

EVOSTC FY17-FY21 INVITATION FOR PROPOSALS
FY19 (YEAR 8) CONTINUING PROJECT PROPOSAL SUMMARY PAGE

Project Number and Title

Gulf Watch Alaska: Pelagic Component Project

19120114-C—Monitoring long-term changes in forage fish distribution, relative abundance, and body condition in Prince William Sound

Primary Investigator(s) and Affiliation(s)

Mayumi Arimitsu and John Piatt, U.S. Geological Survey – Alaska Science Center

Date Proposal Submitted

August 17, 2018

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 FY17 (FY18 sampling begins Sept 11, 2018) indicated predator and prey abundances in PWS were low and forage species such as capelin and sand lance continued a 4-year trend of low occurrence in seabird diets in the GOA. Our continued sampling will provide insight into how forage fish populations respond to the persistence of or recovery from the recent Pacific marine heat wave.

In FY19, we will continue acoustic-trawl sampling for the integrated predator-prey survey in PWS during fall (Sept/Oct), and seabird diet sampling at Middleton Island during spring/summer (Apr-Aug). We are requesting additional funds for FY19-21 to reinstate summer aerial forage fish surveys in PWS previously conducted by the Herring Research and Monitoring Program (HRM). The additional funding would provide the needed species composition and age class validation during HRM aerial forage fish surveys and extend the aerial and acoustic forage fish time-series that began during the North Pacific marine heat wave in 2014-16 and will be used to monitor the recovery of middle-trophic level species following a major Gulf-wide perturbation.

EVOSTC Funding Requested* (must include 9% GA)

FY17	FY18	FY19	FY20	FY21	TOTAL
\$198,800	\$229,800	\$292,100*	\$295,340*	\$302,800*	\$1,318,880

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	\$256,000	\$256,000	\$1,280,000

*Totals in FY19-21 include additional annual requests of \$65,000 (+ 9% GA) that will be used to reinstate summer validation sampling of Herring Research and Monitoring Program aerial juvenile forage fish surveys (funding secured through PWSRCAC) and summer acoustic-trawl surveys. Please see Sections 2C and 6B for details.

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. 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).

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, which is consistent with changes in Gulf-wide recruitment and biomass (Dorn *et al.*, 2016). We found capelin had highest body condition in 2013, which was a year when capelin were widespread and abundant on GOA Integrated Ecosystem Research Program hydroacoustic – trawl surveys (McGowan *et al.*, 2016). On the other hand, age 1 capelin were increasingly scarce throughout PWS and other areas of the GOA, including seabird diets in 2014-2016 (Hatch, 2017; Arimitsu *et al.*, 2018). 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 2014-2017 (Fig. 1, Hatch, 2017).

