

**EVOSTC FY17-FY21 INVITATION FOR PROPOSALS
FY21 (YEAR 10) CONTINUING PROJECT PROPOSAL SUMMARY PAGE**

Project Number and Title

Gulf Watch Alaska: Pelagic Component Project

21120114-C—Monitoring long-term changes in forage fish distribution, relative abundance, and body condition in Prince William Sound

Primary Investigator(s) and Affiliation(s)

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Project Abstract

Identifying drivers of change in forage fish populations is key to understanding recovery potential for piscivorous species injured by the *Exxon Valdez* oil spill. The goals of the Gulf Watch Alaska (GWA) forage fish monitoring project are to provide information on the population trends of forage species in the Gulf of Alaska (GOA) and to better understand how underlying predator-prey interactions influence recovering species and pelagic ecology within Prince William Sound (PWS) and the GOA. Sampling in FY18 indicated predator and prey abundances in PWS were low and forage species such as capelin and sand lance continued a multi-year trend of low occurrence in seabird diets in the GOA. During summer 2019 sampling we encountered spawning capelin and large energy-rich sand lance in PWS, providing the first signals that these forage fish populations may be recovering. Our continued sampling will provide insight into how forage fish populations respond to the persistence of or recovery from the recent Pacific marine heatwave.

Due to COVID-19 pandemic and State/Federal mandates, we were unable to conduct fieldwork in 2020. We propose to redirect FY20 spending that would have occurred for fieldwork to 1) maintenance and update of trawl gear, and 2) funding to support a student or post-doc with training in acoustic data analysis to help accomplish GWA forage fish project goals and synthesis. If approved, these expenditures in FY20 would balance out with no changes to our originally proposed project total budget. Middleton Island work is underway, and sampling will be comparable to previous years. In FY21, we will continue summer aerial survey validation in conjunction with the Herring Research and Monitoring program, summer acoustic-trawl sampling, and the fall integrated predator-prey survey in PWS. We will also conduct seabird diet sampling at Middleton Island during spring/summer (Apr-Aug).

EVOSTC Funding Requested* (must include 9% GA)

FY17	FY18	FY19	FY20	FY21	TOTAL
\$198,800	\$229,800	\$292,100	\$295,400	\$302,800	\$1,318,900

Non-EVOSTC Funds to be used, please include source and amount per source: (see Section 6C for details)

FY17	FY18	FY19	FY20	FY21	TOTAL
\$256,000	\$256,000	\$256,000	\$517,200	\$517,200	\$1,802,400

1. PROJECT EXECUTIVE SUMMARY

Pelagic Component

The pelagic component research team proposed to continue monitoring key pelagic species groups in Prince William Sound (PWS) during FY17-21 using the same five projects focused on killer whales, humpback whales, forage fish, and marine birds (two projects: summer and fall-winter). The two over-arching questions for the pelagic component to answer during this 5-year period are:

1. What are the population trends of key upper trophic level pelagic species groups in PWS – killer whales, humpback whales, marine birds, and forage fish?
2. How do predator-prey interactions, including interannual changes in prey availability, contribute to underlying changes in the populations of pelagic predators in PWS and Middleton Island?

Forage Fish Monitoring

Forage species are important in marine food webs because they are consumed by marine predators such as birds, mammals, and predatory fish. Forage species typically produce many offspring and have short life spans, and these traits predispose populations towards large fluctuations in abundance, with subsequent consequences for their predators. Examples of important forage taxa in PWS include capelin, Pacific sand lance, Pacific herring, juvenile walleye pollock, and krill.

During the current FY17-21 Gulf Watch Alaska (GWA) funding cycle, the primary objectives of the forage fish monitoring project are to: 1) monitor the status and trends of forage fish in areas with known persistent aggregations of predators and prey during fall, and 2) support annual field and laboratory efforts to continue the Middleton Island long-term seabird diet index in spring/summer, 3) assess changes in forage fish abundance indices on acoustic-trawl surveys during summer, and 4) support Herring Research and Monitoring (HRM) program aerial survey validation efforts in summer. To meet our first objective, we integrate directly with the humpback whale and marine bird predation studies to provide estimates of forage biomass in the immediate vicinity of predator aggregations. To meet our second objective, in a collaboration with Scott Hatch (Institute for Seabird Research and Conservation [ISRC]), we use seabirds as samplers of forage fish at Middleton Island to continue the long-term seabird diet data collection program as a cost-effective means to monitor forage fish stocks in the northern Gulf of Alaska (GOA). To meet our third objective, we conduct multi-frequency hydroacoustic transects and trawls to identify species composition and size distributions of ensonified targets. To meet our fourth objective, we sample fish schools from a vessel on the water under the direction of the aerial survey team to validate their observations.

