August 24, 2016

Elise Hsieh, Executive Director
Exxon Valdez Oil Spill Trustee Council
4210 University Drive
Anchorage, AK 99508-4626

Dear Elise:

Final FY 2017-2021 Proposal Submittal for Long-term Monitoring

17120114-C. Monitoring Long-term Changes in Forage Fish in Prince William Sound

Gulf Watch Alaska, the long-term monitoring program of the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC), has finalized our program and project proposals for fiscal years 2017-2021 funding based on comments received from EVOSTC's Science Panel on May 19, 2016. Below is the final budget summary and response to Science Panel comments for the forage fish project.

EVOSTC Funding Requested *(including 9% GA)*

FY17	FY18	FY19	FY20	FY21	TOTAL
$198,800	$229,800	$221,300	$224,700	$232,000	$1,106,600

Non-EVOSTC Funding Available

FY17	FY18	FY19	FY20	FY21	TOTAL
$256,000	$256,000	$256,000	$256,000	$256,000	$1,280,000

Science Panel comment: *While the Panel is supportive of continued forage fish work, there are concerns regarding the actual integration of the three projects. The proposal appears to be an integration of PIs collecting data at the same time and location through a shared vessel. It was unclear from any of the three proposals how the data would actually be integrated to address the hypotheses of the Integrated Predator-Prey Survey. If the intent is not a true integration, then the project should be renamed accordingly.*

PI Response:

- Clarified that the integrated pelagic component projects share a survey platform and explained how the data will be integrated across projects (see the Executive Summary, pages 3-6, and the end of Section 4C, page 15)

Science Panel comment: *Also, based on the focus on known seabird and marine mammal foraging areas, the proposal should note that it does not intend to scale-up results to the level of PWS.*

PI Response:

- Clarified that biomass estimates will be specific to sub-region and will not scale up to all of Prince William Sound (see top of page 9)

Science Panel comment: *Moreover, the Panel was unsure of how the seabird diet data from Middleton Island would be incorporated into the Survey, given its offshore GOA location, 130 km southwest of Cordova. The other projects are benefiting from data collected at the same time and location, but Middleton Island is not within any of the anticipated survey areas. The Panel acknowledges that inclusion of Middleton Island allows incorporation of a set of important seabirds not included elsewhere in the LTM Program, specifically an auklet, black-legged kittiwake, and puffins.*

PI Response:

- Added additional background on the importance of including Middleton Island in the study when it is outside of the spill-affected area (see page 6 "Long-term Data on Seabird Diets")

Science Panel comment: *The proposal is short on methodology. The Panel requests the proposers to expand the description of their methods as there is insufficient information for a thorough review.*

PI Response:

- Added additional project background to explain why the project is shifting directions for the upcoming funding cycle (see abstract and pages 4-5)
- Included the density of humpback whale observations to the survey design figure to demonstrate the rationale for sub-region study site selection (see Figure 1 on page 10)

- Recalculated the power analysis with new area totals and transect lengths; the reanalysis changed the anticipated coefficients of variation and lowered the effect size we could detect in 5 years (see pages 13-14)

- Explained more specifically how the forage fish data could help scientists understand predator-prey interactions while bringing the framework of hypotheses into the analytical methods (see the end of Section 4C, page 15)

Sincerely,

Mandy Lindeberg
Gulf Watch Alaska Program Lead designate

Attachment: Gulf Watch Alaska: Pelagic Component Project Proposal: 17120114-C—Monitoring Long-term Changes in Forage Fish Distribution, Relative Abundance, and Body Condition in Prince William Sound

EVOSTC FY17-FY21 INVITATION FOR PROPOSALS
PROGRAM PROJECT PROPOSAL SUMMARY PAGE

Project Title

Gulf Watch Alaska: Pelagic Component Project:

17120114-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

24 August 2016

Project Abstract

New Direction for Forage Fish Studies: The forage fish proposal will change directions in 2017-2021: we will integrate directly with the humpback whale and marine bird predation studies and apply the methods we have learned in the previous 5 years to provide estimates of forage biomass in the immediate vicinity of predator aggregations. By integrating with these projects, we will sample forage fish in the same locations and times, thus providing valuable prey information for two pelagic predator groups of key value to EVOSTC, governmental and nongovernmental groups and the public while obtaining trend information for our forage fish monitoring program. Obtaining sound-wide forage fish population/biomass estimates is not feasible with the resources available; funds are insufficient to adequately sample the entire area, and the key forage species in PWS differ significantly in their life histories, habitats, and ease of detection (e.g., sand lance are shallow inshore, while euphausiids are usually deep and off shore), making defensible sound-wide holistic estimations impractical. For this reason, the proposed work focuses on smaller geographical areas within Prince William Sound (PWS) and takes advantage of known persistent predator aggregations to locate prey that can then be well monitored over time within reasonable financial resources. Additionally, using predators as samplers of forage fish can provide an important index of changes in prey species composition over time. Thus we will incorporate into the Gulf Watch Alaska (GWA) Pelagic Component a long-term seabird diet data collection program as a cost-effective means to monitor forage fish stocks in the northern Gulf of Alaska.

Integrated Predator-Prey Surveys 2017-2021: Humpback Whales, Marine Birds, Forage Fish
Under the next five year monitoring program, 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 using the same vessels. In the past, the predator studies have attempted to opportunistically sample and identify the forage, but not quantify the forage biomass on an area/depth/volume basis. By 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). Collectively, we will use two platforms; a larger vessel to support the acoustic forage fish transects and marine bird surveys (see Bishop fall/winter marine bird proposal), and a smaller second

vessel to both scout ahead looking for the predator aggregations and to photo ID the whales (see Moran and Straley humpback whale proposal). The integrated survey would be conducted during the fall, providing 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.

Forage fish component: This proposal covers the forage fish component of the integrated study. The forage fish survey will focus on prey availability, 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. Experience indicates that 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 will encompass the known historical locations of the feeding aggregations of predators (Figure 1), and we will also conduct adaptive sampling if predators are found in unexpected locations. Marine bird observations (see Bishop marine bird project proposal) 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 project proposal). The simultaneous surveys of three component projects will reduce vessel cost for overall while combining sampling efforts with spatial and temporal consistency. Combined efforts by GWA's pelagic component humpback whale, marine bird and forage fish principal investigators (PIs) will provide a more comprehensive understanding of the pelagic ecosystem and provide an integrated dataset that facilitates analyses of predator prey relationships within the sampled regions. In addition to a planned research cruise in September/October, the proposed approach may also allow for in-kind contributions from National Oceanic and Atmospheric Administration (NOAA) for vessel charter and an additional survey in March, when humpback whales are returning from their migrations to feed and when we can assess the impact of severe winter conditions on forage fish. The NOAA funds will be applied for and awarded on an annual basis, and a March NOAA cruise, if awarded, would be an added value to the GWA Pelagic monitoring program.

Long-term Data on Predator Diets

Forage fish monitoring using predators as samplers is a proven and cost-effective approach in marine ecosystem research (Hatch & Sanger 1992, Roseneau & Byrd 1997, Thayer et al. 2008). Concordance in trends of key forage species have been observed between GWA studies in PWS and seabird diet sampling at Middleton. Long-term seabird diet data from Middleton Island can provide a useful index of long-term trends in PWS. 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). Furthermore, the Middleton Island seabird diet dataset is the longest continuous dataset on forage fish in the region. Since the project is no longer directly supported by the U.S. Geological Survey after the retirement of the lead PI (i.e., Scott Hatch, Institute for Seabird Research and Conservation [ISRC]) future funding for the program is highly uncertain. Therefore, we propose to support the field effort required to continue this important dataset within the GWA forage fish monitoring program.

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

FY17	FY18	FY19	FY20	FY21	TOTAL
$198.8	$229.8	$221.3	$224.7	$232.0	$1,106.6

Non-EVOSTC Funding Available

FY17	FY18	FY19	FY20	FY21	TOTAL
$256.0	$256.0	$256.0	$256.0	$256.0	$1,280.0

1. Executive Summary

Pelagic Component

In the aftermath of the 1989 *Exxon Valdez* oil spill (EVOS) it was difficult to distinguish between the impacts of the spill and natural variability in affected animal populations. The main problem for assessing impacts on pelagic species was that long-term baseline data were largely absent. As a result, managers struggled to make informed decisions regarding estimation of damages and recommendations for recovery. Ten years after the spill it became widely recognized that climate change adds additional layers of uncertainty to a post spill recovery; there had been a major climatic regime shift (from colder to warmer than average) that altered the marine ecosystem prior to the spill, including marine birds, marine mammals, groundfish, and the shared forage species they all consumed. As we begin to close the second decade of the 2000s we are experiencing anomalous ocean warming events driven by changing atmospheric conditions at both inter-decadal (i.e., Pacific Decadal Oscillation) and shorter (e.g., El Niño Southern Oscillation) time scales. These changes may have profound effects on pelagic ecosystems such as unusual mortality events, harmful algal blooms, and fishery closures.

During the first five years of the Gulf Watch Alaska (GWA) program, the pelagic component research team addressed two main questions: 1) What are the population trends of key pelagic species groups in PWS, and, 2) How can forage fish population trends in Prince William Sound (PWS) be monitored most effectively? To answer these questions, pelagic component projects focused on species that play a pivotal role in the pelagic ecosystem as trophic indicators for short and long-term ecosystem change: forage fish, marine birds (both fall/winter distribution, and summer status and trends), humpback whales, and killer whales. Monitoring of killer whales and marine birds benefitted from having pre-existing long-term data sets as a result of the damage assessment process following the EVOS (>25-year time series).

Moving forward for the next five years, the pelagic research team re-evaluated their primary objectives. The group's primary objective — to determine the long-term population trends of key pelagic species groups in PWS — will remain the same. The second primary objective was fundamentally different: Develop a means to effectively monitor forage fish. Based on knowledge gained in the first five years of the forage fish project, we learned that the goal of moving to a sound wide forage fish assessment was too labor and vessel intensive, thus not feasible. During pilot work in September 2014 that used humpback whales as indicators of high-density prey aggregations we learned that it is more productive to use the predators to find the forage, and focus assessments based on and around predator feeding aggregations. In addition to providing a means to effectively monitor indices of prey availability (species, depth distribution, density and biomass) to predators, our integrated approach will also enhance our understanding of predator-prey relationships and help us identify some mechanisms of change in populations. Ultimately, the integrated surveys along with information from the GWA Environmental Drivers component will provide a way to evaluate perturbations on the PWS pelagic ecosystem.

Thus, the two over-arching questions for the pelagic component to answer in the next five years are:

1. What are the population trends of key upper trophic level pelagic species groups in PWS – killer whales, humpback whales, and marine birds?
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?

The pelagic component research team is proposing to continue monitoring key pelagic species groups in PWS using the same component projects focused on killer whales, humpback whales, forage fish, and marine birds (fall/winter and summer). However, modifications have been made to some projects for greater integration, increased precision of information, and achieving new goals. Ultimately this will provide more information to the EVOS Trustee Council (EVOSTC), agency resource managers, non-governmental organizations, and the public.

Forage Fish Monitoring

Forage species are difficult and expensive to monitor because they are patchy in their distribution, comprised of species with different life histories and habitats, and their life history traits may predispose populations to large fluctuations in abundance. Examples of important forage taxa in PWS include capelin, Pacific sand lance, juvenile walleye pollock, eulachon, Pacific herring, juvenile salmon and euphausiids, all included hereafter under the label of "forage fish".

