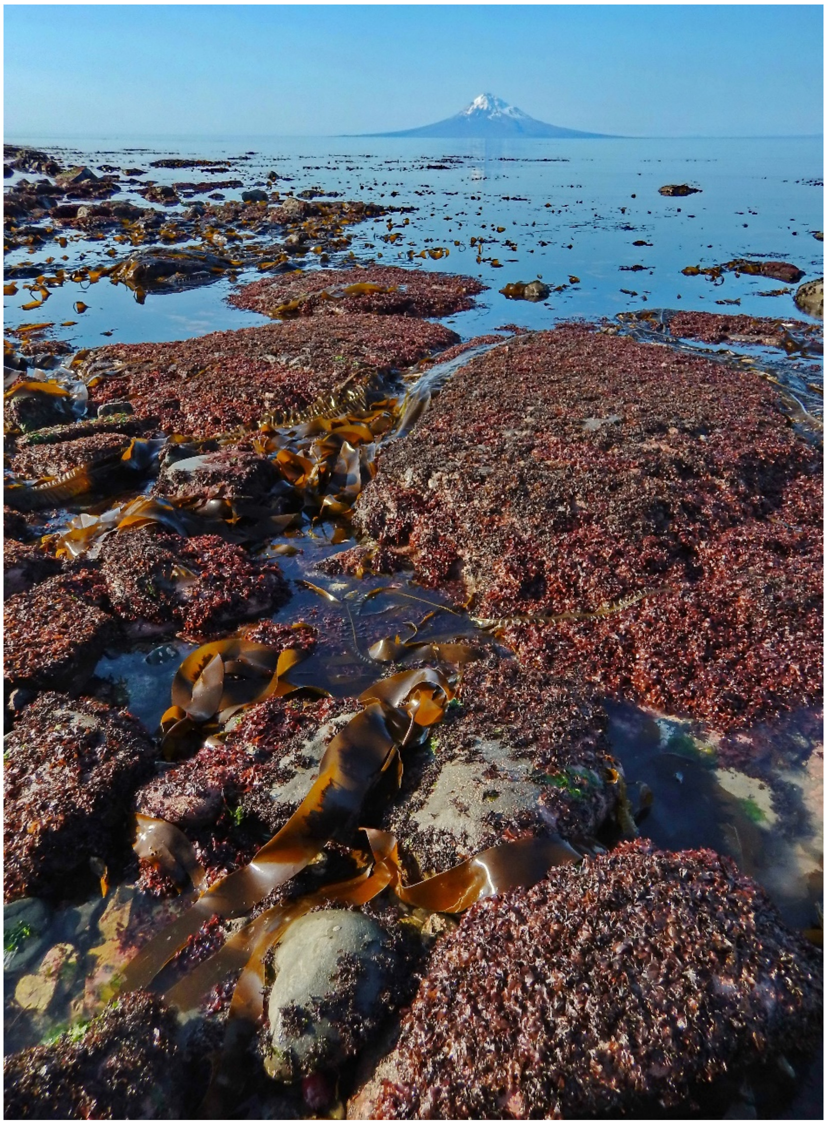
OCS Study
BOEM 2017-045

Evaluation of Nearshore Communities and Habitats in lower Cook Inlet, Alaska



US Department of the Interior
Bureau of Ocean Energy Management
Headquarters

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BOEM 2017-045

Evaluation of Nearshore Communities and Habitats in lower Cook Inlet, Alaska

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DISCLAIMER

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1. Introduction

1.1 Project Overview

The Bureau of Ocean Energy Management's (BOEM) proposed Final Outer Continental Shelf (OCS) Oil & Gas Leasing Program 2012-2017 includes a lease sale in the Cook Inlet Planning Area in 2017. Previous to 2017, an OCS Cook Inlet Lease Sale National Environmental Policy Act (NEPA) analysis has not been undertaken since 2003. Updated information regarding the physical and biological environment, including variability in oceanographic conditions, nearshore benthic communities, as well as data related to sensitive species, may be used to support NEPA analyses conducted for future environmental analysis. The results of these studies may be used to inform subsequent NEPA analyses and documentation for other lease sales, and potential future Explorations Plans (EPs), and Development and Production Plans (DPPs).

