FY 22-31 *PROJECT* PROPOSAL
LONG-TERM RESEARCH AND MONITORING PROGRAM

Does this proposal contain confidential information? ☐Yes ☒No

Project Number and Title

Gulf Watch Alaska Long-Term Monitoring Program: Pelagic Ecosystem Monitoring Component

22120114-C—Monitoring long-term changes in forage fish distribution, relative abundance, and body condition in Prince William Sound and the Northern Gulf of Alaska

Primary Investigator(s) and Affiliation(s)

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Project Abstract (maximum 300 words)

In the wake of the *Exxon Valdez* oil spill (EVOS) and subsequent crash of Pacific herring in Prince William Sound (PWS), efforts to monitor changes in forage fish have been integral to assessing the recovery of injured resources in the spill-affected region. For example, during the first 10-years of Gulf Watch Alaska (GWA), data from this project documented a heatwave-induced forage fish collapse which resulted in reduced energy flow through the pelagic food web that led to unusual mortality events in birds and mammals and fishery closures in the Gulf of Alaska (GOA). The primary goals of the GWA forage fish monitoring project are to: (1) monitor abundance and quality of key forage species, and, (2) better understand how underlying predator-prey interactions influence recovering species and pelagic ecology within PWS and the northern GOA; including top-down and bottom-up regulation of forage fish in the middle trophic level. Proposed work during the FY22-31 funding cycle will include the following objectives: continue (1) fall PWS Integrated Predator Prey (IPP) surveys, (2) spring/summer Middleton Island seabird diet sampling, (3) summer PWS aerial survey validation, and (4) summer/fall forage fish condition indices. We will expand analyses of formerly ancillary samples to provide new indices of juvenile salmon and juvenile walleye pollock. This will include determining hatchery vs. wild proportions and condition (size, energy density) for 10 years of archived plus future samples of juvenile pink and chum salmon collected by seabirds and developing an index of energy content of fall PWS juvenile walleye pollock using samples collected during IPP trawl sampling. Our continued efforts will extend and expand information on forage fish abundance and quality over time, improve our ability to identify drivers of predator-prey interactions, and further document recovery of resources affected by the oil spill and marine heatwaves.

EVOSTC Funding Requested* (must include 9% GA)

FY22	FY23	FY24	FY25	FY26	FY22-26 Total
$347,956	$320,312	$330,005	$340,091	$350,586	$1,688,950
FY27	**FY28**	**FY29**	**FY30**	**FY31**	**FY27-31 Total**
$358,855	$365,665	$373,488	$381,507	$389,726	$1,869,240
				FY22-31 Total	*$3,558,190*

**If the amount requested here does not match the amount on the budget form, the request on the budget form will considered to be correct.*

Non-EVOSTC Funds to be used, please include source and amount per source:

FY22	FY23	FY24	FY25	FY26	FY22-26 Total
$482,500	$482,500	$482,500	$482,500	$482,500	$2,412,500
FY27	**FY28**	**FY29**	**FY30**	**FY31**	**FY27-31 Total**
$482,500	$482,500	$482,500	$482,500	$482,500	$2,412,500
				FY22-31 Total	*$4,825,000*

Non-EVOSTC funds represent anticipated in-kind funding from the U.S. Geological Survey.

1. EXECUTIVE SUMMARY (maximum ~1500 words, not including figures and tables)

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 background variability in pelagic populations of whales, marine birds, and forage fish. The main problem was that long-term baseline data for these species' groups were largely absent. As a result, managers struggled to make informed decisions in their assessment of damages and recommendations for recovery. Ten years after the spill it was widely recognized that there had been a major climatic regime shift that altered the marine ecosystem prior to the spill. Recently, marine heatwaves of unprecedented spatial and temporal scale have led to a large-scale disruption in the pelagic marine food web. Ongoing monitoring is essential for understanding the impacts of natural variability in the pelagic marine ecosystem and for estimating additional impacts from anthropogenic stressors.

The Gulf Watch Alaska Long-Term Research and Monitoring (GWA LTRM) program's Pelagic Component contains five projects focused on four taxa that play a pivotal role in the pelagic ecosystem as trophic indicators for short and long-term ecosystem change: killer whales, humpback whales, forage fish, and marine birds. The overall goals of the Pelagic Component are to (1) determine the population trends of key pelagic species groups in Prince William Sound (PWS) and their abundance in adjacent shelf waters, and (2) improve our understanding of predator – prey relationships and their response to ecosystem changes. The following questions will shape the research of the pelagic team over the next decade:

1. *What are the population trends of key pelagic taxa in PWS - killer whales, humpback whales, marine birds, and forage fish?*
2. *What are indicators of ecosystem flux in these middle- and upper-level predators (e.g., population changes, shifts in distribution or abundance, variation in condition of individuals, changes in predator/prey relationships)?*
3. *How do these indicators interface with Environmental Drivers and with indicators in nearshore coastal and shelf environments to inform a larger picture of ecosystem change?*

Forage Fish Monitoring

Forage species are important in marine food webs because they transfer energy from plankton to seabirds, marine mammals, and predatory fish. Examples of focal forage taxa in PWS and the northern Gulf of Alaska

(GOA) include Pacific capelin (*Mallotus catervarius*), Pacific sand lance (*Ammodytes personatus*), Pacific herring (*Clupea pallasii*), juvenile walleye pollock (*Gadus chalcogrammus*), juvenile salmon (*Oncorhynchus* spp.), juvenile sablefish (*Anoplopoma fimbria*), and krill (Order: Euphausiacea; hereafter included under "forage fish").

Although the key role of forage fish in marine food webs is well documented (Pikitch et al. 2014, Arimitsu et al. 2021), prior to the Gulf Watch Alaska (GWA) program, long-term data on forage fish abundance and condition were relatively scarce within the EVOS-affected zone and adjacent shelf waters for several reasons. Forage fish are difficult and expensive to monitor because they are patchy in their distribution, comprised of species with markedly different life histories and habitat requirements, and they are predisposed to large fluctuations in population abundance. Furthermore, forage fish fisheries are restricted in the northern GOA owing to conservation measures put in place by federal fishery managers in the late-1990s (Witherell et al. 2000), and therefore directed surveys to inform management of most forage fish are non-existent or very limited (Ormseth 2020). One exception is herring, which was the focus of a commercial fishery in PWS for more than a century but has been closed since 1999 due to insufficient biomass (Muradian et al. 2017). Although adult walleye pollock, salmon, and sablefish are commercially fished and managed, long-term data on their juvenile stages are limited because most surveys conducted by state and federal management agencies are designed to target larger size classes.

In response to a lack of recovery of wildlife populations following the oil spill (Peterson et al. 2003), and evidence of natural background changes in forage fish abundance (Anderson and Piatt 1999), a significant effort was made to document forage fish distribution, abundance, and variability in PWS and Cook Inlet in the late 1990s (Thedinga et al. 2000, Brown 2002, Brown et al. 2002, Suryan et al. 2002, Ainley et al. 2003, Abookire and Piatt 2005, Speckman et al. 2005, Piatt et al. 2007). Survey methods for estimating abundance and distribution of forage fish included acoustic-trawl sampling (Haldorson et al. 1998, Speckman et al. 2005, Arimitsu et al. 2018) and aerial surveys for surface-schooling fish (Brown and Moreland 2000, Arimitsu and Piatt 2014, Arimitsu et al. 2018). Additionally, the use of predators as samplers of forage stocks has been widely applied as a complement to more traditional sampling methods (Sinclair and Zeppelin 2002, Boldt 2005, Yang et al. 2005, Piatt et al. 2018, McGowan et al. 2020, Ng et al. 2021). Specifically, the ability of Middleton Island's long term seabird diet data to demonstrate change in forage stocks is increasingly evident (Hatch and Sanger 1992, Thayer et al. 2008, Hatch 2013, Sydeman et al. 2017, Piatt et al. 2018, Thompson et al. 2019, Arimitsu et al. 2021).

Our forage fish synthesis work (Arimitsu et al. 2021) demonstrated the unique ability of the GWA forage fish monitoring project to provide a basis for understanding large-scale changes in higher predators – something that no single agency has been able to do previously. The synthesis work highlighted GWA timeseries on forage fish abundance and quality within PWS and the northern GOA, and also integrated these data with information from other agencies to provide a mechanistic understanding of the role that forage fish played in a large-scale disruption in the pelagic food web. During the Pacific marine heatwave, 2014 – 2016, an unprecedented die-off of common murres along the west coast of the USA signaled a major disruption in the marine ecosystem, and densities of dead birds across the North Pacific were greatest in PWS during winter of 2015/2016 (Piatt et al. 2020). We applied portfolio theory using data from Middleton Island seabird diets, which identified strong trophic instability at the onset of the heatwave (Fig. 1). Unlike decadal-scale variability underlying the regime shift in the late-1970s (Anderson and Piatt 1999), the heatwave's effect on the forage fish portfolio was steep but short-lived, driven by the simultaneous lack of capelin, sand lance, and herring in the system.

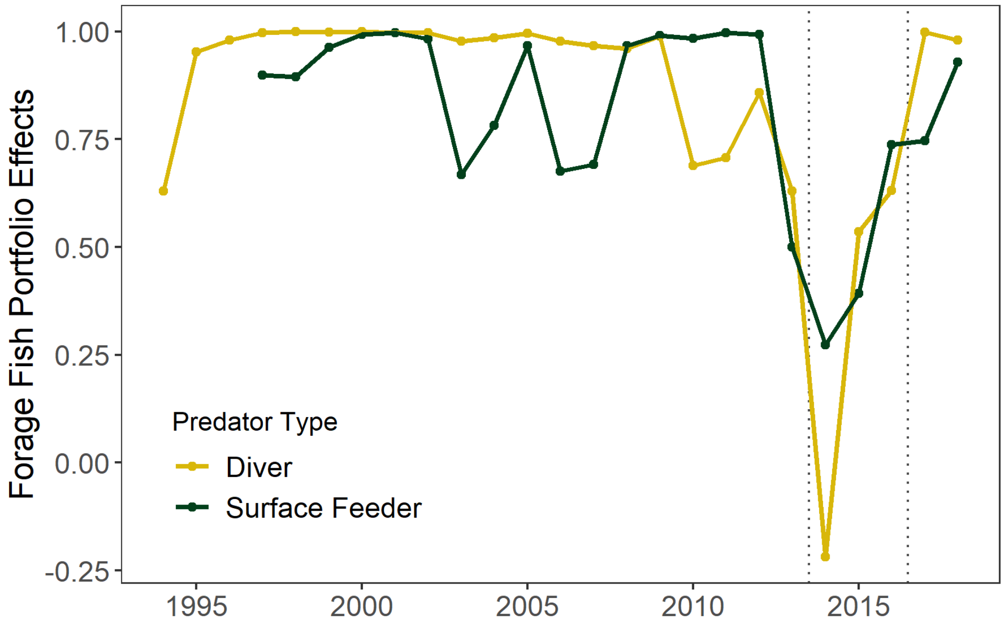

Figure 1. Portfolio effects as a measure of the degree of synchrony among capelin, herring and sand lance indices by seabird feeding guild at Middleton Island. Portfolio effects were computed from variance ratios across three-year centered rolling windows, with lower values indicating greater synchrony and lower buffering capacity by the forage fish community. Adapted from Figure 3 in Arimitsu et al. (2021).

