively disseminates science via social media (Twitter / X), with 17,600 followers and an average of 70,000 impressions (views) per month of posts in FY23. However, since Twitter was bought by Elon Musk in 2022, impressions have declined 89%, and the audience participation has declined markedly. The PI is considering moving to another platform such as BlueSky.

Individual EVOSTC Projects

Modeling data are provided as an annual data product to the Data Management program through the Gulf of Alaska data portal.

Trustee or Management Agencies

Coordination with ADF&G scientists (e.g., Jenni Morella) is ongoing and required for data inputs collected by ADF&G and used in the BASA stock assessment model. BASA model results and MSE simulations are shared and coordinated with Sherri Dressel of ADF&G. It is planned to train an ADF&G scientist (CL Roberts) as a PhD student at the University of Washington, which should further enhance collaborations with the National Oceanic and Atmospheric Administration and facilitate the transfer of the BASA model to ADF&G at the end of this EVOSTC project.

Native and Local Communities

No direct involvement.

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4. Response to EVOSTC Review, Recommendations and Comments:

No comments for FY23.

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5. Budget:

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

Budget Category:	Proposed FY 22	Proposed FY 23	Proposed FY 24	Proposed FY 25	Proposed FY 26	5- YR TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	$62,295	$65,827	$67,599	$69,421	$71,293	$336,435	$66,918
Travel	$4,509	$4,734	$8,719	$7,809	$8,199	$33,970	$4,880
Contractual/Tuition	$18,672	$19,606	$20,586	$21,616	$22,697	$103,177	$14,815
Commodities	$1,542	$800	$3,100	$3,100	$3,100	$11,642	
Equipment	$5,066	$0	$0	$0	$0	$5,066	$5,046
Indirect Costs Rate = 55.5%	$37,932	$39,606	$44,077	$44,583	$45,839	$212,036	$39,848
SUBTOTAL	$130,016	$130,573	$144,082	$146,528	$151,128	$702,327	$131,507
General Administration (9% of subtotal)	$11,701	$11,752	$12,967	$13,188	$13,602	$63,209	N/A
PROJECT TOTAL	$141,717	$142,324	$157,049	$159,716	$164,729	$765,536	$131,507
Other Resources (In-Kind Funds)						$0	

Explanation of spending differences from budgeted: several factors explain the lower spending than budgeted, mostly relating to (1) the late arrival of funds in FY22 and FY23 compared to the 1 February start date and a no-cost extension of funds from the first 10 years of the EVOSTC program, (2) funding of the student from University of Washington fellowship money for one quarter. Expenses related to journal publication costs ($3000) have not yet been invoiced.

Note that a reallocation was approved as follows: $5066 from commodities and indirect costs in the FY22 budget to $5066 in equipment. Justification: originally, I budgeted a total of $3,421 ($2,200 from commodities + 55.5% indirect) in FY22 for a data-crunching PC computer. Due to lingering pandemic supply chain issues and technological advancements (Apple computers are about 5x faster now) since the proposal was approved, the expense for this data-crunching computer was far higher than budgeted. Classifying this purchase as equipment over $5000, which is not subject to indirect charges, was more cost-effective than classifying the purchase as commodities under $5000 which would include the 55.5% indirect charge. Furthermore, purchasing this much faster machine with Apple chips will obviate the need for a second data-cruncher in FY27 as was budgeted originally, saving the Council several thousand dollars.