The focus of this work was in the nearshore area, specifically the intertidal and shallow subtidal zones within the Cook Inlet Lease Area. Specific tasks included collating existing baseline information, and reconnaissance and characterization of the biological populations and ecological systems that are most subject to impact from petroleum exploration and development. This final report describes the 2015 pilot study comprised by 2015 field activities.

The nearshore is considered an important component of the Gulf of Alaska ecosystem because it provides a variety of unique habitats for resident organisms (e.g. sea otters, harbor seals, shorebirds, seabirds, nearshore fishes, kelps, seagrasses, clams, mussels, and sea stars); nursery grounds for marine animals from other habitats (e.g. crabs, salmon, herring, and seabirds); feeding grounds for important consumers, including killer whales, harbor seals, sea otters, sea lions, sea ducks, shorebirds and many fish and shellfish; a source of animals important to commercial and subsistence harvests (e.g., marine mammals, fishes, crabs, mussels, clams, chitons, octopus, and kelp); an important site of recreational activities including fishing, boating, camping, and nature viewing; and a source of primary production for export to adjacent habitats (primarily by kelps, other seaweeds, and eelgrass) (Dean et al. 2014).

Previous work has occurred or been proposed in the littoral zone of lower Cook Inlet in two major pulses: 1) the Outer Continental Shelf Environmental Assessment (OCSEAP) program in the 1970s, which was to ensure that proposed OCS development and production activities would not irreparably damage the marine environment and its resources;2) The second phase was triggered by the Exxon Valdez Oil Spill (EVOS) in 1989. Programs that followed included the Gulf Ecosystem Monitoring (GEM) Program, with a primary objective to "sustain a healthy and biologically diverse marine ecosystem in the northern Gulf of Alaska and the human use of the marine resources in that ecosystem through greater understanding of how its productivity is influenced by natural changes and human activities." CIRCAC (Cook Inlet Regional Citizens Advisory Council) was formed by the Oil Pollution Act of 1990 and among its tasks is to develop a monitoring program to evaluate potential environmental impacts of oil industry operations in Cook Inlet. To meet this mandate, CIRCAC conducts habitat assessments and contaminants monitoring programs in Cook Inlet. Additional existing federal programs include the National Park Service Inventory and Monitoring Program and most recently (2012) the Gulf Watch Alaska program, primarily funded by the Exxon Valdez Oil Spill Trustee Council with multi-agency support. Although each program was developed to meet a variety of objectives, all have a common goal to provide information to the public, resource managers, industry and policy-makers and consumers.

Despite previous assessment and monitoring efforts in Cook Inlet, very limited data have been collected on one of the habitats that is relatively unique to Kamishak Bay and represents a significant portion of the shorelines in the study area – extremely wide and low-angle rock ramps. Of the numerous intertidal sampling methods that have been applied to various monitoring programs throughout Alaska (e.g. NPS

Southwest Alaska Network nearshore program, Gulf Watch Alaska nearshore program, Coastal Habitat Injury Assessment Studies after the Exxon Valdez oil spill, etc.), none are appropriate for this habitat, as they use fixed tidal heights, typically in areas of higher angle, narrower beaches, where zonation occurs typically parallel to the shoreline. The challenges for this survey were to develop and test methods that would sufficiently characterize the algal and invertebrate community assemblages occurring across small-scale topographical changes along massive rock platforms. Aerial imagery (and limited existing on-the-beach surveys) show that the biological habitat mirrors the geology and geomorphology of the rock platforms, with repeating patterns that can be at significant angles (non-parallel) to the shoreline.