An abrupt decline in capelin after the population peak in 2013 was evident in both seabird diets and survey data from the larger GOA region (Arimitsu et al. 2021). As part of the North Pacific Research Board's (NPRB's) Gulf of Alaska Integrated Ecosystem Research Program synthesis efforts, we contributed capelin trawl catch per unit effort (CPUE) and length frequency data collected during GWA (Arimitsu et al. 2018), Alaska Predator Ecosystem Experiment (APEX) work in the late-1990s (Piatt 2002), and other projects throughout coastal GOA (Arimitsu et al. 2007, 2008, 2016; Arimitsu and Piatt 2008) to identify capelin spawning habitat, core distribution (Fig. 2), larval drift, and spatio-temporal trends in abundance (McGowan et al. 2020). This work highlighted the importance of using multiple sources of information to track capelin abundance in the region. The resulting core distribution maps closely resembled spatial distributions of capelin from predator diets (including seabird diet data from Middleton Island) and survey catch per unit effort data compiled by Piatt et al. (2018).

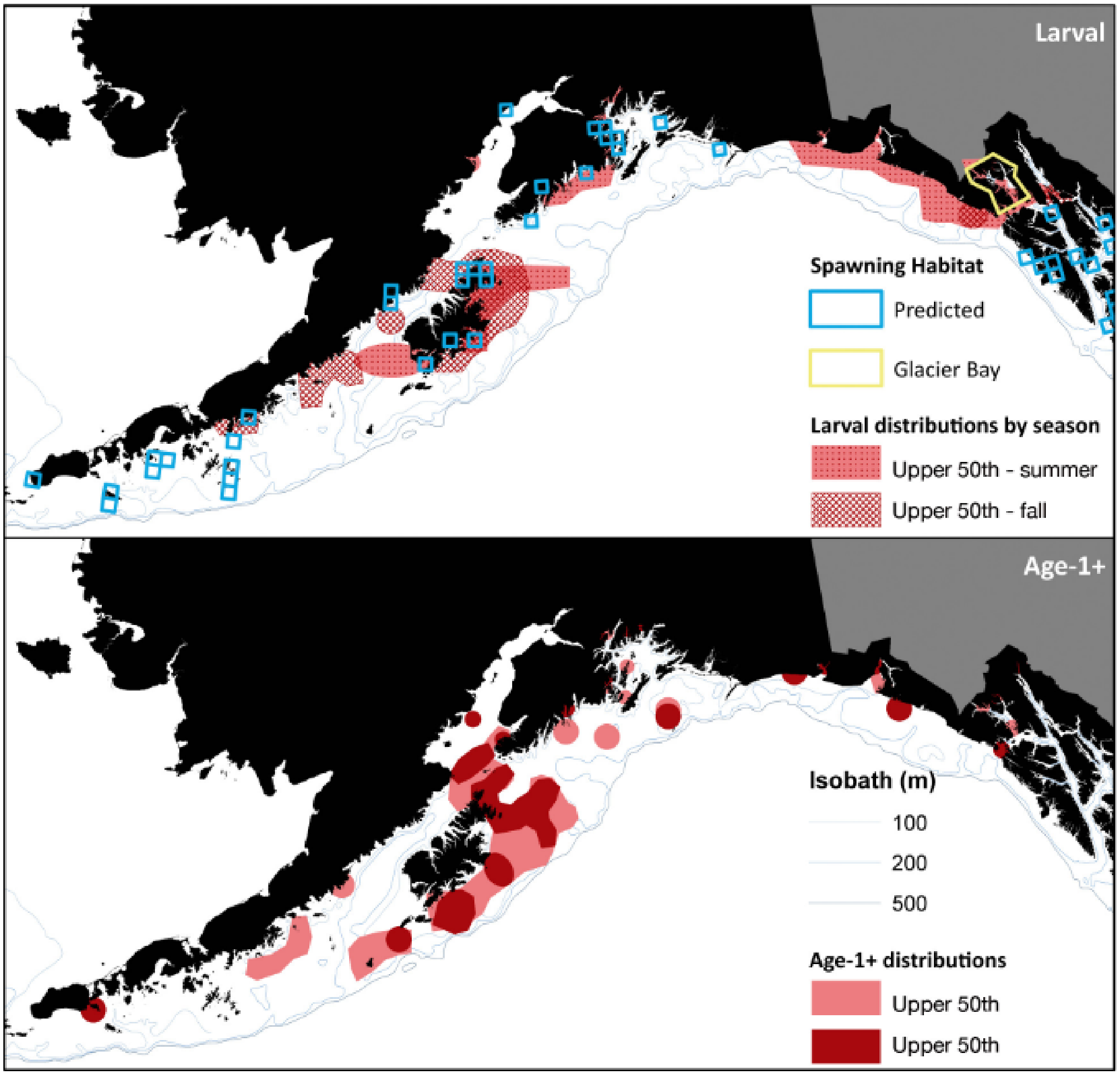

Figure 2. Conceptual diagram of areas that are consistently occupied by capelin in the Gulf of Alaska. (Top) Potential capelin spawning habitat based on the upper 25th log-normalized quartile classification, and larval distributions in summer and fall based on the upper 50th density percentile of catch per unit effort (CPUE). (Bottom) Distributions of age-1+ capelin based on the upper 50th percentile of CPUEs, with core areas indicated by the upper 75th percentile. Adapted from Figure 13 in McGowan et al. (2020).

We documented a reduction in euphausiid biomass during the heatwave due to the loss of cool-water species (Arimitsu et al. 2021). Data from the Seward Line showed that *Thysanoessa inermis* and *T. longipes* had dominated euphausiid communities during the cool years prior to the heatwave but these species declined abruptly by 2015. Similarly, we found that acoustic macrozooplankton indices from the Integrated Predator Prey (IPP) surveys declined in key regions with foraging predator aggregations after 2014 (Arimitsu et al. 2021). Reduced euphausiid biomass, along with historically low herring biomass in PWS, may largely explain the reduction in humpback whale encounter rates in the region (Fig. 3).

In addition to the collapse in the forage community portfolio, we also used GWA forage fish project data to identify compensatory changes in age-structure, size, growth, or energy content across the community. These data suggested that none of the forage fish species were fully able to mitigate adverse impacts of the heatwave despite the diversity of life history strategies employed by the different species that would have buffered the system under more normal seasonal or interannual variation in temperature. Using key data from GWA and Herring Research and Monitoring (HRM) programs we showed an extreme decline in PWS sand lance growth and nutritional quality (von Biela et al. 2019), a shift in capelin spawning age structure towards smaller, younger individuals, and anomalously low growth and weight in pre-spawning herring (Arimitsu et al. 2021).

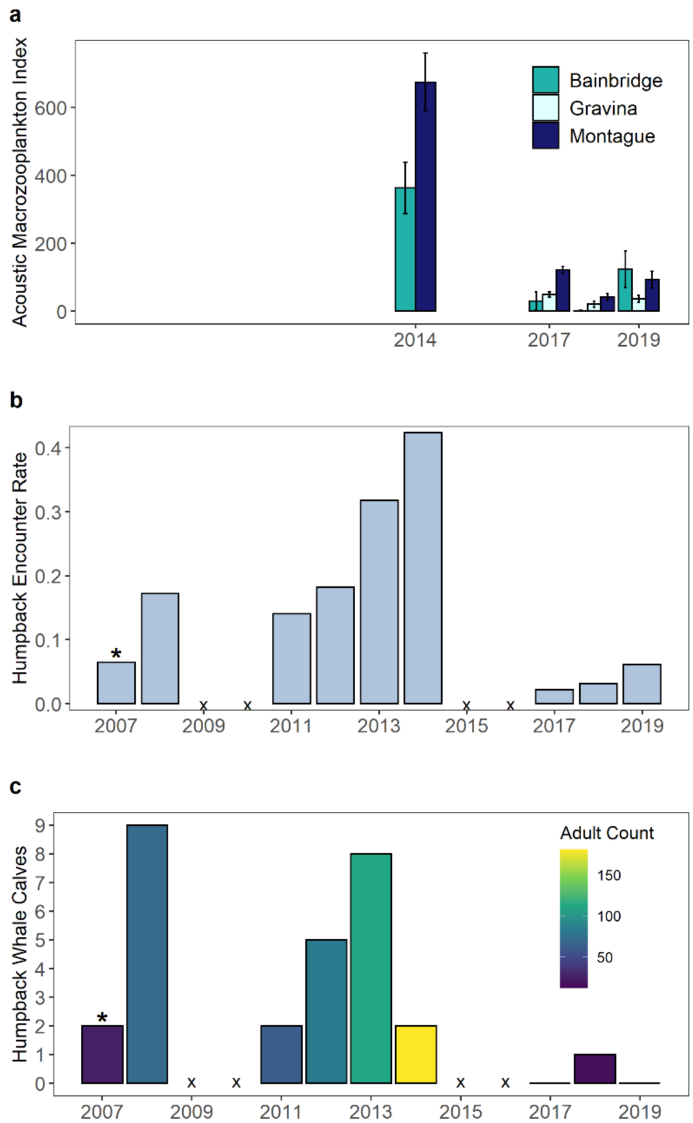

Figure 3. (a) Acoustic macrozooplankton index (nautical area scattering coefficient $m^2 nmi^{-2}$) sampled during the fall Integrated Predator Prey survey in Prince William Sound. (b) Humpback whale encounter rates (individuals km^{-1}). (c) Number of humpback calves (bars) and adult counts (color) observed on surveys. Adapted from Figure 9 in Arimitsu et al. (2021).