Many patterns we observed during forage fish sampling in PWS in the first five years of GWA monitoring were consistent with patterns of recruitment, abundance and/or body condition of forage fish in the larger northern GOA region. For example, young of the year walleye pollock were extremely abundant in trawls during our surveys in 2012 and least abundant in 2015 (Arimitsu et al. 2018), which is consistent with changes in Gulf-wide recruitment and biomass (Dorn et al. 2016). We found capelin had highest body condition in 2013 (Arimitsu et al. 2018), which was a year when capelin were widespread and abundant on GOA Integrated Ecosystem Research Program hydroacoustic – trawl surveys (McGowan et al. 2016, 2020). On the other hand, age-1 capelin were increasingly scarce throughout PWS and other areas of the GOA, including seabird diets in 2014-2016 (Arimitsu et al. 2020). Time series data from Middleton Island, the longest available from any location in Alaska,

show that after several years of high frequency of occurrence in seabird diets in 2008 – 2013, capelin virtually disappeared from diets in 2014-2018 (Fig. 1).

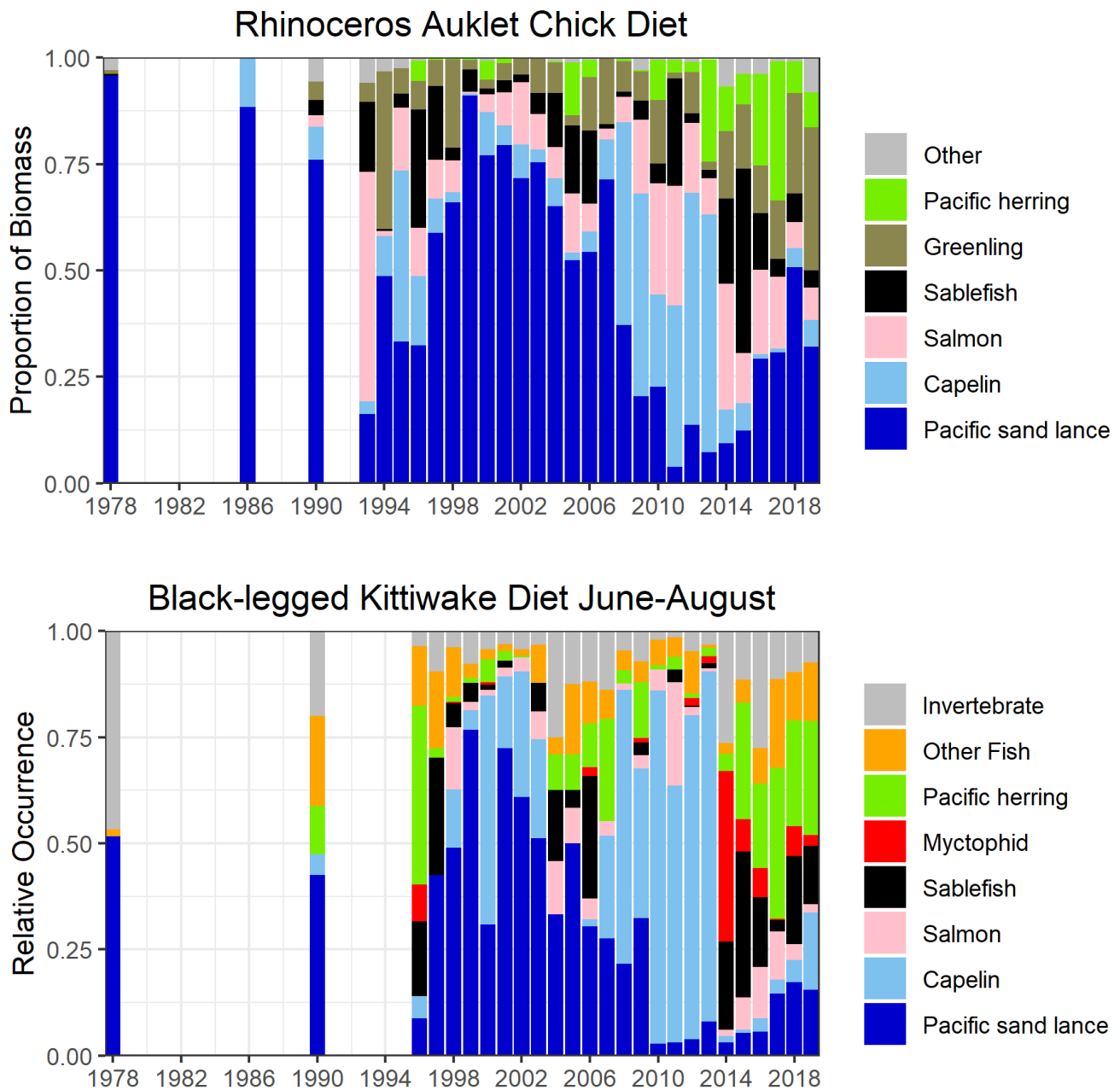


Figure 1. Interannual variation in diet composition of chick-rearing rhinoceros auklets (top) and black-legged kittiwakes (bottom) on Middleton Island, 1978 to 2018.

Integrated Predator-Prey Surveys in PWS

In FY17, we integrated two predator studies (Moran/Straley Humpback whale [project 20120114-O] and Bishop fall/winter marine birds [20120114-E]) with the forage fish study, by operating at the same time and locations, and by using the same vessels. Combining logistics, resources, and expertise, we are able to identify species and estimate the forage biomass at the same locations in which predators are feeding, providing comparable information on both predator density and prey availability (species composition, depth distribution, density and

biomass). The integrated predator-prey (IPP) survey is conducted during the fall to provide insight into predator-prey interactions at a crucial time when forage fish energy is maximized and while marine birds and humpback whales are provisioning for the upcoming winter. In FY21, there is no planned change to the IPP survey.