Many investigators have attempted to document forage fish distribution, abundance, and variability in PWS and Cook Inlet since the 1990s (Norcross et al. 1999, Stokesbury et al. 2000, Thedinga et al. 2000, Brown 2002, Ainley et al. 2003, Abookire & Piatt 2005, Speckman et al. 2005, Piatt et al. 2007), but for PWS, none have provided population estimates that can be tracked annually in a cost-effective and practical manner. Survey methods for estimating abundance and distribution of forage fish included hydroacoustic surveys coupled with trawl-sampling (Haldorson et al. 1998, Speckman et al. 2005) and Sound-wide aerial surveys for surface-schooling fish (Brown & Moreland 2000).

Predator diets can provide quantitative information on abundance, distribution, temporal variability, condition and community structure of local prey stocks (Hatch & Sanger 1992, Roseneau & Byrd 1997, Davoren & Montevecchi 2003, Litzow et al. 2004). Drawbacks of using predators as indicators of forage fish stocks are the potential for prey selectivity among generalist vs. specialist predators, non-random sampling of foraging areas, and restrictions on the depth of sampled prey because of predator limitations (Hunt et al. 1991). For example, tufted puffins (*Fratercula cirrhata*) bring a greater diversity of prey items to their nest than horned puffins (*F. corniculata*) (Hatch & Sanger 1992), suggested that the tufted puffin diets represent a more opportunistic sample of food availability than horned puffins. Some species, like surface-feeding kittiwakes, are limited in their diving depth and their diets are representative only of prey which make it to the surface at some point in their diurnal cycle of vertical migration (Hatch 2013). Nonetheless, the advantages of easy access and sampling can outweigh the known sampling biases or disadvantages, and in the absence of traditional fisheries surveys for forage fish in the region, the information gleaned from predator diets at seabird colonies provides the best continuous long-term information available on some forage fish species in the northern Gulf of Alaska. These time series reveal much about the availability of key forage species in the Gulf of Alaska.

Project Background

During the first 5-year funding period of GWA the forage fish component tested a variety of survey methods that could yield robust indices for monitoring forage fish in the spill-affected region. This started with a traditionally-designed systematic hydroacoustic-trawl survey in 2012-13 that included sampling of fish, seabird, zooplankton, oceanography and nutrients at 27 fixed stations (although one site was sampled in both years) using a stratified systematic design. With the exception of euphausiids near tidewater glaciers, midwater trawl composition at fixed stations throughout the Sound suggested our encounter rate with target species was not sufficient to assess abundance. Frequency of occurrence in trawls (FO) was low for capelin (3.7%), eulachon (3.7%), and euphausiids (11.1%), and catches were overwhelmingly dominated by non-target species (young of the year walleye pollock, FO = 100%, and jelly fish FO = 81.5%). Likewise, beach seines targeting Pacific sand lance had low and variable catches (mean CPUE ± SD = 3.5 ± 10.5 fish per set). Thus we began to look for ways to improve our ability to sample target fish species.

In 2013 we explored the use of adaptive cluster sampling, and tested combined aerial and acoustic surveys with validation ("aerial-acoustic surveys") as means to increase our encounter rate with target species. Adaptive cluster sampling (i.e., intensive sampling right over schools we found during surveys or by chance) generally involved a high degree of effort and did not facilitate a quantitative means of assessing abundance and distribution at the sound-wide scale because of the relatively infrequent and opportunistic nature of this sampling strategy. We devoted 3 days of ship time to validation of limited aerial surveys. An experienced spotting pilot directed the ship or a skiff to forage fish schools visible from the plane. Schools were captured with nets, jigs, video, and hydroacoustics whenever possible. The ground crew recorded, and relayed to the pilot, information about fish species, fish size, and depth of the schools. After the pilot left, we conducted hydroacoustic surveys of the area, and we used midwater trawls, gill nets, cast nets, dip nets, jigs, or video to confirm the species composition and fish size for conversion of acoustic backscatter to biomass. Although this work facilitated a better way to target near-surface forage fish schools available for observation from a plane, our sampling efforts still resulted in relatively low-encounter rate with forage schools below the depth visible to the spotter pilot (> 10-15 m).

We recognized that surveying all of PWS to locate scattered and relatively small aggregations of target forage species was inefficient, and would ultimately require a far greater investment of vessel time and expense than our budget allowed, or warranted. We know, however, that humpback whales are efficient predators of forage species (fish and euphausiids), and whale distribution may be a key indicator of high density prey patches at depths that are not visible to observers in a plane. In July and Sept 2014 we coordinated with the whale survey principal investigators (PIs) to estimate distribution and density of whale prey near Montague Strait, Green Island and Port Chalmers in July, and successfully quantified schools of krill and capelin in association with the whales. We observed considerable differences in whale prey density and depth distribution between July and September 2014. During daytime surveys in July there were few whales, and only a thin layer of krill and dispersed age-1 capelin at 100 m depth. By September humpback whale numbers increased, and whales there co-occurred with thick scattering layers of krill, adult herring and adult walleye pollock. We therefore considered using whales to effectively locate forage aggregations for us, and thus allow us to focus our offshore vessel sampling efforts. Because of the success of this pilot study, and the fact that annual sound-wide biomass estimates of forage fish populations aren't feasible or cost effective, we propose a survey design using systematic and adaptive sampling of persistent whale foraging areas in PWS that can provide us with long-term monitoring data on forage taxa in offshore waters of PWS.

Integrated Predator-Prey Surveys 2017-2021: Humpback Whales, Marine Birds, Forage Fish

In our initial GWA efforts, we have been able to identify several areas in PWS with seasonally predictable predator-prey aggregations. Given limited resources and patchy predator-prey distribution in PWS, we propose using a combination of systematic transects in conjunction with predator guided surveys to home in on important marine mammal and marine bird foraging areas with significant aggregations of prey. Our new proposed integrated predator-prey surveys will allow us to monitor the status and trends of individual pelagic ecosystem elements as a primary goal. Predator-prey indices will be measured concurrently, thus we will also be able to examine spatial and temporal covariance among indices to better understand the effects of perturbations in the environment. Our framework includes the following hypotheses:

1. *Predator distribution and abundance varies with prey availability (availability and quality)*
2. *Changes in prey availability and quality occur in response to changes in habitat quality (phytoplankton/zooplankton and environment/temperature)*
3. *Variation in prey availability occurs in response to predation pressure*

Long-term Data on Seabird Diets

Although avian, fish and marine mammal predator diets have previously been used to infer forage fish availability throughout Alaska (Best & St-Pierre 1986, Roseneau & Byrd 1997, Sinclair & Zeppelin 2002, Yang et al. 2005), the Middleton Island long-term seabird diet data (Hatch 2013) are of particular interest for several reasons. The Middleton forage fish index, which includes 26 years of frequency of occurrence and size data on capelin, sand lance, myctophids, Pacific herring, juvenile sablefish (reflecting nearby slope spawning habitat), and juvenile pink and chum salmon from PWS and southeast Alaska (as evidenced by thermally marked otoliths), 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 Gulf of Alaska (Sydeman et al. *in review*, 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 prep). Although Middleton Island is situated about 100 km from Hinchinbrook entrance, tagged kittiwakes from the Middleton Island colony regularly foraged at locations within and adjacent to PWS (Hatch 2015).

2. Relevance to the Invitation for Proposals

The proposed work meets the Trustee Council's goal to monitor the recovery of resources from the initial injury, and monitor how factors other than oil may inhibit full recovery or adversely impact recovering resources by collecting data on physical and biological environmental factors that drive ecosystem-level changes. In addition, this integrated multi-trophic level approach meets the core science mission of the U.S. Geological Survey (USGS) Ecosystems program. This monitoring provides an important baseline leading to our understanding of how climate change and other perturbations to the ecosystem affect these pelagic species in PWS. This program will also insure the continuation of the Middleton Island seabird diet monitoring, which is the longest continuous forage fish dataset in region.

3. Project Personnel

Mayumi Arimitsu, Ph.D.
Research Ecologist, U.S. Geological Survey – Alaska Science Center
250 Egan Dr., Juneau AK 99801
(907)-364-1593
marimitsu@usgs.gov

John Piatt, Ph.D.
Research Wildlife Biologist, U.S. Geological Survey –Alaska Science Center
4210 University Dr, Anchorage, Alaska 99508
(360)-774-0516
jpiatt@usgs.gov

Please see 2-page CVs at end of this document

4. Project Design

A. Objectives

Pelagic Component

The following lists the two over-arching questions for the pelagic component to address in the next five years:

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

Integrated Predator-Prey Surveys and Forage Fish Monitoring

Fundamental to ecosystem monitoring is a basic understanding of the status and trends of individual biological components within the system. It is increasingly clear, however, that an understanding of the mechanisms underlying change requires knowledge of interactions among predators, prey and habitat. The main objectives of the predator-prey and forage fish monitoring projects are to:

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

   a. Estimate humpback whale abundance, diet, and distribution (see Moran and Straley humpback whale proposal)

   b. Estimate marine bird abundance and distribution in areas with known seasonally predictable aggregations of predators and prey. (See Bishop marine bird proposal)

      i. relate marine bird presence to prey fields identified during hydroacoustic surveys.

      ii. characterize marine bird-humpback whale foraging dynamics

   c. Estimate an index of forage fish availability (this proposal)

i. species composition and biomass within persistent predator foraging areas

ii. density and depth distribution

d. Estimate an index of krill availability (this proposal)

i. species composition and biomass within persistent predator foraging areas

ii. density and depth distribution

e. Relate whale, marine bird and forage fish indices to marine habitat (all integrated project proposals)

Long-term Data on Seabird Diets

2. Support annual field and laboratory efforts to continue the long-term seabird diet index in April-August (this proposal)

B. PROCEDURAL AND SCIENTIFIC METHODS

Integrated Predator-Prey Surveys 2017-2021: Humpback Whales, Marine Birds, Forage Fish

As stated in all three integrated project proposals to meet the goals of the program we propose an integrated survey design that brings together predator and prey components of the pelagic ecosystem. We propose to conduct an annual hydroacoustic-trawl survey that targets persistent humpback whale feeding locations (hereafter, "sub-regions") in Montague Strait, Bainbridge Passage and Port Gravina (Figure 1). As proposed, the survey will be conducted during the fall of each year. However, potential in-kind contributions from NOAA may allow facilitate expansion of the survey into two time periods: fall and winter (Sept./Oct. and March). Proposed time periods will coincide with periods of peak whale abundance in PWS. The pending in-kind contributions would support the charter costs for the vessels. For the humpback whale component of the fall/winter survey the in-kind contributions would free up Trustee funds that would be applied towards the additional data management and processing the increased number samples resulting from an additional survey. For the acoustic survey component, USGS would contribute further in-kind support to ensure that the second survey was staffed and the acoustic data analyzed. The fall/winter marine bird component will ensure that observers are aboard all surveys, however funded.

The basic structure of the survey is for researchers working from the acoustic vessel to collect acoustic backscatter, trawl and marine habitat data (forage fish team) and concurrently conduct surveys for all marine birds and mammals (fall/winter marine bird team) along fixed transect lines within each sub-region (Figure 1). While the acoustic vessel is conducting transects, trawls and habitat sampling, a second smaller vessel will be used to assess whale abundance (humpback whale team). The smaller vessel will depart from the acoustic vessel and work independently in the sub-region where the acoustic data are being collected. This gives the whale vessel the ability to census and sample whales and scout for whales outside the sub-region as necessary.