2. RELEVANCE TO THE INVITATION (maximum 300 words)

We seek to extend and enhance the long-term datasets initiated in 2012-2021 by the GWA forage fish project. Recent work has hypothesized that top-down forcing was important in the forage fish collapse that led to an unprecedented seabird die-off centered in the northern GOA during the peak of the Pacific marine heatwave

(Piatt et al. 2020, Arimitsu et al. 2021, Suryan et al. 2021). Extending forage fish time series on seabird diets, IPP surveys, and forage fish condition metrics (e.g., age, size, growth, and energy) will enable us to monitor signs of synchrony in the forage fish portfolio, and detect age or size truncation as evidence of potential top down regulation of the middle trophic level. In addition, since 2010 herring indices in seabird diets have increased, and variation in age-0 and age-1 herring length frequencies may provide early clues about recruitment and population dynamics of this injured resource. This project seeks to provide sound scientific data and products to inform management agencies and the public of changes in the environment and impact of these changes on injured resources. It will also provide information on changes in herring stocks and the overall health of the PWS ecosystem, and it will provide critical data management to support EVOS Trustee Council (EVOSTC)-funded programs and projects. The lead principal investigator (PI) will also serve on the program coordination team as the Pelagic Component lead through the transition to the GWA LTRM, while also producing high-quality products and science synthesis efforts to communicate results through public outreach to local and native communities. Within the Pelagic Component the forage fish project will provide data and products on forage fish including small pelagic schooling fish, and age-0 salmon, walleye pollock, and sablefish.

3. PROJECT HISTORY (maximum 400 words)

This project proposes to continue the GWA forage fish project (project number 21120114-C). During the first five-year funding cycle we tested and implemented a variety of survey methods that could yield robust indices for monitoring forage fish in the spill-affected region (Arimitsu and Piatt 2014, Arimitsu et al. 2018). Through this work, however, 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 warranted. Given limited resources and patchy predator-prey distribution in the Sound, we used a combination of systematic transects and predator guided surveys in the second five year funding cycle to home in on important marine mammal and marine bird foraging areas with significant aggregations of herring, walleye pollock, and krill. We also incorporated the sampling program at Middleton Island to ensure the continued collection of long-term data on capelin, sand lance, herring, juvenile salmon, juvenile sablefish, and other prey taxa in seabird diets. In 2019 we received additional funds to add aerial survey validation efforts in conjunction with the Herring Research and Monitoring program, and summer acoustic-trawl surveys in areas with high density forage schools. The latter project (i.e., summer acoustic-trawl surveys) will not be continued in FY22-31 due to logistical constraints and resource limitations, however sampling for PWS summer age-1 sand lance total energy and spawning capelin age-length time series will continue. We are proposing to add laboratory analyses for 10 years of archived and future juvenile salmon samples collected by seabirds at Middleton Island, and continue fall juvenile walleye pollock energy density time series.

Our accomplishments during the previous 10 years have resulted in 17 peer-reviewed publications, 3 program synthesis chapters, 10 reports, 14 publicly available datasets and associated metadata on the AOOS Gulf of Alaska Data Portal, 9 datasets and associated Federal Geographic Data Committee (FGDC) compliant metadata in 2 U.S. Geological Survey (USGS) data releases, 51 conference presentations (22 poster, 29 oral), 1 fisheries seminar at University of Alaska Fairbanks (UAF), 4 undergrad or lab lectures at University of Washington or University of Alaska Southeast, 2 invited speakerships at workshops or public community science symposiums, 2 Delta Sounds Connections articles, at least 22 media requests, 2 interviews for an article published in Science Magazine, 2 Alaska Native Science and Engineering Program interns, 1 University of Alaska Anchorage student mentorship, an outreach presentation at Chenega School, a podcast, a USGS website, a Pelagic Component conceptual graphic, and 2 web stories.

4. PROJECT DESIGN

A. Objectives and Hypotheses

Building on work from the first 10 years of the program – by extending and expanding forage fish time series data – is essential to understanding the recovery of resources injured in the spill, the response of the ecosystem to major perturbations, and predator-prey dynamics in the region. During the FY22-31 LTRM program funding cycle, our forage fish monitoring project framework includes the following hypotheses:

H1: Predator distribution and abundance varies with prey availability (abundance and quality)

H2: Changes in prey availability and quality occur in response to changes in habitat quality (e.g., phytoplankton/zooplankton and environment/temperature)

H3: Variation in prey availability occurs in response to predation pressure

Our sampling objectives are designed to identify predator-prey interactions including bottom up and top down regulation of forage fish:

Obj. 1: continue to monitor forage fish in areas where persistent aggregations of predators and prey are known to occur in PWS during fall

Obj. 2: continue long-term sampling of seabird diets on Middleton Island during spring and summer

Obj. 3: continue to ground-truth PWS aerial survey observations of forage fish schools during summer

Obj. 4: continue to assess variation in forage fish quality (e.g., age, size, or energy density) in PWS and the northern GOA during summer and fall

To meet our first sampling objective, we will continue annual fall IPP surveys in PWS to relate directly to the humpback whale (PIs Moran and Straley) and fall/winter marine bird (PIs Schaefer and Bishop) studies. We will share research platforms with these projects and work together in the same locations and times, thus providing valuable prey information for two pelagic-predator groups of key value to EVOSTC and the public while obtaining trend information for our forage fish monitoring program. The IPP provides acoustically determined species-specific forage biomass indices for herring, walleye pollock, capelin, and krill in the immediate vicinity of predator aggregations. To meet our second objective, in collaboration with Scott Hatch and Institute for Seabird Research and Conservation [ISRC] scientists, students, and volunteers, we will extend and expand the long-term seabird diet data collection program during spring and summer at Middleton Island. This work has proven to be a cost-effective means to monitor forage fish stocks and trophic stability in the northern GOA region. To meet our third objective, we will collaborate with the herring research and monitoring aerial survey team to ground-truth their observations and provide analysis support to identify spatio-temporal patterns in herring and sand lance schools, and estimate uncertainty in school characteristics. To meet our fourth objective, we will continue summer sampling of capelin and sand lance in PWS to extend and expand timeseries data on population demographics and condition. We will also continue the fall juvenile walleye pollock energy density timeseries using samples collected during the IPP survey. Finally, working in close coordination with the herring-salmon project (PI: Pete Rand and others), we will analyze otoliths and measure energy density of hatchery vs. wild juvenile pink and chum salmon samples collected by seabirds at Middleton Island.

B. Procedural and Scientific Methods

Obj. 1: continue to monitor forage fish in areas with known persistent aggregations of predators and prey within PWS during fall

We will continue the annual fall IPP survey, which includes annual acoustic-trawl surveys targeting persistent humpback whale feeding locations in Montague Strait, Bainbridge Passage and Port Gravina. 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. Combined efforts by LTRM's Pelagic Component humpback whale, fall/winter marine bird and forage fish PIs will provide an integrated dataset that facilitates analyses of predator prey relationships within the sampled regions (Table 1, Fig. 4).

Table 1. Objectives, indices, and coordinated tasks among Principal Investigators (PIs) for the fall Prince William Sound Integrated Predator Prey Surveys. Objectives in bold are the primary objectives related to the forage fish project.

Objective	Index	Task	PI
1. Estimate humpback whale abundance, diet, and distribution			
	Whale counts by subregion	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)
2. 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 - hydroacoustic transects, whale focal follows	Schaefer/Bishop (PWSSC), Arimitsu/Piatt (USGS), Moran (NOAA)/Straley (UAS)
3. Estimate index of forage fish and euphausiid abundance in seasonally predictable predator foraging areas			
	Species composition and acoustic biomass indices within persistent predator foraging areas	Integrated Surveys: hydroacoustic-trawl data, whale focal follows	Arimitsu/Piatt (USGS), Moran (NOAA)/Straley (UAS)
	Forage fish density and depth distribution	Integrated Surveys: hydroacoustic-trawl data, whale focal follows	Arimitsu/Piatt (USGS), Moran (NOAA)/Straley (UAS)
	Diet, energy density	Sample Analysis: herring, sand lance, capelin, juvenile pollock, euphausiids	Moran (NOAA) Arimitsu/Piatt (USGS)
4. Measure local conditions of marine habitat in seasonally predictable predator foraging areas			
	Oceanographic parameters and zooplankton biomass	Integrated Surveys: CTD, nutrients, and zooplankton samples	Arimitsu/Piatt (USGS)

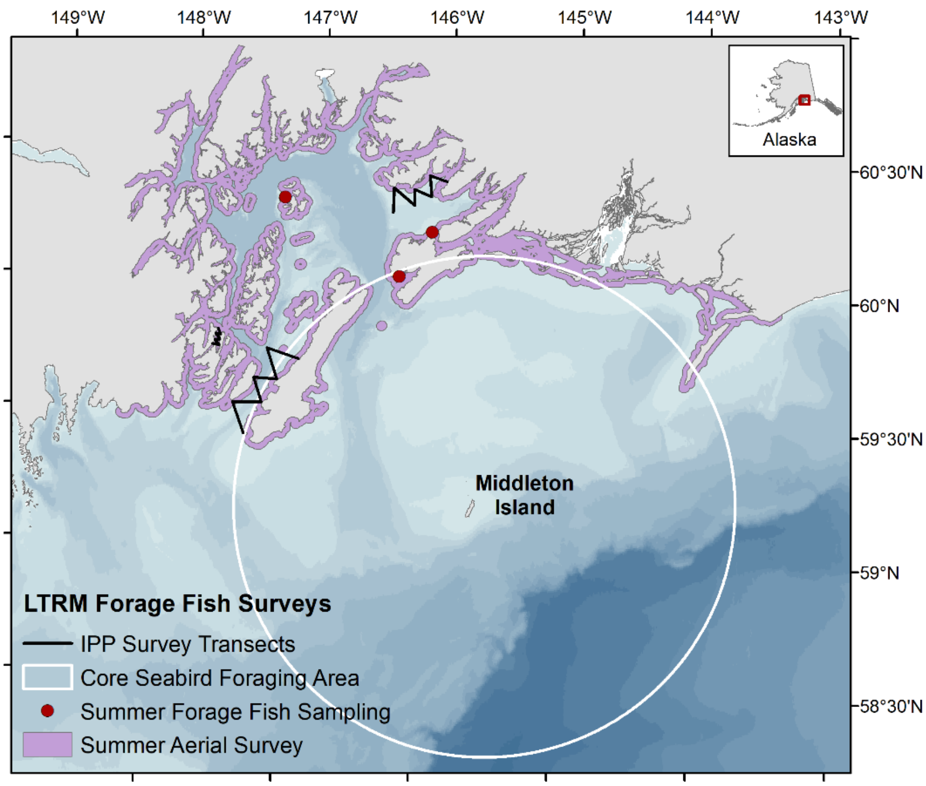

Figure 4. Distribution of Long-term Research and Monitoring (LTRM) forage fish sampling effort in Prince William Sound and northern Gulf of Alaska. Bathymetry is shown in blue with darker shades indicating deeper seafloor depth.

