EVOSTC FY17-FY21 INVITATION FOR PROPOSALS
FY18 CONTINUING PROJECT PROPOSAL SUMMARY PAGE

Project Number and Title

Gulf Watch Alaska: Pelagic Component Project

18120114-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. Forage fish are small pelagic schooling fish such as capelin (*Mallotus villosus*), Pacific sand lance (*Ammodytes personatus),* Pacific herring (*Clupea pallasii*), and juvenile walleye pollock (*Gadus chalcogrammus*) that are important in marine ecosystems because they are primary food resources for marine predators. Krill (Euphausiidae) are also important prey taxa sampled in this study. 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). In FY18 we will conduct acoustic-trawl surveys for forage fish during an integrated predator-prey survey in PWS during fall (Sept/Oct), and conduct seabird diet sampling at Middleton Island during spring/summer (Apr – Aug). Forage fish indices from seabirds on Middleton Island provide the critical mid-trophic level link to spring/summer lower and upper trophic levels studied during GWA Environmental Drivers cruises in the GOA. The FY18 sampling activities will continue newly initiated predator prey studies (FY17-FY21) and ensure the continuity of long-term datasets that will collectively provide an important contribution to knowledge of ecosystem function. Furthermore, 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. Expansion of environmental drivers sampling (National Science Foundation Long-term Ecological Research) to the GOA shelf area adjacent to Middleton Island provides additional linkages to GWA forage fish studies and lower trophic level processes. We are not proposing any major changes to this project for FY18.

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

FY17	FY18	FY19	FY20	FY21	TOTAL
$198,800	$229,800	$221,300	$224,500	$232,000	$1,106,400

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

1. 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 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 will 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 will to 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. We are not proposing any major changes to this project in FY18.

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 Gulf of Alaska (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 – 16 (Arimitsu et al. in review, Hatch 2016). 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 – 16 (Hatch 2016, Figure 1).