The forage fish component of the IPP survey focuses on prey availability, species composition and distribution relative to the predators and geography, energy density, and water column depth using primarily hydroacoustic methods developed in the previous 5-year study. Ground truthing (net sampling and other collection methods) is an important secondary component to confirm species identity and size for acoustic estimates of biomass, provide samples for other analyses (e.g., diet, stable isotopes, energy content), and provides critical information on the size distribution of the forage. Herring and euphausiids are the primary forage in the areas of predator aggregation, although capelin, juvenile pollock, and other forage species are found there as well.

Survey areas encompass the known locations of the feeding aggregations of predators in South Montague Strait, Bainbridge Passage, and Port Gravina. We also conduct adaptive sampling if predators are found in unexpected locations. Marine bird observations (see Bishop wintering marine bird project work plan [project 21120114-E]) are recorded concurrently with acoustic transects, while humpback whale distribution and abundance are assessed from a smaller vessel concurrently in the same area (see Moran and Straley humpback whale project work plan [project 21120114-O]). Combined efforts by GWA's pelagic component humpback whale, marine bird, and forage fish principal investigators (PIs) provide a comprehensive understanding of the pelagic ecosystem and provide an integrated dataset that facilitates analyses of predator-prey relationships.

Forage Fish Indices in the GOA - Long-term Data from Seabird Diets

The Middleton Island forage fish index, which includes nearly three decades of frequency of occurrence and size data on capelin, Pacific sand lance, Pacific herring, and other forage taxa from the northern GOA, represents the longest continuous time series of forage fish species composition and abundance index in the region. Given Middleton Island's location near the continental shelf edge, the data obtained also reflect interannual variability in both pelagic (deep ocean) and neritic (continental shelf) habitats (Hatch 2013) and provides the critical mid-trophic level link to spring/summer lower and upper trophic levels studied during GWA environmental drivers sampling in the GOA (Fig. 1). Thus, the continuation of the longest time series on forage fish in the northern GOA is broadly important for the region. Additionally, expansion of environmental drivers sampling (National Science Foundation Long-term Ecological Research site designation; see Seward Line project work plan [project 21120114-L]) to the GOA shelf area near Middleton Island (Fig. 1) provides further linkages to GWA forage fish studies.

