EVOSTC FY17-FY21 INVITATION FOR PROPOSALS
FY20 (YEAR 9) CONTINUING PROJECT PROPOSAL SUMMARY PAGE

Project Number and Title

Gulf Watch Alaska: Pelagic Component Project

20120114-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 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 heat wave.

In FY20, 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). We are not proposing changes to this project for FY20.

EVOSTC Funding Requested* *(must include 9% GA)*

FY17	FY18	FY19	FY20	FY21	TOTAL
$198,800	$229,800	$292,100	$295,300	$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	$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?

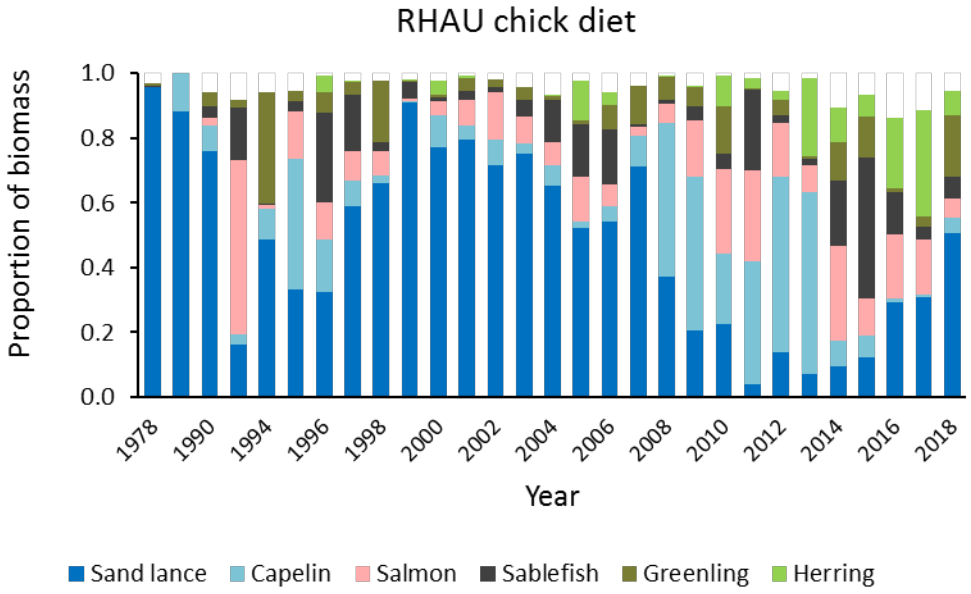
Forage Fish Monitoring

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, 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, McGowan et al. in review). 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 2014-2018 (Fig. 1, Hatch 2018). Although 2019 sampling is still underway, early signs are that there are more capelin than usual in PWS and Cook Inlet, and in seabird diets at Middleton Island.



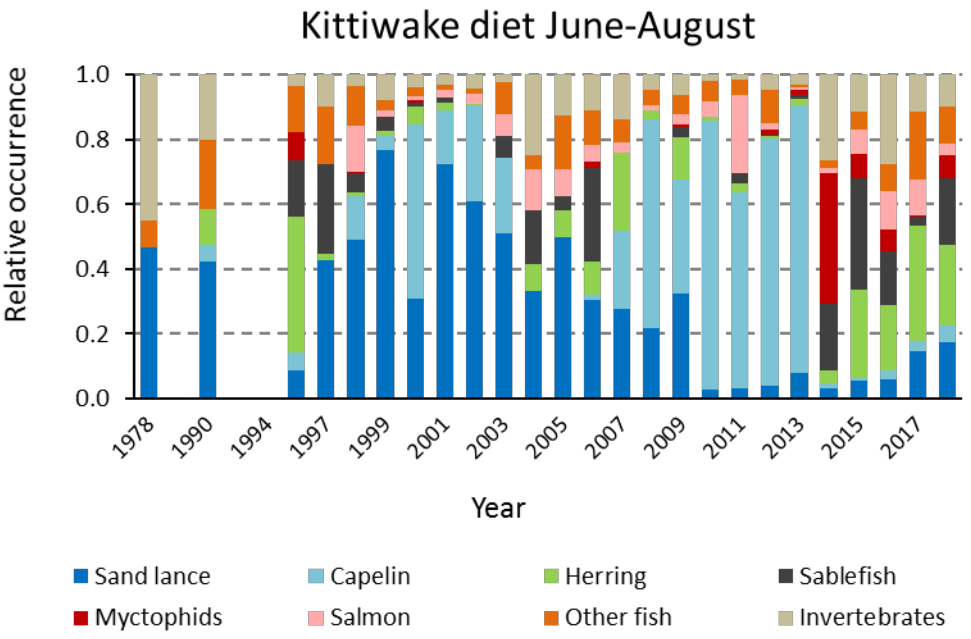


Figure 1. Interannual variation in diet composition of chick-rearing rhinoceros auklets (top) and black-legged kittiwakes (bottom) on Middleton Island, 1978 to 2018.

