1. Program Number:

18120114-H

2. Project Title:

Nearshore Ecosystems in the Gulf of Alaska

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4. Time Period Covered by the Report:

February 1, 2018-January 31, 2019

5. Date of Report:

April 1, 2019

6. Project Website (if applicable):

www.gulfwatchalaska.org

7. Summary of Work Performed:

Overview

Nearshore monitoring occurs in four regions across the Gulf of Alaska (GOA) 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 2018, we sampled in Kachemak Bay (KBAY), Katmai National Park and Preserve (KATM), Kenai Fjords National Park (KEFJ), and Western Prince William Sound (WPWS) following previously established methods (Table 1). Metrics included monitoring abundance and distribution of marine invertebrates, macroalgae, sea grasses, birds, mammals, and physical parameters such as temperature. In addition to taxonspecific 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 FY19. Additions that were implemented in 2018 include black oystercatcher nest monitoring, marine bird and mammal surveys and increased efforts to collect sea otter foraging observations in Kachemak Bay. This is an in-kind contribution from the Department of the Interior agencies within the nearshore component (Table 1). Mussels (*Mytilus trossulus*) were collected across the 21 rocky intertidal sites in 2018 for contaminant analyses. Results are pending.

Table 1. Nearshore component metrics measured by location and year, 2017-2021. Completed activities for 2018 are bolded while completed activities (2017) and planned activities in future years (2019 – 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 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
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

2018 Highlights

Highlights include our contribution to the National Oceanic and Atmospheric Administration (NOAA) Ecosystems Status Report for the Gulf of Alaska (Zador and Yasumiishi 2018). In our summary, we selected three biological indicators that represent key intertidal ecosystem components; 1) primary production (algal cover), 2) prey abundance (mussel density), and 3) predator abundance (sea star abundance). Our algal cover indicator in this report is percent cover of the dominant intertidal alga, rockweed (*Fucus distichus*) sampled in quadrats at the mid intertidal level (1.5 m). Intertidal prey is represented by density estimates of large (≥ 20 mm) Pacific blue mussels (*Mytilus trossulus*) sampled in quadrats within mussel bed sites. Intertidal predator abundance is the total number of sea stars, estimated along 200 m^2 transects at each rocky intertidal site across the Gulf of Alaska. We begin by presenting water temperature data at the 0.5 m tide level to show that these biological indicators appear to change in concert with widespread physical forcing in the Gulf of Alaska.

In addition to the metrics listed above, we present examples of further data exploration that have been conducted in the past year, which include examining static environmental drivers of sea star communities prior to and after sea star wasting disease. The data exploration section also includes updates to two synthesis products focused on nearshore responses to the recent marine heatwave. Additional data syntheses and analyses have been presented in a variety of reports, journal articles, posters, presentations, and outreach events, listed in section 9 of this report.

2018 Intertidal Ecosystem Indicators in the Northern Gulf of Alaska

Water Temperatures

Nearshore water temperature trends in all four intertidal zones from Prince William Sound to the Alaska Peninsula show warming beginning in 2014 that persisted at least through 2017 (Fig. 1). These results confirm that the 2014–2016 marine heatwave in the Gulf of Alaska affected intertidal zones with some indication of lagged effects, most notably continued persistence through 2017 even though some Gulf of Alaska temperature values were trending back toward long-term means. However, during peak warming in 2016, sites in western Prince William Sound and Kenai Fjords appeared to warm slightly less than other areas relative to the long-term temperature trend as indexed by a time-series analysis of NOAA buoy data. In 2018, water temperatures were near the over-all means in all areas. However, Kachemak Bay appeared slightly cooler than normal in 2018, but this is due to the shorter temperature record there, which shifts the mean temperature higher (because a higher proportion were recorded during the warming event) leading to more dramatic cool anomalies and less dramatic warm anomalies within this block.

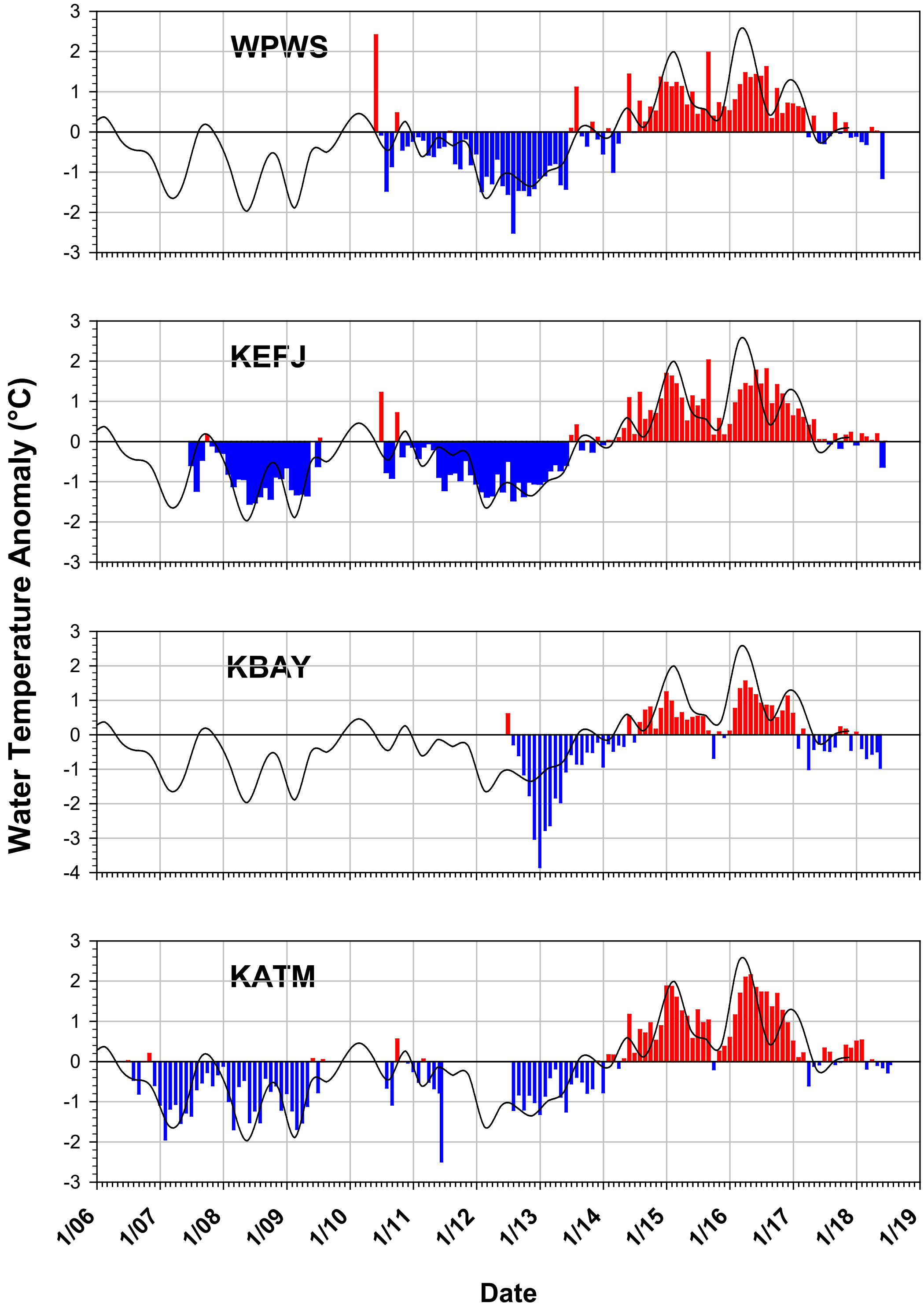

Figure 1. Intertidal temperature anomalies at the 0.5 m tide level four regions of the western Gulf of Alaska (west of 144°W), western Prince William Sound (WPWS; 2011-2018), Kenai Fjords National Park (KEFJ; 2008-2018), Kachemak Bay (KBAY; 2013-2018), and Katmai National Park adjacent to Shelikof Strait (KATM; 2006-2018). The black curved line is the same in each graph and shows the long-temperature trend from a time series analysis of temperature data from NOAA buoys located in or just outside western Prince William Sound (NOAA buoys #46060 and #46061).