Work planned in FY21 will include Middleton Island seabird diet sampling through a collaboration with the program's founder Dr. Scott Hatch (ISRC). Prime samplers are black-legged kittiwakes and rhinoceros auklets, representing an obligate surface feeder and a diving species, respectively. In most years since 2000, regurgitated food samples have been collected from adult and/or nestling kittiwakes during all months April through August. Kittiwake food samples are collected when the adults regurgitate whole fish and other prey soon after capture for morphometrics and/or tagging. Nestling diets of rhinoceros auklets are monitored by collecting whole fish, or bill loads, from chick-provisioning adults, usually once or twice per week from early July through early or mid-August. Seabird diet time series will be continued annually during this study using established methods (Hatch 2013, Hatch and Sanger 1992, Thayer et al. 2008). Middleton Island forage fish data provide an index of forage fish availability during the breeding season (April-Aug).

Summer Forage Fish Sampling in Prince William Sound

The summer forage fish sampling during FY12-16 was jointly conducted with the HRM program’s aerial forage fish surveys and provided PWS-wide indices of distribution, abundance, and condition of juvenile forage fish. HRM’s aerial forage fish surveys were initially unfunded in FY17-21; however, renewed multi-year funding (at least through FY21) from the PWS Regional Citizens’ Advisory Council provides a new opportunity to leverage funds to resume the summer forage fish sampling efforts and continue what are proving to be informative time series. For example, summer forage fish sampling efforts provide 1) the ability to adjust aerial survey fish school counts for uncertainty associated with remote species and size-class identification, 2) species-specific acoustic density indices of age-0 pollock, age-0 herring, age-1 herring, age-2+ herring, and capelin, 3) acoustic index and species composition of microzooplankton (e.g., krill), 4) acoustic index and species composition of gelatinous zooplankton, and 5) indices of capelin and sand lance age structure and body condition during summer. All these indices provide an important baseline for comparison and monitoring the ecosystem recovery following a prolonged warming period in the GOA. For example, the abundance of capelin and condition of sand lance showed clear declines during the heatwave.

Additionally, the continuation of this coordinated HRM-GWA effort will facilitate linkages to other program objectives by providing quantitative indices of 1) juvenile and adult herring for age-structured stock assessments, 2) prey resources influencing marine bird trends during the breeding season, 3) prey resources affecting humpback whale distribution and abundance, 4) PWS forage fish communities to identify context for comparisons with Middleton Island’s longest running forage fish time series in the GOA.

2. PROJECT STATUS OF SCHEDULED ACCOMPLISHMENTS

A. Project Milestones and Tasks

Table 1. This table breaks down project deliverables and their status into milestones and task progress by fiscal year and quarter, beginning February 1, 2017. C = completed, X = planned or not completed, V = cancelled due to COVID-19, P = partially completed, due to constraints of COVID-19. Fiscal year quarters: 1 = Feb 1 – April 30; 2 = May 1 – July 31; 3 = Aug. 1 – Oct. 31; 4 = Nov. 1 – Jan. 31.

Milestone/Task	FY17				FY18				FY19				FY20				FY21			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Milestone 1: admin & logistics																				
Contracting	C	C		C	C	C		C	C	C		C	C	C		X	X	X		X
Permitting			C				C				C			C					X	
Equipment calibration		C				C				C				C				X		
Milestone 2: data acquisition & processing																				
Middleton Island support	C	C	C		C	C	C		C	C	C		C	C	X		X	X	X	
Integrated predator-prey surveys (EVOSTC)			C				C				C				X				X	
Alternate survey schedule (with added NOAA funds)	C		C		C															
Acoustic data processing	C	C	C		C	C	C		C	C	C		C	C	X		X	X	X	
CTD data processing	C				C				C				C				X			
Chlorophyll <i>a</i> fluorometry	C				C				C				C				X			
Milestone 3: data management																				
Database mgmt./QAQC	C	C	C	C	C	C	C	C	C	C	C	C	C	C	X	X	X	X	X	X