Surveys of all three pelagic elements (humpback whales, marine birds and forage fish) will occur during daylight hours for coordinated analyses of predator-prey interactions within and among sub-regions (see also Table 2 in section 5 that details specific tasks and responsibilities by each PI). Our approach to quantifying daytime prey aggregations with hydroacoustics concurrent to predator densities is modeled after work on similar species elsewhere (Gende & Sigler 2006, Friedlaender et al. 2009, Hazen et al. 2009, Boswell et al. 2016). Sub-region-specific biomass estimates, species composition and depth distribution will be comparable within and among years, and thus meet our monitoring objectives of providing an index of prey availability in areas with seasonally predictable predator foraging aggregations. However, our survey design will not provide Sound-wide biomass estimates of forage species because we are unable to sample the entire Sound with existing program resources. Furthermore, although our analytical methods will compensate for changes in acoustical properties of herring with depth and density during daytime surveys (see data analysis and statistical methods section), our biomass estimates for herring by sub-region will not be directly comparable to nighttime hydroacoustic surveys designed specifically to estimate Sound-wide pre-spawning biomass (Thomas & Thorne 2003, Thorne & Thomas 2008).

Hydroacoustic-trawl. The fixed transect layout was chosen to sample areas of persistent humpback whale habitat use identified in surveys conducted in 2006-2014. To estimate depth distribution, density and biomass of prey in the water column a calibrated SIMRAD 38-120 kHz split beam EK60 system will be towed beside the boat along a zig-zag transect layout with a random starting point. Each transect will serve as a sample to estimate the abundance and variance of forage fish and krill biomass in each sub-region (Figure 1) using geostatistical methods (Petitgas 1993).

We will use a midwater trawl and other means as necessary to verify species and size (length in mm, weight to 0.01 g) of fish that contribute to hydroacoustic backscatter in each sub-region. The net has an approximately 154 m^2 mouth (14 m x 11 m) and is 22 m long. Mesh size diminishes from 38 mm at the mouth to 12 mm at the cod end (Innovative Net Systems, Inc.). The net is held open by two 0.4 m^2, series 2000 steel mid-water trawl doors (Nor 'Eastern, Inc.); each weighing approximately 76 lbs. The net will be towed at less than 3 kt, trawl duration will depend on the vertical and horizontal distribution of acoustic targets. Depth of the headrope will be managed with a TrawlMaster system. Although we will try to accomplish ground-truthing of acoustic sign on daytime transects, logistical constraints (daylight hours, trawl depth limitations, etc.) may require that trawls occur at night when the scattering layer ascends in the water column. We will also attempt to ground truth untrawlable (e.g., shallow nearshore areas) acoustic backscatter with other means as necessary (e.g., underwater video, jigs, dipnets, cast nets).

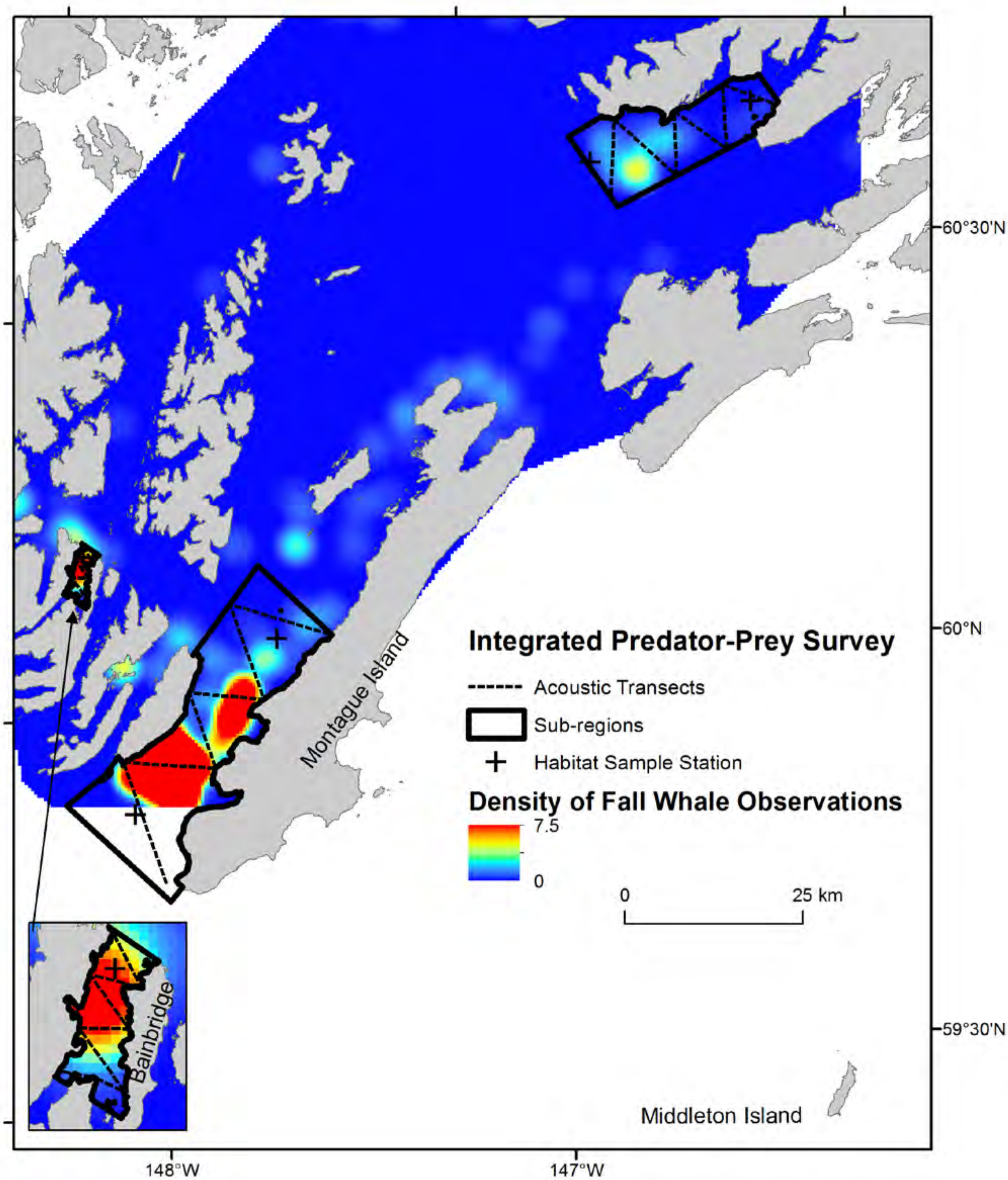


Figure 1. Map of the study area, including Prince William Sound and Middleton Island, and inset of Bainbridge sub-area (lower left). Kernel density of fall whale observations weighted by number of animals in each observation is shown in color (data courtesy of J. Moran and J. Straley, GWA humpback whale project). The GWA integrated predator-prey survey design will include concurrent hydroacoustic and predator transects as well as habitat sampling within each sub-region.

Trawl catches will be enumerated, measured (TL and FL, mm) and weighed (0.01 g) by species. Fish samples will be taken for age, sex, diet, energetics, and isotope analysis. A subsample of the euphausiid catch will be preserved in 3-5% formaldehyde solution for laboratory analysis of species proportion and weight.

In addition to fixed transects in persistent predator aggregation areas, we will also characterize prey density more closely associated with individual or groups of whales in each sub-region (Montague, Bainbridge and Port Gravina). This will involve focal follows of individual whales, and prey mapping near groups of feeding whales.

Marine habitat. Concurrent sampling of ocean and zooplankton indices will provide spatial and temporal overlap of environmental and predator-prey indices. At five fixed stations in the study area we will measure oceanographic variables with a SBE19 plus v2 conductivity-temperature depth profiler (CTD) equipped with a fluorometer, turbidity sensor, beam-transmissometer, PAR sensor, dissolved oxygen and pH sensor and water sampler. Water samples will be taken and analyzed at the University of Washington for nutrients (silica, nitrate, nitrite, ammonium, and phosphate), and chlorophyll *a* (to calibrate the *in situ* fluorometer). After each CTD cast we will also collect zooplankton samples with a 100 m vertical haul of a 150 μ-mesh zooplankton net. Zooplankton samples will be identified to species, enumerated and weighed (0.01 mg) at a laboratory in Fairbanks, AK.

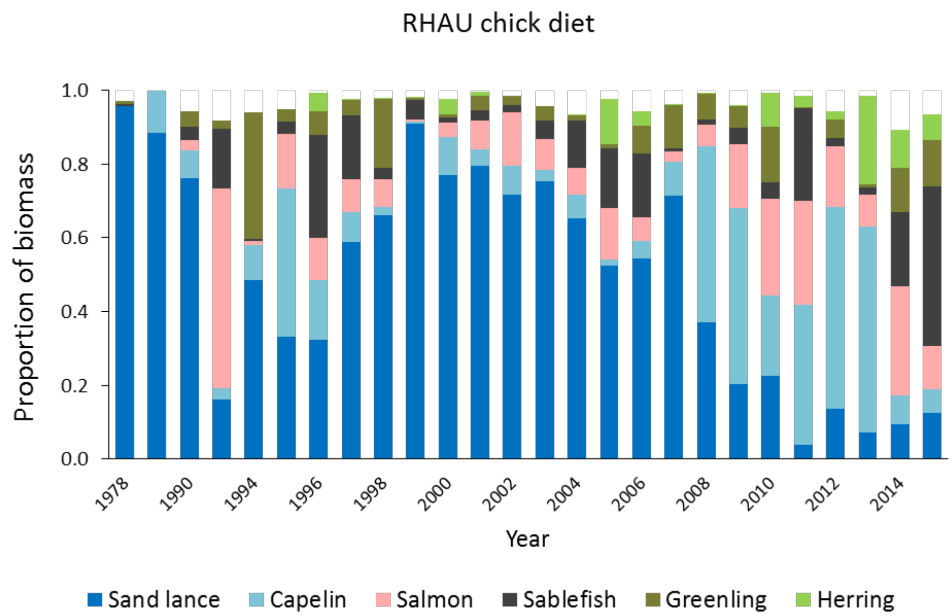
During each cruise we will sample approximately 150 km of transects, with associated trawls (max depth 100 m) for ground-truthing size and species of fish and krill, and 5 CTD/zooplankton stations. We anticipate a typical survey will occur as follows (subject to changes as necessary for logistics and weather conditions):

Day 1. load, travel, calibrate hydroacoustics, passive noise test
Day 2. Montague (82 km tx, 2 trawl, 2 CTD/zoop)
Day 3. Montague (82 km, 2 trawl, 2 CTD/zoop)
Day 4. Finish Montague, focal follows or adaptive tx. Transit.
Day 5. Bainbridge (18 km tx, 1 trawl, 1 CTD/zoop, 1-2 hour focal/adaptive). Transit.
Day 6. Knowles/Gravina (57 km tx , 1-2 trawls, 2 CTD/zoop)
Day 7. Knowles/Gravina (57 km tx, 1-2 trawls, 2 CTD/zoop, 2-3 hour focal/adaptive)
Day 8. Weather or focal/adaptive effort
Day 9. Weather or focal/adaptive effort
Day 10. Transit. Unload.