***Fucus distichus* Percent Cover**

For *F. distichus* cover, despite considerable variability in percent cover among sites and generally positive anomalies through 2014, all regions showed consistently negative trends during the recent marine heatwave, with effects starting in 2015 and continuing through 2018 (Fig. 2).

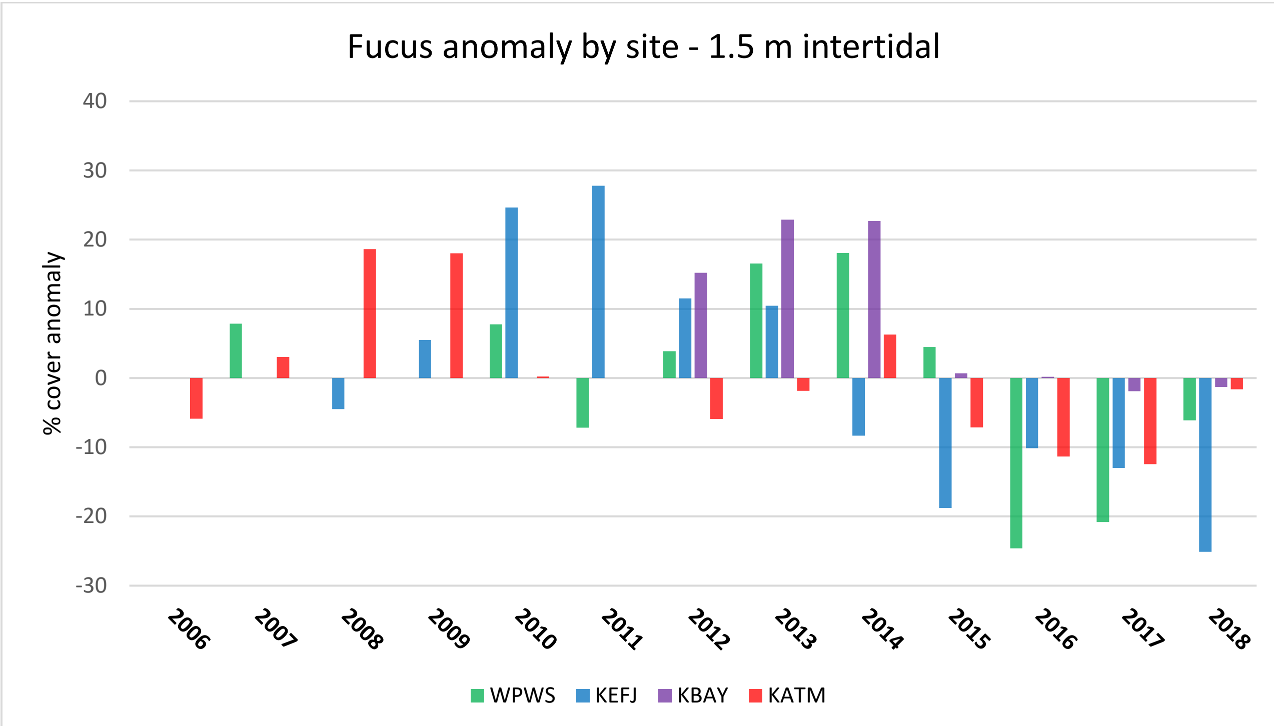

Figure 2. Percent cover anomalies for rockweed (*Fucus distichus*) in four regions of the western Gulf of Alaska, WPWS (2007, 2010-2018), KEFJ (2008-2018), KBAY (2012-2018), and KATM (2006-2010, 2012-2018).

Mussel Density

For large mussel cover, densities of large mussels (≥ 20 mm, Fig. 3) show a strong trend across all regions consistent with the timing of the marine heatwave, in this case switching from generally negative to positive anomalies – an opposite response compared to the other two indicators of *F. distichus* and sea stars (Figs. 2 and 4). Also, in comparison to other indicators, there seems to be higher across-site variability with mussel density, indicating that other variables and local conditions are important drivers of mussel abundance (Bodkin et al. 2018).

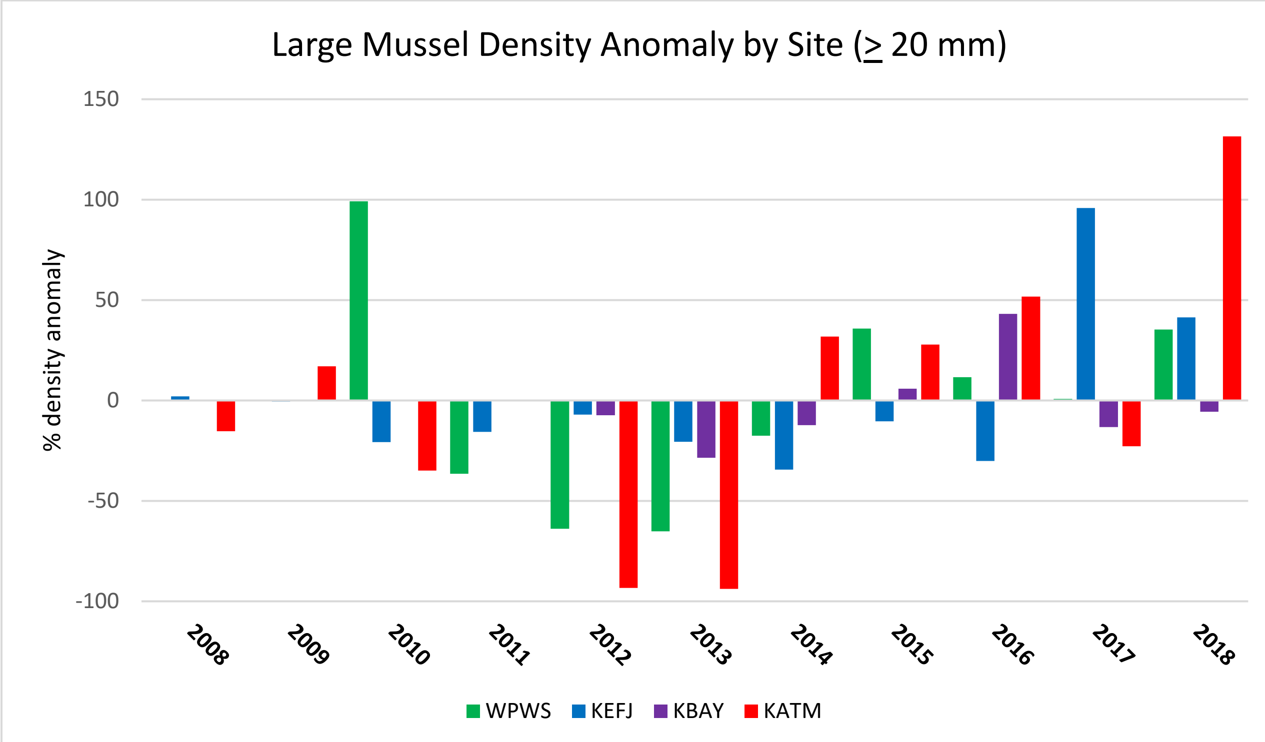

Figure 3. Density anomalies for large mussels (≥ 20 mm) in four study regions spanning the northern Gulf of Alaska. WPWS (2010-2018), KEFJ (2008-2018), KBAY (2012-2018), and KATM (2008-2010, 2012-2018).