Acoustic-trawl surveys: Forage fish surveys will occur during daylight hours from the 15 m USGS R/V *Alaska Gyre* for coordinated study of predator-prey interactions within and among sub-regions. Our approach to quantifying daytime prey aggregations with acoustics concurrent to predator densities is modeled after work on similar species elsewhere (Gende and Sigler 2006, Friedlaender et al. 2009, Hazen et al. 2009, Boswell et al. 2016).

To estimate depth distribution, density and biomass of prey in the water column, a calibrated hull-mounted Kongsberg 38-120 kHz split-beam echosounder will be deployed along a zig-zag transect layout with a random starting point. The fixed transect layout was chosen to sample areas of persistent humpback whale habitat use (Fig. 4). 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. This will involve focal follows of individual whales, and prey mapping near groups of feeding whales.

Where we encounter strong and trawlable acoustic backscatter along a transect we will deploy a modified herring trawl to confirm species and size frequencies of ensonified targets. The net is 37.2 m^2 in area at the mouth, and 62 m in length. Mesh size diminishes from 5 cm at the mouth to 6 mm in the cod end, and there is a 3 mm cod end liner. Maximum fishing depth for this net is 125 m. Real-time trawl depth will be managed with a Notus Trawlmaster depth sensor attached to the headrope. Flow through the net will be recorded with a General Oceanic flowmeter. Vessel speed over ground will be maintained during trawls at less than 3 kt (5.6 km hr^{-1}), although speed varied depending on target depth and sea conditions. We will also use a variety of means to ground truth acoustic backscatter in untrawlable habitats (e.g., shallow nearshore areas) with other means as necessary (e.g., underwater video, jigs, dipnets, cast nets). Trawl catches will be enumerated, measured (total length [TL] and fork length [FL], mm) and weighed (0.05 g) by species at sea using a Marel motion compensating scale. A subsample of the euphausiid catch will be preserved in 3-5% formaldehyde solution for laboratory analysis of species proportion and weight. Subsamples of some forage fish will be frozen for later analyses in the laboratory (e.g., for age, condition, energy content, stable isotopes, harmful algal bloom, stomach samples).

Marine habitat: Concurrent sampling of physical conditions and zooplankton communities 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, photosynthetically active radiation (PAR) sensor, dissolved oxygen and pH sensor and water sampler. Water samples will be processed 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 preserved in formaldehyde in the field, then identified to species, enumerated, and weighed (0.01 mg) at a laboratory in Fairbanks, AK.

Obj. 2: continue the Middleton Island long-term seabird diet sampling during spring/summer

Seabirds nesting at Middleton Island collect forage fish from throughout inshore and offshore waters of the northeastern GOA (Osborne et al. 2020; Fig. 4). Seabird diet samples will be collected between April and August each year (Hatch and Sanger 1992, Thayer et al. 2008). Kittiwake food samples are collected when adults regurgitate whole fish and other prey soon after capture for morphometrics and/or tagging. Nestling diets of rhinoceros auklets are sampled by collecting bill-loads from chick-provisioning adults, usually once or twice per week from early July through early or mid-August. Seabird diet samples will be identified, and individual lengths and weights will be measured whenever possible. Fish morphometrics are more reliably measured for rhinoceros auklet prey items because they deliver whole fish, unlike kittiwakes that regurgitate partially digested prey items. Rhinoceros auklet diet samples will be frozen in the field for further laboratory analysis (e.g., ageing, energetics, stable isotopes).

Obj. 3: continue to ground truth PWS aerial survey observations during summer

In coordination with Scott Pegau's (Prince William Sound Science Center [PWSSC]) proposed forage fish aerial survey project (22220111-K) we will validate aerial forage fish survey observations with vessel-based sampling (Fig. 4). Aerial surveys are conducted from a Cessna 185 (or similar) float plane traveling at speeds of 100-120 kts and an altitude of 300 m. Surveys are flown parallel to shore. The primary observer views from the plane towards the shore and a secondary observer views the offshore side of the plane. Observations collected are the date, time, location, altitude, number, and size of schools of forage fish. Fish schools are identified by species (Pacific herring, Pacific sand lance, and other forage fish) and herring are classified by age (1 or 2+). Species identification is based on characteristics of the school including color, shape, location. Previous work suggests that experienced aerial survey observers can discriminate between herring and sand lance schools on the basis of school characteristics such as shape and color (Norcross et al. 1999, Arimitsu et al. 2018). Herring schools are round (Fig. 5) and the tendency of individuals within schools to roll creates a silver lateral flashing not observed in other species. Younger (smaller) herring show a finer pattern of flashing compared to older fish. Age-0 herring transform from larval- to scaled-states in July, and then school near the surface in protected bays (Stokesbury et al. 2000, Norcross et al. 2001). Adult herring (age-2+) tend to form larger schools in deeper water than age-1 herring. Sand lance schools are darker in color, irregularly shaped and prefer shallow areas with sand and gravel habitats (Fig. 5; Norcross et al. 1999, Ostrand et al. 2005). The size of schools will be estimated by using a sighting tube constructed of PVC pipe with a grid drawn on mylar on the far end (see Norcross et al. 1999 for details). The focal length (F) of the tube is 210 mm, and a full tick mark on the grid is 1 cm. School size will be reported as small (diameter < 0.5 ticks), medium (> 0.5 ticks and < 1.0 ticks), and large (> 1.0 tick marks). From an observation height of 300 m this provides an equivalent surface area of < 93 m^2 for small schools, 93 – 374 m^2 for a medium school and > 374 m^2 for a large school.

During June PWS aerial surveys (Fig. 4), observations of species and age or size will be validated by a ground crew in a skiff with access to shallow nearshore areas. During validation efforts the spotter pilot circles over the fish schools, relays the observation, and guides the skiff to the school via VHF radio. When the fish school is detected by the ground crew they deploy jigs with varying hook sizes, dip nets, cast nets, purse seine, or a submersible video camera to capture fish or images for species and size information. Herring, which is the only species classified by age class during surveys, will be captured during aerial validation and identified to species, aged with scales, and measured for length and weight. Other schools will be verified to species at least, and any fish caught will be measured for length and weight. The ground crew will validate as many schools as possible in an area before the aerial team continues surveys for the day, and we will attempt to work in different regions of the Sound during the survey period. Approximately 10% of flight time (4-6 hours) will be dedicated to validation effort on an annual basis. A total of 80 schools were validated between 2014 and 2021 (average: 13 schools/year, range: 2 in 2020 due to low effort during the pandemic to 25 schools in 2021). Of those, 85% of schools were correctly classified by species, and 75% of herring schools were correctly classified by age-class. Additionally, one school was determined to contain both age-0 herring and age-0 sand lance, and 8% of herring schools contained mixed-age schools (e.g., schools composed of age-1 and age-2+ fish).

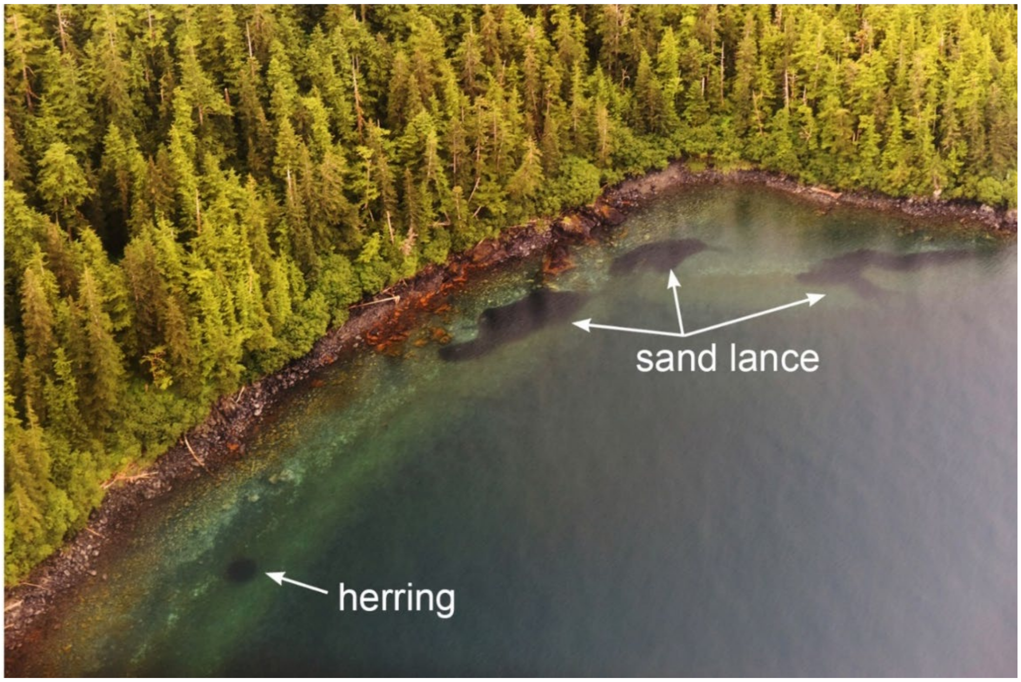

Figure 4. Aerial photograph of typical juvenile Pacific herring (n = 1) and Pacific sand lance schools (n = 3) along shorelines in Prince William Sound, AK. Herring schools are typically round or oval and sand lance schools are darker and irregularly shaped.