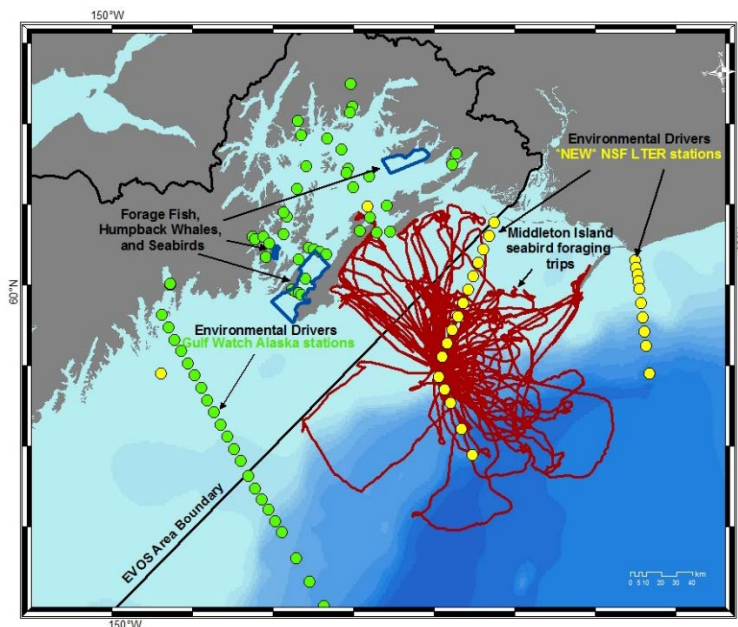
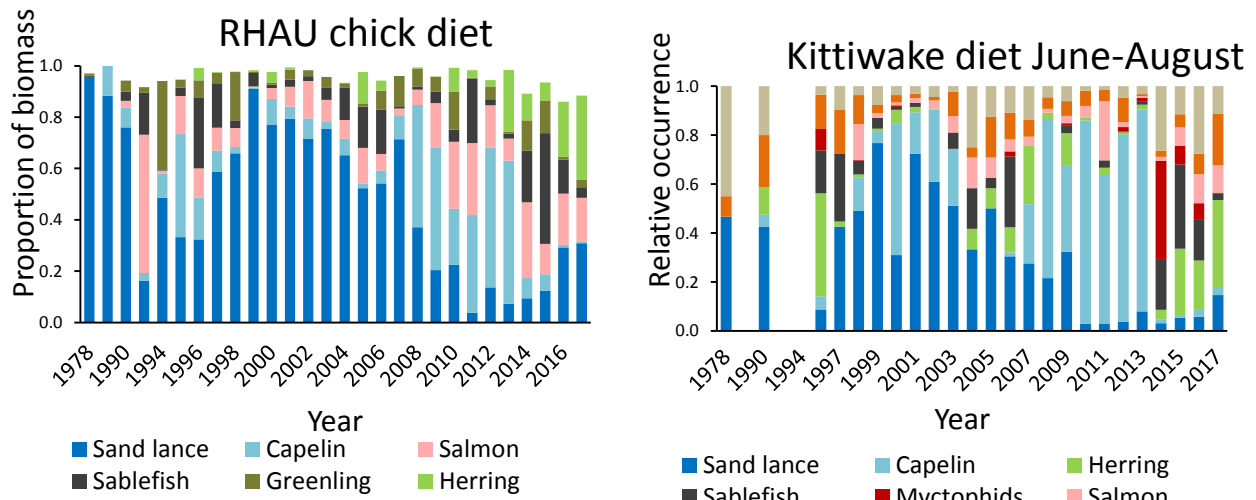


Figure 1. Interannual variation in diet composition of chick-rearing rhinoceros auklets (top left) and black-legged kittiwakes (top right) on Middleton Island, 1978 to 2016. The map (bottom) shows pelagic sampling areas and environmental drivers stations (including new NSF LTER stations) in PWS and GOA, and a sample of foraging trips from GPS-tagged rhinoceros auklets and black-legged kittiwakes returning to Middleton Island with forage fish during 2015 and 2016 breeding seasons.

Integrated Predator-Prey Surveys in PWS

In FY18, we integrated two predator studies (Moran/Straley Humpback whale and Bishop fall/winter marine birds) 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 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 FY19, there is no change to the Integrated Predator-Prey surveys.

The forage fish component of the integrated predator-prey 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 19120114-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 19120114-O]). Combined efforts by GWA's pelagic component humpback whale, marine bird, and forage fish 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 19120114-L]) to the GOA shelf area near Middleton Island (Fig. 1) provides further linkages to GWA forage fish studies.

Work planned in FY19 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 (see below), 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 and Sanger, 1992; Thayer et al., 2008; Hatch, 2013). Middleton Island forage fish data provide an index of forage fish availability during the breeding season (April-Aug).

Request for Reinstatement of Summer Forage Fish Sampling in Prince William Sound

Based on information gained during the first five years of GWA and a funding request cap limiting forage fish sampling to one cruise, we redesigned the integrated predator-prey survey for PWS to include shared vessel platforms and shifted sampling to fall when humpback whale and marine bird predation on forage fishes was greatest. While this redesign allows us to sample forage fish at a point when energy density is maximized and better estimate predator impact on forage species, especially herring, the loss of PWS sampling in June and July left an information gap during the summer breeding season. The summer forage fish sampling during FY12-16 was jointly conducted with the Herring Research and Monitoring (HRM) program’s aerial forage fish surveys and provided a 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 (PWSRCAC) 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 that originated during FY12-16. While our fall sampling is directed to humpback whale focal areas and predator prey aggregations, summer sampling provides PWS-wide indices of forage fish abundance, condition, and important species and age-class validation for HRM aerial surveys (see Sections 2C, 4B, and 6B for more details).