Sea Star Abundance

Sea star abundance varied greatly among regions through 2015 (Fig. 4). In 2016, abundance trends began to decline and have remained strongly negative across all regions through 2018.

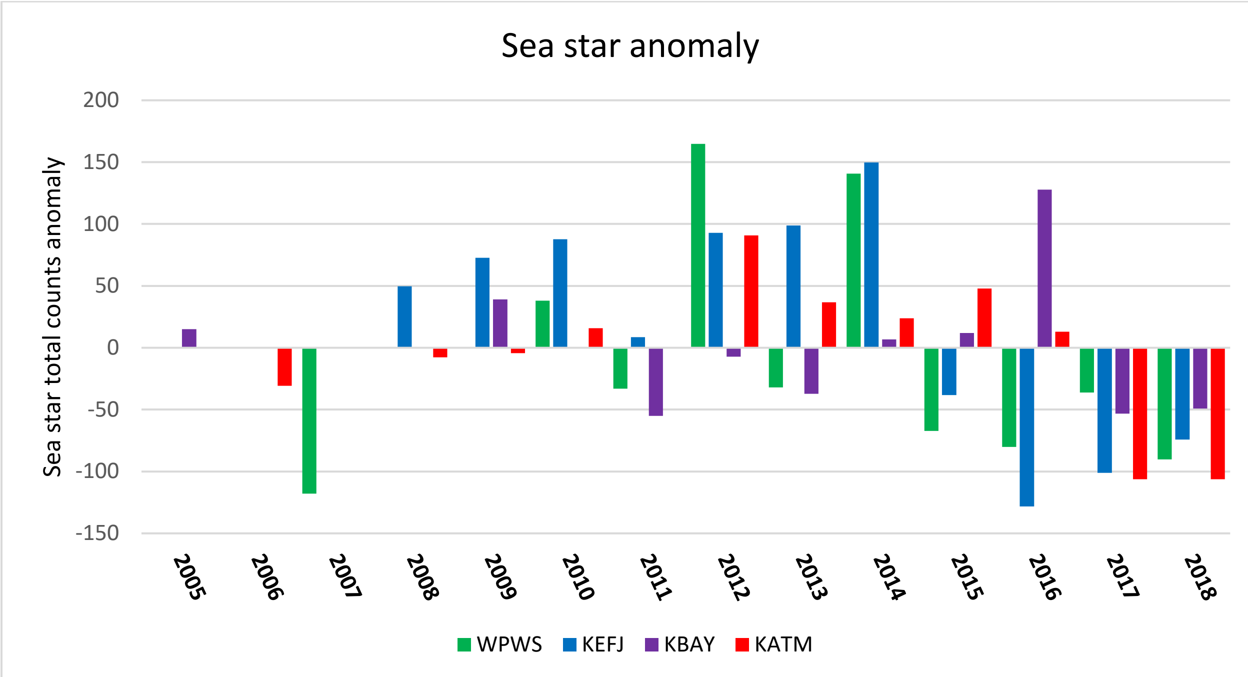

Figure 4. Abundance of sea stars (*Dermasterias imbricata, Evasterias troschelii, Pisaster ochraceus, and Pycnopodia helianthoides*) in four study areas spanning the northern Gulf of Alaska. WPWS (2007, 2010-2018), KEFJ (2008-2018), KBAY (2005, 2009, 2011-2018), and KATM (2006, 2008-2010, 2012-2018).

Discussion

The negative anomalies of rockweed (*F. distichus*) and sea stars are coincident with warm water temperatures in nearshore areas. The decline in sea star abundance was likely due to sea star wasting disease, which was first detected in the study region in 2014 and is generally associated with the warm water temperature anomalies (Eisenlord et al. 2016). The positive anomalies during 2015-2018 for large mussels is consistent with a response to reduced predation pressure precipitated by the decline of sea stars. A decline in small mussel density (an indicator of recruitment) also was observed during this time period through 2017, possibly because of the decrease in *F. distichus* as available settlement habitat (Fig. 5). However, the patterns of small mussel density are highly variable by region with increases at KATM in 2018.

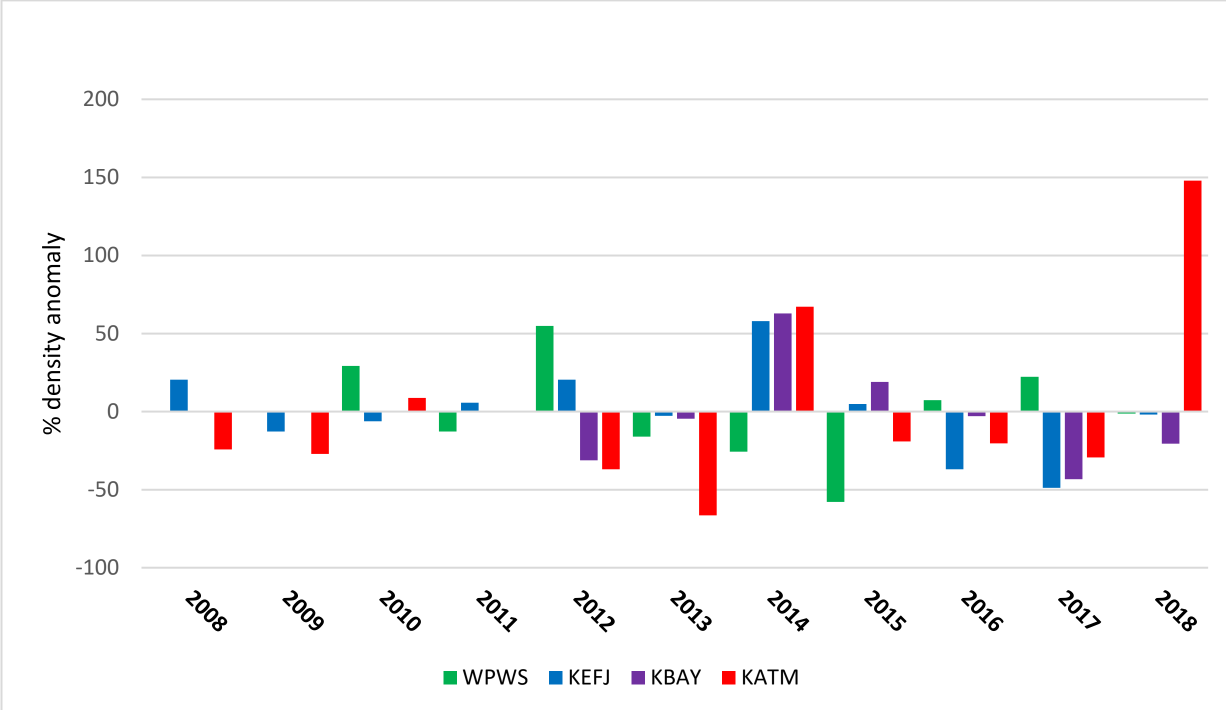

Figure 5. Density anomalies for small mussels in four study regions spanning the northern Gulf of Alaska. WPWS (2010-2018), KEFJ (2008-2018), KBAY (2012-2018), and KATM (2008-2010, 2012-2018).