An underlying premise is that assessment methods will provide information about the nearshore rocky habitats and sampling methods will provide information on how best to sample western Lower Cook Inlet's relatively unique rocky habitats; namely the wide, low-angle rocky ramps and platforms that dominate rocky habitat in the area. The knowledge gained through the testing of sampling methods and the data collected about the distribution of habitats and community assemblages in the study area will guide recommendations for potential future longer-term monitoring programs. By forcing a geographic spread of sampling sites across the overall study area, we can provide information about potential latitudinal gradients along the axis of Cook Inlet in species diversity and assemblages.

Field work in June 2015 focused on conducting an assessment of rocky shorelines between the mouth of the Paint River (in the south) to Tuxedni Bay (in the north). Potential sampling sites were randomly selected from within a population of rocky sites based on ShoreZone coastal habitat classifications (BC Class 1-10). The focus was on collecting detailed site characterizations of tidal heights and topography through Real Time Kinematics (RTK), documenting intertidal and shallow subtidal invertebrate and algal species distributions through various methods, and collecting algal voucher collections.

1.2 Study Approach

The goal of the interagency Agreement (IA) between National Park Service (NPS) and BOEM is to support the collation of existing information on current intertidal and shallow subtidal benthic species across multiple habitat types that are found in proximity of the BOEM Cook Inlet Planning Area proposed in the Final Outer Continental Shelf Oil & Gas Leasing Program 2012-2017. The approach of this work is multi-tiered. The first phase is to collate historical information (and data). The second phase is to utilize the existing historical datasets for use in planning continued assessment efforts. Historical data and potential field assessment trips are being used to draft a sampling approach to collect new information across the many intertidal substrates, especially in those areas that may be susceptible to oil spills. In 2015 (this study), a first sampling approach was recommended and implemented to assess rocky intertidal and shallow subtidal communities.

1.3 Objectives

Specific objectives of this project are:

- Compile existing historical intertidal and shallow subtidal data and literature from Cook Inlet. This information was used in planning the pilot study sampling as well as for use in future site selection.

- Conduct rocky intertidal and shallow subtidal (< 15 m water depth) community assessments as representation of important habitats at sites selected either due to their historical relevance, or through a habitat modeling based approach that uses existing data. Metrics used in site selection and assessments included: accessibility, susceptibility to oiling, biological relevance (either represents a large portion of the OCS area or is biologically unique), cost effective to study, and appropriate for long-term monitoring.

- Evaluate the sampling methods and results in order to make recommendations for potential future sampling plans for evaluating habitats and, where possible, build on existing sampling protocols (such as Gulf Watch Alaska) to aid comparability of results across a broader areas.

2. Methods

2.1 Historical Intertidal Project Compilations

A summary of previous intertidal research in the affected area was conducted in advance of the 2015 field season. For this, select information from identified reports was compiled into a geo-referenced database. The compiled information makes historical data more readily available to researchers and the public and may be used by BOEM and others in development of ecological studies as well as for use in permitting processes and environmental assessments. This information was also used to help identify geographic gaps where research had not occurred in western Lower Cook Inlet.

2.1.1 Scope

Relevant biological historical data were defined to include intertidal and shallow subtidal communities including macroalgae, eelgrass, and bivalves. Nearshore geomorphology was also considered to be relevant. Geographically, scope was limited to the western coast of Lower Cook Inlet. This is the region of Cook Inlet that lies north of Shelikof Strait and south of Kalgin Island, including the coasts of Kamishak Bay and Augustine Island (Figure 1). Historical data were collated into a geospatial format so that information from different studies could be visualized concurrently. Additional functionality included collation of species data, geographic data, limited physical information, and other relevant data about each study.