Long-term Seabird Diet Index

Work planned for GWA at the Middleton Island field station will build upon a 26-year time series that effectively documents forage fish occurrence in seabird diets (Figure 2). 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 bill-loads from chick-provisioning adults, usually once or twice per week from early July through early or mid-August— historically; auklet diet monitoring provides the single best indicator of forage fish availability in the region (Figure 2). 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 & 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), and although not directly comparable to other planned work in the fall, it will provide a prey index for the region that will be useful for relating to the survey for marine bird population and trends conducted biannually in PWS during July (PIs: Kuletz and Kaler).



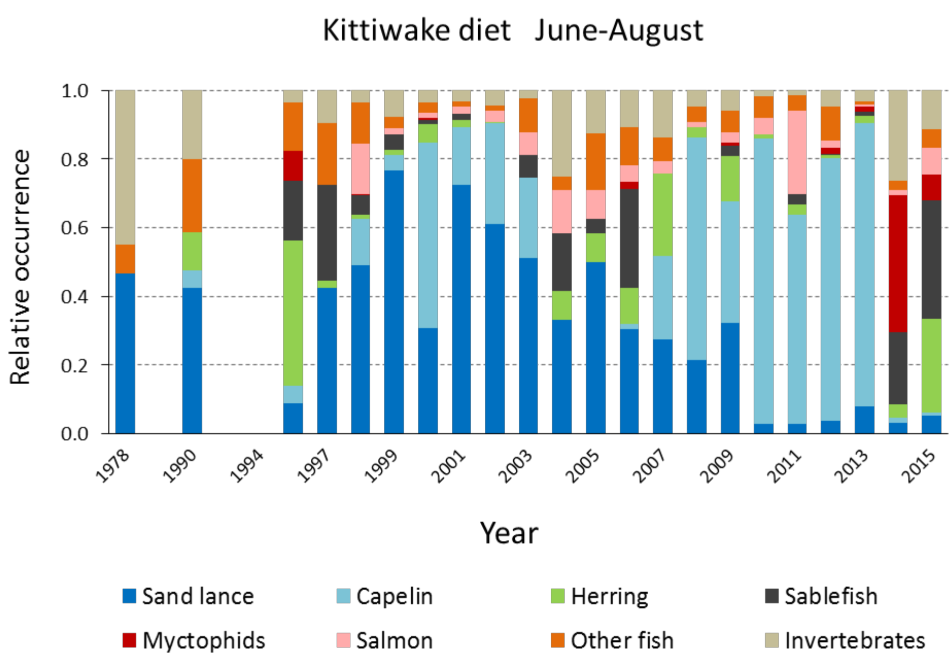


Figure 2. Interannual variation in diet composition of chick-rearing rhinoceros auklets (RHAU) on Middleton Island, 1978 to 2015, with a similar time series for black-legged kittiwakes (lower panel) for comparison. Data are courtesy of Scott Hatch (ISRC).

C. Data Analysis and Statistical Method

We will calculate the echo integral over a given area (mean Nautical Area Scattering Coefficient, NASC, m^2nm^{-2}) using EchoView software (Hobart, Tasmania, Australia). Because acoustic properties of fish are species specific, the target strengths (TS) for captured species will be estimated using the relationships in Table 1 (Thomas et al. 2002, Gauthier & Horne 2004, Boswell et al. 2016). Note that depth effect on TS of herring (Ona 2003) for herring at 38 kHz is specified following Boswell et al. (2016).

Table 1. Theoretical target strength (TS) relationships by species for 2 frequencies.

Species	120 kHz	38 kHz
Capelin	TS = 28.4Log(L)-81.8	TS=20Log(L)-69.3
Pacific herring	TS = 20Log(L)-67.6	TS = 20Log(L)-2.3Log(1+z/10)-65.4
Eulachon	TS = 15.3Log(L)-77.6	TS = 27.3Log(L)-94.0
Walleye pollock	TS=21.1Log(L)-70.5	TS=20Log(L)-67.2
Pacific sand lance	TS=20Log(L)-80	TS=20Log(L)-93.7
Euphausiid	TS = 34.8Log(L) – 127.5	NA

Due to dense aggregative behavior of herring schools during the day, we will compensate for the effects of acoustic shadowing and extinction on the estimates of density and biomass using established methods for Pacific herring (Zhao 2003, Sigler & Csepp 2007, Boswell et al. 2016). Density of fish per unit surface area (ρ_a) will be assessed using the following equation (MacLennan et al. 2002):

$$\rho_a = s_A/\{4\pi\langle\sigma_{bs}\rangle\}$$

where s_A is the echo integral (NASC) and $\sigma_{bs}$is the backscattering cross section (m^2), abundance within each sub-region is calculated as the product of density in the sub-region and the area of the sub-region. Biomass in each sub-region is calculated as the product of the abundance in each sub-region and the average weight of a fish within each sub-region.

Euphausiid biomass will be analyzed by using the difference of mean volume backscattering strengths (ΔMVBS) between 38 and 120 kHz frequencies (Kang 2002, De Robertis et al. 2010). Where ΔMVBS > 10 dB, s_A will be converted to biomass by species using the proportional allocation of euphausiid species identified in trawl catches (Simmonds & MacLennan 2005).

We used the following equations to estimate the effect size we may detect (Gerrodette 1987) given the empirical coefficient of variation (CV), which depends on the degree of hydroacoustic transect coverage Λ (Simmonds and MacLennen 2005):

$$\Lambda = \frac{D}{\sqrt{A}}$$

$$\mathrm{CV} = \frac{0.5}{\sqrt{\Lambda}}$$

$$r^2n^3 = 12CV^2\left(z\alpha_{/2} + z_\beta\right)$$

where D = distance in km of hydroacoustics transects within each sub-area, A = surface area of the water covered by each sub-area, and n = number of years and r = the fractional rate of change of relative biomass over time. During the initial 5 years of this study, at α = β = 0.05, we expect to detect an effect size of 0.18 for all sub-areas combined (n = 5, CV = 0.21), 0.23 in Montague (n = 5, CV = 0.27), 0.22 in Port Gravina (n = 5, CV = 0.26) and 0.20 in Bainbridge (n = 5, CV = 0.24), (Figure 3).

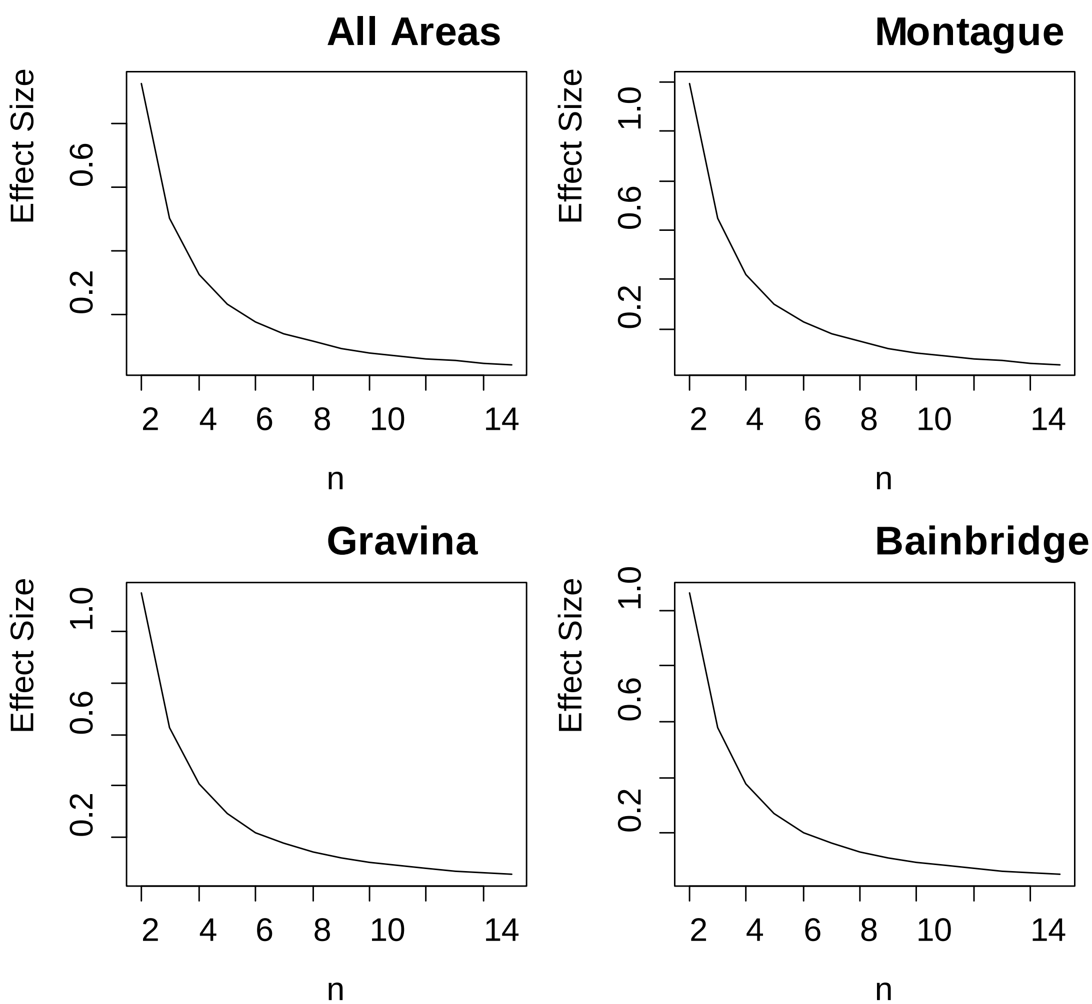


Figure 3. Estimated fractional rate of change (effect size) relative to number of years (n) for all areas and for each sub-region during the Prince William Sound integrated predator-prey surveys.

Forage fish abundance indices will be summarized using simple univariate statistics, and changes among years and subareas tested with ANOVA. We will employ a variety of statistical approaches to examine predator-prey interactions and distributional patterns with respect to bio-physical features. For example, we will use geostatistical models to graphically represent spatial patterns of distribution of predators and prey, Principal Components Analysis (PCA) to identify gradients in physical properties, Generalized Linear Models (GLM) and non-linear methods (e.g., GAMM, gradient boosted regression trees) to assess the relative contributions of different biophysical features in predicting the relative abundance of key forage fish and apex predators. Where appropriate, we will use Detrended Correspondence Analysis (DCA) or Non-metric multidimensional scaling (MDS) to characterize community structure and patterns of community response to physical gradients.

Specifically, with enough years of predator-prey monitoring data we can begin to address our framework hypotheses as follows:

1. *Predator distribution and abundance varies with prey availability (availability and quality)*
    a. *Multiple regression to examine the responses of predators (humpback whales and marine birds) to forage fish (capelin, herring, sand lance, pollock, euphausiid) biomass, species composition, depth distribution over time*
    b. *Multivariate community analysis of predators and prey in each sub-region and all sub-regions combined*
2. *Changes in prey availability and quality occur in response to changes in habitat quality (phytoplankton/zooplankton and environment/temperature)*
    a. *Multiple regression to examine the response of forage fish abundance indices and energy density to changes in habitat (zooplankton biomass, bottom depth, temperature, salinity, beam transmission, dissolved oxygen, chlorophyll a, photic depth, nutrients)*
3. *Variation in prey availability occurs in response to predation pressure*
    a. *Correlation to relate indices of prey availability to predator density within and among sub-areas over time*

D. Description of Study Area

This work will be conducted in spill-affected regions including PWS (bounding coordinates: 61.292, -148.74; 61.168, -146.057; 60.273, -145.677; 59.662, -148.238), and Middleton Island (59.4414, -146.3382).