Collectively, these indicators demonstrate consistent, large scale perturbations to nearshore ecosystems throughout much of the western Gulf of Alaska, including regions both inside (WPWS, KBAY) and outside (KEFJ and KATM) of sheltered marine waters. These indicators signal potentially cascading community level effects arising from warming water temperatures. The decline in *F. distichus* indicates possible habitat loss for settlement of new mussel recruits and a reduction in nearshore sources of primary productivity, whereas the increase in density of large mussels is possibly due in part to the removal of nearshore sea stars via a temperature-influenced disease episode. Other nearshore predators may utilize the abundance of large mussels in the absence of sea stars such as sea otters, sea ducks and black oystercatchers. More in-depth analyses of these metrics is needed.

Intertidal and nearshore ecosystems provide valuable habitat for early life stages of commercially, ecologically and culturally important species in the Gulf of Alaska. These indicators suggest that nearshore biological responses to the recent heatwave appear to continue, even into 2018, and could possibly affect future recruitment of species whose early life stages rely on nearshore habitat. We also expect to see responses of nearshore-reliant species to shifts in prey availability across the Gulf of Alaska from changing ocean conditions.

<u>2018 Data Exploration</u>

The following examples of data exploration provide insight into possible processes driving populations in the nearshore.

Wasting Disease and Environmental Variables Drive Sea Star Assemblages in the Northern Gulf of Alaska

A master of science thesis (Mitchell 2019) project was defended in 2019 that examines the role of static environmental variables (distance to freshwater, tidewater glacial presence, wave exposure, fetch, beach slope, substrate composition, and tidal range) in influencing northern Gulf of Alaska sea star assemblage structure (composition and density) before and after sea star declines due to the sea star wasting epidemic

(Mitchell 2019). Findings show that in the pre-disease years, assemblages were different among regions; structured mainly by tidewater glacier presence, wave fetch, and tidal range. In years after wasting disease, assemblage structure was altered, driven by slope, wave fetch, and tidal range (Fig. 6.). Sea star wasting disease resulted in a sea star assemblage that is responding to different environmental variables, and has a 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 and relatively unstudied species within the northern Gulf of Alaska.

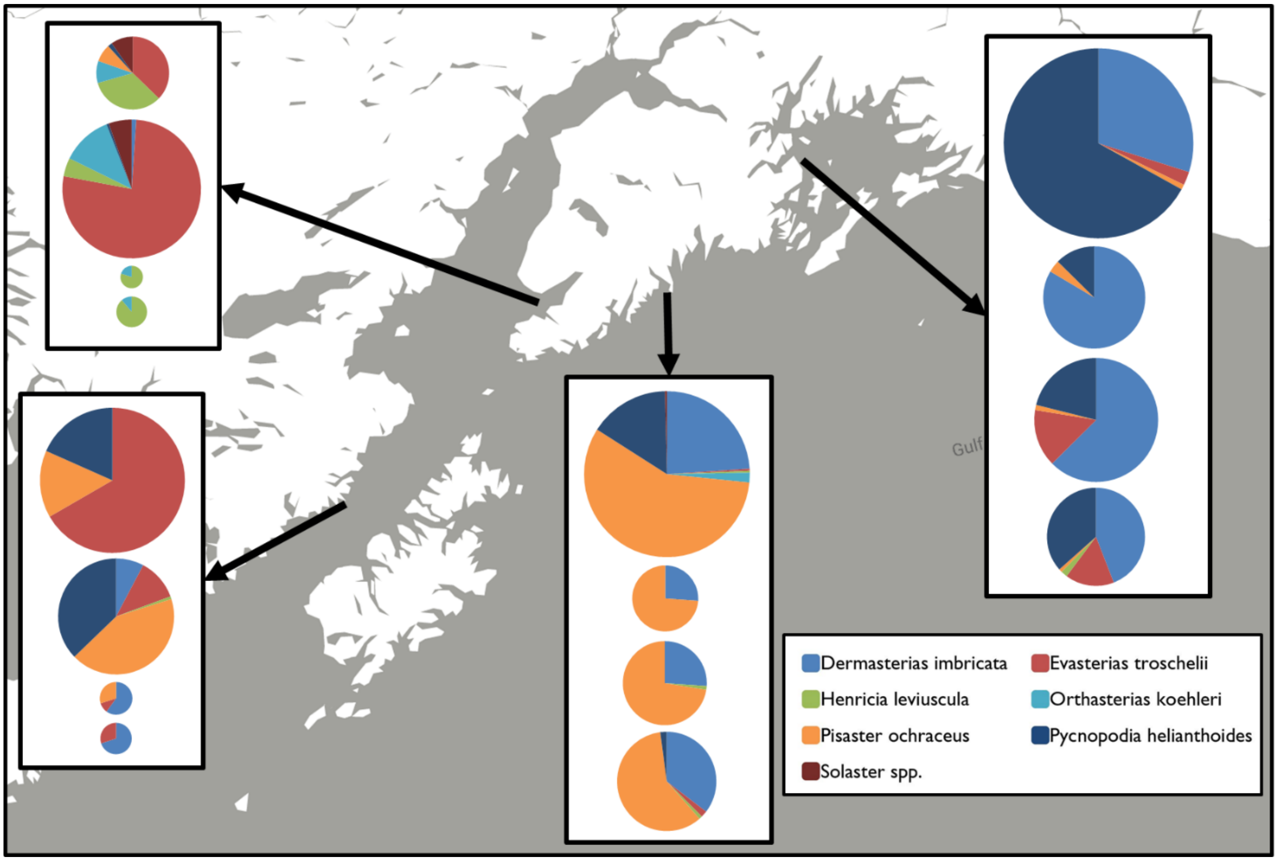

Figure 6. Sea star distribution across regions: KATM, KBAY, KEFJ, and WPWS. The four pie charts from each region going from top to bottom are 2012, 2016, 2017, and 2018. The black line indicates a break in consecutive years. The sizes of the pies are scaled to total sea star abundance to show abundance trends among years as well as among regions.

Coherence in Intertidal to Oceanic Sea Surface Temperatures in the Gulf of Alaska: The Blob Washes Ashore – Monson et al.

This synthesis product will focus on the temporal and spatial 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. Preliminary analyses confirm that large-scale trends such as the "blob" did affect nearshore water temperatures (Fig. 1) though offset by 1 to 2 degrees C depending on local conditions (Fig. 7). Further analysis will look for local-scale lags relative to pelagic water temperature changes along with how local conditions (e.g., weather patterns or proximity to glaciers and glacial features such as glacier created sills) influence nearshore water temperature regimes.