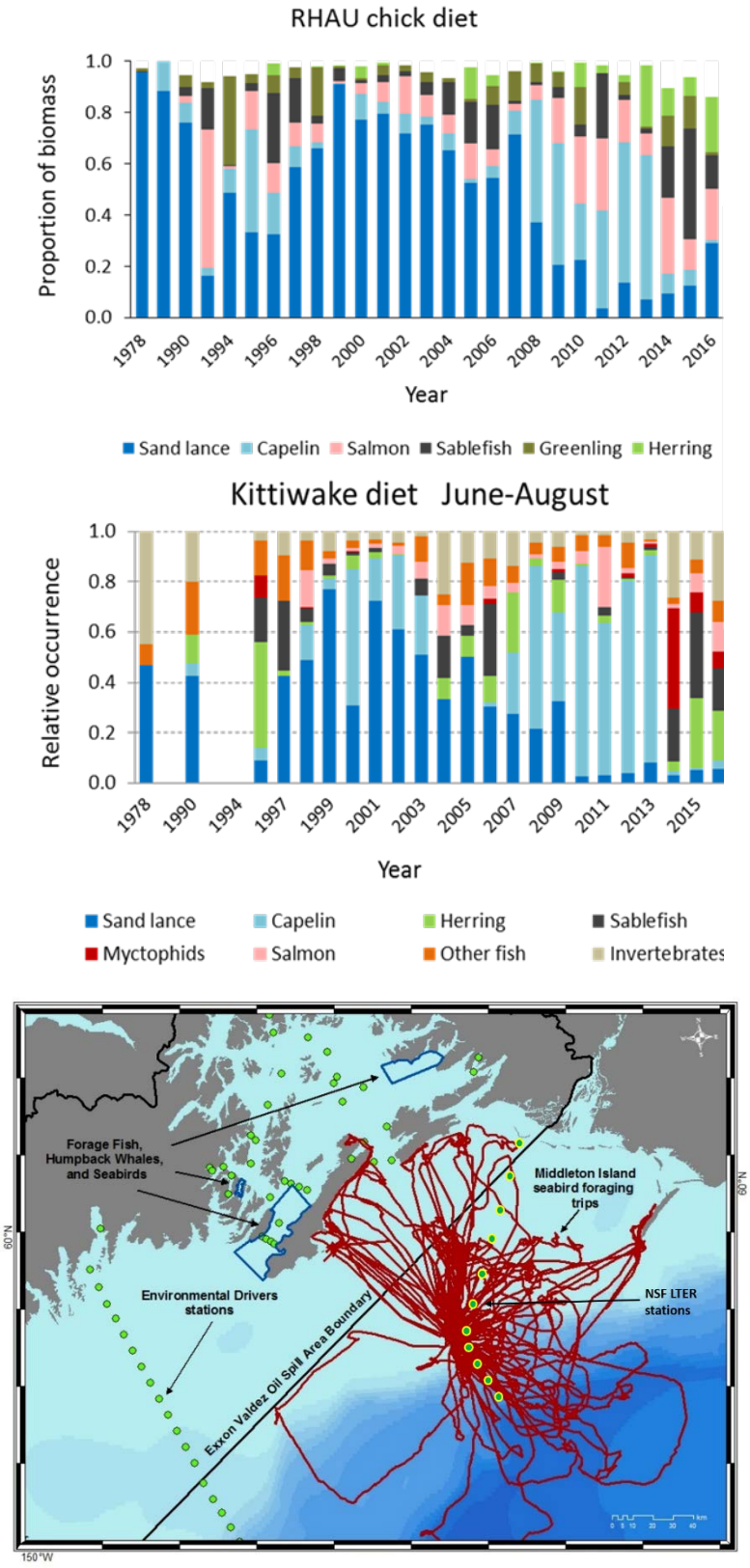

Figure 1. Interannual variation in diet composition of chick-rearing rhinoceros auklets (top) and black-legged kittiwakes (middle) on Middleton Island, 1978 to 2016. The map (bottom) shows pelagic sampling areas and environmental drivers stations (including new NSF LTER stations) in PWS and GOA, and 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 will integrate 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 logistic resources and expertise, we will identify and estimate the forage biomass at the same locations in which predators are feeding, which will provide comparable information on both predator density and prey availability (species composition, depth distribution, density and biomass). The integrated survey will be 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.

The forage fish component of the integrated predator-prey survey will focus 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 (sampling by fishing) 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 will provide 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. Net sampling and other methods will allow us to collect samples of all these species.

Survey areas encompass the known locations of the feeding aggregations of predators in South Montague Strait, Bainbridge Passage, and Port Gravina. We will also conduct adaptive sampling if predators are found in unexpected locations. Marine bird observations (see Bishop marine bird project workplan) will be recorded concurrently with acoustic transects, while humpback whale distribution and abundance will be assessed from a smaller vessel concurrently in the same area (see Moran and Straley humpback whale workplan). Combined efforts by Gulf Watch Alaska's pelagic component humpback whale, marine bird, and forage fish PIs will provide a more 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

Forage fish monitoring using predators as samplers is a proven and cost-effective approach in marine ecosystem research (Hatch and Sanger 1992, Roseneau and Byrd 1997, Thayer et al. 2008, Sydeman et al. 2017). The Middleton Island long-term seabird diet data (Hatch 2013) are of particular interest to the GWA ecosystem monitoring program for several reasons. The Middleton forage fish index, which includes nearly three decades of frequency of occurrence and size data on capelin, 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. Additionally, forage fish data at Middleton Island appear to track climate signals in the GOA (Sydeman et al. 2017, Hatch 2013) and are coherent with changes in forage fish abundance observed in PWS during our own studies in 2012-2015 (Arimitsu et al. *in review*). Although Middleton Island is situated about 100 km from Hinchinbrook entrance, tagged auklets and kittiwakes from the Middleton Island colony regularly foraged at locations within the oil spill affected area and adjacent to PWS (Figure 1) (Hatch 2015). Given Middleton'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 (Figure 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) to the GOA shelf area near Middleton Island (Figure 1) provides further linkages to GWA forage fish studies.

Work planned in FY18 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.

Bill loads are collected by placing a screen over the nest entrance, waiting 2-3 hours until the adult returns with whole fish for the chicks, collecting the discarded prey left at the screen and removing the screen from the next entrance. Both 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 will provide an index of forage fish availability during the breeding season (April – Aug).

2017 Middleton Island field work is currently wrapping up. Spring sampling of kittiwake diets found few fish. Instead, copepods were a major component of spring kittiwake diets, which has occurred only occasionally in the past. Preliminary evidence suggests capelin were not represented in seabird diets again this year, continuing the pattern observed since 2014 (Figure 1).

2. 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 projects 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 (Table 1).

Table 1. 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			

Objective	Index	Task	PI
	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)

Herring Research and Monitoring

We will continue collaborative work with Scott Pegau and the Herring Research and Monitoring Program's proposed 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.

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 (Olav Ormseth, Alaska Fisheries Science Center Resource Ecology and Fisheries Management - Status of Stocks and Multispecies Assessment Program) and related projects (Danielle Dickson, North Pacific Research Board – GOAIERP program), as well as by US Geological Survey (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.

3. PROJECT DESIGN – PLAN FOR FY18

A. *Objectives for FY18*

Objective 1

Estimate an index of forage fish availability in areas of PWS with known persistent aggregations of predators and prey.