Milestone/Task	FY17				FY18				FY19				FY20				FY21			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Metadata	C				C				C				C				X			
Workspace upload		C				C				C				C				X		
Middleton Data QAQC			C	C			C	C			C	C			X	X			X	X
Middleton Data Metadata						C														X
Middleton Data Workspace Upload				C				C				C				X				X
Milestone 4: analysis & reporting																				
Analysis and summary	C	C	C	C	C	C	C	C	C	C	C	C	C	C	X	X	X	X	X	X
Annual Reports	C				C				C				C				X			
Annual PI meeting				C				C				C				X				X
FY Work Plan (DPD)			C				C				C				C					
Permit reports				C				C				C				X				X
Milestone 5: summer sampling																				
Summer HRM aerial survey validation										C				V				X		
Summer acoustic-trawl survey										C				V				X		

In addition to the primary project deliverables in Table 1, during the past year we contributed seabird-derived forage fish indicators from Middleton Island for the 2019 Ecosystem Status Report to the North Pacific Fishery Management Council and gave a poster presentation at the 2020 Alaska Marine Science Symposium. A manuscript was co-authored and published on nutritional value of key forage fish during the Pacific marine heatwave. A second manuscript is in press and a third is in review (see Section 7).

B. Explanation for not completing any planned milestones and tasks

Most milestones and tasks for 2019 and first two quarters of 2020 were completed in accordance with our proposal and with sampling protocols available on the GWA Research Workspace. The summer acoustic-trawl survey was cancelled due to the COVID-19 pandemic. FY20 work at Middleton Island is underway with a smaller crew, but sampling will be comparable to previous years.

C. Justification for new milestones/tasks

No new milestones or tasks are proposed.

3. PROJECT COORDINATION AND COLLABORATION

A. Within an EVOSTC-funded Program

Gulf Watch Alaska

Under the pelagic component of the GWA program, this project shares a research platform and common goals of the humpback whale (project 20120114-O) and fall/winter marine bird (project 20120114-E) projects also associated with the IPP surveys. Summer forage fish surveys and information regarding Middleton Island seabird diets also provide a means to understand trends in piscivorous marine birds (project 20120114-M).

Science synthesis efforts are wrapping up for the GWA program. Forage fish project principal investigator Arimitsu is lead author for a synthesis chapter and manuscript and provided data for the Suryan et al. synthesis manuscript. Science Panel report reviews have been addressed and the forage fish chapter manuscript is in the final stages of preparation.

Herring Research and Monitoring

We will continue collaborative work with Scott Pegau and the HRM Program's aerial surveys for juvenile herring and other forage fish. The forage fish chapter of the GWA synthesis report included input and authorship from HRM program scientists.

Data Management

This project coordinates with the data management program by submitting data and preparing metadata for publication on the Gulf of Alaska Data Portal and DataONE within the timeframes required.

B. With Other EVOSTC-funded Projects

We are working with the Northern GOA Long-term Ecological Research (National Science Foundation) team (Russ Hopcroft et al. [affiliated with GWA project 20120114-L]) to assess connectivity between our collective middle trophic level monitoring efforts. For example, we are taking a lead role in processing fish (bycatch) catches from Methot trawls intended to sample jellyfish. This work will facilitate a better understanding of the relationship between seabird diets at Middleton and the distribution for forage fish in trawls.

C. With Trustee or Management Agencies

Data and fish samples gathered as part of the GWA forage fish study will be used by National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Science in annual stock assessments (Stephani Zador and Ellen Yasumiishi, Ecosystems Considerations Chapter to the Northwest Pacific Fisheries Management Council). We are also collaborating with GOA Integrated Ecosystem Research program PIs and are nearing completion of a synthesis of capelin in the GOA. We also provided forage fish and macrozooplankton samples for studies on harmful algal blooms (North Pacific Research Bboard study PIs: Xiuning Du, Oregon State University, and Rob Campbell, PWS Science Center; US Geological Survey (USGS) study PIs: Sarah Schoen, Matt Smith, Caroline van Hemert). The GWA forage fish work is also complimentary to a related USGS-Bureau of Ocean Energy Management study of forage fish and seabird trends in areas of oil and gas development in Cook Inlet. This continued coordination and collaboration with GWA PIs (Kris Holderied, NOAA; Kathy Kuletz, US Fish and Wildlife Service) in Cook Inlet and Kachemak Bay increases the scope of ecosystem monitoring in the Northern GOA.