Synchronous Region-wide Responses in Intertidal Community Structure to a Marine Heat Wave in the Gulf of Alaska – Dean et al.

This synthesis documented changes in intertidal community structure at long-term monitoring sites that stretch across the Central Gulf of Alaska over the period from 2006 through 2018, with emphasis on changes that occurred during the 2014-2017 warm water "blob". We are proposing to examine 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 blob years over very large spatial scales (see section 7 of this report) suggest influence of large-scale oceanographic events. While mean water temperatures differ across sites and regions (i.e., Katmai generally colder; Fig. 7), all regions exhibited anomalous warming during blob years (Fig. 1) indicating that the "blob" may be driving these synchronous responses of the biological community in the intertidal.

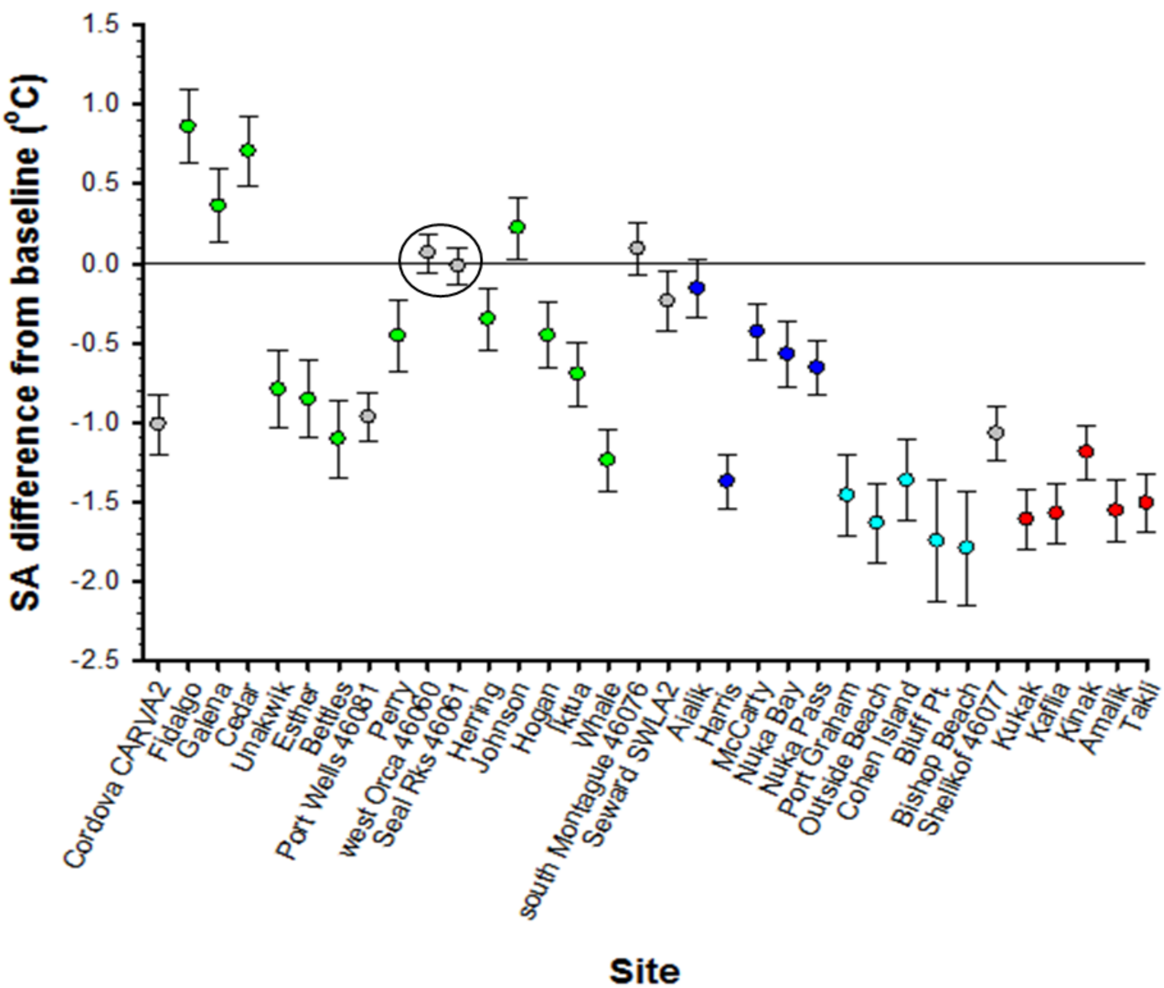

Figure 7. Least Squares mean difference in site specific seasonally adjusted (SA) water temperature values relative to baseline SA values. Sites are ordered east to west and north to south with gray symbols denoting NOAA buoy data, green denoting Prince William Sound sites, blue denoting Kenai Fjords sites, cyan denoting Kachemak Bay sites and red denoting Katmai National Park sites. Sites to the right of the vertical black line are influenced by Cook Inlet. The baseline SA trend is built from combining data from the two circled NOAA buoys.

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. We anticipate this will enhance collaboration across the GWA in the nearshore. For example, data sets were combined across projects for analyses, which were published in a peer reviewed journal (Konar et al. 2016) as well as for a master of science thesis (Mitchell 2019) examining spatial and temporal patterns in sea star communities across the Gulf of Alaska.

A cross-component effort continues (projects 17120114-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. During the November 2018 PI meeting, next steps were drafted for a synthesis of coastal bird survey data. Building on that, the nearshore component worked with ABR Inc. to create a tool to process dlog data for rapid QA/QC as well as automating the processing required to upload dlog data into the North Pacific Pelagic Seabird Database (NPPSD U.S. Geological Survey [USGS]). Incorporation of all GWA marine bird survey data into NPPSD, along with other marine bird survey data (outside of GWA), will allow for larger scale analyses of marine bird trends throughout the Gulf of Alaska over time.

The nearshore component has begun 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. Mussels serve as a model organism for this project as they are an abundant and characteristic species of the nearshore environment that serves critical roles in linking pelagic to nearshore environments and also serves as a key prey species to many 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. All archived samples have been analyzed at the Alaska Stable Isotope Facility at the University of Alaska Fairbanks (UAF) and await data processing and analysis. Preliminary data from 2017 show that mussel stable isotope values are more closely linked to nearshore than offshore POM, but it is likely that mussels consume an even larger amount of macroalgae than is represented in the nearshore POM composite (Fig. 8). Additional data from common macroalgae will allow us to refine carbon source estimates.