Objective 2

Estimate an index of krill availability in areas of PWS with known persistent aggregations of predators and prey.

Objective 3

Support annual field and laboratory efforts to continue the Middleton Island long-term seabird diet index in April-August.

B. *Changes to Project Design*

There are no changes to the proposed project design in FY18.

4. SCHEDULE

A. *Project Milestones for FY18*

Objective 1: Estimate an index of forage fish availability in areas of PWS with known persistent aggregations of predators and prey

- Integrated survey data collection, data analysis, and workspace upload will occur each year of the project.

Objective 2: Estimate an index of krill availability in areas of PWS with known persistent aggregations of predators and prey

- Integrated survey data collection, data analysis, and workspace upload will occur each year of the project.

Objective 3: Support annual field and laboratory efforts to continue the Middleton Island long-term seabird diet index in April-August

- Ongoing throughout the project in collaboration with Scott Hatch (ISRC). Scott will be archiving Middleton Is. Long-term datasets on the Research Workspace.

B. *Measurable Project Tasks for FY18*

FY 2018 (Year 7)

FY 18, 1st quarter	(February 1, 2018 - April 30, 2018)
February:	Middleton Island Contract
	Prior year datasets available to public if applicable
March 1:	Submit Annual Report
February-April:	FY17 Data processing
FY 18, 2nd quarter	(May 1, 2018 - July 31, 2018)
May:	FY18 Fish Resource Permit Application
June:	Contracting, shipping for equipment calibration
May-July:	FY17 Data processing/QAQC
April-August:	Middleton Island support
FY 18, 3rd quarter	(August 1, 2018 - October 31, 2018)
August 23:	Submit FY19 Annual Work Plan
August:	Upload FY17 data to workspace
September:	Integrated predator-prey survey fall cruise
FY 18, 4th quarter	(November 1, 2018 - January 31, 2019)
September:	Data compliance on Research Workspace if applicable
Oct.-Nov.:	Attend annual PI meeting
December:	FY18 Fish Resource Permit Reporting
January:	Contract, prep, ship zooplankton and nutrients samples

5. PROJECT PERSONNEL – CHANGES AND UPDATES

There are no changes to project personnel.

6. BUDGET

A. Budget Forms (See GWA FY18 Budget Workbook)

Please see project budget forms compiled for the program.

B. Changes from Original Proposal

There are no changes from the FY17-21 project proposal.

C. Sources of Additional 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.

7. RECENT PUBLICATIONS AND PRODUCTS

Publications

Arimitsu, M.L., J.F. Piatt, and F. Mueter. 2016. Influence of glacier runoff on ecosystem structure in Gulf of Alaska Fjords. Marine Ecology Progress Series 560:19-40.

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.

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

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.

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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.

Presentations

Heflin, B., M. Arimitsu, J. Piatt, S. Schoen, and E. Madison. Seabird and forage fish response to contrasting cold and warm years in Prince William Sound, Alaska. Pacific Seabird Group meeting, Honolulu, HI, February 2016.

Arimitsu, M.L., S. Pegau, J. Piatt, B. Heflin, and S. Schoen. Spatial and temporal variability of forage fish in coastal waters of Prince William Sound, Alaska, Alaska Marine Science Symposium, Anchorage, AK. January 2017.

Arimitsu, M.L., J. Piatt, B. Heflin, and S. Schoen. Jellyfish blooms in warm water may signal trouble for forage fish in a warming climate. ICES/PICES Symposium on Drivers of Dynamics of Small Pelagic Fish Resources, Victoria, BC Canada, March 2017.

Outreach

Arimitsu, M.L., 2016. “Virtual Field Trip: Forage fish studies”. http://www.alaskasealife.org/gw_Pelagic.

Arimitsu, M., J. Piatt, S. Schoen, and B Heflin. 2017. Forage fish in hot water contribute to seabird die-off. Delta Sounds Connections 2017-18. http://pwssc.org/wp-content/uploads/2017/06/DSC-2017-web2.pdf.

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Dorn, M., K. Aydin, D. Jones, W. Palsson, and K. Spalinger. 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. 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. 2015. Middleton Island Seabird Research and Monitoring 2015 Field Report. Institute for Seabird Research and Conservation. 19 pp.

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McGowan, D. W., J. K. Horne, and S. L. Parker-Stetter. 2016. Variability in species composition and distribution of forage fish in the Gulf of Alaska. Deep Sea Research Part II.

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Thayer, J.A., D.F. Bertram, S.A. Hatch, M.J. Hipfner, L. Slater, W.J. Sydeman, and Y. Watanuki. 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.