Obj. 4: continue to assess changes in forage fish quality (e.g., age, size, growth, or body condition) in PWS and the northern GOA during summer/fall

Identifying changes in age, size and energy content has proven to be a useful way to track the nutritional quality of forage fish over time (von Biela et al. 2019, Arimitsu et al. 2021). To extend timeseries for July-spawning capelin and age-1 sand lance, we aim to collect 200 spawning capelin from Port Etches and 200 sand lance from Naked Island or Middleground Shoal using dip nets, cast nets, or a purse seine. Total length (mm) and weight (±0.05 g) of individual fish will be measured in the field whenever possible, and frozen for laboratory analysis. In the lab, age will be assigned by counting translucent zones on sagittal otoliths (Arimitsu et al. 2018, von Biela et al. 2019). The otoliths will be extracted, dried, and examined under reflected light using a Leica M60® dissection microscope. Under reflected light, translucent zones appear dark and opaque zones appear white. Translucent bands forming on the otolith edge are considered incomplete, assuming a January 1 birth date for sand lance (Robards et al. 2002) and capelin (Rottingen and Alvarez 2011). Digital images of each otolith will be captured using a Leica DFC425 digital camera, and age will be assessed by two independent readers. Energy density will be measured for a random subsample of 10 age-1 sand lance and 10 mature male capelin by using a semimicro Parr 6725 calorimeter. Energy density will be reported per unit dry mass (kJ g^{-1} dry mass), and whole body energy (kJ $fish^{-1}$) will be calculated by multiplying energy density by dry mass (g).

Fall condition of age-0 walleye pollock is sensitive to environmental variation and has been shown to be positively correlated with recruitment (Heintz et al. 2013). In collaboration with John Moran (National Oceanic and Atmospheric Administration [NOAA] Auke Bay Laboratories) we will continue to collect age-0 walleye pollock in trawls conducted during IPP survey work to extend the fall energy density and condition factor K timeseries (Fig. 6). Energy density will be measured with bomb calorimetry following the procedures described above.

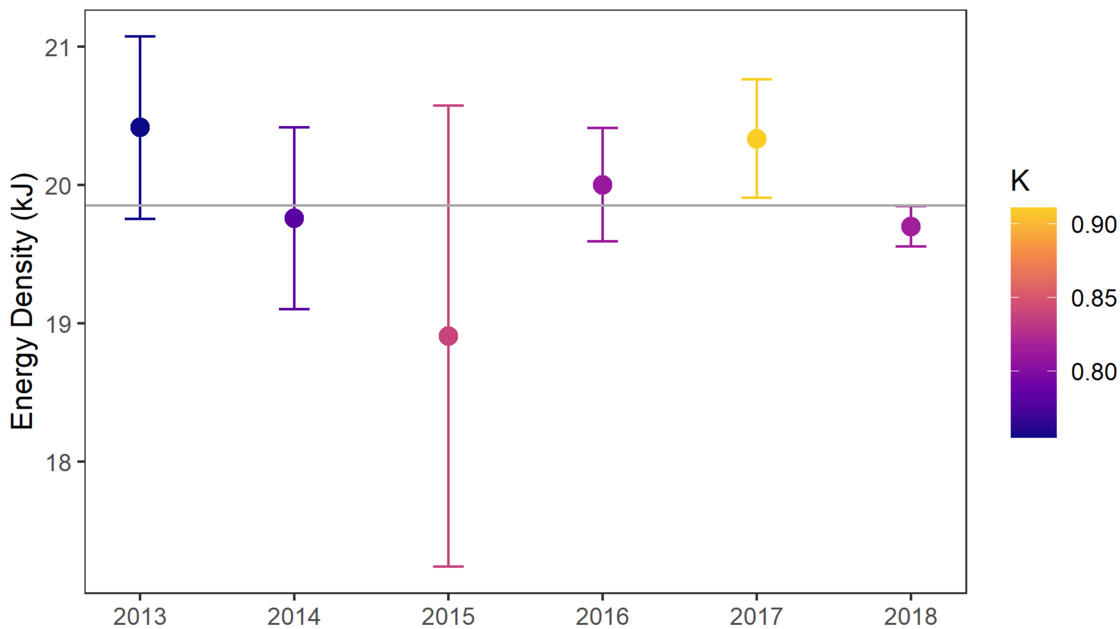

Figure 5. Interannual variation in Prince William Sound fall age-0 walleye pollock energy density (mean ± standard deviation) and Fulton's K condition factor (color).

We propose to begin a new timeseries to complement other work on hatchery vs. wild salmon in the region (Knudsen et al. 2021; P. Rand herring-salmon proposed project [22220111-L]). Rhinoceros auklets at Middleton regularly sample juvenile pink and chum salmon (size range = 56 – 190 mm) within their core foraging range. There are 860 archived (frozen) juvenile pink and chum salmon samples that were collected by provisioning seabirds during July-August from 2010 to 2020 (Fig. 7). These fish are likely from a mix of hatchery and wild origin that have recently out-migrated from streams in the region as smolt and were intercepted by the seabirds as they exited PWS through ocean passages at Hinchinbrook and Montague. For salmon the early ocean migration period is important for survival, and surveys of juvenile salmon have reliably predicted year class strength in southeast Alaska (Orsi et al. 2016). This effort would make use of the samples we already collect at Middleton Island.

In year 1 of the project we will process archived samples and continue processing samples each year thereafter to ultimately create a 21-year timeseries of juvenile pink and chum salmon condition (i.e., size and energy content). To better understand hatchery vs. wild proportions, and potential differences in body condition and lipid content over time (Moss et al. 2016), we will use thermal marks on otoliths to identify hatchery marked individuals, and randomly subsample 10 hatchery and 10 unmarked individuals from each species for each year following the methods described in Orsi et al. (2004). Sample size of 10 fish is based on the sample size we use for similar analysis of sand lance (von Biela et al. 2019). Analyses of juvenile chum from Bristol Bay found relatively low CVs (3%) in energy density measures (Burrill et al. 2018), and therefore we anticipate that our sample size will be successful in detecting change over time.

Because the samples are collected over the course of the chick rearing period (ca. 5- 6 weeks), existing information on size may be useful for understanding interannual variability in growth of juvenile salmon (Fig. 8), as previously documented in juvenile salmonids measured over time in southeast Alaska (Orsi and Ferguson 2017). We found the interaction between Julian day and year explain 53% of the variation in the mean length per day ($p < 0.001$). This relationship could be strengthened once we process otoliths to know which samples originate from wild vs. hatchery populations. The bulk of the costs for this part of the work (i.e., $34K in year 1 of the project) will support GS9 salary for lab work associated with processing 11 years of archived samples. After year 1 no extra costs are incurred to process annual samples in the lab as we are already planning similar work for other forage fish species. We are working closely with Pete Rand (PWSSC) and Jennifer Morella (ADF&G) to ensure that methods are complementary.

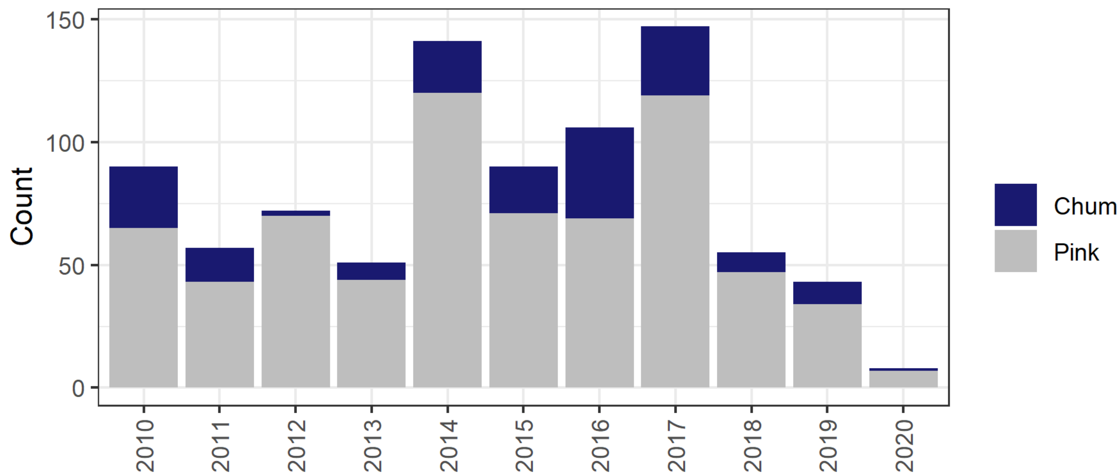

Figure 6. Juvenile pink and chum salmon archived sample counts from seabird diets at Middleton Island.