4. PROJECT DESIGN

A. Overall Project Objectives

Monitor the status and trends of co-occurring pelagic marine ecosystem components during Fall/Winter in areas with known seasonally predictable aggregations of predators and prey (see Table 2).

Table 2. Integrated predator-prey collaborations by objective. Bolded text directly relates to the forage fish project.

Objective	Index	Task	PI
a. Estimate humpback whale abundance, diet, and distribution			
	Whale counts by sub-region	Integrated Surveys: whale counts, biopsies	Moran (NOAA)/ Straley (UAS)
	Whale Identification	Integrated Surveys: Photo ID	Moran (NOAA)/ Straley (UAS)
	Whale Diet	Integrated Surveys: scales, scat, biopsies, visual observations, hydroacoustics	Moran (NOAA)/ Straley (UAS)/ Arimitsu & Piatt (USGS)
b. Estimate marine bird abundance and distribution in seasonally predictable predator aggregation areas			
	Georeferenced marine bird counts, group size, behavior by species	Integrated Surveys: marine bird transects	Bishop (PWSSC)
b.i. Relate marine bird and humpback whale presence to prey fields identified during hydroacoustic surveys.			
	Spatial coherence of bird and whale presence/ absence, acoustic estimates of forage fish and euphausiid biomass	Integrated Surveys: hydroacoustic and marine bird transects, whale focal follows	Arimitsu & Piatt (USGS)/ Bishop (PWSSC)/ Moran (NOAA)/ Straley (UAS)
b.ii. Characterize marine bird-humpback whale foraging dynamics			
	Georeferenced marine bird and whale counts, group size, behavior by species	Integrated Surveys: marine bird transects; whale focal follows	Bishop (PWSSC)/ Moran (NOAA)/ Straley (UAS)/ Arimitsu & Piatt (USGS)
c. Estimate index of forage fish availability in seasonally predictable predator foraging areas			
	Species composition and biomass within persistent predator foraging areas	Integrated Surveys: hydroacoustic-trawl data	Arimitsu & Piatt (USGS)/ Moran (NOAA) Bishop (PWSSC)
	Density and depth distribution	Integrated Surveys: hydroacoustic-trawl data	Arimitsu & Piatt (USGS)
	Diet, energy density	Sample Analysis: forage fish	Moran (NOAA)
d. Estimate an index of euphausiid availability in seasonally predictable predator foraging areas			
	Species composition and biomass within persistent predator foraging areas	Integrated Surveys: hydroacoustic-trawl data	Arimitsu & Piatt (USGS)
	Density and depth distribution	Integrated Surveys: hydroacoustic-trawl data	Arimitsu & Piatt (USGS)
e. Relate whale, marine bird and forage fish indices to marine habitat			

Objective	Index	Task	PI
	Oceanographic metrics and zooplankton biomass	Integrated Surveys: CTD and zooplankton samples	Arimitsu & Piatt (USGS)/ Moran (NOAA)/ Straley (UAS)/ Bishop (PWSSC)

1. Support annual field and laboratory efforts to continue the long-term Middleton seabird diet index in April-August
2. Assess changes in forage fish abundance indices on acoustic-trawl surveys during summer
3. Support HRM aerial shoreline survey validation efforts in summer

B. Changes to Project Design and Objectives

Due to the COVID-19 pandemic we were unable to conduct summer sampling in 2020, including USGS-led efforts to validate June HRM aerial surveys, and the summer acoustic – trawl survey in PWS. As of Aug. 1, 2020 we have not canceled the September IPP survey (scheduled for Sept 15-30, 2020), however, the spike in Alaska’s COVID-19 cases in June-July 2020 and the need to reduce scientific personnel on research vessels due to social distancing requirements makes it unlikely that we will conduct any acoustic-trawl work in 2020.