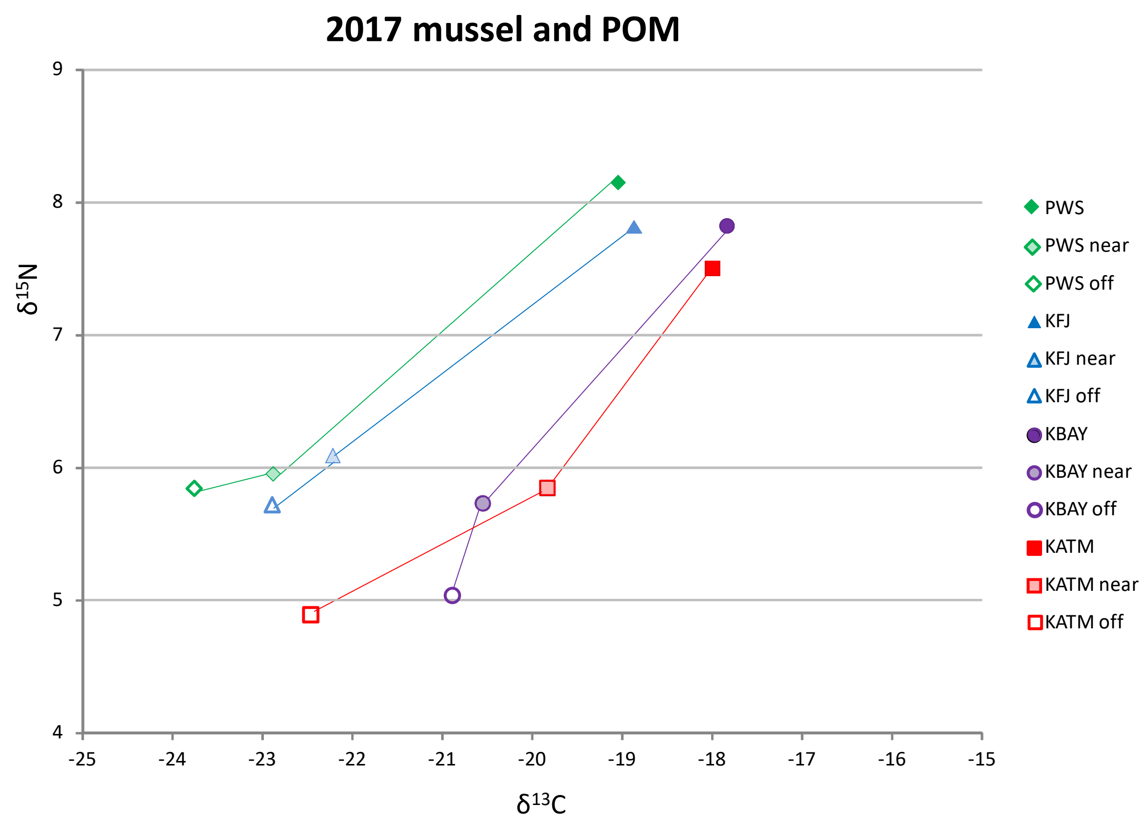

Figure 8. Regional average stable carbon and nitrogen isotope values of mussel tissue (solid symbols), nearshore POM (light symbols) and offshore POM (open symbols) in the three study regions in 2017. The heavier carbon and nitrogen values of nearshore POM stems from suspended macroalgal matter.

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 the nearshore data collection. Students get valuable experience and training from participation in this project, and the project benefits from the involvement of students. In addition, the KBAY portion of this project provides summer funding for one graduate student who can dedicate time to assist in the sampling and sample processing. Additional graduate and undergraduate student funding has been obtained to enable UAF students to take on questions arising from the nearshore monitoring. For example, T.J. Mitchell received a Byrd Award and a Thesis Completion fellowship to finish his thesis on the influence of sea star wasting and environmental conditions on sea star assemblages across the northern Gulf of Alaska (see Data Exploration section). He defended his thesis in February 2019 and will receive his degree in Spring 2019. Similarly, T. Dorsaz is examining if and how the proportion of sea otter versus sea star eaten clams have changed over time (pre and post sea star wasting). This undergraduate capstone project is being funded partially through an Undergraduate Research & Scholarly Activity Award.

In addition, we have worked closely with the other GWA components (Environmental Drivers and Pelagic) over the previous five years 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). For the next five years (2017-2021), we will explore the spatial and temporal variation in productivity across the nearshore and linkages to physical oceanographic processes. It will be a priority to evaluate whether changes in nearshore systems correlate with oceanographic conditions or with synchronous changes in pelagic species and conditions. The geographic scale of our study (Gulf of Alaska-wide) will 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. We will incorporate data on annual and seasonal patterns measured both in the Environmental Drivers and Pelagic components of the overall GWA study. Nearshore data will contribute to several of the year 3 synthesis products proposed by GWA.

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.

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.

c. Lingering Oil

The Nearshore Component of GWA historically has been closely linked with the Lingering Oil component, given that lingering oil occurs in nearshore habitats and primarily affects nearshore species. Although the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) has indicated that Lingering Oil will be treated as a separate program in the current 5-year period, the conceptual and collaborative linkages remain. Data collected by the Nearshore component are relevant for understanding ecosystem recovery with respect to the Lingering Oil program; for example, sea otter abundance, energy recovery rate, and age-at-death data have been used to evaluate population recovery to this point (Bodkin et al. 2014, Ballachey et al. 2014). Contaminants samples (mussels) were collected during the 2018 field season and are currently being analyzed for a broad suite of compounds, including hydrocarbons.

B. Projects not Within a Trustee Council-funded program

None to report.

C. With Trustee or Management Agencies

In addition to the logistical, administrative, and in-kind support that the National Park Service (NPS), USGS, NOAA, and UAF have provided to ensure the 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

Contributed four new nearshore indices to NOAA Fisheries for use in annual stock assessments Ecosystems Considerations Chapter to the North Pacific Fisheries Management Council (Zador and Yasumiishi, 2018). 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 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 (USFWS), Marine Mammals Management, who is responsible for sea otter management (NPRB Project 717 Final Report, Estes, Bodkin and Tinker 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 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. Several 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. Other specimens are being used to perform genetic transcription diagnostics (gene expression) to measure the physiologic responses of individuals to stressors, in collaboration with Liz Bowen and Keith Miles of USGS. 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. Additional work examining the interaction between bears and marine mammals was added in 2016 (initiated by D. Monson). Previously, it was generally believed that bears likely 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 prep).

BOEM Nearshore Community Assessments

Nearshore Component PIs (Coletti, Iken, Konar, and Lindeberg) have been working on the development of recommendations to the Bureau of Ocean Energy Management (BOEM) for nearshore community assessment and long-term monitoring. 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 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 is to provide data on habitats and sensitive species to support environmental analyses for National Environmental Policy Act 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. The project will be in 2019 and, in addition to providing the data to BOEM, 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 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 student poster was presented of the work at the 2019 Alaska Marine Science Symposium (Siegert et al. 2019).

Drones to Collect Monitoring Data in Kachemak Bay

Nearshore GWA PIs (Iken and Konar) tested the use of UASs for various aspects of coastal biological monitoring in KBAY. With BOEM funding, unmanned aircraft systems (UASs) were compared to traditional methods of rocky intertidal and seagrass sampling with some success and suggestions for future work (see Konar and Iken 2018 in Publications below). After this success, UASs were tested to determine their feasibility to complete sea otter foraging observations in KBAY with USGS funding (Monson and Weitzman). We anticipate using UASs to map intertidal sites in KEFJ during FY19. The proposed work will be primarily funded by NPS.

In collaboration with NPS, during recent nearshore monitoring trips on the Katmai coast, the GWA nearshore program continues to test the use of a small UAS 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. Annual collection of UAS based aerial imagery for each site allows for documentation of physical disturbances, which can be valuable when trying to interpret high-frequency variation in community structure within sites.

The Pacific Nearshore Project

In kind support from GWA and NPS was provided to the 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 Gulf of Alaska of a variety of nearshore invertebrates supports the concept that kelps are a primary contributor of carbon to nearshore ecosystems in the Gulf of Alaska (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.