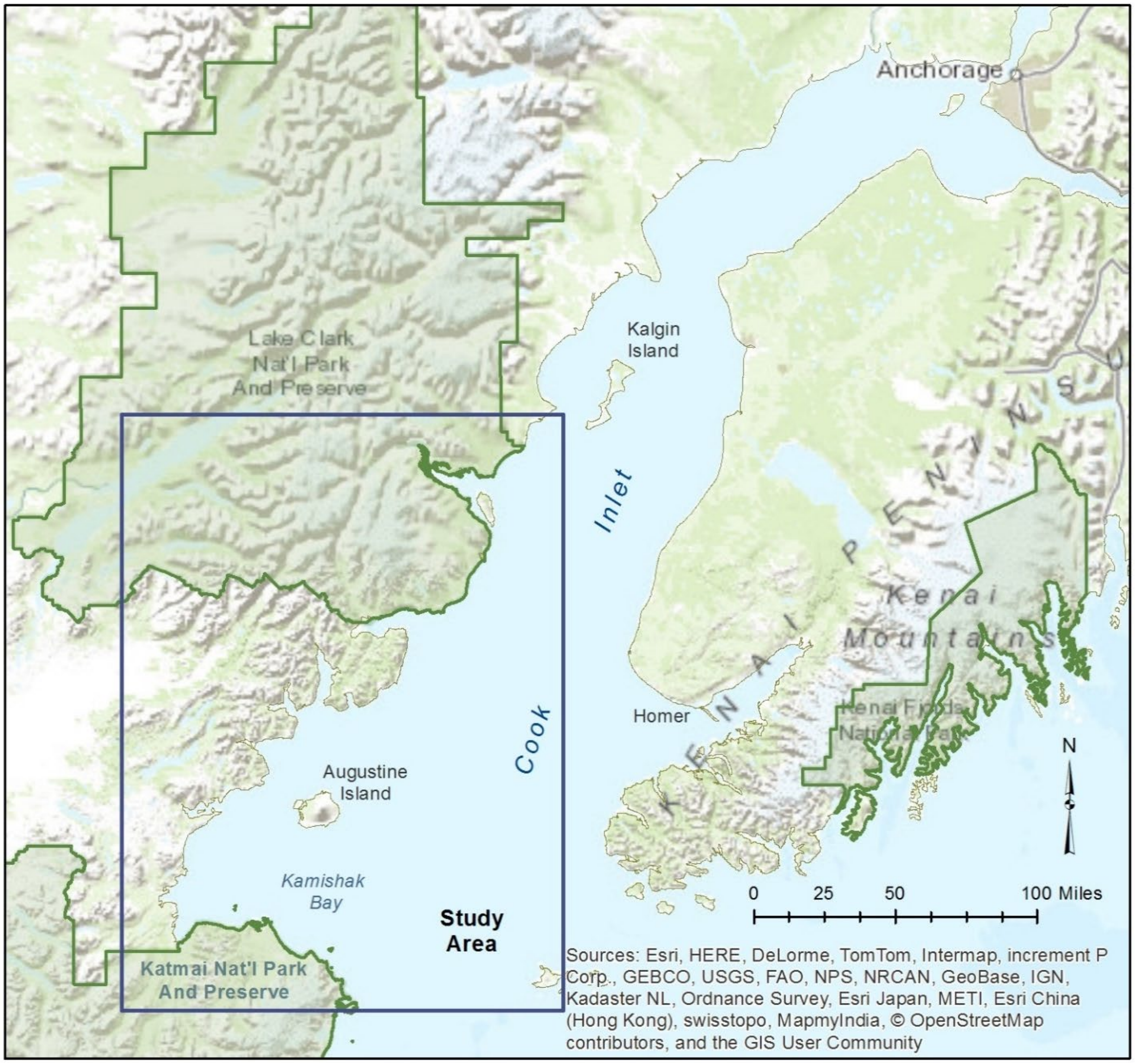

Figure 1. Overview map of Cook Inlet with blue box illustrating location of study area.

2.1.2 Source References

References were located primarily by searching the Alaska Resources Library and Information Services (ARLIS), and the National Park Service's (NPS) Integrated Resource Management Application (IRMA). Additional unpublished reports were provided by Cook Inlet Regional Citizens' Advisory Council (CIRCAC) and by the NPS Southwest Alaska Inventory and Monitoring Network (SWAN).