5. Coordination and Collaboration

Within the Program

The proposed integrated predator-prey surveys will require close coordination with the humpback whale and winter bird component team leads to conduct the work. This collaboration will afford efficiencies in field work, as well as facilitate greater understanding of predator-prey interactions in the Sound (Table 2).

Table 2. Integrated predator-prey collaborations by objective.

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 presence to prey fields identified during hydroacoustic surveys.			

Objective	Index	Task	PI
	Spatial coherence of bird presence/ absence, acoustic estimates of forage fish and euphausiid biomass	Integrated Surveys: hydroacoustic and marine bird transects	Arimitsu & Piatt (USGS)/ Bishop (PWSSC)
b.ii. Characterize marine bird-humpback whale foraging dynamics			
	Georeferenced marine bird and whale counts, group size, behavior by species	Data Collection 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)
	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)

With Other EVOSTC-funded Programs and Projects

We propose to continue collaborative work with Scott Pegau and the Herring Research and Monitoring Program's proposed aerial surveys for juvenile herring and other forage fish, should they occur in the future. This will include in-kind USGS logistical support (equipment, design modifications support) and survey data analysis. Given the existing long-term dataset and recent validation efforts that indicate a reasonably high species identification rate by experienced aerial observers, we believe the continuation of the long-term aerial schools index is important, particularly with respect to understanding changes in nearsurface prey availability for breeding seabirds in the Sound. When NOAA-funded March integrated herring surveys occur we will also coordinate closely with ADF&G and the HRM program to share real-time information relevant to their pre-spawning herring biomass surveys.

With Trustee and Management agencies

We will collaborate closely with Scott Hatch (Institute for Seabird Research and Conservation [ISRC]), who conducted seabird and forage fish work at Middleton under as a Department of Interior research program since 1978. Dr. Hatch now supervises research on Middleton under the auspices of the ISRC, a non-profit research organization. A contract to ISRC will support costs for this long-term monitoring program that is leveraged by addition support from other ISRC partners (e.g., University of Alaska Fairbanks, University of Manitoba, Alaska Sealife Center, and Farallon Institute).

6. Schedule

Program Milestones

Objective 1: Monitor the status and trends of co-occurring pelagic marine ecosystem components during Fall/Winter in areas 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. 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)

Measurable Program Tasks

Measurable program tasks for the forage fish monitoring program include tasks involving administration and logistics, data acquisition and processing, dedicated data management, analysis and reporting (Table 3).

Table 3. Forage fish monitoring task schedule.

Task	FY17				FY18				FY19				FY20				FY21			
	EVOSTC FY Quarter (beginning Feb. 1)																			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Task 1 admin & logistics																				
Contracting	X	X		X	X	X		X	X	X		X	X	X		X	X	X		X
Permitting			X				X				X				X				X	
Equipment calibration		X				X				X				X				X		
Task 2 data acquisition & processing																				
Middleton Island support	X	X	X		X	X	X		X	X	X		X	X	X		X	X	X	
Integrated predator-prey surveys (EVOSTC)			X				X				X				X				X	
Alternate survey schedule (with added NOAA funds)	X		X		X		X		X		X		X		X		X		X	
Acoustic data processing	X	X	X		X	X	X		X	X	X		X	X	X		X	X	X	
CTD data processing	X				X				X				X				X			
Chlorophyll *a* fluorometry	X				X				X				X				X			
Task 3 data management																				
Database mgmt./QAQC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Metadata	X				X				X				X				X			
Workspace upload		X				X				X				X				X		
Task 4 analysis & reporting																				
Analysis and summary	X				X								X				X			
Annual Reports	X				X				X				X				X			
Annual PI meeting				X				X				X				X				X
FY Work Plan (DPD)			X				X				X				X					
Permit reports				X				X				X				X				X

FY 2017 (Year 6)

FY 17, 1st quarter	(February 1, 2017 - April 30, 2017)
February:	*Middleton Island Contract*
March:	*2016 Annual Report*
FY 17, 2nd quarter	(May 1, 2017 - July 31, 2017)
May:	*FY17 Fish Resource Permit Application*
June:	*Contracting, shipping for equipment calibration*
April-August:	*Middleton Island field work*
FY 17, 3rd quarter	(August 1, 2017 - October 31, 2017)
August:	*FY18 project proposal*
September:	*Integrated predator-prey survey cruise*
FY 17, 4th quarter	(November 1, 2017 - January 31, 2018)
November:	*PI Meeting in Anchorage*
December:	*FY17 Fish Resource Permit Reporting*
January:	*Contract, prep, ship zooplankton (Fairbanks AK) and nutrients (Seattle WA) samples*

FY 2018 (Year 7)

FY 18, 1st quarter	(February 1, 2018 - April 30, 2018)
February:	*Middleton Island Contract*
March:	*FY17 Annual Report*
March:	*NOAA Integrated predator-prey survey cruise (TBD)*
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:	*FY19 project proposal*
August:	*Upload FY17 data to workspace*
September:	*Integrated predator-prey survey Fall cruise*
FY 18, 4th quarter	(November 1, 2018 - January 31, 2019)
November:	*PI Meeting in Anchorage*
December:	*FY18 Fish Resource Permit Reporting*
January:	*Contract, prep, ship zooplankton (Fairbanks AK) and nutrients (Seattle WA) samples*

FY 2019 (Year 8)

FY 19, 1st quarter	(February 1, 2019 - April 30, 2019)
February:	*Middleton Island Contract*
February:	*FY18 Annual Report*
March:	*NOAA Integrated predator-prey survey cruise (TBD)*
February-April:	*FY18 Data processing*

FY 19, 2nd quarter (May 1, 2019 - July 31, 2019)
May: *FY19 Fish Resource Permit Application*
June: *Contracting, shipping for equipment calibration*
May-July: *FY18 Data processing/QAQC*
April-August: *Middleton Island field work*

FY 19, 3rd quarter (August 1, 2019 - October 31, 2019)
August: *FY20 project proposal*
August: *Upload FY19 data to workspace*
September: *Integrated predator-prey survey Fall cruise*

FY 19, 4th quarter (November 1, 2019 - January 31, 2020)
November: *PI Meeting in Anchorage*
December: *FY19 Fish Resource Permit Reporting*
January: *Contract, prep, ship zooplankton (Fairbanks AK) and nutrients (Seattle WA) samples*

FY 2020 (Year 9)

FY 20, 1st quarter (February 1, 2020 - April 30, 2020)
February: *Middleton Island Contract*
February: *FY19 Annual Report*
March: *NOAA Integrated predator-prey survey cruise (TBD)*
February-April: *FY19 Data processing*

FY 20, 2nd quarter (May 1, 2020 - July 31, 2020)
May: *FY20 Fish Resource Permit Application*
June: *Contracting, shipping for equipment calibration*
May-July: *FY19 Data processing/QAQC*
April-August: *Middleton Island field work*

FY 20, 3rd quarter (August 1, 2020 - October 31, 2020)
August: *FY21 project proposal*
August: *Upload FY20 data to workspace*
September: *Integrated predator-prey survey Fall cruise*

FY 20, 4th quarter (November 1, 2020 - January 31, 2021)
November: *PI Meeting in Anchorage*
December: *FY20 Fish Resource Permit Reporting*
January: *Contract, prep, ship zooplankton (Fairbanks AK) and nutrients (Seattle WA) samples*

FY 2021 (Year 10)

FY 21, 1st quarter (February 1, 2021 - April 30, 2021)
February: *Middleton Island Contract*
February: *FY20 Annual Report*
March: *NOAA Integrated predator-prey survey cruise (TBD)*
February-April: *FY20 Data processing*

FY 21, 2nd quarter (May 1, 2021 - July 31, 2021)
May: *FY21 Fish Resource Permit Application*
June: *Contracting, shipping for equipment calibration*
May-July: *FY20 Data processing/QAQC*
April-August: *Middleton Island field work*

FY 21, 3rd quarter (August 1, 2021 - October 31, 2021)
August: *FY22 project proposal*
August: *Upload FY21 data to workspace*
September: *Integrated predator-prey survey Fall cruise*

FY 21, 4th quarter (November 1, 2021 - January 31, 2022)
November: *PI Meeting in Anchorage*
December: *FY21 Fish Resource Permit Reporting*
January: *Contract, prep, ship zooplankton (Fairbanks AK) and nutrients (Seattle WA) samples*

7. Budget

BUDGET FORMS (ATTACHED)

Completed budget forms are attached.

SOURCES OF ADDITIONAL FUNDING

Over the life of the project, USGS will make a substantial in-kind contribution of salary (446.8K) for PIs (6 mo. Arimitsu GS-12, 2 mo. Piatt GS-15), and in each year all the field equipment required (6K; nets, underwater cameras, field computers), SIMRAD split beam dual frequency hydroacoustic equipment (141K), Marel Marine Lab Scale (10K), CTD and EcoSampler (40K), and small boats (20K). We will also support aerial survey design and data analysis in conjunction with the HRM program lead.

LITERATURE CITED

Abookire AA, Piatt JF (2005) Oceanographic conditions structure forage fishes into lipid-rich and lipid-poor communities in lower Cook Inlet, Alaska, USA. Mar Ecol Prog Ser 287:229–240

Ainley DG, Ford RG, Brown ED, Suryan RM, Irons DB (2003) Prey resources, competition, and geographic structure of kittiwake colonies in Prince William Sound. Ecology 84:709–723

Best E., St-Pierre G (1986) Pacific halibut as predator and prey. International Pacific Halibut Commission Technical Report No. 21. Seattle WA. 27 pp.

Boswell KM, Rieucau G, Vollenweider JJ, Moran JR, Heintz, RonBlackburn JK, Scepp DJ (2016) Are spatial and temporal patterns in Lynn Canal overwintering Pacific herring related to top predator activity? Can J Fish Aquat Sci:1–58

Brown ED (2002) Life history, distribution, and size structure of Pacific capelin in Prince William Sound and the northern Gulf of Alaska. ICES J Mar Sci 59:983–996

Brown ED, Moreland SM (2000) Ecological factors affecting the distribution and abundance of forage fish in Prince William Sound, Alaska: An APEX synthesis product. Restoration Project 00163T. Final Report. Fairbanks, AK 79 pp.

Davoren GK, Montevecchi W (2003) Signals from seabirds indicate changing biology of capelin stocks. Mar Ecol Prog Ser 258:253–261

Friedlaender AS, Hazen EL, Nowacek DP, Halpin PN, Ware C, Weinrich MT, Hurst T, Wiley D (2009) Diel changes in humpback whale Megaptera novaeangliae feeding behavior in response to sand lance Ammodytes spp. behavior and distribution. Mar Ecol Prog Ser 395:91–100

Gauthier S, Horne JK (2004) Potential acoustic discrimination within boreal fish assemblages. ICES J Mar Sci 61:836–845

Gende SM, Sigler MF (2006) Persistence of forage fish “hot spots” and its association with foraging Steller sea lions (Eumitopias jubatus) in southeast Alaska. Deep Res II 53:432–441

Gerrodette T (1987) A power analysis for detecting trends. Ecology 68:1364–1372

Haldorson LH, Shirley TC, Coyle KO (1998) Forage Species Studies in Prince William Sound. Restoration Project 97163 A. Annual Report. Juneau, AK. 29 pp.