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 Kenai Fjords National Park. 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.

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 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 will examine an array of sites from Lynn Canal in southeast Alaska and Kachemak Bay.

In collaboration with other UAF researchers, GWA PIs (Konar and Iken) received a Field Station and Marine Laboratories Award from the National Science Foundation to install an array of SeapHOx Sensors in Kachemak Bay to monitor pH, oxygen, salinity, and temperature at multiple sites. These data will be available for all GWA PIs.

9. Information and Data Transfer:

A. Publications Produced During the Reporting Period

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. 2018. Gulf Watch Alaska: Nearshore Ecosystems in the Gulf of Alaska. *Exxon Valdez* Oil Spill Restoration Project Annual Report (Restoration Project 17120114-H), *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Coletti, H. A., and T. L. Wilson. 2018. Nearshore marine bird surveys: Data synthesis, analysis and recommendations for sampling frequency and intensity to detect population trends. *Exxon Valdez* Oil Spill Long-Term Monitoring Program (Gulf Watch Alaska) Final Report (*Exxon Valdez* Oil Spill Trustee Council Project 12120114-F). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

Counihan, K., L. Bowen, B. Ballachey, H. Coletti, T. Hollmen, and B. Pister. *In Prep*. Physiological and gene transcription assays in combinations: a new paradigm for marine intertidal assessment.

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

Garlich-Miller, J., Esslinger, G., and Weitzman, B. (2018) Aerial surveys of sea otters (*Enhydra lutris*) in lower Cook Inlet, Alaska, May, 2017. USFWS Technical Report MMM 2018-01. U.S. Fish & Wildlife Service, Marine Mammals Management. Anchorage, AK

Konar, B. and Iken, K., 2018. The use of unmanned aerial vehicle imagery in intertidal monitoring. *Deep Sea Research Part II: Topical Studies in Oceanography*, *147*, pp.79-86.

Konar B., K. Iken, and A. Doroff. 2018. Long-term monitoring: nearshore benthic ecosystems in Kachemak Bay. Long-term Monitoring Program (Gulf Watch Alaska) Final Report (*Exxon Valdez* Oil Spill Trustee Council Project 16120114-L). *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

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

Robinson, B. H., H. A. Coletti, L. M. Phillips, and A. N. Powell. 2018. Are prey remains accurate indicators of chick diet? A comparison of diet quantification techniques for Black Oystercatchers. Wader Study 125(1): 00–00. doi:10.18194/ws.00105. http://www.waderstudygroup.org/article/10823/

Starcevich, L. A. H., T. McDonald, A. Chung-MacCoubrey, A. Heard, J. C. B. Nesmith, H. Coletti, and T. Philippi. 2018. Methods for estimating trend in binary and count response variables from complex survey designs. Natural Resource Report NPS/KLMN/NRR—2018/1641. National Park Service, Fort Collins, Colorado. https://irma.nps.gov/DataStore/Reference/Profile/2253180

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

Presentations

Bowen, L., H. A. Coletti, B. Ballachey, T. Hollmen, S. Waters, and K. Counihan. Transcription as a Tool for Assessing Bivalve Responses to Changing Ocean Conditions. Oral Presentation. Ocean Sciences Meeting. February 11-16, 2018.

Coletti, H. A., P. Martyn, D. H. Monson, D. Esler and A. E. Miller. Using Small Unmanned Aircraft Systems (sUAS) to map intertidal topography in Katmai National Park and Preserve, Alaska. Poster Presentation. Ocean Sciences Meeting. February 11-16, 2018.

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. Oral Presentation. Alaska Marine Science Symposium. January 28 – February 1, 2019.

Dorsaz, T. and B. Konar. 2019. Clam predation patterns as a way of understanding sea star wasting disease's impacts in Kachemak Bay. Poster Presentation. Alaska Marine Science Symposium. January 28 – February 1, 2019.

Iken, K. B. Konar. 2018. Nearshore Gulf Watch Alaska monitoring in Kachemak Bay. Kachemak Bay Science Conference. March 7-10, 2018.

Konar, B., K. Iken, H. Coletti, T. Dean, D. Esler, K. Kloecker, M. Lindeberg, B. Pister, and B. Weitzman. 2018. Trends in intertidal sea star abundance and diversity across the Gulf of Alaska: effects of sea star wasting. Oral Presentation. Ocean Sciences Meeting. February 11-16, 2018.

Konar, B., K. Iken, H. Coletti, T. Dean, D. Esler, K. Kloecker, M. Lindeberg, B. Pister, and B. Weitzman. 2018. Trends in intertidal sea star abundance and diversity across the Gulf of Alaska: effects of sea star wasting. Oral Presentation. Kachemak Bay Science Conference. March 7-10, 2018.

Kurtz, D., D. Esler, T. Jones, B. Weitzman, and B. Robinson. 2019. Spatial and temporal patterns in nearshore physical oceanography in tidewater glacial fjords. Poster Presentation. Alaska Marine Science Symposium. January 28 – February 1, 2019.

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. Alaska Marine Science Symposium. January 28 – February 1, 2019.

Siegert, D., Iken, K., Saupe, S., and Lindeberg, M. 2019. Comparison of intertidal food web structure between two regions of lower Cook Inlet. Alaska Marine Science Symposium. January 28 – February 1, 2019.

Weitzman, B. Esler, D., Coletti, H., Konar, B., and Iken, K. 2018. Can you dig it? Patterns of variability in clam assemblages within mixed-sediment habitats across the Gulf of Alaska. Oral Presentation. Kachemak Bay Science Conference. March 7-10, 2018.

Outreach

Aderhold, D., S. Buckelew, M. Groner, K. Holderied, K. Iken, B. Konar, H. Coletti, and B. Weitzman. 2018. GWA and HRM information exchange event in Port Graham, AK, May 15.

Coletti, H., D. Esler, B. Robinson, and B. Weitzman. 2018. Ocean Alaska Science and Learning Center Teacher Workshop. Kenai Fjords National Park, AK, June.

Konar, B., and K. Iken. 2018. Wasting sea stars in the Gulf of Alaska. Delta Sound Connections 2018-2019. Prince William Sound Science Center.

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

None to report for FY18.

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

Below is a list of the required data to be posted to the workspace and status. All posted data have appropriate metadata and have also been uploaded to the Research Workspace.

