ATTACHMENT B. Annual Project Report Form (Revised 11.21.19)

1. Program Number:

19120114-H

2. Project Title:

Nearshore Ecosystems in the Gulf of Alaska

3. Principal Investigator(s) Names:

Heather Coletti, National Park Service

Dan Esler, U.S. Geological Survey, Alaska Science Center

Brenda Konar, University of Alaska Fairbanks

Katrin Iken, University of Alaska Fairbanks

Kim Kloecker, U.S. Geological Survey, Alaska Science Center

Dan Monson, U.S. Geological Survey, Alaska Science Center

Ben Weitzman, National Oceanic and Atmospheric Administration

Brenda Ballachey, U.S. Geological Survey Emeritus, Alaska Science Center

James Bodkin, U.S. Geological Survey Emeritus, Alaska Science Center

Thomas Dean, Coastal Resources Inc.

George Esslinger, U.S. Geological Survey, Alaska Science Center

Brian Robinson, U.S. Geological Survey, Alaska Science Center

Mandy Lindeberg, National Oceanic and Atmospheric Administration

4. Time Period Covered by the Report:

February 1, 2019-January 31, 2020

5. Date of Report:

March 2020

6. Project Website (if applicable):

www.gulfwatchalaska.org

7. Summary of Work Performed:

Overview

Nearshore monitoring occurs annually in four regions across the Gulf of Alaska and provides ongoing evaluation of the status and trends of more than 200 species, including many of those injured by the 1989 *Exxon Valdez* oil spill. The nearshore monitoring design includes spatial, temporal, and ecological features that strengthen inferences regarding drivers of change.

In 2019, we sampled in Western Prince William Sound (WPWS), Kenai Fjords National Park (KEFJ), Kachemak Bay (KBAY), and Katmai National Park and Preserve (KATM) following previously established methods (Table 1). Metrics included abundance and distribution of marine invertebrates, macroalgae, sea grasses, birds, mammals, and physical parameters such as temperature. In addition to taxon-specific metrics, monitoring included recognized important ecological processes such as predator-prey dynamics and measures of nearshore ecosystem productivity. We are not proposing any major changes to this project for FY20. Additions in KBAY that were implemented in 2018 were continued in 2019, including black oystercatcher nest monitoring, marine bird and mammal surveys, and sea otter foraging observations. A significant add-on project for 2019 was a study to evaluate movement ecology of black oystercatchers in association with annual monitoring; this add on will continue through 2020.

Table 1. Nearshore component metrics measured by location and year, 2017-2021. Completed activities for 2019 are bolded while completed activities (2017 and 2018) and planned activities in future years (2020 – 2021) are not.

Location and Metric	**2017**	**2018**	**2019**	**2020**	**2021**
Western PWS, intertidal invertebrates and algae	x	x	**X**	x	x
Western PWS, intertidal kelps and sea grass	x	x	**X**	x	x
Western PWS, black oystercatchers	x	x	**X**	x	x
Western PWS, contaminants/water quality		x			
Western PWS, sea otter carcass recovery	x	x	**X**	x	x
Western PWS, sea otter spraint observations	x	x	**X**	x	x
Western PWS, sea otter foraging observations	x	x	**X**	x	x
Western PWS, water/air temperature	x	x	**X**	x	x
Kenai NP, intertidal invertebrates and algae	x	x	**X**	x	x
Kenai NP, intertidal kelps and sea grass	x	x	**X**	x	x
Kenai NP, black oystercatchers	x	x	**X**	x	x
Kenai NP, contaminants/water quality		x			
Kenai NP, sea otter carcass recovery	x	x	**X**	x	x
Kenai NP, sea otter spraint observations			**X**	x	x
Kenai NP, sea otter foraging observations	x	x	**X**	x	x
Kenai NP, water/air temperature	x	x	**X**	x	x
Kachemak Bay, intertidal invertebrates and algae	x	x	**X**	x	x
Kachemak Bay, intertidal kelps and sea grass	x	x	**X**	x	x
Kachemak Bay, black oystercatchers		x	**X**	x	x
Kachemak Bay, contaminants/water quality		x			
Kachemak Bay, sea otter spraint observations	x	x	**X**	x	x
Kachemak Bay, sea otter foraging observations		x	**X**	x	x

Location and Metric	2017	2018	2019	2020	2021
Kachemak Bay, water/air temperature	x	x	**X**	x	x
Katmai NP, intertidal invertebrates and algae	x	x	**X**	x	x
Katmai NP, intertidal kelps and sea grass	x	x	**X**	x	x
Katmai NP, black oystercatchers	x	x	**X**	x	x
Katmai NP, contaminants/water quality		x			
Katmai NP, sea otter spraint observations	x	x	**X**	x	x
Katmai NP, sea otter carcass recovery	x	x	**X**	x	x
Katmai NP, sea otter foraging observations	x	x	**X**	x	x
Katmai NP, water/air temperature	x	x	**X**	x	x
Western PWS, sea otter aerial survey	x			x	
Kenai NP, sea otter aerial survey			**X**		
Kachemak Bay, sea otter aerial survey*	x				
Katmai NP, sea otter aerial survey		x			x
PWS Nearshore marine bird survey**		x		x	
Kenai NP nearshore marine bird survey	x	x	**X**	x	x
Kachemak Bay nearshore marine bird survey		x	**X**	x	x
Katmai NP nearshore marine bird survey	x	x	**X**	x	x

*Funded by USFWS in 2017

**Under Pelagic component Restoration Project 18120114-M

2019 Highlights

As in 2018, contributions from the Nearshore component were included in the 2019 National Oceanic and Atmospheric Administration (NOAA) Ecosystems Status Report for the Gulf of Alaska (Zador et al. 2019), which is intended to provide current, broad-scale information on the state of the Gulf of Alaska in support of fisheries management. We submitted trends in 4 key metrics, including 1) physical conditions (intertidal water temperature), 2) primary production (algal cover), 3) prey abundance (mussel density), and 4) predator abundance (sea star abundance), presented in brief below.

Intertidal Water Temperatures

Nearshore water temperature trends in all four intertidal zones from Prince William Sound to the Alaska Peninsula show warming beginning in 2014 (Fig. 1), corresponding to the large marine heatwave phenomenon (“the Blob”) detected by more pelagic sensors (Danielson et al. 2019). Our data confirm that the physical manifestations of this large-scale oceanographic event were expressed in nearshore ecosystems. A science synthesis paper has been prepared in collaboration with the Environmental Drivers component of Gulf Watch Alaska (GWA) evaluating coherence of water temperatures across the central Gulf of Alaska, including how Gulf-scale temperature trends measured in the pelagic realm manifest in nearshore waters (Danielson et al. 2019).

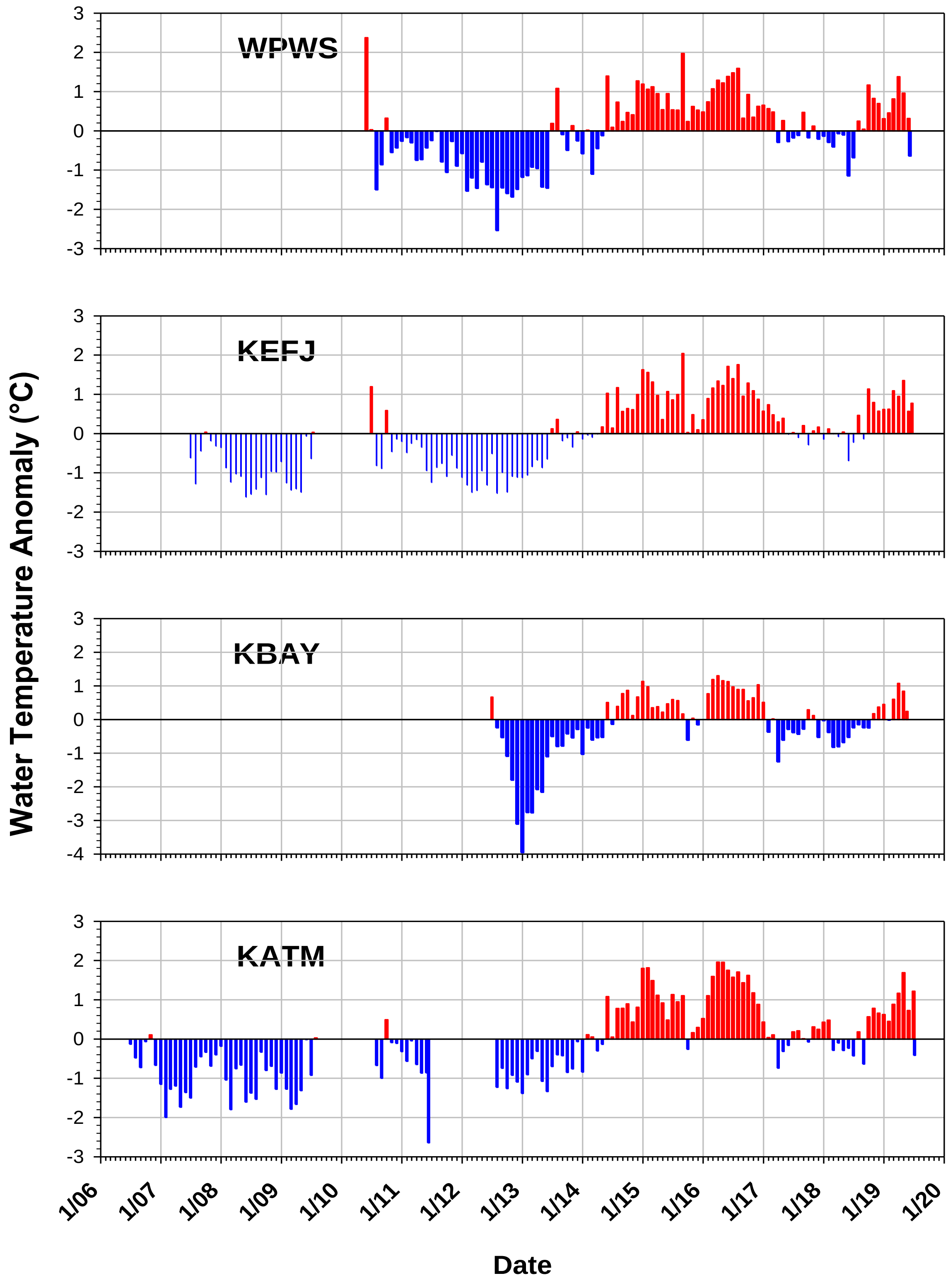


Figure 1. Intertidal temperature anomalies at the 0.5 m tide level four regions of the western Gulf of Alaska (west of 144°W), western Prince William Sound (WPWS; 2011-2019), Kenai Fjords National Park (KEFJ; 2008-2019), Kachemak Bay (KBAY; 2013-2019), and Katmai National Park and Preserve (KATM; 2006-2019).

Algal Cover

We used percent cover of the perennial intertidal, dominant alga *Fucus distichus* as a metric of trends in a primary producer (Fig. 2). Since the onset of the marine heatwave in 2014, we have quantified generally negative anomalies, although results in 2019 are trending back towards average conditions. *F. distichus* is known to cycle in abundance at local scales; the broad, consistent patterns in our data suggest that a large-scale phenomenon, presumably the marine heatwave, was acting on this metric at the scale of the northern Gulf of Alaska. Variation in *F. distichus* abundance is included as part of two science synthesis papers (Weitzman et al. 2019) evaluating intertidal community responses to the marine heatwave and (Suryan et al. 2019) evaluating Gulf of Alaska (GOA) ecosystem response to the marine heatwave.

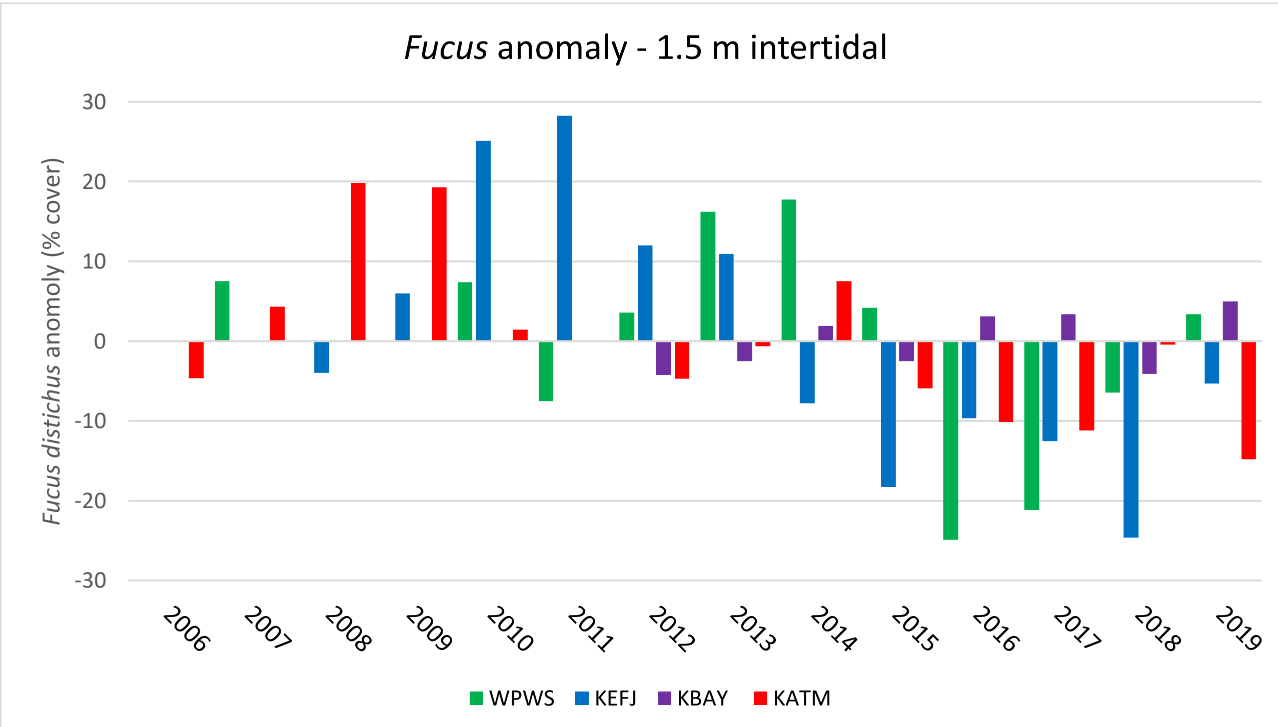


*Figure 2. Percent cover anomalies for rockweed (*Fucus distichus*) in four regions of the western Gulf of Alaska, western Prince William Sound (WPWS; 2007, 2010-2019), Kenai Fjords National Park (KEFJ; 2008-2019), Kachemak Bay (KBAY; 2012-2019), and Katmai National Park and Preserve (KATM; 2006-2010, 2012-2019).*

Mussel Density

We present trends in abundance of the mussel *Mytilus trossulus*, a ubiquitous invertebrate filter feeder, as a common nearshore prey species that transfers primary production to higher trophic levels, including various sea stars. Densities of large mussels (≥ 20 mm, Fig. 3) show a strong trend across all regions consistent with timing of the marine heatwave, but in this case switching from generally negative to positive anomalies – an opposite response compared to *F. distichus* and sea stars (Figs. 2 and 4). Variation in mussel abundance through 2017 was described in detail in a recent paper (Bodkin et al. 2018) and % cover data up to the present are included as part of two science synthesis papers evaluating intertidal community responses (Weitzman et al. 2019) and GOA ecosystem response (Suryan et al. 2019) to the marine heatwave.