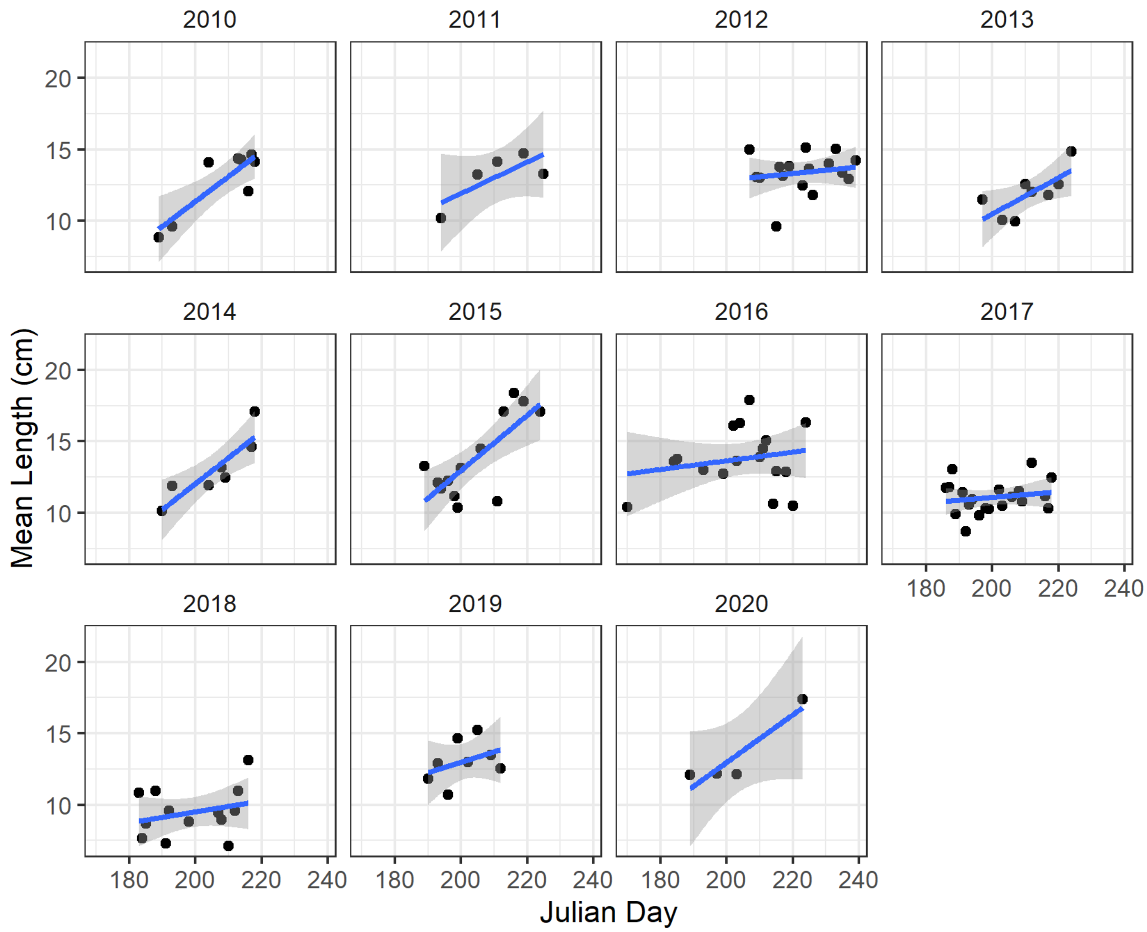

Figure 7. Juvenile pink salmon mean length by Julian day and year (OLS: $R^2 = 0.53$, $p < 0.001$). Samples were collected by seabirds at Middleton Island.

C. Data Analysis and Statistical Methods

Acoustic analysis

Acoustic data will be analyzed following standard methods (Simmonds and MacLennan 2005, De Robertis et al. 2010, McGowan et al. 2016, Arimitsu et al. 2021). Echo integration of acoustic data between 1 m above the bottom (or max depth of 500 m) and 4 m below the surface will be performed in EchoView software (Hobart, Tasmania, Australia). Ambient and vessel-generated noise will be removed (De Robertis and Higginbottom 2007). Linear measurements of volume backscatter (s_v, m^{-1}) will be averaged in 100 m horizontal by 5 m vertical cells and converted to logarithmic units (mean volume backscattering strength, MVBS, dB re 1 m^{-1}).

To identify broad-scale differences in fish and macrozooplankton indices by region among years, we will classify acoustic backscatter in the water column using frequency response methods described for inshore waters (De Robertis and Ormseth 2018). Relative frequency response ($\Delta S_{v_{120kHz - 38\ kHz}}$) in each 5 ping by 5 m cell was computed, and samples in the range of -16 to 8 dB were classified as fish, and samples in the range of 8 to 30 dB were classified as macrozooplankton. We will use a minimum threshold of -67 dB for fish, in order to exclude jellyfish (Parker-Stetter et al. 2016) that overlap in acoustic frequency response with fish at lower thresholds, and -75 dB for macrozooplankton (Arimitsu et al. 2021). Because acoustic properties of fish are species specific, the target strengths (TS) for captured species will be estimated using the relationships in Table 2 (Thomas et al. 2002, Gauthier and 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 2. 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 and Ona 2003, Sigler and 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.

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 acoustic transect coverage Λ (Simmonds and MacLennen 2005):

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

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

$$r^2 n^3 = 12CV^2\left(z\alpha/_2 + z_\beta\right)$$

where D = distance in km of acoustics 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 0.05 for all sub-areas combined (n = 15, CV = 0.21), 0.06 in Montague (n = 15, CV = 0.27), 0.06 in Port Gravina (n = 15, CV = 0.26) and 0.05 in Bainbridge (n = 15, CV = 0.24), (Fig. 9).

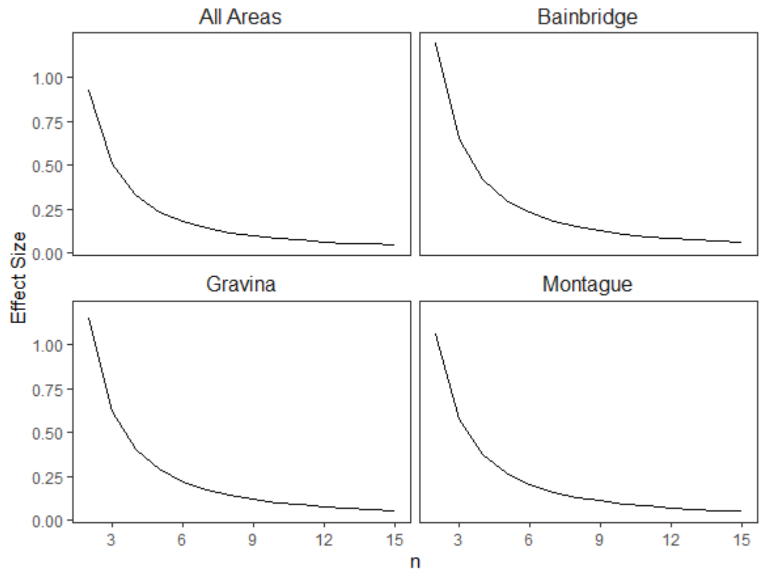

Figure 8. Power analysis for acoustic data.

Seabird Diet Analysis

Predator diets are increasingly recognized for their ability to provide cost-effective and accurate indices of prey biomass (Ng et al. 2021). The proposed work will expand timeseries that use surface-feeding kittiwakes and diving rhinoceros auklet diet proportions (relative frequencies and proportion of biomass, respectively) to characterize changes in forage fish availability over time (Hatch and Sanger 1992, Hatch 2013, Sydeman et al. 2017, Piatt et al. 2018). Notably, seabird diets were a key indicator of an abrupt decline in capelin at the onset of the marine heatwave, a finding that mirrored CPUE data from NOAA acoustic and trawl surveys in the GOA (McGowan et al. 2020, Arimitsu et al. 2021). More recently portfolio effects have been used as a measure of synchrony among frequencies of forage fish by seabird feeding guild (Fig. 1; Arimitsu et al. 2021). To identify patterns across relatively short time-scales, we will calculate variance ratios $VR_{i,j}$ for each of *i* three-year centered rolling time windows and *j* feeding guilds such that:

$$VR_{i,j} = {var\left(\sum F_{i,j}\right)}\Big/{\sum var\left(F_{i,j}\right)}$$

where $var\left(\sum F_{i,j}\right)$ is variance of the frequencies summed across forage fish species at time window *i*, for feeding guild *j*, and $\sum var\left(F_{i,j}\right)$ is the sum of the variance of frequencies summed across forage fish species at time window *i* for feeding guild *j*. Portfolio effects will be calculated as 1 - $VR_{i,j}$ so that lower values indicate greater synchrony across species and therefore lower trophic stability in the system (Thorson et al. 2018). Analysis of portfolio effects in this way has tremendous potential to provide an early warning signal for managers in the future. For example, a collapse of the forage fish portfolio in the northern GOA was first signaled by seabird diets after the 2015 summer field season, which was *before* the peak of the common murre die-off later that winter.

Aerial Survey Analysis

Georeferenced flight paths and school observations will be mapped in GIS. Effort will be estimated by calculating the length (km) of shoreline covered in each survey period. Annual distributions of schools by species will be evaluated with kernel density estimates at 500x500 m cell resolution. For each species group we will compute an index of shoreline school density in each of 13 regions by multiplying the error rate identified by validation efforts by the size-weighted number of schools counted and dividing by effort following Brown et al. (2002). We will use a ratio estimator to calculate mean school density scaled by effort. Bootstrapped bias-corrected and accelerated (BC_a) 95% confidence intervals will be calculated by resampling the density estimates 1000 times (DiCiccio and Efron 1996). We also plan to evaluate the use of more sophisticated modeling approaches such as vector autoregressive spatio-temporal models (Thorson 2019) for these data.

Fish Condition Analysis

Changes in spawning capelin and sand lance age structure will be evaluated as the proportion of each age class in the sample population. Using samples we collect during the summer, we will use log normal mixture models to identify proportions, and mean (and standard deviation) length of each size class (MacDonald and Pitcher 1979) using the R package 'mixtools' (Benaglia et al. 2009).

To identify the statistically significant effect size based on the sample size for calorimetry data we intend to measure in each year of the study, we conducted a power analysis using the anticipated number of years (n), assuming 10 samples per year (following von Biela et al. 2019 for age-1 sand lance in PWS) per species. We set $\alpha = 0.05$, and estimated power at three levels: 0.8, 0.85, and 0.9 following methods described in Cohen (1988) with the R package 'pwr' (Fig. 10, Table 3).