2. PROJECT STATUS OF SCHEDULED ACCOMPLISHMENTS

A. Project Milestones and Tasks

Table 1. Project milestone and task progress by fiscal year and quarter, beginning February 1, 2017. A requested additional milestone and tasks with additional funding are included in red. C = completed, X = not completed or planned. 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		X	X	X		X	X	X		X	X	X		X
Permitting			C				X				X				X				X	
Equipment calibration		C			C				X				X				X			
Milestone 2: data acquisition & processing																				
Middleton Island support	C	C	C		C	C	X		X	X	X		X	X	X		X	X	X	
Integrated predator-prey surveys (EVOSTC)			C				X				X				X				X	
Alternate survey schedule (with added NOAA funds)	C		C		C															
Acoustic data processing	C	C	C		C	C	X		X	X	X		X	X	X		X	X	X	
CTD data processing	C				C				X				X				X			
Chlorophyll <i>a</i> fluorometry	C				C				X				X				X			
Milestone 3: data management																				
Database mgmt./QAQC	C	C	C	C	C	C	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Metadata	C				C				X				X				X			
Workspace upload		C			C				X				X				X			
Middleton Data QAQC			C	C			X	X			X	X			X	X			X	X

Middleton Data Metadata						X													X
Middleton Data Workspace Upload				C				X				X				X			X
Milestone 4: analysis & reporting																			
Analysis and summary	C	C	C	C	C	C	X	X	X	X	X	X	X	X	X	X	X	X	X
Annual Reports	C				C				X					X				X	
Annual PI meeting				C				X				X				X			X
FY Work Plan (DPD)			C				C				X				X				
Permit reports				C				X				X				X			X
Milestone 5 (new)*: summer sampling																			
*Summer HRM aerial survey validation											X				X				X
*Summer acoustic-trawl survey											X				X				X

*tasks associated with new funding request. HRM aerial surveys are funded by the PWS RCAC.

B. Explanation for not completing any planned milestones and tasks

Milestones and tasks have been completed as planned. In addition, we are actively working on metadata for the historical forage fish data from Middleton Island. This task requires that we adapt the existing SQL database, which is currently on the workspace and contains all the historical data, into a more user-friendly format (e.g., .csv). We anticipate this task will be completed in fall 2018.

C. Justification for new milestones/tasks

New funding from the PWSRCAC has allowed HRM to resume annual June aerial forage fish surveys. These aerial surveys along with our acoustic-trawl surveys for forage fish in PWS (Fig. 2) were part of HRM and GWA during FY12-16 but were discontinued in FY17-21. Leveraging the new PWSRCAC funding would allow us to resume needed species composition and age-class validation during HRM aerial surveys. At the same time, leveraging existing resources by the U.S. Geological Survey (USGS) and the GWA forage fish program would support a research platform for acoustic-trawl surveys in summer. These combined efforts would extend summer forage fish abundance and condition indices initiated during FY12-16.

More specifically, 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 zooplankton (especially 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 of 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 age-2 herring (Fig. 3) and condition of sand lance (Fig. 4) showed clear declines during the heatwave. Continuing these indices into the future will facilitate an understanding of the magnitude of response of middle-trophic level species to this major perturbation.

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, and 4) PWS forage fish communities to identify context for comparisons with Middleton Island's longest running forage fish time series in the GOA.