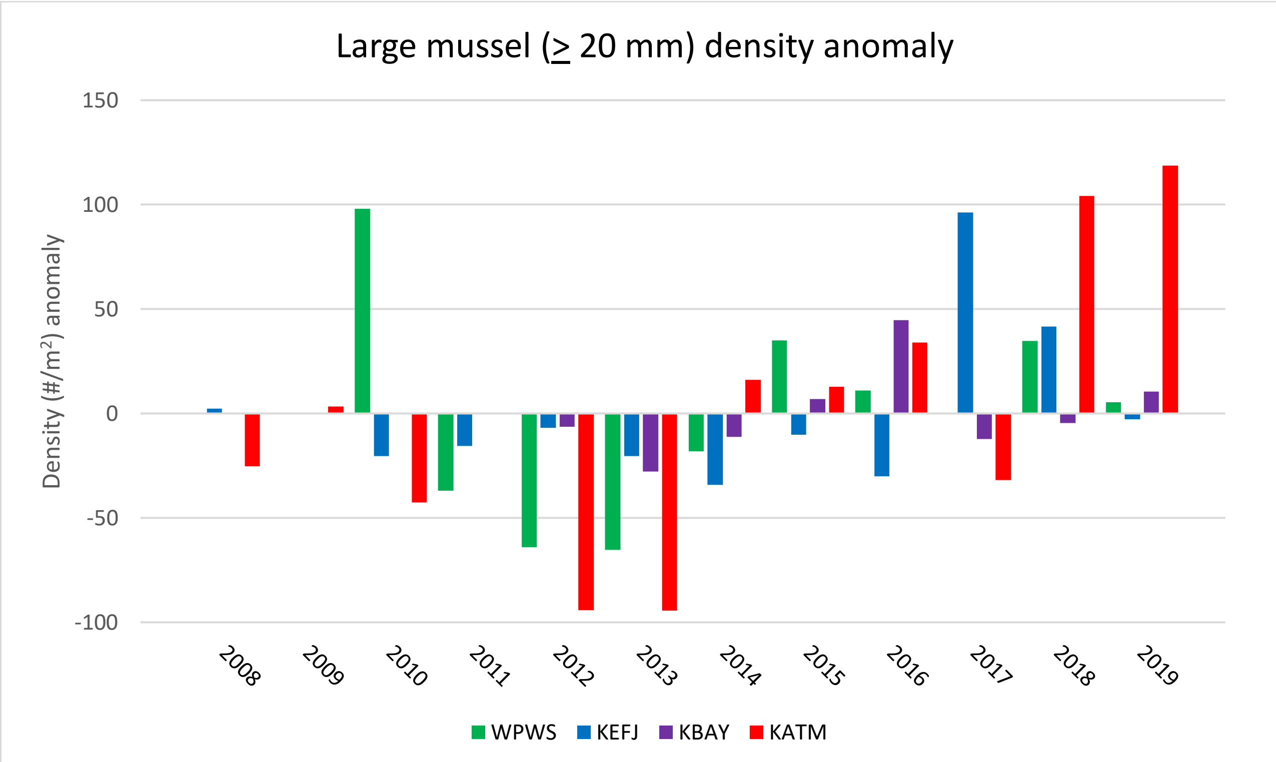


Figure 3. Density anomalies for large mussels (> 20 mm) in four study regions spanning the northern Gulf of Alaska. Western Prince William Sound (WPWS; 2010-2019), Kenai Fjords National Park (KEFJ; 2008-2019), Kachemak Bay (KBAY; 2012-2019), and Katmai National Park and Preserve (KATM; 2008-2010, 2012-2019).

Sea Star Abundance

As an important predator in structuring nearshore communities (including mussel populations) we present trends in sea star abundance. Sea star abundance varied greatly among regions through 2015 (Fig. 4). However, in 2016, abundance of all species combined began to decline due to the sea star wasting disease epidemic and remained strongly negative across all regions during the marine heatwave, with trends towards potential recovery evident in 2019. These findings are described in detail in a recent paper (Konar et al. 2019) and included in one of the GWA science synthesis chapters (Suryan et al. 2019).

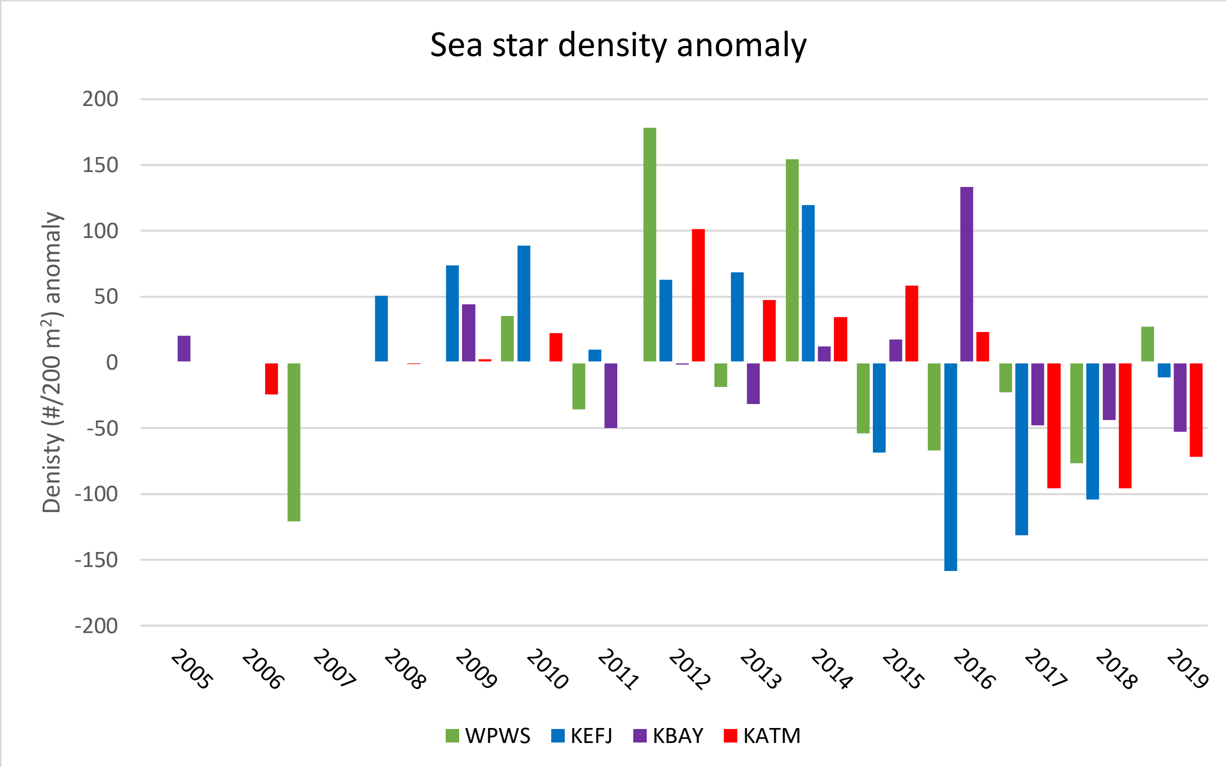


*Figure 4. Density of sea stars (*Dermasterias imbricata, Evasterias troschelii, Pisaster ochraceus, *and* Pycnopodia helianthoides*) in four study areas spanning the northern Gulf of Alaska. Western Prince William Sound (WPWS; 2007, 2010-2019), Kenai Fjords National Park (KEFJ; 2008-2019), Kachemak Bay (KBAY; 2005, 2009, 2011-2019), and Katmai National Park and Preserve (KATM; 2006, 2008-2010, 2012-2019).*

Inter-specific Interactions and Interpretation of NOAA Ecosystem Status Metrics

The negative anomalies of rockweed (*F. distichus*) and sea stars are coincident with warm water temperatures in nearshore areas, although very different mechanisms likely are driving observed patterns. *F. distichus* declines likely are due to direct effects of warming temperatures on survival or recruitment. The decline in sea star abundance likely was due to sea star wasting disease, which was first detected in the study region in 2014 (Eisenlord et al. 2016) and is likely exacerbated by higher-than-average water temperature. Positive anomalies during 2015-2019 for large mussels are consistent with a response to reduced predation pressure precipitated by the decline of sea stars. Sea stars are known to have strong top-down effects on intertidal communities, including mussels specifically (Paine 1974), so this inter-specific interaction is a plausible explanation for observed patterns. Further, we speculate that other nearshore predators, including sea otters, sea ducks, and black oystercatchers, may benefit from increased abundance of large mussels when sea stars decline.

Intertidal and nearshore ecosystems provide valuable habitat for early life stages of commercially, ecologically and culturally important species in the Gulf of Alaska. These time series presented above illustrate various factors that contribute to change in the species composition of nearshore ecosystems, the abundance of dominant taxa and underlying processes. Trends in these indicators suggest that some nearshore biological responses to the recent heatwave appear to continue, in some cases into 2019, and could affect future recruitment and survival of species whose early life stages rely on nearshore habitat. With the warm water anomalies continuing in to 2019 (see Fig. 1), we also expect to see responses of nearshore-reliant species to shifts in prey availability across the Gulf of Alaska from changing ocean conditions.

Black Oystercatcher Spatio-temporal Variation in Diet

Upper trophic-level predators can be useful indicators of ecosystem status (Estes 1996, Croll et al. 2005). In nearshore marine ecosystems, black oystercatcher chick diets, which are comprised of intertidal macroinvertebrates, may reflect prey community composition, which varies on both spatial and temporal scales. Because of their reliance on the nearshore and susceptibility to change that occurs there, black oystercatchers have been monitored by the Southwest Alaska National Park Service (NPS) Inventory and Monitoring and Gulf Watch Alaska Nearshore programs since 2006. We examined spatial and temporal patterns of variation in the diet of black oystercatcher chicks in the northern Gulf of Alaska.

We collected 23,171 prey items delivered by parents to chicks at 193 nests, representing 30 taxa identified to the genus or species level. Diet was dominated by three species of limpets (*Lottia pelta*, *L. persona*, *L. scutum*), that cumulatively made up 67% of prey by number, followed by Pacific blue mussels (*Mytilus trossulus*; 22%), and black katy chitons (*Katharina tunicata*; 5%). Diet composition did not vary by year or among regions, which were three broad areas in the northern Gulf of Alaska (WPWS, KEFJ, and KATM) (Fig. 5). However, diet did vary significantly among sites (bay-level areas within regions). Proportions of limpets and mussels in the diet at sites ranged from 88 ± 1.3% (mean ± SE) limpets and 2.5 ± 1.3% mussels to 56 ± 4.7% limpets and 32 ± 4.3% mussels. Overall, these findings suggest that while diet has been relatively consistent over time and among regions, local variation at the site level influences patterns of prey composition in black oystercatcher populations. Black oystercatcher surveys were implemented in KBAY in 2018, therefore with only two years of data from that region, results are not included here.

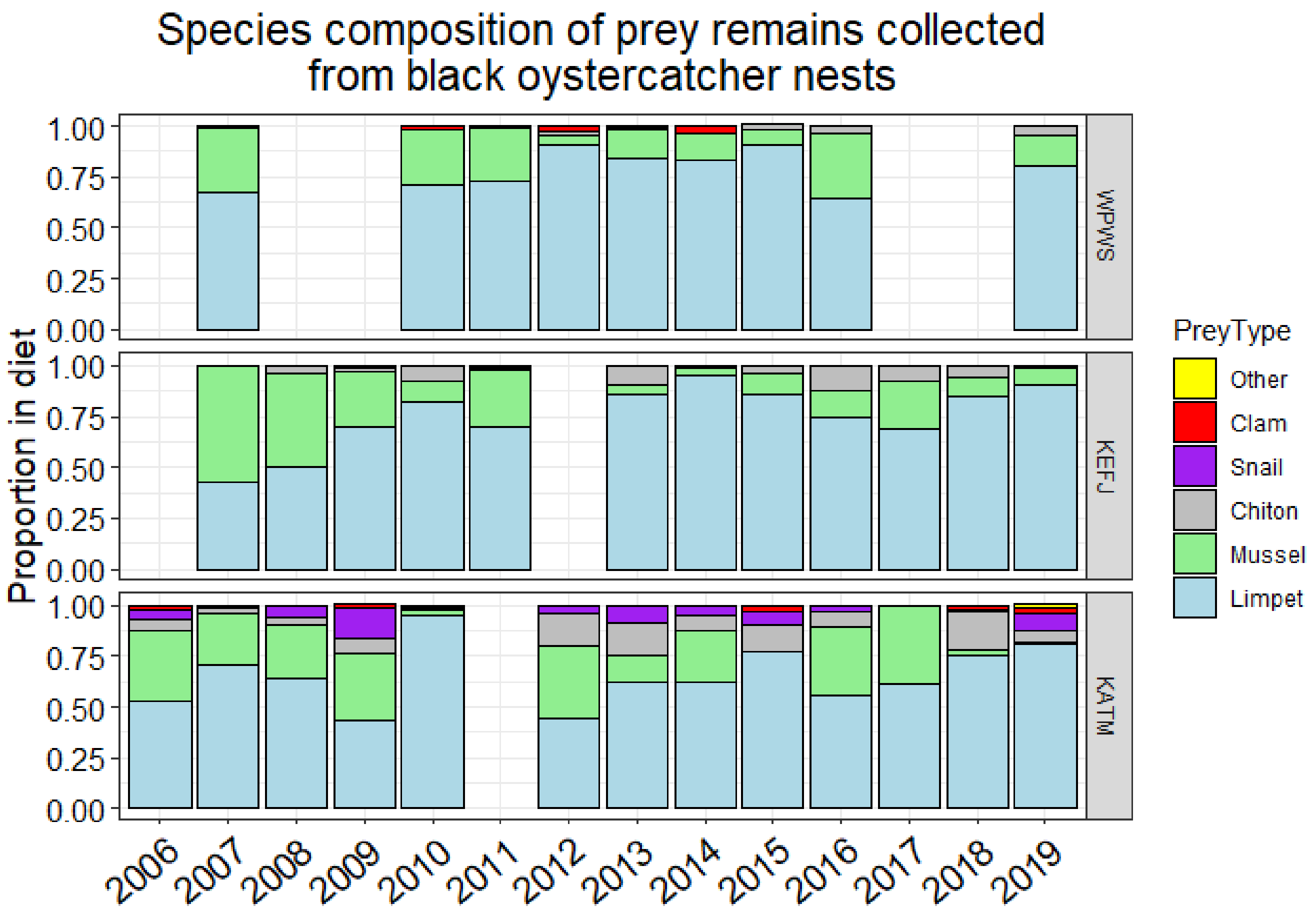


Figure 5. Composition of prey items delivered by Black Oystercatcher parents to chicks in three study areas (Western Prince William Sound [WPWS], Kenai Fjords National Park [KEFJ], and Katmai National Park and Preserve [KATM]) spanning the northern Gulf of Alaska, 2006-2019.