Hatch SA (2013) Kittiwake diets and chick production signal a 2008 regime shift in the Northeast Pacific. Mar Ecol Prog Ser 477:271–284

Hatch SA (2015) Middleton Island Seabird Research and Monitoring 2015 Field Report. Institute for Seabird Research and Conservation. 19 pp.

Hatch SA, Sanger GA (1992) Puffins as samplers of juvenile pollock and other forage fish in the Gulf of Alaska. Mar Ecol Prog Ser 80:1–14

Hazen EL, Friedlaender AS, Thompson MA, Ware CR, Weinrich MT, Halpin PN, Wiley DN (2009) Fine-scale prey aggregations and foraging ecology of humpback whales Megaptera novaeangliae. Mar Ecol Prog Ser 395:75–89

Hunt GLJ, Piatt JF, Erikstad KE (1991) How do foraging seabirds sample their environment? In: Bell BD, Cossee RO, Flux JEC, Heather BD, Hitchmough RA, Robertson CJR, Williams MJ (eds) Proceedings of the 20th International Ornithological Congress, 2-9 Dec. 1990. New Zealand Ornitological Congress Trust Board, Christchurch, New Zealand, p 2272–2279

Kang M (2002) Effective and accurate use of difference in mean volume backscattering strength to identify fish and plankton. ICES J Mar Sci 59:794–804

Litzow MA, Piatt JF, Abookire AA, Robards MD (2004) Energy density and variability in abundance of pigeon guillemot prey: support for the quality-variability trade-off hypothesis. J Anim Ecol 73:1149–1156

MacLennan D, Fernandes PG, Dalen J (2002) A consistent approach to definitions and symbols in fisheries acoustics. ICES J Mar Sci 59:365–369

Norcross BL, Brown ED, Foy RJ, Frandsen M, Seitz J, Stokesbury KDE (1999) Juvenile herring growth and habitats, Exxon Valdez Oil Spill Resoration Project Final Report (Resoration Project 99320T). Fairbanks, Alaska

Ona E (2003) An expanded target-strength relationship for herring. ICES J Mar Sci 60:493–499

Petitgas P (1993) Geostatistics for fish stock assessments: a review and acoustic application. ICES J Mar Sci 50:285–298

Piatt JF, Harding A, Shultz M, Speckman SG, Pelt T van, Drew GS, Kettle A (2007) Seabirds as indicators of marine food supplies: Cairns revisited. Mar Ecol Prog Ser 352:221–234

Robertis A De, McKelvey DR, Ressler PH (2010) Development and application of an empirical multifrequency method for backscatter classification. Can J Fish Aquat Sci 67:1459–1474

Roseneau DG, Byrd GV (1997) Using predatory fish to sample forage fishes, 1995-1999. APEX project 99163K Final Report. USFWS Homer, AK. 25 pp.

Sigler MF, Csepp DJ (2007) Seasonal abundance of two important forage species in the North Pacific Ocean, Pacific herring and walleye pollock. Fish Res 83:319–331

Simmonds E, MacLennan D (2005) Fisheries Acoustics: Theory and Practice, Second Edition. Blackwell Science, Ames, Iowa. 437 pp.

Sinclair EH, Zeppelin TK (2002) Seasonal and Spatial Differences in Diet in the Western Stock of Steller Sea Lions (Eumetopias Jubatus). J Mammal 83:973–990

Speckman SG, Piatt JF, Mintevera C, Parrish J (2005) Parallel structure among environmental gradients and three trophic levels in a subarctic estuary. Prog Oceanogr 66:25–65

Stokesbury KDE, Kirsch J, Brown ED, Thomas GL, Norcross BL (2000) Spatial distributions of Pacific herring, Clupea pallasi, and walleye pollock, Theragra chalcogramma, in Prince William Sound, Alaska. Fish Bull 98:400–409

Sydeman WJ, Piatt JF, Thompson SA, García-Reyes M, Hatch SA, Arimitsu ML, Slater L, Williams JC, Rojek NA, Zador SG, Renner HM Puffins reveal contrasting relationships between forage fish and ocean climate in the N. Pacific. Fish Oceanogr

Thayer J a., Bertram DF, Hatch SA, Hipfner MJ, Slater L, Sydeman WJ, Watanuki Y (2008) Forage fish of the Pacific Rim as revealed by diet of a piscivorous seabird: synchrony and relationships with sea surface temperature. Can J Fish Aquat Sci 65:1610–1622

Thedinga JF, Hulbert LB, Coyle KO (2000) Abundance and distribution of forage fishes in Prince William Sound. Restoration Project 00163A Final Report. Juneau, AK. 58 pp.

Thomas GL, Kirsch J, Thorne RE (2002) Ex situ target strength measurements of Pacific herring and Pacific sand lance. North Am J Fish Manag 22:1136–1145

Thomas GL, Thorne RE (2003) Acoustical-optical assessment of Pacific Herring and their predator assemblages in Prince William Sound, Alaska. Aquat Living Resour 16:247–253

Thorne RE, Thomas GL (2008) Herring and the "Exxon Valdez" oil spill: An investigation into historical data conflicts. ICES J Mar Sci 65:44–50

Yang M, Aydin KY, Greig A, Lang G, Livingston P (2005) Historical Review of Capelin (Mallotus villosus) Consumption in the Gulf of Alaska and Eastern Bering Sea. NOAA Technical Memorandum NMFS-AFSC-155.

Zhao X (2003) Estimation and compensation models for the shadowing effect in dense fish aggregations. ICES J Mar Sci 60:155–163

PROJECT DATA ONLINE

http://portal.aoos.org/gulf-of-alaska.php#metadata/3ca497e2-3421-4fa4-a550-f4d397a73c07/project/files

Mayumi L. Arimitsu, Ph.D.
Curriculum Vitae
Research Ecologist, USGS-Alaska Science Center
250 Egan Dr. Juneau AK 99801, 907-364-1593, marimitsu@usgs.gov

EDUCATION

University of California, Santa Cruz CA	B.S. Biology (1998)
University of Alaska Fairbanks, Juneau AK	M.S. Fisheries (2009)
University of Alaska Fairbanks, Juneau AK	Ph.D Fisheries (2016)

TECHNICAL TRAINING

Secondary Education Credential Program, Humboldt State University, 2000
Wildlife and Fisheries Survey Design and Analysis, Oz Garton, 2008
Experimental Design, University of Alaska Fairbanks, 2008
Physical Oceanography, University of Alaska Fairbanks, 2008
Fish Population Dynamics, University of Alaska Fairbanks, Terry Quinn, 2008
Community Ecology, University of Alaska Fairbanks, 2011
Spatial Statistics, University of Alaska Fairbanks, 2012
Advanced R programming for Fisheries Statistics, University of Washington, 2013
Fisheries Acoustics, John Horne University of Washington, 2013

RELEVANT RESERACH EXPERIENCE

Monitoring Strategies to Improve Detection of Change in Forage Fish Stocks (2011- present). Co-Principal Investigator on the GWA long-term monitoring program in Prince William Sound. Designed surveys that include broad-scale aerial surveys coupled with hydroacoustic-trawl surveys to assess status and trends of prey species such as capelin, sand lance, juvenile herring, and krill.

Glacial-marine Ecosystem Studies (2004 – present). Principal Investigator on a program to investigate the influence of freshwater runoff from melting glaciers on seabirds and forage fish in the Gulf of Alaska. Work includes field measurements of oceanography, nutrient, zooplankton, fish and seabirds to model trophic interactions, and stable isotopes and radiocarbon to estimate the contribution of terrestrial subsidies to marine food webs.

Seabirds as Indicators of Forage Fish Stocks in Alaska (2012 – present). Collaborator on project that compiled historical data and collected new data on the feeding ecology of Puffins throughout coastal Alaska. Field work involved visiting colonies to collect prey samples, measure chick health, conduct at-sea surveys of marine bird density, hydroacoustic surveys for forage fish and other indices of marine habitat. These data along with historical data from more than 30 sites over 30 years contributed to analyses of geographic structure, temporal variability and marine habitat of key forage fish from southeast Alaska to the western Aleutians.

Kittlitz's Murrelet Distribution, Marine Habitat Use and Seasonal Movements (2008 – present). Co-Principal Investigator on a range-wide study of the breeding ecology of murrelets, which are seabird species of conservation concern. Used line transect methods to estimate abundance at sea, conducted hydroacoustic-trawl and oceanography surveys to identify characteristics of prey availability and marine habitat, used satellite tags to document post-breeding movement.

Forage Fish Ecology in the Aleutian Islands (2005 – 2010). Co-Principal Investigator during a large-scale forage fish and oceanography study that sampled 1500 km along the Alaska Peninsula and Aleutian Archipelago. I oversaw fishing, plankton and oceanography data collection efforts, data analysis and reporting.

Inventory and Monitoring in Southeast Alaska National Parks (2002 – 2006). Lead biologist during two inventory and monitoring projects in Alaska's national parks. I conducted a marine and estuarine fish inventory in Glacier Bay, Sitka, Klondike Gold, and Wrangell St. Elias National Parks, and was in charge of bottom and midwater trawl fishing operations, voucher specimen identification and curating, data analysis, interpretation, and reporting. I also led a ground-nesting marine bird inventory in Glacier Bay, and was responsible for all aspects of the work, including permitting, staffing, data collection, analysis and reporting.

SELECTED PUBLICATIONS

Arimitsu, M.L. 2016. Influence of Glaciers on Coastal Marine Ecosystems in the Gulf of Alaska. Dissertation. University of Alaska Fairbanks. 160 pp.

O'Neel, S., Hood, E., Bidlack, A., Fleming, S., Arimitsu, M., Arendt, A., Burgess, E., Sergeant, S. Beaudreau, A., Timm, K., Hayward, G., Reynolds, J. and Pyare, S. 2015. Icefield-to-Ocean Linkages across the Northern Pacific Coastal Temperate Rainforest Ecosystem. BioScience 65:499-512.

Fellman, J., Hood, E., Raymond, P., Hudson, J., Bozeman, M. and Arimitsu, M. 2015. Evidence for the assimilation of ancient glacier organic carbon in a proglacial stream food web. Limnology and Oceanography 60:1118-1128.

Arimitsu, M. and Piatt, J. 2015. Forage fish populations in Prince William Sound: Designing efficient monitoring techniques to detect change. In: Quantifying temporal and spatial variability across the Northern Gulf of Alaska to understand mechanisms of change (Hoem Neher et al., eds). Science Synthesis Report for the Gulf Watch Alaska Program, Anchorage AK. 247 pp.

Renner, M., M.L. Arimitsu, and J.F. Piatt. 2012. Structure of marine predator and prey communities along environmental gradients in a glaciated fjord. Canadian Journal of Fisheries and Aquatic Sciences. 69:2029-2045

Arimitsu, M.L., J.F. Piatt, E.N. Madison, J.S. Conaway, and N. Hillgruber. 2012. Oceanographic gradients and seabird prey community dynamics in glacial fjords. Fisheries Oceanography 21:148-169.