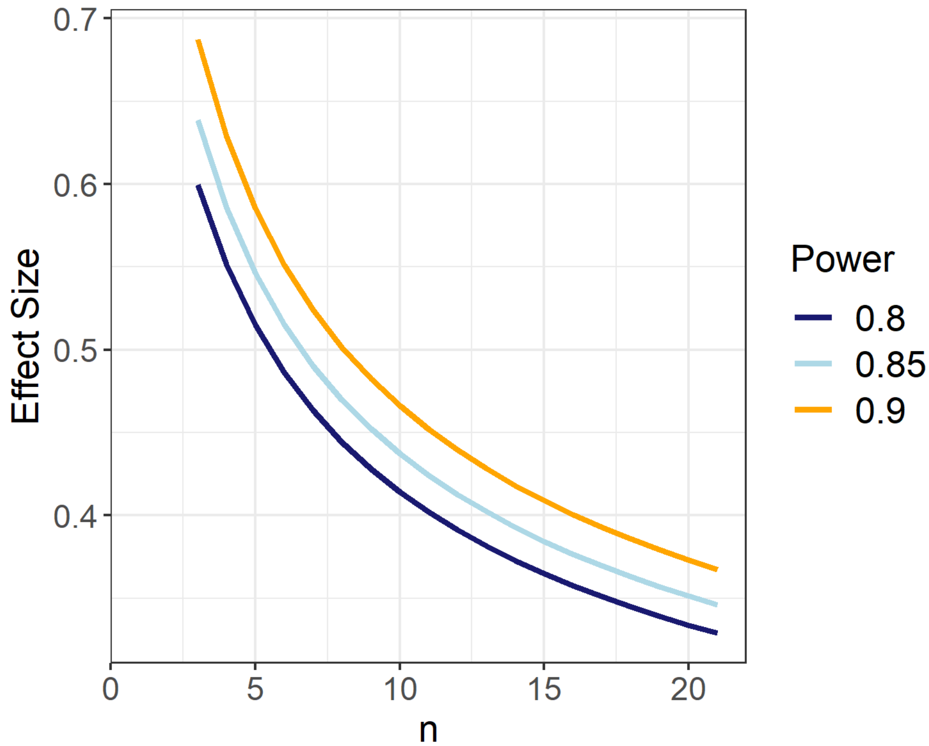

Figure 9. Effect size as a function of number of years (n) for calorimetry measurements assuming 10 samples per species per year and α=0.05.

Table 3. Effect size for calorimetry data by species.

Species	n	Power = 0.8	Power = 0.85	Power = 0.9	α
capelin	13	0.42	0.40	0.43	0.05
Age-0 walleye pollock	16	0.40	0.38	0.40	0.05
Sand lance	18	0.39	0.36	0.39	0.05
Juvenile salmon	21	0.37	0.35	0.37	0.05

D. Description of Study Area

The proposed work falls within the spill area in PWS and adjacent shelf region within the northern GOA (Fig. 4). The approximate bounding coordinates of the study area are: 61.39472, -148.719; 57.94556, -148.392; 58.90972, -144.254; 61.41222, -144.686.

5. COORDINATION AND COLLABORATION

A. With the Alaska SeaLife Center or Prince William Sound Science Center

We work closely with PWSSC scientists Scott Pegau, Mary Anne Bishop, Anne Schaefer, Rob Campbell, Caitlin McKinstry, Pete Rand, and Kristin Gorman to coordinate field work and collaborate on products. We coordinate our deliverables through Donna Aderhold, PWSSC, and have provided articles for the PWSSC annual publication Delta Sound Connections. We collaborate with Tuula Hollman at the Alaska SeaLife Center.

B. Within the EVOSTC LTRM Program

Environmental Drivers Component

We have demonstrated strong collaborative relationships with all the Environmental Drivers PIs through recent synthesis publications (Arimitsu et al. 2021, Suryan et al. 2021). For example, variability in zooplankton indices and physical oceanography are important drivers of forage fish distribution, abundance, and quality. We will continue to work across components in a similar manner.

Pelagic Monitoring Component

Mayumi Arimitsu is the Pelagic Component lead and regularly coordinates science products, professional presentations, and pelagic program updates among the team of PIs. Additionally, in fall 2020 Arimitsu coordinated a marine bird working group meeting and continues to promote greater integration among pelagic projects. The forage fish project collaborates closely with humpback whale and fall/winter marine bird survey PIs to conduct the fall IPP surveys.

Nearshore Monitoring Component

We collaborated with the nearshore team on recent synthesis work by incorporating nearshore marine bird survey data in synthesis publications, and we will continue to work together within the marine bird working group for future syntheses. We also engage with nearshore PIs regularly at PI meetings and anticipate future work across components for synthesis activities.

Lingering Oil Monitoring Component

Because lingering oil data are collected once in a 5-year period and the oil is not currently bioavailable, we do not anticipate incorporating these data into our project. We look forward to status reports from the lingering oil component.

Herring Research and Monitoring component

We work closely with Scott Pegau during aerial surveys and in program coordination activities. Herring are forage fish and our work logically dovetails with the herring research and monitoring program. Recently we have been looking into how the Middleton Island seabird diets may provide additional information (length frequencies) that may be relevant to herring recruitment. We are also working with Pete Rand (PWSSC) and Stormy Haught (ADF&G) on juvenile salmon otolith and calorimetry methods to ensure our respective projects are complimentary.

Synthesis and Modeling Component

Our engagement in synthesis and modeling activities is and will continue to be substantial. We led a synthesis report chapter and manuscript (Arimitsu et al. 2020, 2021), and presented this work at Alaska Marine Science Symposium in 2018 and 2021, Ocean Sciences meeting in 2018, and the PICES meeting in 2019. We also participated as coauthors and provided data for the synthesis paper by Rob Suryan et al. (2021). During the 2018, 2019, and 2020 fall PI meetings Mayumi Arimitsu led group synthesis discussions and will continue strong collaborations with the Synthesis and Modeling Component (PI R. Suryan) in FY22-31.

Data Management Project

We work with Alaska Ocean Observing System data managers to ensure our data and metadata responsibilities are met in a timely manner. This includes annual meetings with Stacey Buckelew. We also work with USGS data managers to publish program datasets according to agency data policies.

C. With Other EVOSTC-funded Projects (not within the LTRM Focus Area)

We regularly share data and information with U.S. Fish and Wildlife Service (USFWS) biologists working on murrelet and pigeon guillemot restoration projects including Robb Kaler, Liz Labunski, and Marc Romano, all with USFWS, and Tuula Hollman at the Alaska SeaLife Center. We are working with USFWS, National Park Service, Alaska SeaLife Center, and ABR Inc. researchers on new at-sea survey logging and data processing software, which will be made freely available to the public. As the EVOSTC funds future projects outside the GWA LTRM program we will evaluate their applicability to our project and coordinate as appropriate.

D. With Proposed EVOSTC Mariculture Focus Area Projects

We look forward to working with the EVOSTC's Mariculture Program and projects they embark on. We anticipate they will be interested in GWA LTRM datasets and we expect there will be opportunities for coordination and collaboration.

E. With Proposed EVOSTC Education and Outreach Focus Area Projects

The GWA LTRM program will develop an outreach plan that includes coordination and collaboration with the Trustee's Education and Outreach Program and projects. We look forward to participating in education and outreach opportunities where our project findings can contribute to a better understanding of the GOA ecosystem by the general public.

F. With Trustee or Management Agencies

Data and fish samples gathered as part of the GWA LTRM forage fish study will be used by NOAA National Marine Fisheries Science in annual stock assessments (Bridget Ferriss and Stephani Zador, Ecosystems Status Report to the Northwest Pacific Fisheries Management Council). We are collaborating on research to better understand the effects of harmful algal blooms on seabirds and food webs (North Pacific Research Board study: Xiuning Du, Oregon State University, and Rob Campbell, PWS Science Center; Wayne Litaker, Steve Kibbler and Kris Holderied (NOAA), US Geological Survey (USGS) study PIs: Sarah Schoen, Matt Smith, Caroline van Hemert). The GWA LTRM forage fish work is also complementary to a related USGS-Bureau of Ocean Energy Management study of forage fish and seabird trends in areas of oil and gas development in Cook Inlet. This continued coordination and collaboration with GWA PIs (Kris Holderied, NOAA; Kathy Kuletz, US Fish and Wildlife Service) in Cook Inlet and Kachemak Bay increases the scope of LTRM ecosystem monitoring in the Northern GOA.

G. With Native and Local Communities

The GWA LTRM program and this project are committed to involvement with local and Alaska Native communities. Our vision for this involvement will include active engagement with the Education and Outreach Focus Area (see above), program-directed engagement through the Program Management project (2222LTRM-A&B), and project-level engagement. During the first year of the funding cycle (FY22), the GWA LTRM program will reach out to local communities and Alaska Native organizations in the spill affected area to ask what engagement they would like from us and develop an approach that invites involvement of PIs from each project, including this one. Our intent as a program is to provide effective and meaningful community involvement that complements the work of the Education and Outreach Focus Area and allows communities to engage directly with scientists based on local interests.

In addition, this project will continue engaging with local communities as we have during the first 10 years of the program, including community lectures or communications through popular articles like *Delta Sound Connections*. We will also continue to provide mentorships to students, as well as opportunities for volunteers or Alaska Native Science and Engineering Program interns to work in the field or lab settings.

6. DELIVERABLES

We will submit progress reports, work plans, and a final report according to required schedules. Data will be uploaded to the research workspace within 1 year of data collection. We anticipate leading at least three peer reviewed publications and contributing data to many others over the course of the program (1.7 publications/year average during the first 10 years of GWA). We will give scientific presentations (oral and poster) on a regular basis at professional conferences. Finally, we will also maintain an informational website hosted by USGS and provide public outreach articles or presentations whenever possible.

7. PROJECT STATUS OF SCHEDULED ACCOMPLISHMENTS

Project milestones and tasks by fiscal year and quarter, beginning February 1, 2022. Fiscal Year Quarters: 1= Feb. 1-April 30; 2= May 1-July 31; 3= Aug. 1-Oct. 31; 4= Nov. 1-Jan 31.

	FY22				FY23				FY24				FY25				FY26			
Milestone/Task	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Milestone 1: admin and 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		
Milestone 2: data acquisition																				
Middleton Island Seabird Diets	X	X	X		X	X	X		X	X	X		X	X	X		X	X	X	
Aerial Survey Validation		X				X				X				X				X		
Summer Forage Fish Sampling		X				X				X				X				X		
Integrated Predator Prey Survey			X				X				X				X				X	
Milestone 3: data management																				
Data processing, lab analyses, 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			
Reporting																				
Annual reports					X				X				X				X			
Deliverables																				
Peer reviewed paper										X										
Data posted online				X				X				X				X				X

Milestone/Task	FY27				FY28				FY29				FY30				FY31			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Milestone 1: admin and 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		
Milestone 2: data acquisition																				
Middleton Island Seabird Diets	X	X	X		X	X	X		X	X	X		X	X	X		X	X	X	
Aerial Survey Validation		X				X				X				X				X		
Summer Forage Fish Sampling		X				X				X				X				X		
Integrated Predator Prey Survey			X				X				X				X				X	
Milestone 3: data management																				
Data processing, lab analyses, 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			
Reporting																				
Annual reports	X				X				X				X				X			
Final report																				X
Deliverables																				
Peer reviewed paper								X												X
Data posted online				X				X				X				X				X

8. BUDGET

A. Budget Forms (Attach)

Please see Gulf Watch Alaska Long-Term Research and Monitoring workbook.