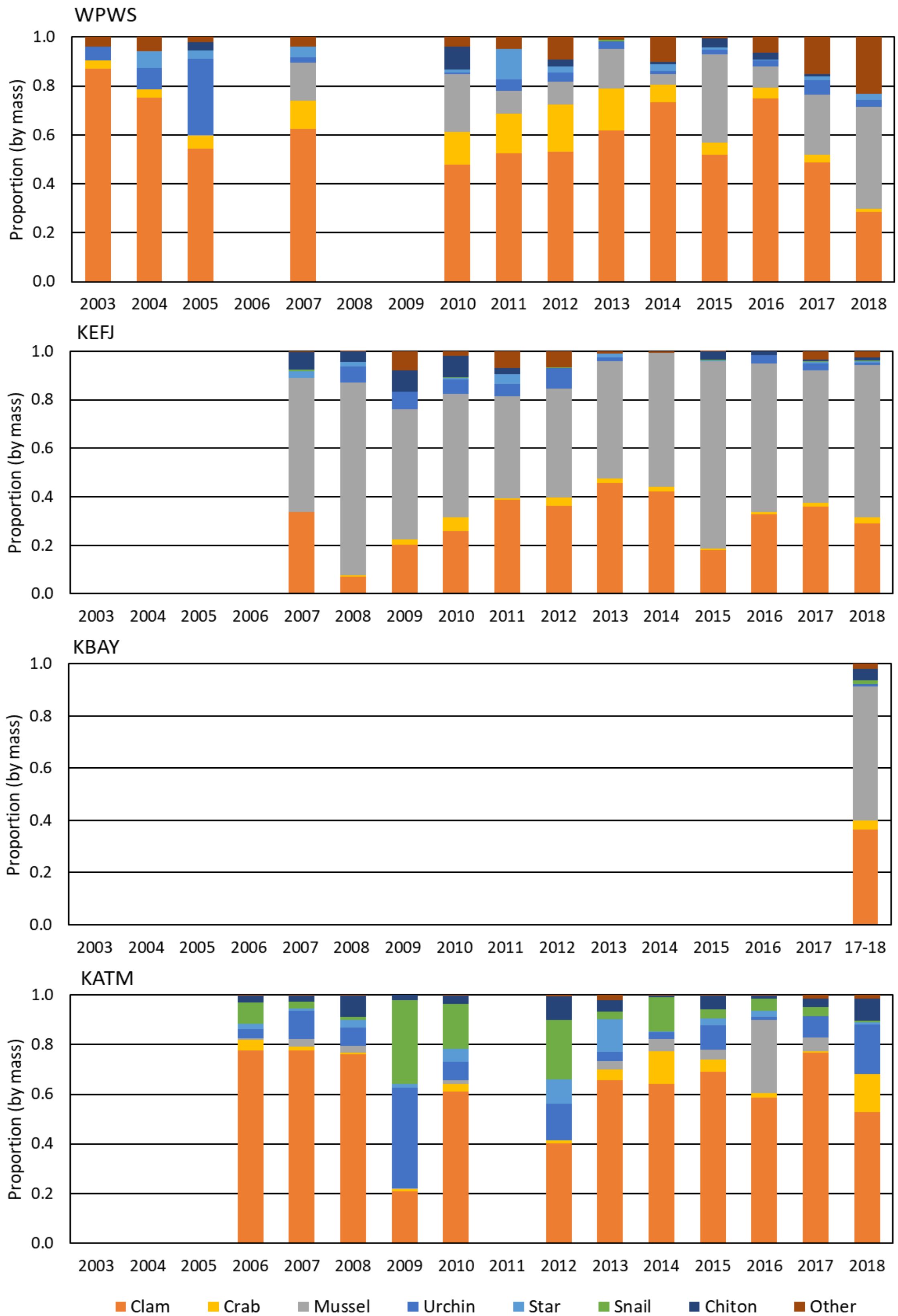
Sea Otter Spatio-temporal Variation in Diet

Sea otters can dramatically affect the structure and complexity of their nearshore ecological community. They cause well described top-down cascading effects on community structure by altering abundance of prey (e.g., sea urchins) which can in turn alter abundance of lower trophic levels (e.g., kelps) (Kenyon 1969, Estes and Palmisano 1974, Estes and Duggins 1995, Estes 2015). As a keystone species (Paine 1969), sea otters have been monitored by the Southwest Alaska NPS Inventory and Monitoring and GWA Nearshore programs since 2006 (Dean et al. 2014). Sea otter metrics include 1) carcass recovery to evaluate mortality, 2) aerial surveys to estimate abundance, and 3) foraging behavior and spraint observations, which provide insight into the diet of sea otters. Here we present preliminary analysis of prey composition for foraging observations collected on sea otters across all four regions beginning in 2003 (WPWS) through 2018 (all regions). To provide context as to possible drivers of prey composition differences across space and time, the Nearshore component independently measures prey resources of the sea otter in the intertidal, including sampling of clams, mussels, and other invertebrates. Patterns in prey composition and clam density and biomass are presented here, and mussel abundance in Fig. 3.

In contrast to the black oystercatcher, variation by region is evident in the proportion of prey types in the diet of sea otters (Fig. 6). The sea otter diet at KEFJ continues to be dominated by mussels (*Mytilus trossulus*), while in contrast, KATM continues to be dominated by clams with a diversity of other prey. WPWS appears to have shifted recently from a diet primarily of clams to one higher in mussels in 2018. KBAY foraging observations were initiated in 2017 and suggest a relatively high proportion of mussel consumption. Coinciding with increases in mussel consumption, we have documented an increase in large (≥20 mm) mussels across the study areas (Coletti et al. 2019, see Fig. 3 of this report). It should be noted that sea otter foraging data have been analyzed through 2018, 2019 is pending analysis.

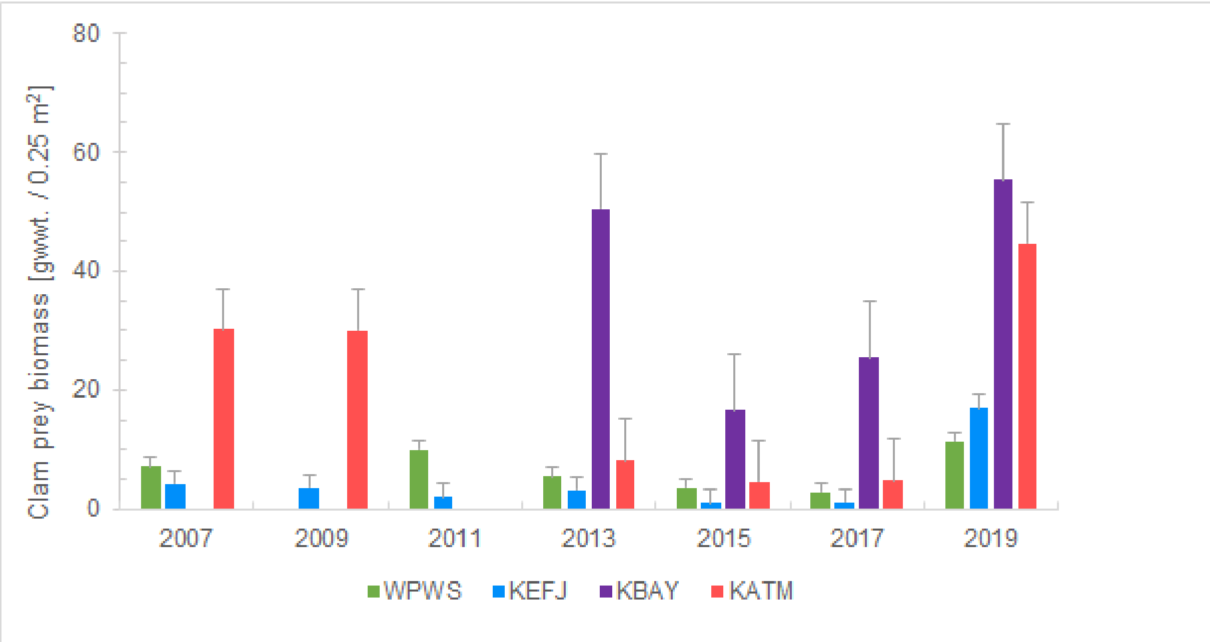
Clam densities and biomass varied by regions over time, with KATM and KBAY tending to have higher clam densities and biomass than KEFJ or WPWS (Fig. 7). To account for the higher biomass but similar density, data suggest that clams at KBAY are larger relative to KATM and the other regions (all clams were measured at the time of collection; these data are being processed and will confirm any differences among regional sizes of clams). From 2017 to 2019 there was an increase in the density and biomass of clams at all regions, though especially so in KATM. A student project is relating annual clam recruitment in cores to the subsequent standing stock of clams at those same beaches. Preliminary results suggest that recruitment cores may predict adult standing stock (Zhang et al. 2020 poster presentation). By 2021, we will have 5 years of complementary quadrat and core data allowing us to evaluate potential relations between recruitment of juveniles and adult clam populations.

In summary, preliminary analysis of the diet and prey data streams indicates the abundance of clams measured in the intertidal may not necessarily correlate to the proportion of clams in the sea otters' diet. We do see some response in the otters' diet to increased mussel abundance consistent with recovery of mussel populations across the Gulf of Alaska after 2013. Clearly, a variety of factors can influence relations between predator and prey, including abundance, availability, quality and preference. The ability of nearshore monitoring data to inform resource management will continue to benefit from explicit design features incorporating these complex relations.



WPWS
KEFJ
KBAY
KATM
Proportion (by mass)
1.0
0.8
0.6
0.4
0.2
0.0
2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018
17-18
Clam
Crab
Mussel
Urchin
Star
Snail
Chiton
Other

Figure 6. Sea otter prey proportions by region. Western Prince William Sound (WPWS; 2003-2005, 2007, 2010-2018), Kenai Fjords National Park (KEFJ; 2007-2018), Kachemak Bay (KBAY; 2017-2018 – combined due to low sample size in 2017), and Katmai National Park and Preserve (KATM, 2006-2010, 2012-2018).



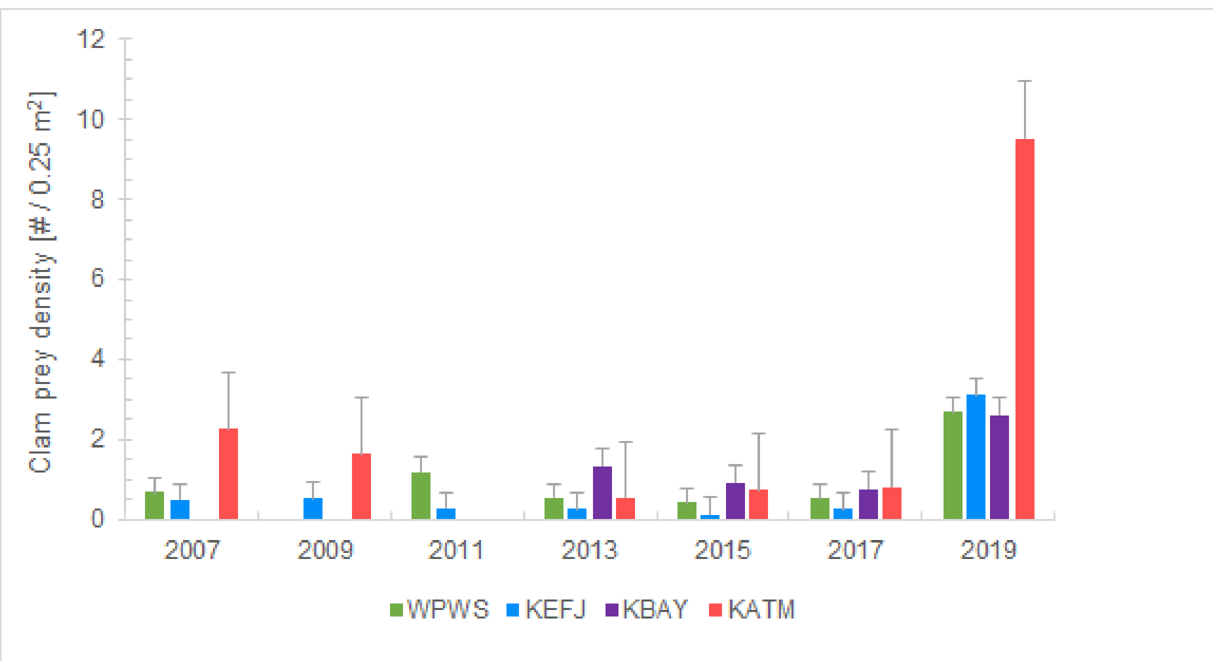


Figure 7. Mean ± SE clam biomass (grams of wet weight per quarter m^2 of edible tissue; upper panel) and density (number of individuals per quarter m^2; lower panel) by region: Western Prince William Sound (WPWS), Kenai Fjords National Park (KEFJ), Kachemak Bay (KBAY), and Katmai National Park and Preserve (KATM).