Arimitsu, M.L., J.F. Piatt, M.A. Litzow, A.A. Abookire, M.D. Romano, and M.D. Robards. 2008. Distribution and spawning dynamics of capelin (*Mallotus villosus*) in Glacier Bay, Alaska: A cold water refugium. Fisheries Oceanography 17:137-146.

Arimitsu, M. L., J. F. Piatt, M. D. Romano, and D. C. Douglas. 2007. Distribution of Forage Fishes in Relation to the Oceanography of Glacier Bay National Park. Pages 102–106 *in* J. F. Piatt and S. M. Gende, editors. Proceedings of the Fourth Glacier Bay Science Symposium. USGS Scientific Investigations Report 2007 – 5047.

COLLABORATIONS: Anne Beaudreau (UAF), Allison Bidlack (ACRC), Mary Anne Bishop (PWSSC), Gary Drew (USGS), Jason Fellman (UAS), Keith Hobson (University of Ottowa), Brielle Heflin (USGS), Eran Hood (UAS), Erica Madison (USGS), John Moran (NOAA), Franz Mueter (UAF), Shad O'Neel (USGS), Scott Pegau (PWSSC), John Piatt (USGS), Martin Renner (Tern Again Consulting), Sarah Schoen (USGS), Jan Straley (UAS), Bill Sydamen (Farralon's Institute), Darcy Webber (Quantifish, New Zealand)

John F. Piatt

Curriculum Vitae

Research Biologist (GS-15), Marine Ecology Project Leader, Alaska Science Center, U.S. Geological Survey, 4210 University Drive, Anchorage, Alaska, U.S.A. 99508.

E-mail: john_piatt@usgs.gov

Web: http://www.absc.usgs.gov/research/seabird_foragefish/index.html

ACADEMICS:

Affiliate Professor, School of Aquatic and Fisheries Sciences, University of Washington, Seattle.

Ph.D., Marine Biology, 1987, Department of Biology, Memorial University of Newfoundland, St. John's, Canada. Thesis: Behavioural Ecology of Common Murre and Atlantic Puffin Predation on Capelin: Implications for Population Biology.

B.Sc. (Hons.) Biochemistry, 1977, Memorial University of Newfoundland, St. John's, Canada.

RELEVANT RESEARCH EXPERIENCE

Functional Response of Seabirds to their Prey (1995-2015). Principal Investigator of integrated studies of oceanography, forage fish (seining, trawling, hydroacoustics), and seabirds (e.g., diets, breeding, foraging behavior, genetics, etc.) in and around seabird colonies in Prince William Sound, Cook Inlet, Gulf of Alaska, Aleutians and Bering Sea. Work with an international group of scientists to examine the global responses of seabirds to fluctuations in prey abundance.

Endangered Species Studies (2001-2015). Principal Investigator for studies on rare and threatened seabirds in Alaska, including Kittlitz's Murrelet, Marbled Murrelet and Short-tailed Albatross. Studies include detailed investigations of marine ecology, forage fish and habitat use, radio and satellite telemetry, physiology, surveys for distribution and abundance in Alaska, etc.

North Pacific Pelagic Seabird Database (2002-2015). Principal Investigator responsible for the compilation of ca. 350,000 transects that document the distribution of seabirds at sea in the North Pacific Ocean. Work is proceeding to map seabird distribution at different spatial scales, and relate distribution to currents, sea temperature, productivity and prey abundance.

Studies (1991- 1999, 2012-2015) on Tufted and Horned Puffin population and feeding ecology at 40 colonies in the Aleutian Archipelago and Gulf of Alaska (chick diets and growth, adult diets, seabird distribution at sea, hydroacoustic surveys).

Participated in 43 research cruises in 1977-2014 to study oceanography, plankton, forage fish and seabirds in the North Atlantic, Labrador Sea, eastern Canadian Arctic, North Central Pacific, Gulf of Alaska, Aleutians, Bering Sea and Chukchi Sea.

OTHER ACTIVITIES

Contributing Editor, Marine Ecology Progress Series (2007- current)

Science Panel, North Pacific Research Board, Anchorage, Alaska (2005-2011)

Past or Current advisor and/or graduate committee member for: A. Agness *U. Washington*; S. Speckman, *U. Washington*.; M. Romano, *Oregon State U.*; M. Robards, *Memorial U. Newfoundland*; T. Van Pelt, *U. Glasgow*; M. Litzow, *U. California, Santa Cruz*; A. Kitaysky, *U. Washington*; Ann Harding, *Sheffield U.;* K. Kuletz*, U. Victoria,* S. Zador*, U. Washington,* M. Renner*, U. Washington,* Mayumi Arimitsu, *U. Alaska, Fairbanks*, J. Lawonn, *Oregon State U.*, J. Cragg, *U. Victoria*.

SELECTED PUBLICATIONS:

Drew, G.S., Piatt J.F., and M. Renner. 2015. User's Guide to the North Pacific Pelagic Seabird Database 2.0; U.S. Geological Survey Open-File Report 2015-1123, 52pp.

Piatt, John F., Mayumi Arimitsu, William Sydeman, et al. 2015. Geographic structure of coastal marine food webs in the Alaskan North Pacific. Marine Ecology Progress Series. (*In review*)

Renner, M., J.K. Parrish, J.F. Piatt, K.J. Kuletz, A.E. Edwards, and G.L. Hunt, Jr. 2013. Modeled distribution and abundance of a pelagic seabird reveal trends in relation to fisheries. Marine Ecology Progress Series 484: 259-277.

Drew, G.S., J.F. Piatt, and D.F. Hill. 2012. Effects of currents and tides in fine-scale use of marine bird habitats in a Southeast Alaska hotspot. Marine Ecology Progress Series 487: 275-286.

Renner, M., M.L. Arimitsu, and J.F. Piatt. 2012. Structure of marine predator and prey communities along environmental gradients in a glaciated fjord. Canadian Journal of Fisheries and Aquatic Sciences 69: 2029-2045.

Arimitsu, M.L, J.F. Piatt, E.N. Madison, J.S. Conaway, N. Hillgruber. 2012. Oceanographic gradients and seabird prey community dynamics in a glacial fjord. Fisheries Oceanography. 21: 148-169.

Cury, P.M., I.L. Boyd, S. Bonhommeau, T. Anker-Nilssen, R.J.M. Crawford, R.W. Furness, J.A. Mills, E. Murphy, H. Osterblom, M. Paleczny, J.F. Piatt, J.P. Roux, L. Shannon, W.J. Sydeman. 2011. Global seabird responses to forage fish depletion – one-third for the birds. Science 334: 1703-1706.

Kitaysky, A.S., J. F. Piatt, S. A. Hatch, E.V. Kitaiskaia, Z. M. Benowitz-Fredericks, M.T. Shultz, and J.C. Wingfield. 2010. Food availability and population processes: severity of nutritional stress during reproduction predicts survival of long-lived seabirds. Functional Ecology. 24:625-637.

Shultz, M.T., J.F. Piatt, A.M. A. Harding, A.B. Kettle, T.I. Van Pelt. 2009. Timing of breeding and reproductive performance in murres and kittiwakes reflect mismatched seasonal prey dynamics. Marine Ecology Progress Series 393: 247-258.

Piatt, J.F., A.M.A. Harding, M. Shultz, S.G. Speckman, T. I. van Pelt, G.S. Drew, A.B. Kettle. 2007. Seabirds as indicators of marine food supplies: Cairns revisited. Marine Ecology Progress Series 352: 221-234.

Harding, A.M.A., Piatt, J.F., Schmutz, J.A., Shultz, M.T., Van Pelt, T.I., Kettle, A.B., and Speckman, S.G. 2007. Prey density and the behavioral flexibility of a marine predator: the Common Murre (*Uria aalge*). Ecology 88: 2024-2033.

Piatt, J.F., and A.M.A. Harding. 2007. Population Ecology of Seabirds in Cook Inlet. Pp. 335-352 *in*: Robert Spies (ed.), Long-term Ecological Change in the Northern Gulf of Alaska. Elsevier, Amsterdam.

Speckman, S., J.F. Piatt, C. Minte-Vera and J. Parrish. 2005. Parallel structure among environmental gradients and three trophic levels in a subarctic estuary. Progress in Oceanography 66: 25-65.

Litzow, M.A., J.F. Piatt, A.A. Abookire, and M. Robards. 2004. Energy density and variability in abundance of pigeon guillemot prey: support for the quality-variability tradeoff hypothesis. Journal of Animal Ecology 73: 1149-1156.

Abookire, A.A. and J.F. Piatt. 2005. Oceanographic conditions structure forage fishes into lipid-rich and lipid-poor communities in lower Cook Inlet, Alaska, USA. Marine Ecology Progress Series 287: 229-240.

COLLABORATORS Josh Adams (USGS), Mayumi Arimitsu (USGS), Alan Burger (U. Victoria, Canada), Robin Corcoran (USFWS), Philippe Cury (Ctr. Tropical Fish. Res., France), Vicki Friesen (Queen's U., Canada), Bob Furness (U. Glasgow, UK), Keith Hobson (U. Saskatchewan, Canada), David Irons (USFWS), Alexander Kitaysky (U. Alaska, Fairbanks), Kathy Kuletz (USFWS), Ellen Lance (USFWS), Bill Montevecchi (Memorial U., Canada), John Moran (NMFS), Scott Pegau (PWSSC), Bill Pyle (USFWS), Heather Renner (USFWS), Martin Renner (U. Wash.), Dan Roby (Oregon State U.), Jan Straly (UAS), Rob Suryan (OSU), William Sydeman (Farallon Inst.), Stephani Zador (NOAA).

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	$135.5	$139.8	$146.7	$671.7	
Travel	$8.6	$7.3	$8.6	$7.3	$7.3	$39.0	
Contractual	$47.5	$47.5	$47.5	$47.5	$47.5	$237.5	
Commodities	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	
Equipment	$4.3	$28.4	$11.4	$11.4	$11.4	$66.9	
SUBTOTAL	$182.4	$210.8	$203.0	$206.0	$212.8	$1,015.1	
General Administration (9% of subtotal)	$16.4	$19.0	$18.3	$18.5	$19.2	$91.4	N/A
PROJECT TOTAL	$198.8	$229.8	$221.3	$224.5	$232.0	$1,106.4	
Other Resources (Cost Share Funds)	$256.0	$256.0	$256.0	$256.0	$256.0	$1,280.0	

COMMENTS:
Over life of the project, USGS will make a substantial contribution of salary (446.8K) for PIs (6 mo. GS-12, 2 mo. GS-15), and in each year all the field equipment required including sampling nets (6K; purse seine, beach seine, cast nets), SIMRAD split beam dual frequency hydroacoustic equipment (141K), and small boats (20K). We will also support aerial survey design, vaildation and data analysis in conjunction with the HRM program.