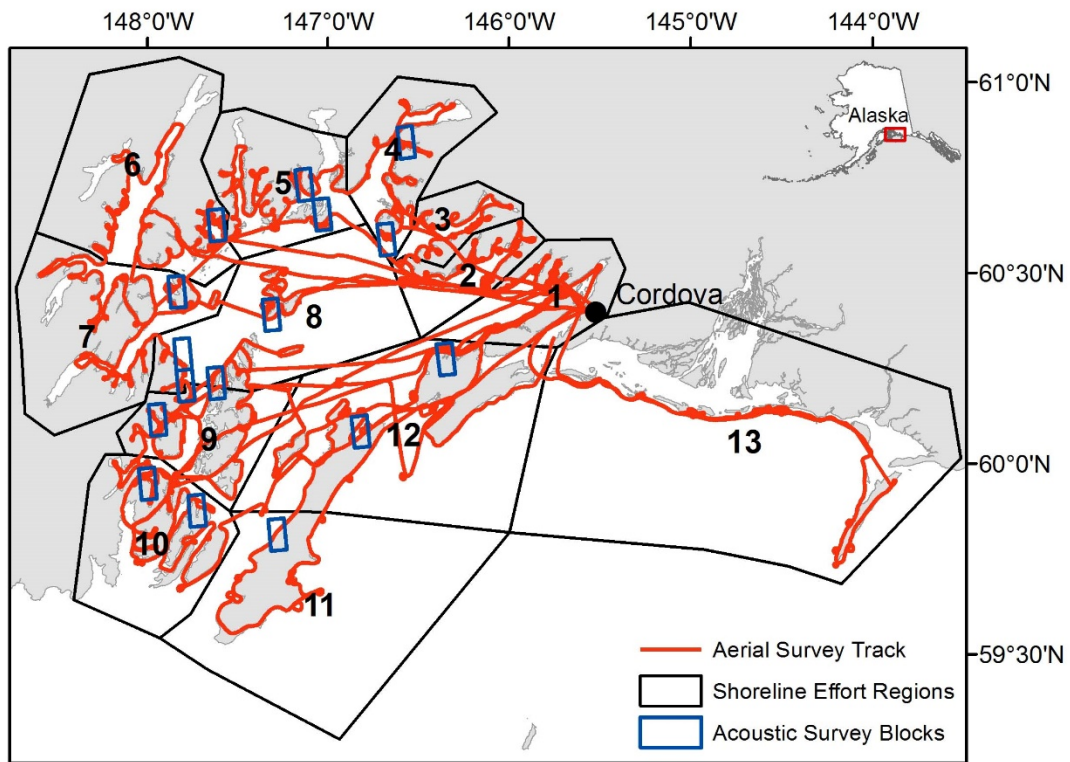


Figure 2. Map of aerial shoreline surveys (red lines) conducted in 1995-1997, 2010, 2012-2016 within 13 shoreline survey regions (black polygons) under the Alaska predator experiment, HRM, and GWA programs. Acoustic survey blocks (blue rectangles) were conducted as part of the GWA forage fish monitoring project in 2014-2016.

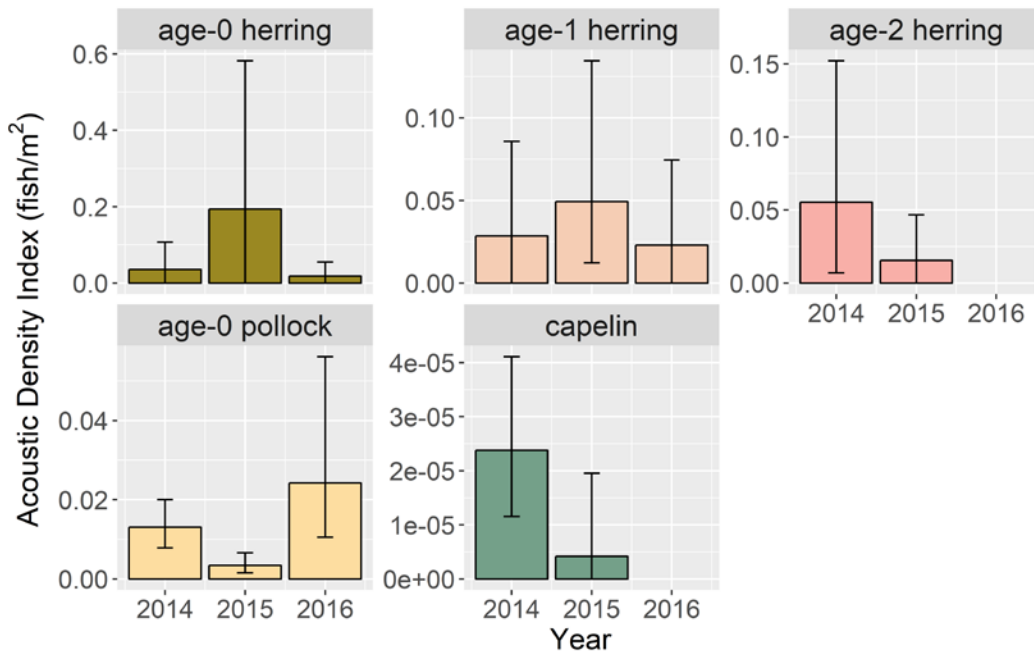


Figure 3. Mean (\pm 95% CI) species-specific acoustic density indices of forage fish in Prince William Sound, Alaska. Due to their different scattering characteristics and schooling behavior, herring were analyzed as discrete schools (38 kHz), while pollock and capelin were analyzed as mixed-species assemblages (120 kHz). Note differing scales on the y-axis. In 2016, capelin and age-2+ herring were not encountered during acoustic-trawl surveys in high enough numbers to estimate densities.