Contaminants in Mussel Tissue

In 2018, we collected mussels for analysis of a broad suite of contaminants across all four regions. This work is not conducted annually but rather is slated to occur every 8 years unless a contaminant-specific issue emerges. In 2019, we received results from the laboratory analysis conducted by NOAA; we note that these analyses were conducted following protocols for the Mussel Watch program, ensuring comparability to other times and places. In fact, results from these analyses are being combined with those from other locations in the northern Gulf of Alaska in a report to be published in 2020 (Apeti et al. in prep). Preliminary results indicate that there are no contaminants concerns at this time within our study areas.

8. Coordination/Collaboration:

A. Projects Within a Trustee Council-funded program

1. Within the Program

The Nearshore Component of GWA is a highly coordinated effort involving multiple principal investigators (PIs) with expertise on various aspects of nearshore ecosystems; the overall design and coordination are critical for drawing inference about factors affecting the nearshore. Beginning in 2012 under GWA, there were two nearshore projects (16120114-R Nearshore Benthic Systems in the Gulf of Alaska and 16120114-L, Ecological Trends in Kachemak Bay). The two projects have worked closely over the past several years to ensure that data from all sites are comparable when possible, allowing the strongest possible inferences about the causative factors and spatial extent of changes in nearshore systems. In 2017, the two nearshore projects integrated into a single, coordinated project to enhance collaboration across the GWA. For example, nearshore data sets were combined across projects for analyses that resulted in two peer reviewed journal articles to date (Konar et al. 2016 and 2019) as well as contributions to three chapters of the draft science synthesis report to the *Exxon Valdez* Oil Spill Trustee Council (Danielson et al. 2019, Suryan et al. 2019, and Weitzman et al. 2019). The synthesis of rocky intertidal data (Weitzman et al. 2019) revealed that intertidal communities became more similar

Figure 8. Images from a rocky intertidal monitoring site depicting the change in community structure across the sampling transects, before (a. 2013) and after (f. 2019) the Pacific Marine Heatwave (Weitzman et al. 2019).

among study regions and generally, that rocky intertidal habitats shifted from a macroalgal dominated community to a community dominated by filter-feeding invertebrates, such as mussels (Fig. 8.) The synthesis manuscript marks the third publication written that synthesizes data between the two nearshore projects and the first publication for the nearshore group to begin incorporating data from the Environmental Drivers component.

A cross-component (Nearshore and Pelagic) effort continues (projects 19120114-C, E, H, L, M, and O) with the intent to integrate bird survey data to examine spatial and temporal trends in a variety of species and guilds across the northern Gulf of Alaska. The Nearshore component worked with ABR Inc. to create a tool to process survey data for rapid QA/QC as well as automating the processing required to upload survey data into the North Pacific Pelagic Seabird Database (NPPSD) maintained by the U.S. Geological Survey (USGS). Nearshore survey data from all four regions were processed and provided to USGS for the NPPSD v3 release in 2020 (Drew and Piatt 2015). Incorporation of all GWA marine bird survey data into NPPSD will allow for larger scale analyses of marine bird trends throughout the Gulf of Alaska over time. Further collaboration between the Nearshore and Pelagic components is highlighted in chapter 3 of the synthesis effort (Arimitsu et al. 2019) which utilized GWA nearshore marine bird survey data from KATM. Nearshore marine bird survey data were also used in the GWA science synthesis chapter 4 (Suryan et al. 2019)

The Nearshore component has coordinated sampling of mussels, offshore and nearshore particulate organic matter (POM) and select macroalgae to discern the role of carbon produced by macro-algae in the nearshore food web using stable isotope analyses across all four regions. Mussels serve as a model organism for this project as they are an abundant and characteristic species of the nearshore environment that plays a critical role in linking pelagic to nearshore environments and also are a key prey for many species at higher trophic levels. In several of the sampling regions, collections reach back as far as 2014, but a concerted and coordinated effort across regions was initiated in 2017. Preliminary data from 2017 show that mussels likely consume some proportion of macroalgal detritus and additional macroalgal samples collected in 2019 are soon ready to be analyzed for stable isotope values. A regional comparison of mussel stable carbon and nitrogen values across all years (2014-2018) showed that mussels in KEFJ and WPWS were on average depleted in ^{13}C compared with those from KATM and KBAY (Fig. 9). This may indicate that mussels in KATM and KBAY feed on a higher proportion of macroalgae or could reflect an inherent regional difference in inorganic carbon sources. POM and macroalgal samples collected in 2019 in all regions will help us shed more light on these alternative hypotheses.

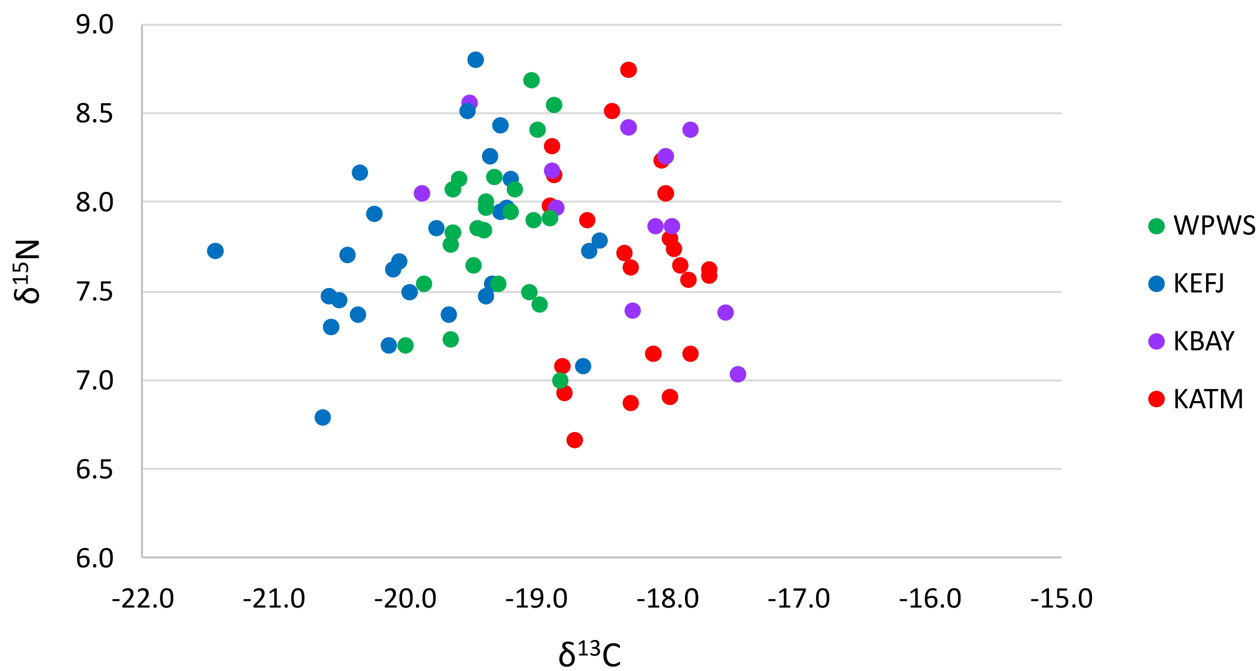


Figure 9. Mussel stable carbon and nitrogen isotope values (from 5 sites per region from 2014-2018), showing heavier carbon isotope values in Katmai National Park and Preserve (KATM) and Kachemak Bay (KBAY) than western Prince William Sound (WPWS) and Kenai Fjords National Park (KEFJ). This may be due to higher proportions of macroalgal detritus in mussel diets in those two regions.

An educational collaboration continues to exist within the GWA Nearshore project. Two University of Alaska field courses taught by GWA Nearshore PIs, Konar and Iken, at the Kasitsna Bay Lab, contribute to nearshore data collection. Students get valuable experience and training from participation in this project, and the project benefits from their involvement. In addition, the KBAY portion of this project provides summer funding for one student to assist in the sampling and sample processing. In 2019, Emily Williamson was that student. In addition to assisting with field work, she also completed a project investigating mussel size frequency distributions from KBAY GWA and other sites in KBAY and is presenting this information as a poster at the Alaska Marine Science Symposium in Anchorage in January 2020. Another undergraduate, Brian Zhang, received a BLAST (Biomedical Learning and Student Training) fellowship and URSA (Undergraduate Research and Scholarly Activity) from University of Alaska Fairbanks (UAF) to complete a project comparing clam recruitment to adult standing stock across all the GWA intertidal sites. He is also presenting a poster at the Alaska Marine Science Symposium in Anchorage in January 2020. Similarly, Tibor Dorsaz completed an Undergraduate Senior Thesis at UAF examining if and how the proportion of sea otter versus sea star eaten clams have changed over time (pre and post sea star wasting). We have recruited a UAF graduate student, Liza Hasan, to complete a project mapping sea otter habitat at many of the GWA sites. This student started in Spring 2020 and will complete her field work in summer 2021. Lastly, we are working with Lena Ware, a graduate student at Simon Fraser University, to study the migration patterns of black oystercatchers across the north Pacific using GPS and geolocator technology. Black oystercatchers throughout all four regions (WPWS, KEFJ, KBAY and KATM) were captured and tagged in 2019. With the field support of GWA, recaptures will occur in 2020.

In addition to supporting undergraduate and graduate students, the Nearshore component has been actively engaged in 'Floating Teacher Workshops', a program supported by the NPS Ocean Alaska Science and Learning Center (OASLC). The NPS OASLC mission is to 'promote stewardship of the marine influenced ecosystems of Alaska's coastal national parks through education and research'. Through these workshops, educators from around the country (K-12) have participated in field data collection with Nearshore component PIs during our annual summer GWA sampling trips to KEFJ. In 2020, it will be our third year of participation. The workshop focus has been to provide hands-on field experience that has resulted in classroom curriculum development and community engagement that would not otherwise be possible. A YouTube video documenting the experience of some of the educators will be shown at the 2020 Alaska Forum for the Environment Film Festival, where GWA is acknowledged as a contributor to the program. In addition to GWA, NPS and the OASLC, other partners include: USGS, Prince William Sound Regional Citizens Advisory Council, and Alaska Geographic (https://www.youtube.com/watch?v=N14pfHOoN0U&feature=youtu.be).

In addition, we have worked closely with the other GWA components (Environmental Drivers and Pelagic) to identify data sets that can be shared. For example, Environmental Drivers data were used extensively in an analysis of mussel trends across the Gulf of Alaska, presented in the GWA Science Synthesis report (Monson et al. 2015). More recently, we collaborated on two synthesis chapters for the draft report submitted to the *Exxon Valdez* Oil Spill Trustee Council (Suryan et al. 2019): we collaborated with the Environmental Drivers component to evaluate whether temperature changes in nearshore systems correlate with oceanographic conditions (Danielson et al. 2019) and we collaborated with the Pelagic component to assess how the synchronous collapse of forage species disrupted trophic transport during the marine heatwave (Arimitsu et al. 2019). In general, the geographic scale of our study (Gulf of Alaska-wide) will continue to provide greater ability to discern both potential linkages across these diverse components, as well as among the study areas within the nearshore, allowing us to evaluate variability and relations among the nearshore resources. Overall, the Nearshore component contributed to all of the FY17-21 science synthesis products produced by GWA.

Ben Weitzman recently began a position with NOAA at the Kasitsna Bay Lab in Kachemak Bay. In his new position, he will continue to collaborate not only with the Nearshore component of GWA but also provide a stronger linkage to the Environmental Drivers component.

2. Across Programs

a. Herring Research and Monitoring

The Nearshore component does not have any collaborations to date with the Herring Research and Monitoring program, but discussions are in progress with respect to coastal herring spawning habitat.

b. Data Management

This project coordinates with the data management program by submitting data and preparing metadata for publication on the Gulf of Alaska Data Portal and DataONE within the timeframes required.

B. Individual Projects

In collaboration with researchers at University of Alaska Anchorage (UAA) and University of Alaska Southeast (UAS), Nearshore GWA PIs (Konar and Iken) have received funding from the National Science Foundation Established Program to Stimulate Competitive Research (EPSCoR) program to examine how the timing, duration, and character of the freshwater flux from precipitation vs glacial melt influences nearshore biological communities. This five-year project (Titled Fire and Ice) will examine an array of sites from Lynn Canal in southeast Alaska to Kachemak Bay. GWA and EPSCoR are sharing environmental data (temperature, salinity) and also some biological data. One EPSCoR graduate student, Amy Dowling, is going to use the KBAY GWA sites as oceanic endpoints in her MS research, which is examining mussel demographics (size, age, and growth) along a glacial gradient.

In collaboration with other UAF researchers, GWA PIs (Konar and Iken) received a Field Station and Marine Laboratories Award from the National Science Foundation. An array of SeapHOx sensors in Kachemak Bay to monitor pH, oxygen, salinity, and temperature at multiple sites and an experimental system to manipulate ocean variables to determine responses in marine organisms was installed at the Kasitsna Bay Marine Lab in 2019. These data will be available for all GWA PIs.

In collaboration with GWA PIs (Esler, Coletti, and Robinson), a study was initiated with Simon Fraser University to determine the connectivity between breeding areas and non-breeding areas of black oystercatchers in the north Pacific. We recognize that migration strategies and large-scale movements of the black oystercatcher may play a role in their overall condition, in addition to the diet monitoring conducted by GWA. By using GPS and geolocator technology, this work will elucidate the degree to which Alaskan breeding birds' winter in the same locations. Black oystercatchers were captured and tagged in all four Nearshore regions in 2019. Recaptures will occur in 2020. Taken together this work will highlight the times and places when and where conservation action can directly benefit black oystercatchers that breed in Alaskan coastal parks and will serve to facilitate risk assessment to a key wildlife species throughout the year.

C. With Trustee or Management Agencies

In addition to the logistical, administrative, and in-kind support that the NPS, USGS, NOAA, and UAF have provided to ensure success of the GWA Nearshore Component, there are several additional projects with trustee and management agencies that the Nearshore Component of

GWA has collaborated with. Below are several recent examples. We expect to continue these kinds of related projects.