ARLIS maintains a large collection of Alaskan natural resource related materials from multiple federal agencies including NPS, U.S. Geological Survey (USGS), Fish and Wildlife Service (FWS), Bureau of Land Management (BLM), BOEM, State of Alaska Department of Fish and Game (ADFG), the University of Alaska system, and the Exxon Valdez Oil Spill Trustee Council. Search terms used in the ARLIS and IRMA (NPS Integrated Resource Management Applications) portal searches included topical keywords pertaining to the biological and physiographic resources of interest, place names, and the names of certain authors known to have conducted intertidal research in Lower Cook Inlet (Table 1).

Table 1. Search terms used to identify potential source references.

Bivalve Taxa	Other Biological Categories	Site Area	Author	Other geographical categories
Bivalve	Kelp	Kamishak	Pentec Environmental	Cook Inlet
Clam	Seaweed	Tuxedni	Lees	Benthic
Mya	Algae	Chinitna	Dames and Moore	Intertidal
Siliqua	Eelgrass	Iliamna	Schoch	Subtidal
Razor clam	Intertidal bird	Iniskin	Bennett	Nearshore
Mussel	Herring Spawn	Augustine		Coastal geomorphology

Approximately 150 references were found initially using keyword searches. Co-authors from NPS, UAF and CIRCAC were consulted to inquire if other resources were known. All references were scanned and converted to PDFs with OCS text recognition and tables of contents if necessary.

Some references were excluded due to factors including: (1) Referenced data did not fall within the geographic area of interest; (2) reference topics were excluded if pelagic or freshwater focused and data were not from intertidal or shallow subtidal areas; (3) there was a lack of geo-referenced data, or; (3) the reference focused on a species that uses resources of interest in the intertidal zone, but the reference itself did not address the intertidal zone. The final database contains 39 references.

2.1.3 Database design

A relational geodatabase was created to record relevant data. The database contains a reference table, a site table, an algal occurrence table, and a bivalve occurrence table. Multiple sites or geographic locations are associated with each reference, and multiple references may be associated with each site. Each record in the bivalve and algal tables contains keyed fields referring to the Reference ID and Site ID tables. The data may be visually displayed from the site, algal or bivalve tables (Figure 2).