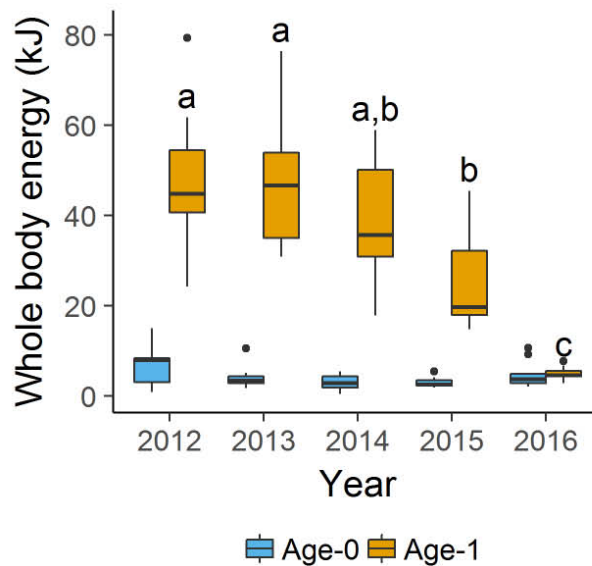


Figure 4. Pacific sand lance condition index (whole body energy) by age class in Prince William Sound. Different letters among years denote significant pairwise differences in the mean value for age-1 fish based on one-way ANOVA with Tukey's HSD post hoc test ($P < 0.05$), (Von Biela et al. *in review*).

3. PROJECT COORDINATION AND COLLABORATION

A. *Within an EVOSTC-funded Program*

Gulf Watch Alaska

This project is a component of the integrated GWA-Long-term Monitoring of Marine Conditions and Injured Resources and Services. This project shares research platform and common goals of the humpback whale (Moran and Straley) and fall/winter marine bird (Bishop) projects also associated with the Integrated Predator-Prey Surveys.

Herring Research and Monitoring

We will continue collaborative work with Scott Pegau and the Herring Research and Monitoring Program's aerial surveys for juvenile herring and other forage fish. We also are collaborating with the Pigeon Guillemot Restoration Research (17100853) project to compare seabird diets and initiate efforts to collect summer PWS forage fish samples to continue our index of prey condition indices originated in FY12-16.

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.

Lingering Oil

None.

B. *With Other EVOSTC-funded Projects*

This project will coordinate with other EVOSTC-funded projects as appropriate by providing data, discussing the relevance and interpretation of data, and collaborating on reports and publications.

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 National Marine Fisheries Science in annual stock assessments (Stephani Zador and Ellen Yasumiishi, Ecosystems Considerations Chapter to the Northwest Pacific Fisheries Management Council) and related projects (Danielle Dickson, North Pacific Research Board – GOA Integrated Ecosystem Research Program), as well as by USGS to understand the ecosystem response to recent anomalous conditions in the GOA that led to widespread and unprecedented seabird mortality event in winter 2015-16.

4. PROJECT DESIGN

A. Overall Project Objectives

1. 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			
	Oceanographic metrics and zooplankton biomass	Integrated Surveys: CTD and zooplankton samples	Arimitsu & Piatt (USGS)/ Moran (NOAA)/ Straley (UAS)/ Bishop (PWSSC)

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

4. Support HRM aerial shoreline survey validation efforts in summer

B. Changes to Project Design and Objectives

We are seeking additional funding to support a summer forage fish sampling effort to include 1) validation of June Herring Research and Monitoring program (HRM) aerial surveys that provide indices of relative abundance for juvenile herring and other forage fish (Fig. 5), and 2) continue the summer acoustic-trawl surveys in PWS to provide abundance indices of fish, krill, gelatinous zooplankton, herring, walleye pollock and capelin (Figs. 3 and 6, Arimitsu et al. 2018). This effort would include aerial-directed fish school sampling, species/age class verification, and forage fish collection for condition indices (e.g., Age-1 Pacific sand lance whole body energy content, Fig. 4), all tasks that were conducted along with the acoustic-trawl forage fish survey in the first five years of GWA. Furthermore, sampling methods and protocols would be consistent with those approved during the first five years of GWA. Resuming summer forage fish sampling in PWS would help achieve overall GWA and HRM program goals and provide value-added information on mid-trophic level species during the summer breeding season.