NOAA Fisheries

The Nearshore Component contributed nearshore indices to NOAA Fisheries for the annual Gulf of Alaska Ecosystems Considerations Report to the North Pacific Fisheries Management Council (Zador et al. 2019). The health of nearshore ecosystems informs managers on essential fish habitat and sensitive early life stages of federally managed fish species mandated through the Magnuson-Stevens Act.

NPS sea otters in KEFJ

In 2013, building on GWA findings indicating that sea otters in KEFJ consume mussels at much higher frequencies than at other areas, we initiated a study of annual patterns in mussel energetics and sea otter foraging at KEFJ, funded by NPS and USGS. The field portion of the study was completed in 2016. Lab analyses have been completed. Initial data analyses indicate that mussel energy density varies seasonally, likely corresponding to spawning condition. Further, we found that mussel consumption by otters varied seasonally in association with varying mussel energy density, but overall mussel consumption was high in KEFJ across seasons.

NPRB sea otter study

Our GWA nearshore data from KATM and WPWS contributed to USGS and North Pacific Research Board (NPRB) studies of the status of the southwest Alaska stock of sea otters, which is listed as threatened under the Marine Mammal Protection Act. These data are shared with the U.S. Fish and Wildlife Service, Marine Mammals Management, who is responsible for sea otter management (NPRB Project 717 Final Report, Estes et al. 2010).

NPS Changing Tides

Nearshore GWA PIs (Ballachey, Bodkin, Coletti, and Esler) are working with NPS on the ‘Changing Tides’ Project. This study examines the linkages between terrestrial and marine ecosystems and is funded by the National Park Foundation. Field work was initiated in July 2015 with in-kind support from our GWA KATM vessel charter. National Parks in Southwest Alaska are facing a myriad of management concerns that were previously unknown for these remote coasts, including increasing visitation, expanded commercial and industrial development, and environmental changes due to natural and anthropogenic forces. These are concerns because of their potential to significantly degrade and potentially impair resources in coastal systems. The Changing Tides project has three key components: (1) brown bear fitness and use of marine resources, (2) health of bivalves (clams and mussels), and (3) an integrated outreach program. We (GWA Nearshore Component) assisted with the collection of a variety of bivalve species from the coast of KATM. Specimens were kept live in small aquarium-like containers, and condition and performance metrics were assessed in the laboratory by Alaska SeaLife Center collaborators Tuula Hollmen and Katrina Counihan. Additional specimens were used to for genetic transcription diagnostics (gene expression) to measure the physiologic responses of individuals to stressors, in collaboration with Liz Bowen and Keith Miles of USGS. Several papers have been published stemming from this work including two focused on the bivalve portion (Counihan et al. 2019, Bowen et al. in review). This project will increase our understanding of how various stressors may affect both marine intertidal invertebrates and bear populations at multiple spatial and temporal scales.

Building on the Changing Tides work and earlier *Exxon Valdez* Oil Spill Trustee Council studies (Bowen et al. 2018), GWA PIs (Coletti and Ballachey) are collaborating with L. Bowen (USGS) and A. Love (Prince William Sound Regional Citizens Advisory Council) to further develop genetic transcription diagnostics (gene expression) to measure the responses of individuals to stressors in *Mytilus trossulus*. Results on mussels sampled in in 2019 in Prince William Sound (various sites in Port Valdez) have been summarized and suggest gene transcription assays in mussels will be a useful additional tool for monitoring of contaminants; this collaboration is anticipated to continue in 2020 (Bowen et al. 2019).

Further building on GWA and Changing Tides work, in the summer of 2019, we (Coletti and Ballachey) collaborated with Maya Groner, Maureen Purcell and Paul Herschberger (USGS Western Fisheries Research Center) on their study of the bacterial gill pathogen NIX in razor clams. Razor clams are economically and ecologically important along coastlines in Alaska, as well as in Washington and Oregon where they are known to be affected by NIX disease. However, NIX is not thought to affect razor clams in Alaska, and thus we provided razor clams from the KATM coast for the NIX study as a negative control sample. We also provided additional sample of razor clam tissue to the Alaska Department of Fish and Game for genetic and morphometric analyses.

Additional work examining the interaction between bears and marine mammals was added in 2016 (initiated by D. Monson). Previously, it was believed that bears generally utilize marine mammals via scavenging of beached carcasses. This component will shed light on the importance of marine mammals (primarily sea otters and harbor seals) as live prey taken on offshore islands along the Katmai coast (Monson et al. in review).

BOEM Nearshore community assessments

Nearshore Component PIs (Coletti, Iken, Konar, and Lindeberg) have completed recommendations to the Bureau of Ocean Energy Management (BOEM) for nearshore community assessment and long-term monitoring (Jones et al. 2020). The BOEM Proposed Final Outer Continental Shelf (OCS) Oil and Gas Leasing Program included proposed Lease Sale 258 in the Cook Inlet Planning Area in 2021. Until this leasing program, an OCS Cook Inlet Lease Sale National Environmental Policy Act (NEPA) analysis had not been undertaken since 2003. Updated nearshore information was needed to support the environmental analyses associated with the planned lease sale. The overall objective of this study was to provide data on habitats and sensitive species to support environmental analyses for NEPA documents, potential future Exploration Plans, and Development and Production Plans. Throughout this process, a goal has been to utilize existing nearshore monitoring protocols already developed through GWA when possible to ensure data comparability across all regions. All data are being provided to the Alaska Ocean Observing System Gulf of Alaska Data Portal.

CMI Nearshore food webs in Cook Inlet

Funded through the Coastal Marine Institute (CMI), a partnership between BOEM and UAF, GWA PIs Iken and Konar are working with a student on analyzing food web structure in western Cook Inlet (above-mentioned BOEM project) and at GWA sites in Kachemak Bay by using carbon and nitrogen stable isotope analysis. Intertidal taxa at western Cook Inlet are clearly adapted to utilizing some of the more terrestrial material available from river and glacial discharge than the more marine production-feeding taxa in Kachemak Bay. This adds valuable information about the energetic links among the species that are analyzed for their abundance and distribution through GWA. A draft final report has been submitted to CMI and BOEM.

Drones to collect monitoring data in Kachemak Bay

Nearshore GWA PIs (Iken and Konar) tested the use of unmanned aircraft systems (UASs) for various aspects of coastal biological monitoring in KBAY. With BOEM funding, UASs were compared to traditional methods of rocky intertidal and seagrass sampling with some success and suggestions for future work (Konar and Iken 2018). After this success, UASs were tested to determine their feasibility to complete sea otter foraging observations in KBAY with USGS funding (Monson and Weitzman).

In August 2019, GWA PIs (Hondolero and Weitzman) with an academic collaborator (Tom Bell – University of California Santa Barbara) used a UAS to map canopy kelp and eelgrass habitats in Kachemak Bay with support from NOAA – Kasitsna Bay Lab. The pilot effort proved successful, resulting in a poster at the Alaska Marine Science Symposium and plans to pursue more UAS mapping in 2020.

In collaboration with NPS, during recent nearshore monitoring trips on the Katmai coast, the GWA Nearshore project (GWA PI Monson and NPS collaborator Martyn) tested the use of a small UASs to map intertidal sites. The elevation data collected by the UAS will allow us to track changes in topography over time and enable us to correlate species presence and abundance with elevation in the intertidal zone. The high-resolution elevation data may also be critical for future assessments of ecosystem change due to sea-level rise, earthquakes, or other natural phenomena. Collection of UAS based aerial imagery for each site allows for documentation of physical disturbances, which can be valuable when trying to interpret variation in community structure within sites. Data collected from 2017-2019 are currently being analyzed. UAS flights in KATM will not take place in 2020 as the Department of Interior has issued a ‘stand down’ of all NPS UAS operations.

The Pacific nearshore project

In kind support from GWA and NPS was provided to the USGS Pacific Nearshore Project (https://pubs.usgs.gov/fs/2010/3099/) that investigated methods to asses overall health of nearshore ecosystems across the north Pacific. In particular, samples were collected during GWA trips to KATM and WPWS to examine the sources of primary productivity to two fish species that differed in their feeding mode (kelp greenling/nearshore benthic vs. black rockfish/pelagic). Stable isotope analyses showed that both benthic foraging and pelagic foraging fish species derive their energy from a combination of macro- (kelps) and micro-algae (phytoplankton) sources (von Biela 2016a). Initial stable isotope analyses from across the GOA of a variety of nearshore invertebrates supports the concept that kelps are a primary contributor of carbon to nearshore ecosystems in the GOA (unpublished data). Further work was completed by von Biela et al. (2016b), with support from GWA, examining the role of local and basin-wide ocean conditions on growth rates of benthic foraging and pelagic foraging fish species. In 2018, we initiated a pilot study to build on the Pacific Nearshore Project by sampling fish and mussels across all four regions. Objectives are to 1) examine relative contributions of macroalgae and phytoplankton to nearshore intertidal mussels and subtidal fishes over space and time, 2) examine variation in the relative contributions of primary producers and determine if that variation is related to growth performance, and 3) assess annual growth rates of mussels and fish to determine if they are synchronous with other GWA environmental drivers or indicators of productivity in nearshore or pelagic ecosystems. Sample collection is on-going throughout all four regions of the Nearshore component.

Nearshore ecosystem responses to glacial inputs

Nearshore GWA PIs (Esler, Coletti, Weitzman), in collaboration with NPS, have initiated work aimed at documenting variation in nearshore physical oceanography in relation to tidewater glacial input, and quantify biological responses to that variation across trophic levels in KEFJ. This work will allow prediction of changes in nearshore ecosystems in the face of ongoing glacier mass loss and retreat from the marine environment. This proposed work relies heavily on GWA nearshore monitoring data and will build on our understanding of nearshore marine processes.

9. Information and Data Transfer:

A. Publications Produced During the Reporting Period

1. Peer-reviewed publications

Bowen, L., K. Counihan, B. Ballachey, H. Coletti, T. Hollmen, B. Pister and T. Wilson. *In review*. Monitoring Nearshore Ecosystem Health Using Pacific Razor Clams (*Siliqua patula*) as an Indicator Species. PeerJ

Counihan, K., L. Bowen, B. Ballachey, H. Coletti, T. Hollmen, and B. Pister. 2019. Physiological and gene transcription assays in combinations: a new paradigm for marine intertidal assessment. PeerJ 7:e7800 https://doi.org/10.7717/peerj.7800

Davis, R., J. L. Bodkin, H. A. Coletti, D. H. Monson, S. E. Larson, L. P. Carswell, and L. M. Nichol. 2019. Future direction in sea otter research and management. Frontiers in Marine Science. 5:510. doi:10.3389/fmars.2018.00510

Konar, B., T.J. Mitchell, K. Iken, H. Coletti, T. Dean, D. Esler, M. Lindeberg, B. Pister, and B. Weitzman. 2019. Wasting disease and environmental variables drive sea star assemblages in the northern Gulf of Alaska. Journal of Experimental Marine Biology and Ecology. https://doi.org/10.1016/j.jembe.2019.151209

Monson D., R. Taylor, G. Hilderbrand, J. Erlenbach, and H. Coletti. *In review*. Brown Bears and sea otters along the Katmai coast: Terrestrial and nearshore communities linked by predation.

Piatt, J. F., J. K. Parrish, H. M. Renner, S. K. Schoen, T. Jones, M. L. Arimitsu, K. J. Kuletz, B. Bodenstein, M. García-Reyes, R. S. Duerr, R. M. Corcoran, R. Kaler, G. McChesney, R. Golightly, H. Coletti, R. M. Suryan, H. Burgess, J. Lindsey, K. Lindquist, P. Warzybok, J. Jahnke, J. Roletto, and W. J. Sydeman. 2020. Extreme mortality and reproductive failure of common murres resulting from the northeast Pacific marine heatwave of 2014-2016. PLoS ONE.

Robinson, B. H., L. M. Phillips and A. N. Powell. 2019. Energy intake rate influences survival of Black Oystercatcher *Haematopus bachmani* broods. Marine Ornithology 47: 277–283

2. Reports

Apeti, D.A., A. Jacobs, and M. Rider. 2019. A Synthesis of Ten Years of Chemical Contaminants Monitoring in National Park Service - Southeast and Southwest Alaska Networks. A collaboration with the NOAA National Mussel Watch Program. NOAA Technical Memorandum NOS NCCOS xxx-xxx. Silver Spring, MD. Xx pp.

Arimitsu, M., J. Piatt, R.M. Suryan, S. Batten, M.A. Bishop, R.W. Campbell, H. Coletti, D. Cushing, K. Gorman, S. Hatch, S. Haught, R.R. Hopcroft, K.J. Kuletz, C. Marsteller, C. McKinstry, D. McGowan, J. Moran, R.S. Pegau, A. Schaefer, S. Schoen, J. Straley, and V.R. von Biela. 2019. Chapter 3 Synchronous collapse of forage species disrupts trophic transfer during a prolonged marine heatwave. In M.R. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (Exxon Valdez Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Bowen L., A. Love, S. Waters, K. Counihan, B. Ballachey, and H. Coletti. 2019. Report: Port Valdez Mussel Transcriptomics. Prepared for Prince William Sound Regional Citizens' Advisory Council. Contract Number 951.20.06

Coletti, H., D. Esler, B. Konar, K. Iken, K. Kloecker, D. Monson, B. Weitzman, B. Ballachey, J. Bodkin, T. Dean, G. Esslinger, B. Robinson, and M. Lindeberg. 2019. Gulf Watch Alaska: Nearshore Ecosystems in the Gulf of Alaska. *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 18120114-H), *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Coletti, H., J. Bodkin, T. Dean, D. Esler, K. Iken, B. Ballachey, K. Kloecker, B. Konar, M. Lindeberg, D. Monson, B. Robinson, R. Suryan and B. Weitzman. 2019. Intertidal Ecosystem Indicators in the Northern Gulf of Alaska in Zador, S.G., and E.M.

Yasumiishi. 2019. Ecosystem Status Report 2019: Gulf of Alaska. Report to the North Pacific Fishery Management Council, Anchorage, AK.

Danielson, S.L., T.D. Hennon, D.H. Monson, R.M. Suryan, R.W. Campbell, S.J. Baird, K. Holderied, and T.J. Weingartner. 2019. Chapter 1 A study of marine temperature variations in the northern Gulf of Alaska across years of marine heatwaves and cold spells. In M.R. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Jones, T., S. Saupe, K. Iken, B. Konar, S. Venator, M. Lindeberg, H. Coletti, B. Pister, J. Reynolds, and K. Haven. 2019. Evaluation of nearshore communities and habitats: Lower Cook Inlet nearshore ecosystem. Anchorage (AK): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2019-075. 219 pp.