-Black oystercatcher for the KATM, KEFJ and WPWS regions:
https://workspace.aoos.org/project/4650/folder/2591589/bloy

-HOBO temperature data for the KATM, KBAY, KEFJ and WPWS regions:
https://workspace.aoos.org/project/4650/folder/2617326/hobo

-Marine bird and mammal survey data for the KATM and KEFJ regions:
https://workspace.aoos.org/project/4650/folder/2591593/mbm

-Mussel site data for the KATM, KEFJ and WPWS regions:
https://workspace.aoos.org/project/4650/folder/2765217/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/2591591/rocky

-Sea otter forage data for the KATM, KEFJ and WPWS regions:
https://workspace.aoos.org/project/4650/folder/2591590/seot

-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/2769975/spraint

-Sea otter carcass data for KATM, KEFJ and WPWS regions:

https://workspace.aoos.org/project/4650/folder/2796389/carcass

- Sea otter aerial survey data for WPWS region:

https://workspace.aoos.org/project/4650/folder/2796391/aerialsurvey

For the KBAY region specifically, the following final data sets with appropriate metadata have been uploaded as csv files to the Research Workspace:

-Mussel size-frequency distribution for six sites in 2017: KB2017_Mytilus_SFD.cvs: https://workspace.aoos.org/project/4653/folder/2762861/mussel-data

-Rocky intertidal community data: KB2017_percentcover_RockyIntertidal_data.csv: https://workspace.aoos.org/project/4653/folder/2762860/rocky-intertidal-community-data

-Rocky intertidal swath data: KB2017_rockyintertidal_swath_counts.csv: https://workspace.aoos.org/project/4653/folder/2762911/rocky-intertidal-swath-data

-Rocky intertidal substrate data: KB2017_substrate_percentcover.csv: https://workspace.aoos.org/project/4653/folder/2762910/rocky-intertidal-substrate-data

-Seagrass shoot count data: KB2017_Zostera_shootdensity.csv: https://workspace.aoos.org/project/4653/folder/2762912/seagrass-data

The following datasets have been uploaded to the AOOS workspace and are awaiting finalized metadata:

-Eelgrass percent cover data for KATM, KEFJ and WPWS:

https://workspace.aoos.org/project/4650/folder/2578986/eegr

10. Response to EVOSTC Review, Recommendations and Comments:

Science Panel Comment (EVOSTC FY18 Work Plan)**:** *The Panel appreciates the amount of data being collected on multiple nearshore sites. There is not a clear integration with oceanographic studies, but there is enough substance to make this a meaningful, standalone nearshore ecosystem project. The Panel is very pleased with their productivity and integration of students into the studies.*

PI Response: The nearshore component greatly appreciates the Science Panel's support of our progress towards an integrated nearshore program. There has been progress to date on the use of oceanographic data, initially temperature, across all components to examine linkages between offshore and nearshore systems (Monson et al. in prep). We anticipate that analyses of temperature data will be our first step in integrating other oceanographic processes to pelagic and coastal systems for the GWA program.

Science Panel Comment (EVOSTC FY18 Work Plan)**:** *The Panel would like to see more of the synoptic surveys, what they are finding or not finding temporally and on a spatial scale. A question from the Panel for the PIs to ponder: Have egg-eating seabirds/waterfowl changed their distribution in regards to location in time and space to herring spawning?*

PI Response: Several PIs in the nearshore program did publish a paper in Ecosphere (http://onlinelibrary.wiley.com/doi/10.1002/ecs2.1489/full) in 2016 that examined temporal trends in sea otter abundance, energy recovery rates, and demographics at varying spatial scales. In addition to the published paper, the nearshore component also contributed to the NOAA Gulf of Alaska Ecosystem Status Report to the North Pacific Fisheries Management Council (Zador and Yasumiishi, 2018). 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. While preliminary, these indicators suggest that nearshore biological responses to the heatwave appear to continue, even into 2018, and could possibly affect future recruitment of species whose early life stages rely on nearshore habitat. We also expect to see responses of nearshore-reliant species (such as sea otters and sea ducks) to shifts in prey availability across the Gulf of Alaska from changing ocean conditions. Based on the design of the nearshore component, exercises examining trends across space and time can be done for a variety of species. We continue to meet annually (outside of the GWA PI meeting) as a component to discuss products, analyses and questions. We also continue to support collaboration across components as evident in the nearshore contributions to upcoming synthesis products.

Specific to the Science Panel's question about whether egg eating seabirds/waterfowl are changing their distribution with respect to herring spawn. Our sampling is not designed to answer this question, however seabird survey data collected synoptically with adult herring surveys (GWA PI Bishop, 18130114-E) has the best potential to address this question.

Specific to the Science Panel's question about changing seabird/waterfowl distribution, across-component effort continues (projects 17120114-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 GOA. During the November 2018 PI meeting, next steps were drafted for a synthesis of coastal bird survey data. Building on that, the nearshore component worked with ABR Inc. to create a tool to process dlog data for rapid QA/QC as well as automating the processing required to upload dlog data into the North Pacific Pelagic Seabird Database (NPPSD USGS). Incorporation of all GWA marine bird survey data into NPPSD, along with other marine bird survey data (outside of GWA), will allow for larger scale analyses of marine bird trends throughout the Gulf of Alaska over time.

11. Budget:

A. Budget Forms (See GWA FY18 Budget Workbook for cumulative spending)

Please see project budget forms compiled for the program.

Budget Category:	Proposed FY 17	Proposed FY 18	Proposed FY 19	Proposed FY 20	Proposed FY 21	TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	$228.8	$229.1	$229.4	$229.9	$230.1	$1,147.2	$465.2
Travel	$17.4	$17.5	$17.6	$17.7	$17.8	$88.0	$33.2
Contractual	$83.1	$125.5	$83.1	$83.1	$83.1	$457.9	$168.3
Commodities	$23.9	$23.0	$23.0	$23.0	$23.0	$115.9	$23.1
Equipment	$5.0	$10.0	$14.0	$5.0	$5.0	$39.0	$15.7
Indirect Costs (*will vary by proposer*)	$10.5	$10.3	$10.3	$10.4	$10.5	$52.0	$13.6
SUBTOTAL	$368.7	$415.4	$377.4	$369.1	$369.5	$1,900.0	$719.1
General Administration (9% of	$33.2	$37.4	$34.0	$33.2	$33.3	$171.0	N/A
PROJECT TOTAL	$401.9	$452.7	$411.4	$402.3	$402.8	$2,071.0	
Other Resources (Cost Share Funds)	$410.0	$410.0	$410.0	$392.0	$392.0	$2,014.0	

B. Changes from Original Project Proposal

No changes to the overall Nearshore budget have been made; however, a few items have been re-allocated within the project. For FY18 - FY21, the $6,000.00 allocated to USGS (Coletti and Esler) for stable isotope analyses have been moved to UAF (Konar and Iken). UAF has the capacity to manage and analyze the samples for the nearshore project as a whole. Salary support to collect sea otter foraging observations in KBAY has been moved from Konar and Iken to Coletti and Esler (FY18 5.7k, FY19 5.8k, FY20 6.0K and FY21 6.1k). This will ensure the continued integration of the nearshore project.

C. Sources of Additional Project Funding

Annual in-kind contributions consist of staff time (USGS = $92K; NPS = $130k; NOAA = $10k), reduced charter costs (USGS = $45K; NPS= $25K), winter bird surveys (NPS=$18K through 2019), use of equipment such as rigid-hull inflatable, inflatables/outboards, GPSs, spotting scopes, field laptops, sounding equipment (USGS = $40K; NPS = $40K) and commodities (USGS = $5k; NPS = $5K).

Literature Cited

Ballachey, B.E., D.H. Monson, G.G. Esslinger, K.A. Kloecker, J.L. Bodkin, L. Bowen, and A.K. Miles. 2014. 2013 update on sea otter studies to assess recovery from the 1989 Exxon Valdez oil spill, Prince William Sound, Alaska. Report 2014-1030, Reston, VA.

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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.

Zador, S., and E. Yasumiishi. 2018. Ecosystem Assessment. In: Ecosystem Considerations 2018: Status of the Gulf of Alaska Marine Ecosystem. Report, North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306, Anchorage, AK 99301.