In lieu of contracts to process zooplankton and nutrients samples we proposed to collect in 2020, we contracted Rob Campbell at the PWSSC to provide local support for aerial survey validation efforts and for forage fish sample collections (e.g., to continue capelin and sand lance age-structure and energetics time series). This was a 1:1 exchange in cost, therefore no changes are made to the 2020 contracts budget.

5. PROJECT PERSONNEL – CHANGES AND UPDATES

There are no changes to project personnel.

6. PROJECT BUDGET

A. Budget Forms (See GWA FY20 Budget Workbook)

Please see project budget forms compiled for the program.

**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	\$122.0	\$127.7	\$159.5	\$185.3	\$170.6	\$765.1	
Travel	\$8.6	\$7.3	\$11.6	\$7.3	\$10.3	\$45.0	
Contractual	\$47.5	\$47.5	\$53.5	\$53.5	\$53.5	\$255.5	
Commodities	\$0.0	\$0.0	\$32.0	\$0.0	\$32.0	\$64.0	
Equipment	\$4.3	\$28.4	\$11.4	\$24.9	\$11.4	\$80.4	
SUBTOTAL	\$182.4	\$210.8	\$268.0	\$271.0	\$277.8	\$1,210.0	\$0.0
General Administration (9% of	\$16.4	\$19.0	\$24.1	\$24.4	\$25.0	\$108.9	N/A
PROJECT TOTAL	\$198.8	\$229.8	\$292.1	\$295.4	\$302.8	\$1,318.9	
Other Resources (Cost Share Funds)	\$256.0	\$256.0	\$256.0	\$517.2	\$517.2	\$1,802.4	

B. Changes from Original Project Proposal

We canceled field work in 2020 due to the COVID-19 pandemic and this changed the amounts spent in some categories in this year, e.g., we spent \$33K less in salary and overtime, \$3K less in travel for field work, and \$32K less in vessel charter costs. We propose to redirect FY20 spending that would have occurred for field

work to 1) maintenance and update of trawl gear for \$13.5K, and 2) funding to support a student or post-doc with training in acoustic data analysis to help accomplish GWA forage fish project goals and synthesis for \$54.5K. If approved, these expenditures in FY20 would balance out such that there are no changes to our originally proposed project total budget.

C. Sources of Additional Project Funding

USGS Alaska Science Center will provide in-kind contributions of salary (\$110.8K) and equipment (\$252K, including \$141K acoustic equipment, \$55K oceanography sampling equipment, \$20K trawl depth monitor system, \$20K small boats and outboards, \$10K marine scale, \$6K net sampling gear) to facilitate the GWA forage fish project in FY20. In addition, ISRC will provide in-kind contributions of salary (\$34.5K) and facilities (\$120K) for Middleton Island forage fish sampling efforts.