Robinson, B., D. Esler, H. Coletti. 2019. Long-term monitoring of Black Oystercatchers in the Gulf of Alaska. Annual Summary Compilation: New or ongoing studies of Alaska shorebirds. Alaska Shorebird Group, Anchorage, Alaska.

Suryan, R.M., M. Arimitsu, H. Coletti, R.R. Hopcroft, M.R. Lindeberg, S. Batten, M.A. Bishop, R. Brenner, R. Campbell, D. Cushing, S. Danielson, D. Esler, T. Gelatt, S. Hatch, S. Haught, K. Holderied, K. Iken, D. Irons, D. Kimmel, B. Konar, K. Kuletz, B. Laurel, J.M. Maniscalco, C. Matkin, C. McKinstry, D. Monson, J. Moran, D. Olsen, S. Pegau, J. Piatt, L. Rogers, A. Schaefer, J. Straley, K. Seeeney, M. Szymkowiak, B. Weitzman, J. Bodkin, and S. Zador. 2019. Chapter 4 Ecosystem response to a prolonged marine heatwave in the Gulf of Alaska. In M.R. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Ware, L., D. Green, D. Esler, B. Robinson, H. Coletti. 2019 Field Report: Movement Ecology of the Black Oystercatcher in Alaska. Prepared for the Bird Banding Laboratory, Laurel, MD.

Weitzman, B., B. Konar, K. Iken, H. Coletti, D. Monson, R.M. Suryan, T. Dean, D. Hondolero, and M.R. Lindeberg. 2019. Chapter 2 Changes in rocky intertidal community structure during a marine heatwave in the northern Gulf of Alaska. In M.R. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

3. Popular articles

Anonymous. 2019. Our ocean, Great Lakes and coasts—Up close and from a distance (Gulf Watch Alaska Nearshore project photographs). Special photo issue Newswave News from the U.S. Department of the Interior: Oceans, Great Lakes, and Coasts. Summer Issue.

Backensto, S. and H. Coletti. 2019. Another Year of Seabird Die-Offs. High Latitude Highlights, the NPS Alaska Region Resource Newsletter. Fall Issue: Pp 2-3.

Coletti, H., S. Backensto, and N. Chambers. 2019. (Special Feature) Long-term monitoring of nearshore marine ecosystems: Gulf of Alaska 30 years since the *Exxon Valdez* Oil Spill. Newswave News from the Department of the Interior: Ocean, Great Lakes, and Coasts. Spring Issue. Pp 15-17.

National Park Service Press Release

Links to NPS press releases and press response related to NPS efforts to track seabird die offs are listed below. These press releases and articles link to the NPS die-off webpage, which in turn, summarizes statewide, including Gulf of Alaska, data. The Nearshore component of GWA provides data to these summaries.

https://www.nps.gov/orgs/1840/2019-alaska-seabird-die-off.htm

https://www.nps.gov/subjects/aknatureandscience/commonmurrewreck.htm

https://www.washingtonpost.com/climate-environment/2019/05/29/thousands-seabirds-starved-death-bering-sea-scientists-see-fingerprint-climate-change/

https://www.arctictoday.com/alaska-seabird-die-offs-now-in-their-fifth-year-are-a-red-flag-in-warming-climate/

https://www.alaskapublic.org/2019/10/11/as-seabird-die-offs-continue-unalaskans-train-to-track-local-mortalities/

https://www.nationalparkstraveler.org/2019/09/seabird-die-reported-bering-land-bridge-national-preserve

TV Coverage:

https://www.ktuu.com/content/news/Unangan-culture-impacted-by-mass-die-off-of-seabirds-in-the-Bering-Sea-510746261.html

https://www.ktva.com/story/41030559/researchers-investigate-annual-seabird-dieoffs-in-alaska

Impacts of climate disruption linked to seabird die-off https://www.ktuu.com/video/?vid=510653162

Radio Coverage:

https://www.knba.org/post/it-s-starvation-biologists-alaska-see-fifth-year-significant-seabird-die-offs

International coverage/Australia that includes link to NPS website
https://www.abc.net.au/news/2019-10-05/mutton-birds-delayed-migratory-vic-arrival-alarms-birdwatchers/11572220

https://www.abc.net.au/news/2019-10-25/mutton-bird-mystery-deepens-griffiths-island/11627720

National Park Service Social Media Outreach

Web article on 1/28/2020: Marine Heatwave Linked to Seabird Die-off (Piatt et al. 2020)

Facebook post on 1/28/2020 linked to the Piatt et al. 2020

#ParkScience Ocean ecosystems are changing, driven largely by ocean heatwaves and, specifically, the massive heatwave of 2014-2016 known as The Blob. This paper focuses on the common murre die-off that killed as many as a million birds. Other ecosystem changes were found in conjunction with the marine heatwave that made sense in connection to the murre starvation. The base of the food chain, plankton, were impacted and had an impact on many other marine species. These changes, while especially pronounced in 2014-2016, continue with warming ocean waters today. #AMSS2020 [10,434 people reached, 425 engagements, 22 shares, 17 comments]

NPS Twitter post on 1/28/2020, link to the web article and tagged #AMS2020

Updates to NPS webpage: Seabird die-offs:
https://www.nps.gov/subjects/aknatureandscience/commonmurrewreck.htm

Facebook post on 12/17/2019 about black oystercatchers linked to Nearshore Vital Signs page on the NPS Southwest Alaska Network (SWAN) website. [26,249 people reached, 2,597 engagements, 34 shares, 4 comments]

Facebook post on 12/5/2019 about seabird die-offs [20,037 people reached, 1.433 engagements, 121 shares, and 23 comments]

Facebook post on 11/15/2019 about mussel monitoring, pointing to a web article on physiological and gene transcription assays [6,579 people reached, 126 engagements]

Facebook post on 9/10/2019 about seabird die-off, link to USFWS page with latest update [7,127 people reached, 165 engagements, 4 shares, 1 comment]

Facebook post on 9/9/2019 about seabird die-offs featuring an image from COASST and linking to our seabird die-off web page [13,543 people reached, 667 engagements, 35 shares, 6 comments (Fukishima comments addressed)]

Facebook post on 8/26/2019 about sea star wasting disease with links to your resource brief [24,593 people reached, 2,081 engagements, 76 shares, and 12 comments]

Facebook post on 8/132019 on marine mammal and seabird die-offs (more specifically addressing all the comments we get about Fukushima) [13,132 people reached, 761 engagements, 27 shares, and 15 comments]

Facebook post on 5/30/2019 on phytoplankton, warming oceans, with links to NPS web article on the Blob and a science magazine article on marine heatwaves [8,043 people reached, 232 engagements, 5 shares]

Facebook post on 4/22/2019 on the Winter Marine Bird and Mammal Survey [10,500 people reached, 377 engagements, 10 shares, and 4 comments]

Facebook post on 4/21/2019 on the Winter Marine Bird and Mammal Survey [12,227 people reached, 540 engagements, 7 shares, and 1 comment]

Facebook post on 4/20/2019 on the Winter Marine Bird and Mammal Survey [11,996 people reached, 414 engagements, 13 shares, and 1 comment]

Facebook post on 4/19/2019 on the Winter Marine Bird and Mammal Survey [12,919 people reached, 476 engagements, 10 shares]

Facebook post on 4/16/2019 on the Winter Marine Bird and Mammal Survey [14,498 people reached, 498 engagements, 47 shares, and 13 comments]

Facebook post on 3/24/2019 on anniversary of EVOS [9,056 people reached, 263 engagements, 20 shares, 1 comment]

Facebook post on 3/23/2019 about the EVOS [9,548 people reached, 186 engagements, 5 shares, 6 comments]

Facebook post on 3/22/2019 about the EVOS [10,434 people reached, 448 engagements, 17 shares, 2 comments]

Facebook post on 3/21/2019 about the EVOS [9,745 people reached, 343 engagements, 7 shares, 9 comments]

Facebook post on 3/20/2019 about the EVOS [9,227 people reached, 348 engagements, 28 shares, 5 comments]

Facebook post on 3/23/2019 about the EVOS and link to two of your papers on drivers of change in intertidal communities [9,420 people reached, 222 engagements, 13 shares, 1 comment]

Facebook post on 3/18/2019 about the EVOS, link to Gulf Watch Alaska [11,436 people reached, 562 engagements, 158 shares, 13 comments]

Facebook post on 3/17/2019 about the EVOS, link to Listening to the Sound [9,231 people reached, 395 engagements, 21 shares, 9 comments]

Facebook post on 2/22/2019 on sea otters, link to web article on future directions in sea otter research [12,262 people reached, 348 engagements, 14 shares, 3 comments]

Kenai Fjords National Park Facebook page:

Facebook post on 4/7/19 3rd in a series about the winter marine bird and mammal survey, with links to Marine Birds webpage, [3900 people reached, 220 engagements, 4 shares, 1 comment]

Facebook Post on 4/6/19 2nd in a series about the winter marine bird and mammal survey [3900 people reached, 287 engagements, 3 comments]

Facebook post on 4/5/19 1st in a series about the winter marine bird and mammal survey, [3560 people reached, 191 engagements, 1 share]

B. Dates and Locations of any Conference or Workshop Presentations where EVOSTC-funded Work was Presented

1. Conferences and workshops

Coletti, H.A. 2019. Gulf Watch Alaska overview and updates. MARINe and BOEM joint meeting. September.

Coletti, H.A., R. Suryan, D. Esler, R. Kaler, T. Hollmen, M. Arimitsu, J. Bodkin, T. Dean, K. Kloecker, K. Kuletz, J. Piatt, B. Robinson and B. Weitzman. 2019. Birds of a feather flock together… or do they? Regional and temporal patterns of community composition and abundance in nearshore marine birds across the Gulf of Alaska. Oral Presentation, Alaska Bird Conference. March.

Coletti, H. A., G. Hilderbrand, D. Monson, J. Erlenbach, B. Ballachey, B. Pister and B. Mangipane. 2019. Where carnivores clash: Evidence of competition - Prey-shifting by brown bears during a period of sea otter recovery. Oral Presentation, Sea Otter Conservation Workshop 2019. March.

Griffin, K., and H. Coletti. 2020. Seabird colonies on the Katmai coast. Poster Presentation, Alaska Marine Science Symposium. January.

Hondolero, D., T. Bell, B. Weitzman, and K. Holderied. 2020. Kelp forest mapping in Kachemak Bay, Alaska using a drone. Poster Presentation, Alaska Marine Science Symposium. January.

Monson, D., R. Taylor, G. Hilderbrand, J. Erlenbach, and H. Coletti. 2019. Top-Level Carnivores Linked Across the Marine / Terrestrial Interface: Sea Otter Haulouts Offer a Unique Foraging Opportunity to Brown Bears. Oral Presentation. Sea Otter Conservation Workshop 2019. March.

Parrish, J.K., H. Burgess, T. Jones, J. Lindsey, A. Lestenkof, B. Bodenstein, B. Mangipane, E. Labunski, E. Lujan, H. Coletti, H. Renner, J. Christensen, J. Piatt, K. Hilwig, K. Lewandowski, K. Plentnikoff, K. Lefebvre, K. Kuletz, K. Griffin, L. Divine, L. Wilson, M. Romano, M. Cady, M. Good, M. Brubaker, N. Graff, N. Stellrecht, P. Lestenkof, P. Fitzmorris, P. Melovidov, R. Kaler, R. Corcoran, S. Schoen, S. Backensto, S. Knowles, S. Thomas, T. Mullet, C. Wright, A. Will and T. Lewis. 2020. Unabated Mass Mortality of Marine Birds in the Northeast Pacific. Oral Presentation, Alaska Marine Science Symposium. January.

Siegert, D., K. Iken, S. Saupe, and M. Lindeberg. 2019. Comparing intertidal food web and community structure across two regions of lower Cook Inlet. Oral Presentation. CMI Annual Review, Anchorage, February.

Suryan, R.M., M.R. Lindeberg, M. Arimitsu, H. Coletti, R.R. Hopcroft, D. Aderhold and K. Hoffman. 2020. Ecosystem response to a prolonged marine heatwave in the Gulf of Alaska. Perspectives from Gulf Watch Alaska. Oral Presentation, Alaska Marine Science Symposium. January.

Suryan, R., S. Zador, M. Lindeberg, M. Arimitsu, J. Piatt, J. Straley, H. Coletti, D. Monson, S. Hatch, T. Dean, R. Hopcroft, S. Batten, S. Danielson, B. Konar, K. Iken, B. Laurel, M.A. Bishop, A. Schaefer, S. Pegau, R. Kaler, and D. Irons. 2019. Ecosystem response to a marine heat wave in the Gulf of Alaska: Seabirds are the tip of the iceberg. Oral Presentation. The 46th Meeting of the Pacific Seabird Group, Kauai, HI. 27 February – 2 March 2019.

Weitzman, B. 2019. Can you dig it? Patterns of variability in clam assemblages across the Gulf of Alaska. Oral presentation. UAF College of Fisheries & Ocean Sciences Special Seminar, Fairbanks, AK. February.

Williamson, E., B. Konar, K. Iken, and M.K. McCabe. 2020. Size frequency distribution of Mytilus trossulus in Kachemak Bay. Poster Presentation, Alaska Marine Science Symposium. January.

Zhang, B., B. Konar, B. Weitzman, H. Coletti, and D. Esler. 2020. Associating clam recruitment with adult standing stock in the Northern Gulf of Alaska. Poster Presentation, Alaska Marine Science Symposium. January.

2. Public presentations

Ballachey, B. 2019. The *Exxon Valdez* Oil Spill: Perspectives & Lessons, 30 years later. University of Calgary Continuing Education class; Course BMC153 Environmental Site Assessment. Calgary, CA, March 2019.

Coletti, H., B. Robinson, et al. 2019. Ocean Alaska Science and Learning Center Teacher Workshop. Kenai Fjords National Park, AK, June.

Esler, D. 2019. Sea Ducks in Nearshore Marine Systems: Contrasting Responses to Oil Spill and Heat Wave Perturbations. Oral Presentation. Prince William Sound RCAC Science Night.

Grobelny, C. and J. Pfeiffenberger. 2020. Exploring the Fjords: A Hands-On Teacher Workshop. NPS OASLC YouTube video https://www.youtube.com/watch?v=N14pfHOoN0U&feature=youtu.be

Robinson, B., H. Coletti, D. Green, L. Ware, D. Esler. 2019. The Black Oystercatcher: Migration, Movement and Monitoring. Oral Presentation. Gulf Watch Alaska Community Outreach Event. Kachemak Bay Campus, Homer, AK. 8 October.