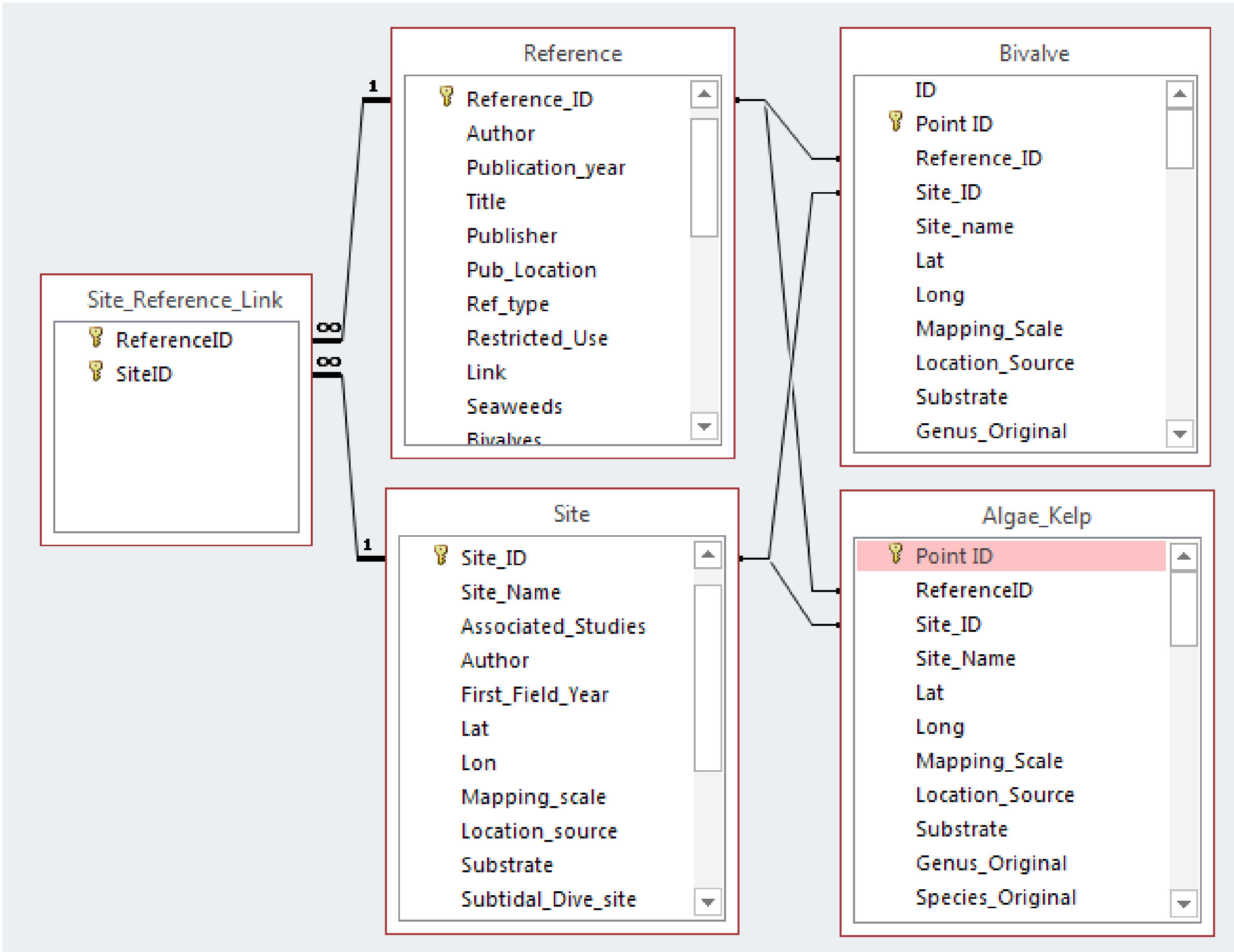

Figure 2. Schematic of table relational structure in geodatabase.

2.1.4 References Table

The References Table includes a unique key for each reference. The table contains bibliographic details, including citation, author, publication year, title, publication location, reference type, and any copyright protection or distribution restriction on the document.

Other fields hold information on the reference's subject matter content including whether the reference addresses algae, bivalves, characteristics of the physical environment, and whether sediment and tissue were tested and analyzed for contaminants or other chemical markers. Because the References Table lacks geospatially referenced data, several fields indicate whether studies were conducted in certain geographic areas. Note fields provide a brief description and additional information on each reference, respectively.

2.1.5 Sites Table

Information in the Sites Table is relevant to the understanding of the study sites as a whole. For each site, this includes the substrate, site access methods used by researchers, which studies occurred, whether or not shallow subtidal surveys were part of any studies, and whether or not tissues were sampled for contaminants.

The Sites Table also contains the geographic data used to display the dataset in ArcGIS. Each site has an assigned Site ID used to link the sites to the algal and bivalve species occurrence tables. Only where the author specifically referred to revisiting a site from a previous study was the site considered to be the same in multiple studies. In such cases, the most accurate site coordinates were used.

2.1.6 Algal and Bivalve Tables

The algal and bivalve tables contain individual species occurrence records and their geographic data. Each combination of species, site, survey date, and survey parameters was given a new record. Because accepted scientific names may change over time, the bivalve and algal tables contain fields for legacy genus and species, and current genus and species. This allows the same species to be cross-referenced among studies. The Seaweeds of Alaska website (http://www.seaweedsofalaska.com) and AlgaeBase (http://www.algaebase.org/) were used to cross-reference and update algal species and genus names. The World Register of Marine Species (http://www.marinespecies.org/index.php) was used to cross-reference and update bivalve species and genus names.