Integrated Predator-Prey Surveys in PWS

In FY18, 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 FY20, there is no 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 20120114-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 20120114-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 20120114-L]) to the GOA shelf area near Middleton Island (Fig. 1) provides further linkages to GWA forage fish studies.

Work planned in FY20 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).

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, 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 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 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 tasks by fiscal year and quarter, beginning February 1, 2017. Yellow highlight indicates proposed fiscal year workplan. 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.

	FY17				FY18				FY19				FY20				FY21			
Milestone/Task	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		X	X	X		X	X	X		X
Permitting			C				C				C				X				X	
Equipment calibration		C				C				C				X				X		
Milestone 2: data acquisition & processing																				
Middleton Island support	C	C	C		C	C	C		C	C	C		X	X	X		X	X	X	
Integrated predator-prey surveys (EVOSTC)			C				C				X				X				X	
Alternate survey schedule (with added NOAA funds)	C		C		C															

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
Acoustic data processing	C	C	C		C	C	C		C	C	X		X	X	X		X	X	X	
CTD data processing	C				C				C				X				X			
Chlorophyll *a* fluorometry	C				C				C				X				X			
Milestone 3: data management																				
Database mgmt./QAQC	C	C	C	C	C	C	C	C	C	C	X	X	X	X	X	X	X	X	X	X
Metadata	C				C				C				X				X			
Workspace upload		C				C				C				X				X		
Middleton Data QAQC			C	C			C	C			X	X			X	X			X	X
Middleton Data Metadata						C														X
Middleton Data Workspace Upload				C				C				X				X				X
Milestone 4: analysis & reporting																				
Analysis and summary	C	C	C	C	C	C	C	C	C	C	X	X	X	X	X	X	X	X	X	X
Annual Reports	C				C				C				X				X			
Annual PI meeting				C				C				X				X				X
FY Work Plan (DPD)			C				C				C				X					
Permit reports				C				C				X				X				X
Milestone 5: summer sampling																				
Summer HRM aerial survey validation										C				X				X		
Summer acoustic-trawl survey										C				X				X		

In addition to the primary project deliverables in Table 2, during the past year we contributed seabird-derived forage fish indicators from Middleton Island for the 2018 Ecosystem Status Report to the NPRMC and gave an oral presentation at the 2019 Alaska Marine Science Symposium. A manuscript was co-authored and published on nutritional value of key forage fish during the Pacific marine heat wave. As second manuscript is in press and a third is in review (see Section 7). We anticipate completing FY19 and FY20 milestones and tasks as planned.

B. Explanation for not completing any planned milestones and tasks

All sampling, milestones, and tasks for 2018 and first two quarters of 2019 were completed in accordance with our proposal and with sampling protocols available on the GWA Research Workspace.

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 Integrated Predator-Prey Surveys. Summer forage fish surveys and information regarding Middleton Seabird diets also provide a means to understand trends in piscivorous marine birds (project 20120114-M).

Science synthesis efforts are also under way for the GWA program. Forage fish project principle investigator Arimitsu is lead author for a synthesis manuscript and providing data for the Suryan et al. synthesis manuscript (see Section 7).

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. In July 2019 we also coordinated closely with Kristin Gorman (project 20170111-D, studies of reproductive maturity among age cohorts of Pacific herring in PWS) to aid in collection of adult herring for a maturation study.

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

NA

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 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 Managment 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 Gulf of Alaska.

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

With additional funding from EVOSTC, in FY19 we conducted summer forage fish surveys to validate June HRM program aerial surveys and summer acoustic-trawl surveys to provide indices of fish, macrozooplankton, and gelatinous zooplankton. The aerial survey validation includes directed sampling of specific fish schools detected by the aerial observer. To do this, our team on the ground (in skiffs or a larger vessel) was directed to schools by the pilot after he had assessed the species and age of the schools. We collected fish using jigs, purse seine, cast net, or video to ground-truth the pilot's observations, which ultimately provide a measure of uncertainty in the pilot's observations. The summer acoustic surveys include transects in regions with historically high densities of forage fish schools throughout the Sound. Sampling methods and protocols are consistent with those approved during the first five years of GWA.

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.