Weitzman, B. 2019. Sea otter and clam population dynamics in Kachemak Bay. Kachemak Bay National Estuarine Research Reserve Lunch Lecture Series, Kachemak Bay Campus, Homer, AK. 6 December.

Weitzman, B. 2019. Monitoring nearshore ecosystems in the Gulf of Alaska through sea otters. Fireweed Academy Community Outreach and Lecture Series, Homer, AK. 13 December.

C. Data and/or Information Products Developed During the Reporting Period, if Applicable

No new contributions for this reporting period.

D. Data Sets and Associated Metadata that have been Uploaded to the Program's Data Portal

The Nearshore component has met all obligations for publishing 2018 data (https://portal.aoos.org/gulf-of-alaska#metadata/53c052b6-8874-46d1-b40a-acc615a3879a/project/files). The Nearshore component has also exceeded obligations by sharing all 2019 data to the workspace. Below is a list of the required 2018 data and links.

-Black oystercatcher for the KATM, KEFJ and WPWS regions: https://workspace.aoos.org/project/4650/folder/5058401/bloy

-HOBO temperature data for the KATM, KBAY, KEFJ and WPWS regions: https://workspace.aoos.org/project/4650/folder/5058390/hobo

-Marine bird and mammal survey data for the KBAY, KEFJ and KATM regions: https://workspace.aoos.org/project/4650/folder/6321863/mbm

-Mussel site data for the KATM, KEFJ and WPWS regions: https://workspace.aoos.org/project/4650/folder/5055045/mussel

-Rocky intertidal community data (including percent cover, sea star counts, invertebrate counts and substrate) for the KATM, KEFJ and WPWS regions: https://workspace.aoos.org/project/4650/folder/5034222/rocky

-Sea otter forage data for the KATM, KEFJ and WPWS regions: https://workspace.aoos.org/project/4650/folder/5060904/forage

-Mixed-sediment (soft) data for the KATM, KBAY, KEFJ and WPWS regions: https://workspace.aoos.org/project/4650/folder/2591592/soft

-Sea otter spraint data for the KATM, KEFJ and WPWS regions:https://workspace.aoos.org/project/4650/folder/5060903/seot

-Sea otter carcass data for KATM, KEFJ and WPWS regions:https://workspace.aoos.org/project/4650/folder/5060903/seot

- Sea otter aerial survey data for KEFJ region:https://workspace.aoos.org/project/4650/folder/6323564/aerialsurvey

For the KBAY region specifically, the following final data sets have been uploaded as csv files to the Research Workspace and published through 2019:

-Mussel size-frequency distribution for six sites in 2017-2019: KB201#_Mytilus_SFD.cvs: https://workspace.aoos.org/project/4653/folder/2762861/mussel-data

-Rocky intertidal community data 2017-2019: KB201#_percentcover_RockyIntertidal_data.csv: https://workspace.aoos.org/project/4653/folder/2762860/rocky-intertidal-community-data

-Rocky intertidal swath data 2017-2019: KB201#_rockyintertidal_swath_counts.csv: https://workspace.aoos.org/project/4653/folder/2762911/rocky-intertidal-swath-data

-Rocky intertidal substrate data 2017-2019: KB201#_substrate_percentcover.csv: https://workspace.aoos.org/project/4653/folder/2762910/rocky-intertidal-substrate-data

-Seagrass shoot count data 2017-2019: KB201#_Zostera_shootdensity.csv: https://workspace.aoos.org/project/4653/folder/2762912/seagrass-data

10. Response to EVOSTC Review, Recommendations and Comments:

Science Panel Comment (FY20): *The Panel would like to see more detail on the increase in operating costs. Is the additional request for $24K for previous costs or for this year's increase in operating costs? Will this be an annual request? Regarding the additional funding request to cover increased expenses for the Gyre: How many less field days would the project incur if the additional funding for Gyre is not approved? And there is emphasis on providing more details on what the money will pay for.*

In FY19 we requested the exploration of the relationships among species. The PIs did not address this inquiry. We note the PIs responded with an example that mussel density has increased, and Fucus and sea stars have declined but no other interpretations were offered or reported in the FY18 annual report. The Panel requests PIs address this and present possible mechanisms for this change. This certainly should be included in the synthesis paper(s). We appreciate the listed collaborations with a wide variety of groups.

PI Response (FY20):

The costs of operating the US Geological Survey (USGS) research vessel Alaskan Gyre are increasing through time, while the base contribution of USGS facilities money has remained static (Fig. 1). The base contribution from USGS still allows the boat to be used at a fraction of the cost of charter vessels (see estimates below); however, this does not cover as much of the total operating costs as in past years. USGS has prepared a business plan for operating and maintaining the Alaskan Gyre, which resulted in the need to increase costs to projects. These increased costs are being required of all users of the Alaskan Gyre, not just Gulf Watch Alaska projects.

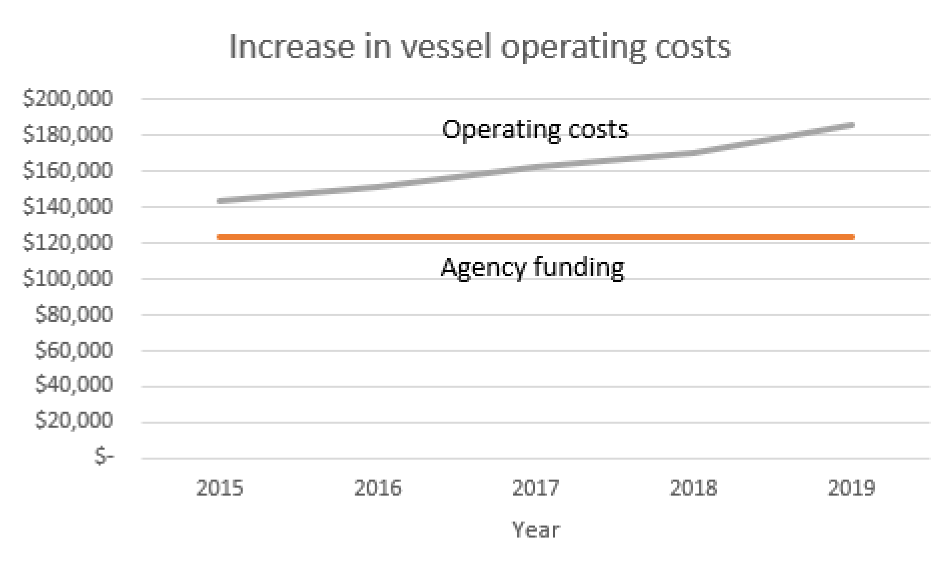


Figure 1. Annual costs of operating the USGS research vessel Alaskan Gyre relative to the agency funding allocation.

The increase in overall operating costs reflects increases in nearly all of the specific costs of running the Alaskan Gyre. However, a sizeable proportion of the increased costs are associated with a few specific items, including personnel (captain salary and benefits), maintenance (shop rates and material costs are increasing), and harbor fees. All of these costs are essential for safely and effectively operating the vessel. The budget request for FY20 is for costs anticipated in that fiscal year, not previous years' costs. We also are requesting funds for FY21, anticipating that operating costs will not go down. If additional funding is not approved, field time on the Alaskan Gyre could be reduced by as many as 19 days.

Charter boats used for nearshore sampling have ranged from $3600 to $5000 per day. Our request for additional funds, assuming at least 50 days of Gulf Watch Alaska use annually, is less than $500 per day. Moreover, some of the Gulf Watch Alaska work involves trawling for forage fish and the Alaskan Gyre has been specifically outfitted to do this work.

We agree with the science panel that understanding inter-specific relationships is important and that the nearshore component is particularly well-suited for evaluating those, given the large number of species monitored across multiple trophic levels and the sampling design in which all data streams are spatially coordinated. Below we describe our efforts to date along these lines, as well as plans for additional exploration in the near future.

The Nearshore program is the lead on two of the Gulf Watch Alaska synthesis manuscripts currently in progress. One of the these manuscripts is specifically focused on inter-species and community relationships and titled "Synchronous Region-wide Responses in Intertidal Community Structure to a Marine Heat Wave in the Gulf of Alaska." This synthesis product will focus on changes in intertidal community structure at long-term monitoring sites that stretch across the Gulf of Alaska from Prince William Sound to the Katmai Peninsula over the period from 2006 through 2018, with emphasis on changes that occurred during the 2014-2016 marine heatwave. We are examining site specific changes in intertidal temperature as well as changes in percent cover of intertidal algae and invertebrates during this period. Preliminary analyses indicate that differences in community structure exist across sites; however, synchronous trends across sites in heatwave years over very large spatial scales suggest influence of large-scale oceanographic events. While mean water temperatures differ across sites and regions (i.e., Katmai generally colder), all regions exhibited anomalous warming during heatwave years indicating that the heatwave may be driving these synchronous responses of the biological community in the intertidal.

We also will be continuing to explore inter-specific relationships within the nearshore component and across components. The USGS postdoc position, recently funded by the EVOSTC, will support an early-career scientist as they work with Gulf Watch Alaska principal investigators to evaluate interspecific relationships as part of synthesis efforts.

Additional species-environmental relationships are in our FY18 Annual Report (Coletti et al. 2019), as well as in the annual NOAA Gulf of Alaska Ecosystem Status Report (Coletti et al. 2018), we identified warming water temperatures (heatwave) as a possible driver for coincident responses of several species, representing various trophic levels, across the nearshore environment in the northern Gulf of Alaska. These include both direct responses of warming surface temperatures and also indirect effects through interspecific interactions. We documented negative anomalies of rockweed in three of the four regions and sea stars across all regions coincident with warm water temperatures. We hypothesized that the decline in sea star abundance was likely due to sea star wasting disease (Konar et al. 2019), which was first detected in 2014 and is generally associated with warm water temperature anomalies (Eisenlord et al. 2016). We documented positive anomalies during 2015-2019 for large mussels. This is likely due, in part, to a response to the reduced predation pressure given the synoptic decline of sea stars. Continued positive anomalies of large mussels in Katmai National Park and, to a lesser degree, in Kachemak Bay coincide with continued negative anomalies of sea stars in these two regions. A decline in small mussel density (an indicator of recruitment) was also observed during the 2015-2017 period, possibly because of the decrease in Fucus as available settlement habitat or some reduction in primary productivity.

We also published a paper specific to the sea star decline to document pre- and post-heatwave community structure and examined possible static drivers of those communities (Konar et al. 2019). Sea star wasting disease and then subsequent declines in sea stars resulted in a sea star assemblage that is responding to different environmental variables, and has drastically altered ecological function by the reduction of species composition and loss of large predatory sea stars. Understanding the delicate interplay of environmental variables that influence sea star assemblages could expand knowledge of the habitat preferences and tolerance ranges of important sea star species within the northern Gulf of Alaska.

In 2016, a paper was published in Ecosphere (Coletti et al. 2016) highlighting the overall nearshore monitoring program while simultaneously providing examples of linkages across metrics to detect and infer causes of change. In one example specific to Kenai Fjords National Park, we documented changes in the proportion of various prey types in the sea otter diet that coincided with changes in the abundance of the mussel, *Mytilus trossulus*. This is likely a bottom-up driven interaction as mussel abundance in Kenai Fjords is very high while sea otter abundance is considered low, but stable and likely at carrying capacity for this region.

Coletti, H. A., J. L. Bodkin, D. H. Monson, B. E. Ballachey, and T. A. Dean. 2016. Detecting and inferring cause of change in an Alaska nearshore marine ecosystem. Ecosphere 7(10):e01489. 10.1002/ecs2.1489.

Coletti, H., J. Bodkin, T. Dean, K. Iken, B. Konar, D. Monson, D. Esler, M. Lindeberg, R. Suryan. 2018 Intertidal Ecosystem Indicators in the Northern Gulf of Alaska in Zador, S. G., and E. M. Yasumiishi. 2018. Ecosystem Status Report 2018: Gulf of Alaska. Report to the North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99301. https://www.fisheries.noaa.gov/resource/data/2018-status-gulf-alaska-ecosystem.

Coletti, H., D. Esler, B. Konar, K. Iken, K. Kloecker, D. Monson, B. Weitzman, B. Ballachey, J. Bodkin, T. Dean, G. Esslinger, B. Robinson, and M. Lindeberg. 2019. Gulf Watch Alaska: Nearshore Ecosystems in the Gulf of Alaska. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 18120114-H), Exxon Valdez Oil Spill Trustee Council, Anchorage, Alaska.

Eisenlord, M. E., M. L. Groner, R. M. Yoshioka, J. Elliott, J. Maynard, S. Fradkin, M. Turner, K. Pyne, N. Rivlin, R. van Hooidonk, and C. D. Harvell. 2016. Ochre star mortality during the 2014 wasting disease epizootic: role of population size structure and temperature. Philosophical Transactions of the Royal Society B: Biological Sciences 371.

Konar, B., T. J. Mitchell, K. Iken, H. Coletti, T. Dean, D. Esler, M. Lindeberg, B. Pister, and B. Weitzman. 2019. Wasting disease and environmental variables drive sea star assemblages in the northern Gulf of Alaska. Journal of Experimental Marine Biology and Ecology. https://doi.org/10.1016/j.jembe.2019.151209

Science Panel Comment (FY19): *Science Panel is curious to know if this project interacts with the LTER program and specifically whether LTER and EVOSTC funding are responsible for different sampling locations.*

We recognize that there are several informative time series of individual species but would like to see analyses to explore the relationships among species. Current analyses only report single species trends over time, which are certainly useful, but given the rich literature on species interactions in these nearshore systems (e.g., keystone effects of sea stars) it seems that assessing correlations among taxa across space and/or time would be a profitable approach that might produce hypotheses for the extent to which changes observed were the direct effect of environmental variation vs indirect effects mediated through species interactions.

PI Response (FY19): With the start of a new long-term ecological research (LTER) site in the northern GOA, the Nearshore component continues to actively engage with the Environmental Drivers component as we explore linkages from the offshore to the nearshore environments. Currently, that includes a synthesis product examining the relationship between offshore and coastal temperatures (Danielson et al.). As for the sampling sites within the Nearshore component, they were randomly selected to allow for inference across the regions of the GOA prior to the start of GWA. Kachemak Bay sites are the exception and are a continuation of historical sampling.