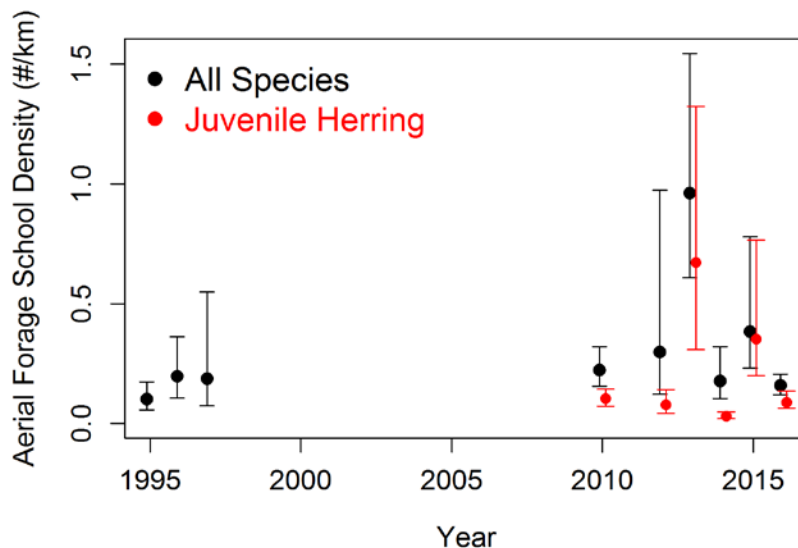


Figure 5. Index of aerial school density (number of schools per km shoreline surveyed) in Prince William Sound. June aerial surveys for herring and other forage fish will be continued by Scott Pegau (PWSSC) through FY21. Aerial survey data from 1995-1997, 2010, and 2012 were provided by Evelyn Brown (Flying Fish Ltd.), 2013 – 2016 surveys were conducted as a collaborative effort by HRM and GWA programs.

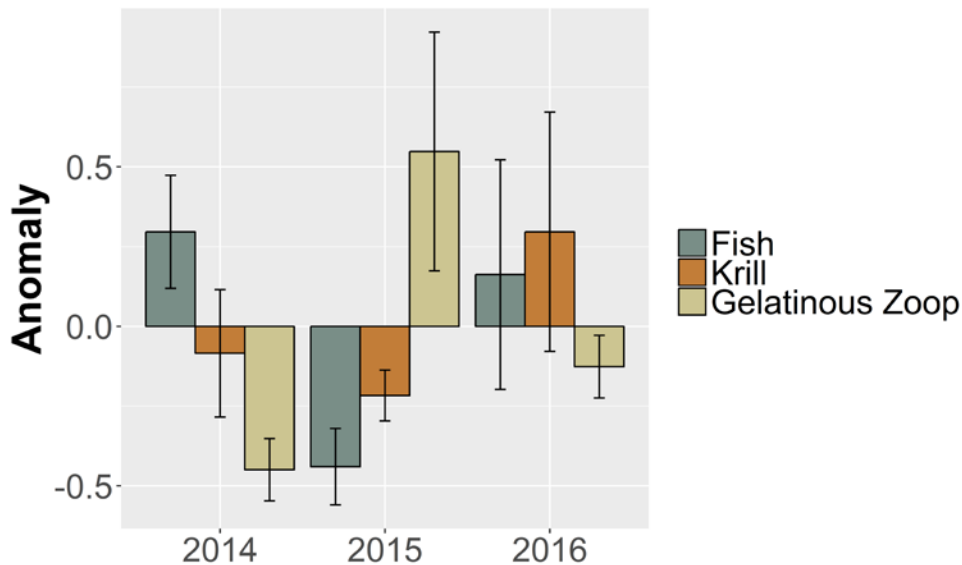


Figure 6. Interannual variability in mean (\pm 1SE) acoustic indices during acoustic-trawl surveys in Prince William Sound, Alaska. Acoustic indices were derived from 120 kHz hydroacoustic data (s_a , area backscattering coefficient, $m^2 m^{-2}$) using a combination of multi-frequency response and density criteria (Arimitsu et al. 2018). Indices were scaled to a mean of 0 and SD of 1 to facilitate plotting on a common scale.