2.2 Defining the Sampling Area

The 2015 field component of this project was focused on obtaining data for rocky habitat in western Lower Cook Inlet, where much of the rocky habitat is dominated by wide, low-angle ramps or platforms. Though the goal was to provide the most complete geographic coverage of western Lower Cook Inlet, an overflight conducted in May 2015 prior to the field sampling showed that parts of Kamishak Bay could not be realistically sampled by boat and would be sampled in later years with additional air support for logistical access. Also, the June 2015 tidal cycle dictated that no more than six intertidal sites would be sampled during the field project. Thus, due to these habitat distribution, access, and time considerations, the project area was constrained between Tuxedni Bay and the northern side of Chenik Head to the south.

2.3 Site Selection within Sampling Area

Since the entire Cook Inlet shoreline was surveyed and mapped to Alaska ShoreZone protocols (Harper and Morris 2004) in 2001-2004 (as well as being reimaged in 2009), that habitat dataset (www.shorezone.org and https://alaskafisheries.noaa.gov/mapping/szflex/) was used to select specific habitat types for the study. ShoreZone classifications were used in ArcGIS to select rocky or mixed rock and gravel shorelines (BC Class of 1-10). A geoprocessing tool was then applied to generate spatially balanced random points within the shoreline segments. The first ten random sites were examined using ShoreZone imagery and aerial photographs and narrowed to six sites using the following criteria:

1. Where a site was within 5 miles of another site, only one site was selected by random draw and the other discarded. In one instance, three sites of the same habitat, exposure and aspect fell within a total of a ten mile distance (e.g. the middle site was within 5 miles of the two outer sites). Thus, of these three, one was randomly selected.

2. No random sites in the top 10 fell into the southern region of the study area. The lowest numbered site in that region, Site 19, was selected to ensure a site fell in the southern-most region and thereby filled an approximately 10-mile gap in coverage. This site was selected as the sixth site to provide greater geographic coverage.

3. A contingency field protocol was developed. If a site could not be surveyed in the field, the nearest sample-able location would be surveyed instead. This contingency was applied only once, when onshore swells precluded landing the boats onshore at the random site (or anywhere within walking distance for that tide) on Augustine Island. The site was moved to the nearest sample-able rocky habitat.

Figure 3 shows the final six site locations where sampling took place in June 2015. Figure 4 shows ShoreZone aerial photographs of those site locations used to confirm that the sites were appropriate habitat for the study. Specific methods and locations at each site are described below for intertidal and subtidal sampling.