Budget Category:		Proposed FY 22	Proposed FY 23	Proposed FY 24	Proposed FY 25	Proposed FY 26	5- YR TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel		$155,284	$126,623	$132,135	$137,923	$144,000	$695,965	
Travel		$14,492	$14,854	$15,226	$15,606	$15,996	$76,175	
Contractual		$106,800	$109,470	$112,207	$115,012	$117,887	$561,376	
Commodities		$32,000	$32,000	$32,000	$32,000	$32,000	$160,000	
Equipment		$10,650	$10,916	$11,189	$11,469	$11,756	$55,980	
Indirect Costs Rate =	0%	$0	$0	$0	$0	$0	$0	
SUBTOTAL		$319,226	$293,864	$302,757	$312,010	$321,639	$1,549,495	
General Administration (9% of subtotal)		$28,730	$26,448	$27,248	$28,081	$28,947	$139,455	N/A
PROJECT TOTAL		$347,956	$320,312	$330,005	$340,091	$350,586	$1,688,950	
Other Resources (In-Kind Funds)		$482,500	$482,500	$482,500	$482,500	$482,500	$2,412,500	

Budget Category:		Proposed FY 27	Proposed FY 28	Proposed FY 29	Proposed FY 30	Proposed FY 31	5- YR TOTAL PROPOSED	ACTUAL CUMULATIVE	TEN YEAR TOTAL
Personnel		$147,943	$150,460	$153,812	$157,248	$160,769	$770,231		$1,466,196
Travel		$16,396	$16,806	$17,226	$17,657	$18,099	$86,185		$162,359
Contractual		$120,834	$123,855	$126,952	$130,125	$133,379	$635,145		$1,196,521
Commodities		$32,000	$32,000	$32,000	$32,000	$32,000	$160,000		$320,000
Equipment		$12,051	$12,351	$12,660	$12,976	$13,300	$63,337		$119,317
Indirect Costs Rate =	0%	$0	$0	$0	$0	$0	$0		$0
SUBTOTAL		$329,225	$335,472	$342,649	$350,006	$357,547	$1,714,899		$3,264,394
General Administration (9% of subtotal)		$29,630	$30,193	$30,838	$31,501	$32,179	$154,341	N/A	$293,795
PROJECT TOTAL		$358,855	$365,665	$373,488	$381,507	$389,726	$1,869,240		**$3,558,190**
Other Resources (In-Kind Funds)		$482,500	$482,500	$482,500	$482,500	$482,500	$2,412,500		**$4,825,000**

B. Sources of Additional Funding

Non-EVOSTC Funds to be used, please include source and amount per source:

FY22	FY23	FY24	FY25	FY26	FY22-26 Total
$482,500	$482,500	$482,500	$482,500	$482,500	$2,412,500
FY27	**FY28**	**FY29**	**FY30**	**FY31**	**FY27-31 Total**
$482,500	$482,500	$482,500	$482,500	$482,500	$2,412,500
				FY22-31 Total	*$4,825,000*

USGS will make substantial in-kind contributions of salary for Pelagic Component lead and PIs (6 months GS-13 at $74K, 2 months GS-15 at $35K), and field equipment required to conduct the work including acoustic echosounders ($141K), oceanography sampling equipment ($55K), a trawl depth monitor system ($21.5K), small boats ($20K), a marine scale ($10K), and net sampling and camera gear ($6K) for forage fish work in PWS. ISRC will also make substantial in-kind contributions for the use of facilities ($120K) at Middleton Island.

However, USGS funds included as in-kind or as contributions are included for planning purposes only and nothing contained in this proposal shall be construed as binding the USGS to expend in any one fiscal year any sum in excess of its appropriations or funding in excess or what it has received for the collaborative work outlined in this proposal or involving the Federal government in any obligation to pay money before funds have been appropriated for that purpose unless otherwise allowed by law.

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10. PROJECT PERSONNEL

MAYUMI LYNN ARIMITSU
Research Ecologist, USGS-Alaska Science Center
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RELEVANT PROFESSIONAL EXPERTISE

Long-Term Research and Monitoring Program Pelagic Component Lead (2017 – present). Leads the Pelagic Component in proposals, science synthesis activities, and information transfer, group presentations at annual PI meetings and professional conferences, and acts as an intermediary in communications between the program management team and pelagic PIs.

Monitoring Strategies to Improve Detection of Change in Forage Fish Stocks (2011- present). Principal Investigator on the Gulf Watch Alaska long-term monitoring program. Designed and implemented forage fish monitoring strategies that include broad-scale aerial surveys coupled with hydroacoustic-trawl surveys, integrated predator-prey surveys, and predator diets to assess status and trends of prey species such as capelin, sand lance, juvenile herring, and krill.

Monitoring the Recovery of Seabirds and Forage Fish Following a Major Ecosystem Disruption in Lower Cook Inlet (2016 – present). Principal Investigator on project to document changes in seabird and forage fish populations during and following the North Pacific marine heatwave. Lead scientist during ship-based acoustic-trawl and predator surveys in Kachemak Bay and Lower Cook Inlet, and supervision of 2-5 scientists conducting measurements of breeding population and reproductive success of murres and kittiwakes at two colonies.

MOST RELEVANT PUBLICATIONS

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.

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EDUCATION

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

COLLABORATIONS

Sonia Batten (PICES), Mary Anne Bishop (PWSSC), Rob Campbell (PWSSC), Heather Coletti (NPS), Dan Cushing (Pole Star Ecological), Kristen Gorman (UAF), Scott Hatch (ISRC), Keith Hobson (University of Ottowa), Russ Hopcroft (UAF), Kathy Kuletz (USFWS), Caitlin Marsteller (USGS), Craig Matkin (NGOS), David McGowan (NOAA), Caitlin McKinstry (PWSSC), John Moran (NOAA), Dan Olsen (NGOS), W. Scott Pegau (PWSSC), John Piatt (USGS), Heather Renner (USFWS), Anne Schaeffer (PWSSC), Sarah Schoen (USGS), Jan Straley (UAS), Rob Suryan (NOAA), Bill Sydeman (Farallons Institute), Jim Thorson (NOAA), Caroline Van Hemert (USGS), Vanessa von Biela (USGS), Stephani Zador (NOAA).

JOHN FORREST PIATT

Senior Scientist (GS-15), Seabird & Forage Fish Ecology Program, Alaska Science Center, U.S. Geological Survey, 4210 University Dr., Anchorage, AK, U.S.A. 99508, 360-774-0516, jpiatt@usgs.gov

RELEVANT PROFESSSIONAL EXPERTISE

Functional Response of Seabirds to their Prey. More than 30 years of integrated studies in the North Pacific on oceanography, forage fish, and seabirds in and around seabird colonies in SE Alaska, Prince William Sound, Cook Inlet, Gulf of Alaska, Aleutians and Bering Sea. Work with Alaska, U.S., and international fisheries and wildlife research collaborators to assess biological responses of seabirds and whales to fluctuations in prey abundance.

North Pacific Pelagic Seabird Database. Directed effort to compile data from ~460,000 survey transects conducted by hundreds of biologists that document the distribution of seabirds at sea in the North Pacific Ocean. Working now with collaborators to model seabird distribution at different spatio-temporal scales and relate distribution to environmental features and prey distribution.

Status and Trends of Endangered Species. 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.

Tufted and Horned Puffin Feeding Ecology and Breeding Biology. Studies at 40 colonies in the Aleutian Archipelago and Gulf of Alaska (chick diets and growth, adult diets, seabird distribution at sea, marine food webs).

MOST RELEVANT PUBLICATIONS:

Arimitsu, M. L., J. F. Piatt, S. A. Hatch, R. M. Suryan, … et al. 2021. Heatwave-induced synchrony within forage fish portfolio disrupts energy flow to top pelagic predators. Global Change Biology. https://doi.org/10.1111/gcb.15556

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EDUCATION

Ph.D., Marine Biology, 1987, Memorial University of Newfoundland, St. John's, Canada

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

COLLABORATIONS

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United States Department of the Interior
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July 15, 2021

To: Mandy Lindeberg - NOAA, GWA-LTRM Program Lead
Shiway Wang, EVOSTC Executive Director

Re: Letter of Commitment

We are pleased to provide this letter of commitment for the proposed project "22120114-C Monitoring long-term changes in forage fish distribution, relative abundance, and body condition in Prince William Sound and the Northern Gulf of Alaska" led by principal investigators (PIs), Mayumi Arimitsu and John Piatt. This proposal was drafted by the PIs in response to the EVOSTC's FY22-31 Invitation for Proposals and subsequent request for final submission on August 13, 2021. The cost for this project over a ten-year period will be $3264 K (without EVOSTC GA). This includes some non-EVOSTC funds that are in-kind contributions we support totaling an estimated $4825 K for the life of the project (e.g., salaries of permanent staff, laboratory facilities, and equipment use).

This project proposal is part of the larger multi-agency Gulf Watch Alaska Long-Term Research and Monitoring (GWA-LTRM) program proposal package. This package represents a continued commitment of the successful long-term research and monitoring projects supported by the EVOSTC and various agencies and organizational investments since 2012.

USGS funds, however, included as in-kind or as contributions are included for planning purposes only and nothing contained in this proposal shall be construed as binding the USGS to expend in any one fiscal year any sum in excess of its appropriations or funding in excess or what it has received for the collaborative work outlined in this proposal or involving the federal government in any obligation to pay money before funds have been appropriated for that purpose unless otherwise allowed by law.

Sincerely,

Digitally signed by member: 720CC750-FB79-4BCC-8333-30E70ED4311F C059F91D-241C-4DFA-B845-A2FEE3F297A8
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