5. PROJECT PERSONNEL – CHANGES AND UPDATES

There are no changes to project personnel.

6. PROJECT BUDGET FOR FY19

A. Budget Forms (See GWA FY19 Budget Workbook)

Please see project budget forms compiled for the program.

B. Changes from Original Project Proposal

We are requesting an additional \$70,850 per year (including 9% GA) for FY19-21 to conduct summer forage fish surveys, including vessel support to validate HRM aerial shoreline forage fish surveys, and acoustic-trawl surveys (Table 3). These additional funds would cover the cost of a 2-week vessel-based research effort, including \$32K for vessel charter (14 days at \$2.3K per day), \$24K in salary and overtime (1 PP GS 7 at \$3K, and 1 PP GS 9 at \$4K, 44 hours of overtime for GS13, GS11, GS9 and GS7 at \$19K total), \$3K for travel (airfare, lodging, and per diem for GS13 and GS11 from Juneau to Anchorage/field at \$1.5 each), and \$6K for sample processing and shipping (zooplankton identification and enumeration 16 samples at \$250 each, nutrients 50 samples at \$20 each, chlorophyll a 50 samples at \$15 each, and \$250 for shipping).

Table 3. Request for additional funding (in thousands of dollars) by budget category including GA. Funds will support summer forage fish studies in PWS through FY21.

Budget Category	New Request FY19	New Request FY20	New Request FY21	Total New Request
Personnel	\$24.0	\$24.0	\$24.0	\$72.0
Travel	\$3.0	\$3.0	\$3.0	\$9.0
Contractual	\$6.0	\$6.0	\$6.0	\$18.0
Commodities	\$32.0	\$32.0	\$32.0	\$96.0
Equipment	\$0.0	\$0.0	\$0.0	\$0.0
Annual Subtotal	\$65.0	\$65.0	\$65.0	\$195.0
9% GA	\$5.9	\$5.85	\$5.85	\$17.6
Total with GA	\$70.9	\$70.9	\$70.9	\$212.6

C. Sources of Additional Project Funding

USGS Alaska Science Center provides in-kind contributions of salary, equipment, and other support to facilitate the GWA forage fish project. Middleton Island seabird studies are additionally supported by the Institute for Seabird Research and Conservation, McGill University, and CNRS France. PWSRCAC provides funding to support aerial surveys for forage fish conducted by the HRM program.

7. FY18 PROJECT PUBLICATIONS AND PRODUCTS

Publications

Arimitsu, M. L., J. F. Piatt, B. Heflin, V. von Biela, 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)*, Exxon Valdez Oil Spill Trustee Council, Anchorage, Alaska.

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.

Piatt, J.F., M. Arimitsu, W. Sydeman, S.A. Thompson, H. Renner, S. Zador, D. Douglas, S. Hatch, A. Kettle, J. Williams. 2018. Biogeography of Pelagic Food Webs: Forage Fish Distribution and Habitat Use in the North Pacific Revealed by Puffins. *Fisheries Oceanography*. 27:366-380.

von Biela, V., M. Arimitsu, J. Piatt, B. Heflin, S. Schoen, J. Trowbridge, C. Clawson. In review. Declining condition of a key forage fish in the Gulf of Alaska during the North Pacific marine heatwave.

Published and updated datasets

Research Workspace: Posting of datasets are on an out of cycle schedule associated with fall sampling. We will post 2017 forage fish datasets to the Research Workspace in the fall of 2018, 1 year later as planned.

Presentations

Arimitsu, M.L., Bishop, M.A., Hatch, S., Kaler, R., Kuletz, K., Matkin, C., Moran, J., Olsen, D., Piatt, J.F., Schaeffer, A., Straley, J. 2018. Changes in marine predator and prey populations in the aftermath of the North

Pacific heat wave: Gulf Watch Alaska Pelagic update 2017. Alaska Marine Science Symposium, Anchorage, AK, Jan. 2018.