We agree with the science panel that understanding inter-specific relationships is important and that the Nearshore component is particularly well-suited for evaluating those, given the large number of species monitored across multiple trophic levels and the sampling design in which all data streams are spatially coordinated. Below we describe our efforts to date along these lines, as well as plans for additional exploration in the near future.

The Nearshore component is the lead on one of the Gulf Watch Alaska synthesis manuscripts (Weitzman et al.) and a contributor on the other three synthesis manuscripts that are currently in review. One of the these manuscripts is specifically focused on inter-species and community relationships and titled "Changes in rocky intertidal community structure during a marine heatwave in the northern Gulf of Alaska." This synthesis product will focus on changes in intertidal community structure at long-term monitoring sites that stretch across the Gulf of Alaska from Prince William Sound to the Katmai Peninsula over the period from 2012 through 2019, with emphasis on changes that occurred during the 2014-2016 marine heatwave. Analyses indicate that differences in community structure exist across sites; however, synchronous trends across sites in heatwave years over very large spatial scales suggest influence of large-scale oceanographic events. While mean water temperatures differ across sites and regions (i.e., Katmai generally colder), all regions exhibited anomalous warming during heatwave years indicating that the heatwave may be driving these synchronous responses of the biological community in the intertidal.

We will continue to explore inter-specific relationships within the Nearshore component and across components. The USGS postdoc position, recently funded by the EVOSTC, will support an early-career scientist as they work with Gulf Watch Alaska PIs to evaluate interspecific relationships as part of synthesis efforts. Additional species-environmental relationships are in our FY18 Annual Report (Coletti et al. 2019), as well as in the annual NOAA Gulf of Alaska Ecosystem Status Report (Coletti et al. 2018, 2019). We identified warming water temperatures (heatwave) as a possible driver for coincident responses of several species, representing various trophic levels, across the nearshore environment in the northern Gulf of Alaska. These include both direct responses of warming surface temperatures and also indirect effects through interspecific interactions. We documented negative anomalies of rockweed in three of the four regions, and sea stars across all regions coincident with warm water temperatures. We hypothesized that the decline in sea star abundance was likely due to sea star wasting disease (Konar et al. 2019), which was first detected in 2014 (Eisenlord et al. 2016). We documented positive anomalies during 2015-2019 for large mussels. This is likely due, in part, to a response to the reduced predation pressure given the synoptic decline of sea stars. Continued positive anomalies of large mussels in KATM and, to a lesser degree, in KBAY coincide with continued negative anomalies of sea stars in these two regions. A decline in small mussel density (an indicator of recruitment) was also observed during the 2015-2017 period, possibly because of the decrease in *Fucus* as available settlement habitat or some reduction in primary productivity.

We also published a paper specific to the sea star decline to document pre- and post-heatwave community structure and examined possible static drivers of those communities (Konar et al. 2019). Sea star wasting disease and then subsequent declines in sea stars resulted in a sea star assemblage that is responding to different environmental variables and has drastically altered ecological function by the change in species composition and loss of large predatory sea stars. Understanding the delicate interplay of environmental variables that influence sea star assemblages will expand knowledge of the habitat preferences and tolerance ranges of important sea star species within the northern Gulf of Alaska.

In 2016, a paper was published in Ecosphere (Coletti et al. 2016) highlighting the overall nearshore monitoring program while simultaneously providing examples of linkages across metrics to detect and infer causes of change. In one example specific to KEFJ, we documented changes in the proportion of various prey types in the sea otter diet that coincided with changes in the abundance of the mussel, *Mytilus trossulus*. This is likely a bottom-up driven interaction as mussel abundance in Kenai Fjords is very high while sea otter abundance is considered low, but stable and likely at carrying capacity for this region.

Coletti, H. A., J. L. Bodkin, D. H. Monson, B. E. Ballachey, and T. A. Dean. 2016. Detecting and inferring cause of change in an Alaska nearshore marine ecosystem. Ecosphere 7(10):e01489. 10.1002/ecs2.1489.

Coletti, H., J. Bodkin, T. Dean, K. Iken, B. Konar, D. Monson, D. Esler, M. Lindeberg, R. Suryan. 2018 Intertidal Ecosystem Indicators in the Northern Gulf of Alaska in Zador, S. G., and E. M. Yasumiishi. 2018. Ecosystem Status Report 2018: Gulf of Alaska. Report to the North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99301. https://www.fisheries.noaa.gov/resource/data/2018-status-gulf-alaska-ecosystem.

Coletti, H., D. Esler, B. Konar, K. Iken, K. Kloecker, D. Monson, B. Weitzman, B. Ballachey, J. Bodkin, T. Dean, G. Esslinger, B. Robinson, and M. Lindeberg. 2019. Gulf Watch Alaska: Nearshore Ecosystems in the Gulf of Alaska. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Project 18120114-H), Exxon Valdez Oil Spill Trustee Council, Anchorage, Alaska.

Coletti, H., J. Bodkin, T. Dean, D. Esler, K. Iken, B. Ballachey, K. Kloecker, B. Konar, M. Lindeberg, D. Monson, B. Robinson, R. Suryan and B. Weitzman. 2019 Intertidal Ecosystem Indicators in the Northern Gulf of Alaska in Zador, S. G., and E. M. Yasumiishi. 2019. Ecosystem Status Report 2019: Gulf of Alaska. Report to the North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99301.

Eisenlord, M. E., M. L. Groner, R. M. Yoshioka, J. Elliott, J. Maynard, S. Fradkin, M. Turner, K. Pyne, N. Rivlin, R. van Hooidonk, and C. D. Harvell. 2016. Ochre star mortality during the 2014 wasting disease epizootic: role of population size structure and temperature. Philosophical Transactions of the Royal Society B: Biological Sciences 371.

Konar, B., T. J. Mitchell, K. Iken, H. Coletti, T. Dean, D. Esler, M. Lindeberg, B. Pister, and B. Weitzman. 2019. Wasting disease and environmental variables drive sea star assemblages in the northern Gulf of Alaska. Journal of Experimental Marine Biology and Ecology. https://doi.org/10.1016/j.jembe.2019.151209

11. Budget:

Please see provided program workbook.

Federal Agencies: For FY17, deviation from travel was due to NPS personnel being unable to attend meetings in the winter of 2017/2018 (AMSS and the Ocean Sciences) because of medical issues. Deviation from contracting was due to charter costs being less than anticipated in summer 2017. Those funds are to be put into another contract to assist with stable isotope analyses of past samples from GWA sites, as well as a contract to assist with the ingestion of all MBM survey data into NPPSD. The deviation in spending from commodities and equipment is an artifact of USGS budget categorization. When combined, there is < 10% deviation. FOR FY18: There are only minor deviations in actual spending relative to budgeted. These include slightly higher Personnel costs, offset by lower Commodities costs, than expected. Contracts to date have been lower than anticipated, largely due to lower charter vessel costs. However, FY19 charter costs have been higher than expected, which will result in equilibration of Contract expenses.

UAF: Discrepancies in dollars spent to date are due to salaries and services not yet rendered because one PI was unable to participate in field work in 2019 and has not charged salary for that time. An undergraduate student enlisted to help with sampling incurred less cost than the PI would have been. Stable isotope analysis is behind schedule because 2019 samples from all sites have not been sent to UAF yet. We anticipate services and salary to be spent on schedule in subsequent years.

Budget Category:	Proposed FY 17	Proposed FY 18	Proposed FY 19	Proposed FY 20	Proposed FY 21	TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	$34.7	$29.3	$29.5	$29.7	$29.9	$153.1	$58.4
Travel	$1.9	$2.0	$2.1	$2.2	$2.3	$10.5	$5.2
Contractual	$2.2	$8.2	$8.2	$8.2	$8.2	$35.0	$13.2
Commodities	$3.2	$1.5	$1.5	$1.5	$1.5	$9.2	$5.3
Equipment	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
Indirect Costs (25%)	$10.50	$10.25	$10.33	$10.40	$10.49	$51.96	$20.53
SUBTOTAL	$52.50	$51.3	$51.6	$52.0	$52.4	$259.8	$102.6
General Administration (9% of subtotal)	$4.7	$4.6	$4.6	$4.7	$4.7	$23.4	N/A
PROJECT TOTAL	$57.2	$55.9	$56.3	$56.7	$57.2	$283.2	
Other Resources (Cost Share Funds)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	

LITERATURE CITED

Apeti, D.A., A. Jacobs, and M. Rider. In prep. A Synthesis of Ten Years of Chemical Contaminants Monitoring in National Park Service - Southeast and Southwest Alaska Networks. A collaboration with the NOAA National Mussel Watch Program. NOAA Technical Memorandum NOS NCCOS xxx-xxx. Silver Spring, MD. Xx pp.

Arimitsu, M., J. Piatt, R.M. Suryan, S. Batten, M.A. Bishop, R.W. Campbell, H. Coletti, D. Cushing, K. Gorman, S. Hatch, S. Haught, R.R. Hopcroft, K.J. Kuletz, C. Marsteller, C. McKinstry, D. McGowan, J. Moran, R.S. Pegau, A. Schaefer, S. Schoen, J. Straley, and V.R. von Biela. 2019. Chapter 3 Synchronous collapse of forage species disrupts trophic transfer during a prolonged marine heatwave. In R.M. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Bodkin, J.L., H. Coletti, B. Ballachey, D.H. Monson, D. Esler, and T.A. Dean. 2018. Variation in abundance of Pacific Blue Mussel (*Mytilus trossulus*) in the Northern Gulf of Alaska, 2006–2015. Deep Sea Research Part II: Topical Studies in Oceanography 147:87-97.

Bowen L., A. Love, S. Waters, K. Counihan, B. Ballachey, and H. Coletti. 2019. Report: Port Valdez Mussel Transcriptomics. Prepared for Prince William Sound Regional Citizens' Advisory Council. Contract Number 951.20.06

Bowen, L., A.K. Miles, B. Ballachey, S. Waters, J. Bodkin, M. Lindeberg, and D. Esler. 2018. Gene transcription patterns in response to low level petroleum contaminants in Mytilus trossulus from field sites and harbors in southcentral Alaska. Deep Sea Research Part II: Topical Studies in Oceanography 147:27-35.

Croll D.A., J.L. Marion, J.A. Estes, E.M. Danner, and G.V. Byrd. 2005. Introduced Predators Transform Subarctic Islands from Grassland to Tundra. Science Vol. 307, Issue 5717, pp. 1959-1961. DOI: 10.1126.

Danielson, S.L., T.D. Hennon, D.H. Monson, R.M. Suryan, R.W. Campbell, S.J. Baird, K. Holderied, and T.J. Weingartner. 2019. Chapter 1 A study of marine temperature variations in the northern Gulf of Alaska across years of marine heatwaves and cold spells. In R.M. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Dean, T. A., J. L. Bodkin, and H. A. Coletti. 2014. Protocol narrative for nearshore marine ecosystem monitoring in the Gulf of Alaska: version 1.1. Natural Resource Report NPS/SWAN/NRR – 2014/756. Fort Collins, Colorado, USA

Drew, G.S., and Piatt, J.F. 2015. North Pacific Pelagic Seabird Database (NPPSD): U.S. Geological Survey data release (ver. 3.0, February 2020), https://doi.org/10.5066/F7WQ01T3.

Estes J.A., and Palmisano, J.F. 1974. Sea otters: their role in structuring nearshore communities. Science 185, 1058-1060.

Estes J.A., and D.O. Duggins. 1995. Sea otters and kelp forests in Alaska – generality and variation in a community ecological paradigm. Ecol. Mono. 65, 75-100.

Estes, J.A. 1996. Predators and Ecosystem Management. Wildlife Society Bulletin 24:390-396.

Estes, J.A., A. Burdin, and D.F. Doak. 2015. Sea otters, kelp forests, and the extinction of Steller's sea cow. Proceedings of the National Academy of Sciences Oct 2015, 201502552; DOI: 10.1073/pnas.1502552112

Kenyon, K.W. 1969. The sea otter in the eastern Pacific Ocean. North American Fauna 68, 352 pgs.

Konar, B., T.J. Mitchell, K. Iken, H. Coletti, T. Dean, D. Esler, M. Lindeberg, B. Pister, and B. Weitzman. 2019. Wasting disease and static environmental variables drive sea star assemblages in the northern Gulf of Alaska. Journal of Experimental Marine Biology and Ecology 520.

Paine, R.T. 1969. A note on trophic complexity and community stability. American Naturalist 103:91–93.

Paine, R.T. 1974. Intertidal community structure: experimental studies on the relationship between a dominant competitor and its principal predator. Oecologia 15, 93-120.

Suryan, R. M., M. R. Lindeberg, and D. R. Aderhold. 2020. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Long-Term Monitoring Program (Gulf Watch Alaska) Synthesis Report, (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

von Biela, V.R., S.D. Newsome, J.L. Bodkin, G.H. Kruse, and C.E. Zimmerman. 2016a. Widespread kelp-derived carbon in pelagic and benthic nearshore fishes. Estuarine, Coastal, and Shelf Science 181:364-374.

von Biela, V.R., C.E. Zimmerman, G.H. Kruse, F.J. Mueter, B.A. Black, D.C. Douglas, and J.L. Bodkin. 2016b. Influence of basin- and local-scale environmental conditions on nearshore production in the northeast Pacific Ocean. Marine and Coastal Fisheries 8:502-521.

Weitzman, B., B. Konar, K. Iken, H. Coletti, D. Monson, R.M. Suryan, T. Dean, D. Hondolero, and M.R. Lindeberg. 2019. Chapter 2 Changes in rocky intertidal community structure during a marine heatwave in the northern Gulf of Alaska. In M.R. Suryan, M.R. Lindeberg, and D.R. Aderhold, eds. The Pacific Marine Heatwave: Monitoring During a Major Perturbation in the Gulf of Alaska. Gulf Watch Alaska Long-Term Monitoring Program Draft Synthesis Report (*Exxon Valdez* Oil Spill Trustee Council Program 19120114). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Zador, S., E. Yasumiishi, and G.A. Whitehouse. 2019. Ecosystem Status Report 2019 Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK.

Zhang B, Konar B, Weitzman B, Coletti H, Esler D. 2020. Associating clam recruitment with adult standing stock in the Northern Gulf of Alaska. Poster Presentation. Alaska Marine Science Symposium. January 27-30, 2020.