FY17-21

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

TRUSTEE AGENCY SUMMARY PAGE

Personnel Costs:		Months	Monthly		Personnel
Name	Project Title	Budgeted	Costs	Overtime	Sum
Piatt GS-15 (in-kind)	Team Leader	2.0	0.0	0.0	0.0
Arimitsu GS-12 (in-kind)	Project Leader	6.0	0.0	0.0	0.0
GS-9	Biologist & Data Manager	11.0	7.2	5.0	84.6
GS-7	Biologist	6.5	5.1	4.0	37.4
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
		Subtotal	12.4	9.0	
				Personnel Total	$122.0

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
Piatt Meeting: Airfare, hotel, M&IE	1.0	1	5	0.2	2.0
Arimitsu Meeting: Airfare, M&IE	0.6	1	4	0.2	1.4
Arimitsu Field: Airfare, hotel, M&IE	0.6	2	15	0.1	2.0
GS 9 Field Site: Airfare, M&IE	0.5	1	10	0.0	0.7
GS 9 Field Site: Airfare, M&IE	0.5	1	15	0.1	1.3
GS 7 Field Site: Airfare, M&IE	0.6	1	15	0.1	1.4
					0.0
					0.0
					0.0
					0.0
				Travel Total	$8.6

FY17

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B
PERSONNEL & TRAVEL DETAIL

Contractual Costs: Description	Contract Sum
Stark - Zooplankton/euphausiid ID, enumeration and weights	6.3
UW Marine Chemisty Lab - nutrients	1.3
ISRC - Middleton Island	40.0
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$47.5

Commodities Costs: Description	Commodities Sum
Commodities Total	$0.0

FY17

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B
CONTRACTUAL &
COMMODITIES DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
CTD calibration	1.0	3.3	3.3
other field supplies	1.0	1.0	1.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
		New Equipment Total	$4.3

Existing Equipment Usage: Description	Number of Units	Inventory Agency
SIMRAD 38-120 kHz split beam hydroacoustics system	1	USGS
RECON handheld data loggers, cameras	4	USGS
CastAway CTD	1	USGS
SBE19plus V2 + fluorometer/turb + PAR + Beam transmissometer + pH + DO + SBE55 autofire water sampler	1	USGS
Trawlmaster Net Sounder	1	USGS
Zooplankton sampling gear	1	USGS

FY17

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B
EQUIPMENT DETAIL

Personnel Costs:		Months	Monthly		Personnel
Name	Project Title	Budgeted	Costs	Overtime	Sum
Piatt GS-15 (in-kind)	Team Leader	2.0	0.0	0.0	0.0
Arimitsu GS-12 (in-kind)	Project Leader	6.0	0.0	0.0	0.0
GS-9	Biologist & Data Manager	11.0	7.6	5.0	88.6
GS-7	Biologist	6.5	5.4	4.0	39.1
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
		Subtotal	13.0	9.0	
				Personnel Total	$127.7

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
Piatt Meeting: Airfare, hotel, M&IE	1.0	1	5	0.2	2.0
Arimitsu Meeting: Airfare, M&IE	0.6	1	4	0.2	1.4
Arimitsu Field: Airfare, hotel, M&IE	0.6	2	15	0.1	2.0
Biologist Field (Middleton)	0.5	1	10	0.0	0.7
Biologist Field (Cordova)	0.5	1	15	0.1	1.3
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$7.3

FY18

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B
PERSONNEL & TRAVEL
DETAIL

Contractual Costs: Description	Contract Sum
ISRC - Middleton Island	40.0
Stark - Zooplankton/euphausiid ID, enumeration and weights	6.3
UW marine chemistry dept - nutrients	1.3
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$47.5

Commodities Costs: Description	Commodities Sum
Commodities Total	$0.0

FY18	**Project Title: Forage Fish Monitoring** **Primary Investigator: John Piatt & Mayumi Arimitsu** **Agency: USGS**	**FORM 4B** **CONTRACTUAL &** **COMMODITIES DETAIL**

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
EchoView Data Processing Software upgrade	1.0	24.1	24.1
CTD calibration			3.3
other field supplies			1.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
		New Equipment Total	$28.4

Existing Equipment Usage: Description	Number of Units	Inventory Agency
SIMRAD 38-120 kHz split beam hydroacoustics system	1	USGS
RECON handheld data loggers, cameras	4	USGS
CastAway CTD	1	USGS
SBE19plus V2 + fluorometer/turb + PAR + Beam transmissometer + pH + DO + SBE55 autofire water sampler	1	USGS
Trawlmaster Net Sounder	1	USGS
Zooplankton sampling gear	1	USGS

FY18

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B
EQUIPMENT DETAIL

Personnel Costs:		Months	Monthly		Personnel
Name	Project Title	Budgeted	Costs	Overtime	Sum
Piatt GS-15 (in-kind)	Team Leader	1.0	0.0	0.0	0.0
Arimitsu GS-12 (in-kind)	Project Leader	6.0	0.0	0.0	0.0
GS-9	Biologist & Data Manager	11.0	8.0	5.0	92.9
GS-7	Biologist	6.5	5.9	4.0	42.6
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
		Subtotal	13.9	9.0	
				Personnel Total	$135.5

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
Piatt Meeting: Airfare, hotel, M&IE	1.0	1	5	0.2	2.0
Arimitsu Meeting: Airfare, M&IE	0.6	1	4	0.2	1.4
Arimitsu Field: Airfare, hotel, M&IE	0.6	2	15	0.1	2.0
Biologist Field (Middleton)	0.5	1	10	0.0	0.7
Biologist Field (Cordova)	0.5	1	15	0.1	1.3
Biologist Field (Cordova)	0.6	1	15	0.1	1.4
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$8.6

FY19

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B
PERSONNEL & TRAVEL DETAIL

Contractual Costs: Description	Contract Sum
ISRC - Middleton Island	40.0
Stark - Zooplankton/euphausiid ID, enumeration and weights	6.3
UW Marine Chemistry Lab - nutrients	1.3
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$47.5

Commodities Costs: Description	Commodities Sum
Commodities Total	$0.0

FY19

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B
CONTRACTUAL &
COMMODITIES DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
EchoView Data Processing Software annual upgrade			7.1
CTD calibration			3.3
other field supplies			1.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
		New Equipment Total	$11.4

Existing Equipment Usage: Description	Number of Units	Inventory Agency
SIMRAD 38-120 kHz split beam hydroacoustics system	1	USGS
Small boats (Naiad RIB, Zodiac)	2	USGS
RECON handheld data loggers	4	USGS
Inshore fish sampling gear (beach seine, cast-nets, purse seine)	4	USGS
CastAway CTD	1	USGS
SBE19plus V2 + fluorometer/turb + PAR + Beam transmissometer + pH + DO + SBE55 autofire water sampler	1	USGS
Trawlmaster Net Sounder	1	USGS
Zooplankton sampling gear	1	USGS

FY19

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B
EQUIPMENT DETAIL

Personnel Costs:		Months	Monthly		Personnel
Name	Project Title	Budgeted	Costs	Overtime	Sum
Piatt GS-15 (in-kind)	Team Leader	2.0	0.0	0.0	0.0
Arimitsu GS-12 (in-kind)	Project Leader	6.0	0.0	0.0	0.0
GS-9	Biologist & Data Manager	11.0	8.4	5.0	97.2
GS-7	Biologist	6.5	5.9	4.0	42.6
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
		Subtotal	14.3	9.0	
				Personnel Total	$139.8

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
Piatt Meeting: Airfare, hotel, M&IE	1.0	1	5	0.2	2.0
Arimitsu Meeting: Airfare, M&IE	0.6	1	4	0.2	1.4
Arimitsu Field: Airfare, hotel, M&IE	0.6	2	15	0.1	2.0
Biologist Field (Middleton)	0.5	1	10	0.0	0.7
Biologist Field (Cordova)	0.5	1	15	0.1	1.3
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$7.3

FY20

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B
PERSONNEL & TRAVEL DETAIL

Contractual Costs: Description	Contract Sum
ISRC - Middleton Island	40.0
Stark - Zooplankton/euphausiid ID, enumeration and weights	6.3
UW Marine Chemistry Lab - nutrients	1.3
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$47.5

Commodities Costs: Description	Commodities Sum
Commodities Total	$0.0

FY20

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B CONTRACTUAL & COMMODITIES DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
EchoView Data Processing Software annual upgrade			7.1
CTD calibration			3.3
other field supplies			1.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
		New Equipment Total	$11.4

Existing Equipment Usage: Description	Number of Units	Inventory Agency
SIMRAD 38-120 kHz split beam hydroacoustics system	1	USGS
Small boats (Naiad RIB, Zodiac)	2	USGS
RECON handheld data loggers	4	USGS
Inshore fish sampling gear (beach seine, cast-nets, purse seine)	4	USGS
CastAway CTD	1	USGS
SBE19plus V2 + fluorometer/turb + PAR + Beam transmissometer + pH + DO + SBE55 autofire water sampler	1	USGS
Trawlmaster Net Sounder	1	USGS
Zooplankton sampling gear	1	USGS

FY20

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B
EQUIPMENT DETAIL

Personnel Costs:		Months	Monthly		Personnel
Name	Project Title	Budgeted	Costs	Overtime	Sum
Piatt GS-15 (in-kind)	Team Leader	2.0	0.0	0.0	0.0
Arimitsu GS-12 (in-kind)	Project Leader	6.0	0.0	0.0	0.0
GS-9	Biologist & Data Manager	11.0	8.8	5.0	101.8
GS-7	Biologist	6.5	6.2	4.3	44.9
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
					0.0
		Subtotal	15.0	9.3	
				Personnel Total	$146.7

Travel Costs:	Ticket	Round	Total	Daily	Travel
Description	Price	Trips	Days	Per Diem	Sum
Piatt Meeting: Airfare, hotel, M&IE	1.0	1	5	0.2	2.0
Arimitsu Meeting: Airfare, M&IE	0.6	1	4	0.2	1.4
Arimitsu Field: Airfare, hotel, M&IE	0.6	2	15	0.1	2.0
GS 9 Field Site: Airfare, M&IE	0.5	1	10	0.0	0.7
GS 9 Field Site: Airfare, M&IE	0.5	1	15	0.1	1.3
GS 7 Field Site: Airfare, M&IE	0.6	0	15	0.0	0.0
					0.0
					0.0
					0.0
					0.0
					0.0
				Travel Total	$7.3

FY21

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B PERSONNEL & TRAVEL DETAIL

Contractual Costs: Description	Contract Sum
ISRC - Middleton Island	40.0
Stark - Zooplankton/euphausiid ID, enumeration and weights	6.3
UW Marine Chemistry Lab - nutrients	1.3
capelin sandlance otolith	0.0
If a component of the project will be performed under contract, the 4A and 4B forms are required. **Contractual Total**	$47.5

Commodities Costs: Description	Commodities Sum
Commodities Total	$0.0

FY21

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B CONTRACTUAL & COMMODITIES DETAIL

New Equipment Purchases: Description	Number of Units	Unit Price	Equipment Sum
EchoView Data Processing Software annual upgrade			7.1
CTD calibration			3.3
other field supplies			1.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
			0.0
		New Equipment Total	$11.4

Existing Equipment Usage: Description	Number of Units	Inventory Agency
SIMRAD 38-120 kHz split beam hydroacoustics system	1	USGS
Small boats (Naiad RIB, Zodiac)	2	USGS
RECON handheld data loggers, cameras	4	USGS
Inshore fish sampling gear (beach seine, cast-nets, purse seine)	4	USGS
CastAway CTD	1	USGS
SBE19plus V2 + fluorometer/turb + PAR + Beam transmissometer + pH + DO + SBE55 autofire water sampler	1	USGS
Trawlmaster Net Sounder	1	USGS
Zooplankton sampling gear	1	USGS

FY21

Project Title: Forage Fish Monitoring
Primary Investigator: John Piatt & Mayumi Arimitsu
Agency: USGS

FORM 4B
EQUIPMENT DETAIL