Arimitsu, M.L., Piatt, J.F., Schoen, S.S., Heflin, B.H., von Biela, V.R., Hatch, S. 2018. Changes in forage fish during the winter 2015-16 seabird die-off and the North Pacific marine heat wave. Alaska Marine Science Symposium, Anchorage, AK, Jan. 2018.

Arimitsu, M.L., Piatt, J.F., Heflin, B.M., Schoen, S.K., von Biela, V.R. 2018. Ripples of the North Pacific heatwave: signals from seabirds and their forage base in the Gulf of Alaska. Ocean Sciences, Portland, Oregon, Feb. 2018.

Lindeberg, M., Suryan, R., Aderhold, D., Hoffman, K., Hopcroft, R., Coletti, H., and Arimitsu, M. 2018. Gulf Watch Alaska Report: Residual effects of the marine heatwave persist in the Gulf of Alaska. Alaska Marine Science Symposium, Anchorage, AK, Jan. 2018.

Schoen, S., Van Hemert, C., Holland, W., Piatt, J., Arimitsu, M., Pearce, J., Smith, M., Hardison, R., Kibler, S. Harmful algal blooms and seabirds and forage fish: assessment of tissues during and after the 2015-2016 seabird die-off. Pacific Seabird Group, La Paz, Mexico, Feb. 2018.

Sydeman, W.J., Thompson, S.A., Garcia-Reyes, M., Arimitsu, M., Piatt, J., Renner, H., Hatch, S. 2018. Puffins as samplers of forage fish in Alaska: variation in length and condition relative to ocean climate in the Gulf of Alaska. Alaska Marine Science Symposium, Anchorage, AK, Jan. 2018.

Thompson, S.A., Sydeman, W.J., Arimitsu, M., Piatt, J., Renner, H., Hatch, S. 2018. Morphometrics of forage fish sampled by puffins in Alaska: describing the data. Alaska Marine Science Symposium, Anchorage, AK, Jan. 2018.

Van Hemert, C. Schoen, S., Holland, W., Piatt, J., Arimitsu, M., Pearce, J., Smith, M., Hardison, R., Kibler, S. 2018. Algal toxin assessments in seabird and forage fish tissues during the 2015-2016 seabird die-off. Alaska Marine Science Symposium, Anchorage, AK, Jan. 2018.

Von Biela, V.R., Arimitsu, M.L., Schoen, S.K., Heflin, B.M., and Piatt, J.F. 2018. Declining condition of a key forage fish in the Gulf of Alaska during the North Pacific marine heatwave. American Fisheries Society, Anchorage, Alaska. May 2018.

Outreach

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.

LITERATURE CITED

Arimitsu, M. L., Piatt, J. F., Heflin, B., von Biela, V. R., and Schoen, S. K. 2018. Monitoring long-term changes in forage fish distribution, abundance and body condition. Exxon Valdez Oil Spill Restoration Project Final Report (Restoration Project 16120114-O). U.S. Geological Survey Alaska Science Center. Anchorage, AK.

Dorn, M., Aydin, K., Jones, D., Palsson, W., and Spalinger, K. 2016. Assessment of the Walleye Pollock Stock in the Gulf of Alaska. North Pacific Fisheries Management Council. 605 W 4th Ave, Suite 306, Anchorage AK 99501.

- Hatch, S. A., and Sanger, G. A. 1992. Puffins as samplers of juvenile pollock and other forage fish in the Gulf of Alaska. *Marine Ecology Progress Series*, 80: 1–14.
- Hatch, S. A. 2013. Kittiwake diets and chick production signal a 2008 regime shift in the Northeast Pacific. *Marine Ecology Progress Series*, 477: 271–284.
- Hatch, S. A. 2017. Middleton Island Seabird Research and Monitoring 2017 Field Report. Institute for Seabird Research and Conservation. Anchorage, AK. 27 pp.
- McGowan, D. W., Horne, J. K., and Parker-Stetter, S. L. 2016. Variability in species composition and distribution of forage fish in the Gulf of Alaska. *Deep Sea Research Part II*.
- Thayer, J. A., Bertram, D. F., Hatch, S. A., Hipfner, M. J., Slater, L., Sydeman, W. J., and Watanuki, Y. 2008. Forage fish of the Pacific Rim as revealed by diet of a piscivorous seabird: synchrony and relationships with sea surface temperature. *Canadian Journal of Fisheries and Aquatic Sciences*, 65: 1610–1622.