B. Changes from Original Project Proposal

Our FY19 workplan requested funding from EVOSTC to conduct summer forage fish surveys in PWS. We thank EVOSTC for the additional funding ($65K for FY19, 20, and 21 for a total of $195K).

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. FY17-19 PROJECT PUBLICATIONS AND PRODUCTS

Publications

Arimitsu, M., et al. in prep. Environmental drivers and prey condition leading to the murre die-off in the Gulf of Alaska. EVOSTC Science Synthesis Report.

Arimitsu, M.L., K.A. Hobson, D.N. Webber, J.F. Piatt, E.W. Hood, 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.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.

Hatch, S.A., M. Arimitsu, 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.

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.

Piatt, J.F., M. Arimitsu, W. Sydeman, S.A. Thompson, H. Renner, S. Zador, D. Douglas, S. Hatch, A. Kettle, and 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.

Suryan, R. et al. in prep. Ecosystem variability in the Gulf of Alaska during a marine heatwave. EVOSTC Science Synthesis Report.

Sydeman, W.J., J.F. Piatt, S. Thompson, M. Garcia-Reyes, S.A. Hatch, M.L. Arimitsu, L. Slater, J.C. Williams, N.A. Rojek, S. G Zador, and H.M. Renner. 2017. Puffins reveal contrasting relationships between forage fish and ocean climate in the N. Pacific. Fisheries Oceanography. DOI: 10.1111/fog.12204.

Sydeman, W.J., S.A. Thompson, T. Anker-Nilssen, M.L. Arimitsu, et. al. 2017. Best practices for assessing forage fish fisheries – seabird resource competition. Fisheries Research 194: 209-221. doi 10.1016/j.fishres.2017.05.018.

Thompson, S.A., M. Garcia-Reyes, W.J. Sydeman, M. Arimitsu, S. Hatch, and J. Piatt. In press. Effects of ocean climate on the size and condition of forage fish in the Gulf of Alaska: regional, species, and age-class comparisons. Fisheries Oceanography.

von Biela, V.R., M.L. Arimitsu, J.F. Piatt, B. Heflin, S. Schoen, J. Trowbridge, and C. Clawson. 2019. Extreme reduction in nutritional value of a key forage fish during the Pacific marine heatwave of 2014-2016. Marine Ecology Progress Series. doi: 10.3354/meps12891

Published and updated datasets

DataONE Published Datasets

Arimitsu, M.L., J.F. Piatt, and B. Heflin. 2017. Gulf Watch Alaska Forage Fish Component: Fish morph data in Prince William Sound, Alaska 2012-2015. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace. https://doi.org/10.5066/F74J0C9Z.

Arimitsu, M.L., J.F. Piatt, and B. Heflin. 2017. Gulf Watch Alaska Forage Fish Component: Marine bird and mammal surveys in Prince William Sound, Alaska 2012-2013 and 2015. Dataset. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace. https://doi.org/10.5066/F74J0C9Z.

Arimitsu, M.L., J.F. Piatt, and B. Heflin. 2017. Gulf Watch Alaska Forage Fish Component: Oceanographic profile data from various regions in Prince William Sound, 2012-2015. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace. https://doi.org/10.5066/F74J0C9Z.

Arimitsu, M.L., J.F. Piatt, and B. Heflin. 2017. Gulf Watch Alaska Forage Fish Component: Zooplankton biomass data from 2012-2015 in Prince William Sound, Alaska. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace. https://doi.org/10.5066/F74J0C9Z.

Arimitsu, M.L., J.F. Piatt, and B. Heflin. 2017. Gulf Watch Alaska Forage Fish Component: Nutrients data from CTD sampling stations in Prince William Sound, Alaska 2012-2015. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace. https://doi.org/10.5066/F74J0C9Z.

Arimitsu, M.L., J.F. Piatt, and B. Heflin. 2017. Gulf Watch Alaska Forage Fish Component: Fish catch data in Prince William Sound, Alaska 2012-2015. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace. https://doi.org/10.5066/F74J0C9Z.

Arimitsu, M.L., J.F. Piatt, and B. Heflin. 2017. Gulf Watch Alaska Forage Fish Component: Hydroacoustic surveys in Prince William Sound, Alaska 2014-2015. *Exxon Valdez* Oil Spill Trustee Council Long-Term Monitoring program, Gulf Watch Alaska. Research Workspace. https://doi.org/10.5066/F74J0C9Z.

Gulf of Alaska Data Portal Datasets

Note: Posting of datasets for this project are on an out of cycle schedule associated with fall sampling.

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