7. FY17-20 PROJECT PUBLICATIONS AND PRODUCTS

Publications

- Arimitsu, M.L., K.A. Hobson, D.N. Webber, J.F. Piatt, E.W. Hood, and J.B. Fellman. 2018. Tracing biogeochemical subsidies from glacier runoff into Alaska coastal marine food webs. *Global Change Biology* 24:387-398
- Arimitsu, M., J.F. Piatt, and S. Hatch. 2018. Monitoring long-term changes in forage fish distribution, abundance, and body conditions in PWS. FY17 annual report to the *Exxon Valdez* Oil Spill Trustee Council, project 17120114-C.
- Arimitsu, M., J.F. Piatt, and S. Hatch. 2019. Monitoring long-term changes in forage fish distribution, abundance, and body conditions in PWS. FY18 annual report to the *Exxon Valdez* Oil Spill Trustee Council, project 18120114-C.
- Arimitsu, M., J.F. Piatt, and S. Hatch. 2020. Monitoring long-term changes in forage fish distribution, abundance, and body conditions in PWS. FY20 annual report to the *Exxon Valdez* Oil Spill Trustee Council, project 18120114-C.
- Arimitsu, M.L., J.F. Piatt, B. Heflin, V. von Biela, and S.K. Schoen. 2018. Monitoring long-term changes in forage fish distribution, abundance and body condition in Prince William Sound. *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 16120114-O), U. S. Geological Survey Alaska Science Center, Anchorage, AK. 64 pp.
- Arimitsu, M., J. Piatt, R. Suryan, S. Batten, M.A. Bishop, R. Campbell, H. Coletti, D. Cushing, K. Gorman, S. Hatch, S. Haight, R. Hopcroft, K. Kuletz, C. Marsteller, C. McKinstry, D. McGowan, J. Moran, W.S. Pegau, A. Schaeffer, S. Schoen, J. Straley, and V. von Biela. 2020. Synchronous collapse of forage species disrupts trophic transfer during a prolonged marine heatwave. *In: The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Long-Term Monitoring Program (Gulf Watch Alaska) Synthesis Report Exxon Valdez Oil Spill Trustee Council Program 19120114* (Eds: Suryan, R.M., M.R. Lindeberg, and D.R. Aderhold). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.
- Hatch, S.A., M. Arimitsu, and J.F. Piatt. 2018. Seabird-derived forage fish indicators from Middleton Island *in* Zador, S. G., and E. M. Yasumiishi. 2018. Ecosystem Status Report 2018: Gulf of Alaska. Report to the North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99301. <https://www.fisheries.noaa.gov/resource/data/2018-status-gulf-alaska-ecosystem>

- McGowan, D.W., E.D. Goldstein, M.L. Arimitsu, A.L. Dreary, O. Ormseth, A. De Robertis, J.K. Horne, L.A. Rogers, M.T. Wilson, K.O. Coyle, K. Holderied, J.F. Piatt, W.T. Stockhausen, and S. Zador. In review. Spatial and temporal dynamics of Pacific capelin (*Mallotus catervarius*) in the Gulf of Alaska: implications for ecosystem-based fisheries management. *Marine Ecology Progress Series* 637:117-140.
- Moran, J., M. O'Dell, M. Arimitsu, J. Straley, and D. Dickenson. 2018. Seasonal distribution of Dall's porpoise in Prince William Sound. *Deep Sea Research II* 147:164-172.
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Note: Posting of datasets for this project are on an out of cycle schedule associated with fall sampling.

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Arimitsu, M.L. 2018. Monitoring forage fish in Alaska: Detecting change in non-commercial prey populations. Oral Presentation. Department of Fisheries and Oceans Canada Forage Fish Workshop. Pacific Biological Station, Nanaimo, BC. 13-15 March. [Invited, travel paid by DFO]

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- Moran, J., M. O'Dell, D. Dickson, J. Straley, and M.L. Arimitsu. 2017. Seasonal distribution of Dall's Porpoise in Prince William Sound, Alaska. Alaska Marine Science Symposium. January.
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- von Biela, V, J. Piatt, M. Arimitsu, and L. Ball. Fish and wildlife responses to prolonged heatwaves: A window to the future? Symposium Organizers. Joint American Fisheries Society-The Wildlife Society Meeting. Reno, NV. 1-4 October.
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Outreach

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- Arimitsu, M.L. 2018. Monitoring forage fish in Alaska: Detecting change in non-commercial prey populations. Department of Fisheries and Oceans Canada forage fish workshop. Pacific Biological Station, Nanaimo, BC, Mar. 2018.
- Arimitsu, M. 2019. Forage fish, jellyfish, and other touchable marine creatures in Prince William Sound. Outreach presentation at Chenega School. 20 September.
- Arimitsu, M., 2019. Forage fish in changing seas. Invited Speaker. Sitka Whalefest, Sitka, AK. 31 October – 2 November.
- Arimitsu, M. 2020. Last Chance Endeavors podcast about research on changes in forage fish populations that were first signaled by large die-offs of seabirds during the 2014-2016 North Pacific marine heatwave – aka "The Blob." Last Chance Endeavors mission is to connect students to the environment. Listen to the podcast at: <https://www.lastchanceendeavors.com/podcast/episode/2507d869/mayumi-arimitsu-research-ecologist-at-whalefest-2019-or-why-are-the-birds-dead-or-episode-028>.
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