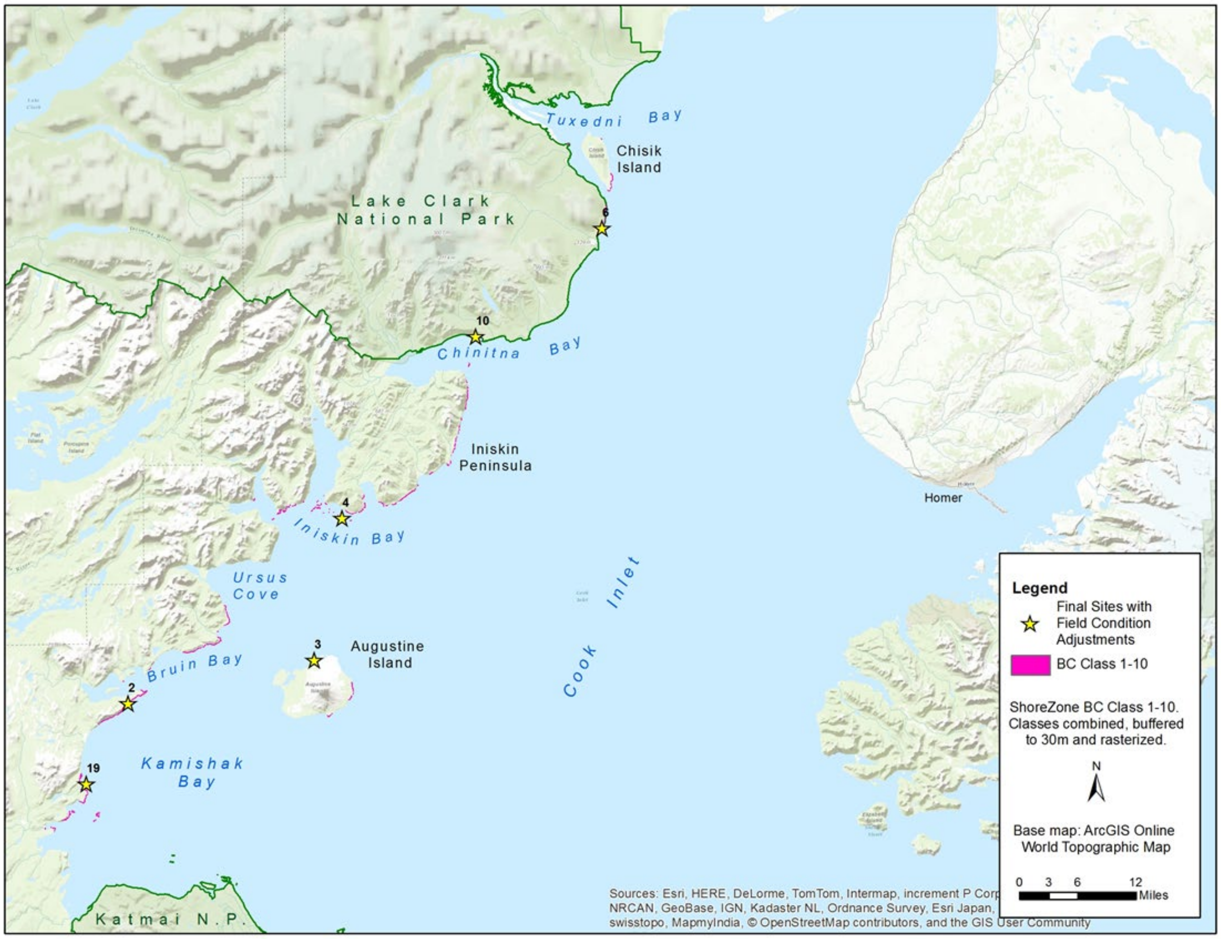

Figure 3. Locations where intertidal and subtidal sampling took place on rocky habitat in western Lower Cook Inlet in June 2015.

Figure 4. Aerial photographs of the six site locations where sampling took place. Photos are from Alaska ShoreZone program.

2.4 Real-Time Kinematic (RTK)

In order to evaluate intertidal communities on the wide, low-angle habitat of this study, it is important that high-resolution tidal elevation data can be linked to the data collection locations (data transects and quadrats). A survey-grade Real-Time Kinematic (RTK) GPS system was used to collect GPS data during the intertidal surveys. The RTK system is capable of collecting data to an accuracy and precision of 1-2 cm, both horizontally and vertically. This resolution depends on the distance from control stations and other survey or geodetic monuments, and on whether or not the location data can be corrected by using NOAA's Online Positioning User Service (OPUS).

2.4.1 Survey control

A base station consisting of a tripod and a Trimble R8 GPS receiver was set up above high tide line near the top of each transect (transect placement described below). When possible, the base station was set up on bedrock in an area with a clear view of the planned sampling transect (transect layout described below). In the absence of exposed bedrock, the base station was set up on a large boulder. OPUS solutions were achieved at all sites. This required a minimum 4-hour occupation of each base station site.

2.4.2 GPS Settings and File Management

At each site, a new job was created on the GPS controllers using the Trimble Access program. Each job used the NAD 1983 (2011) State Plane Alaska Zone 5 coordinate system, and vertical datum Geoid 12A (Alaska). Map units were meters. Two GPS rover units were used to collect point data. The intertidal survey group was divided into two teams, "A" and "B," and one rover was dedicated to each team. Each rover's job file was given a unique name identifying project, operator, site, and date. Naming conventions were also used at the individual point level for data management. Quadrat locations were collected in the "topo" method, which collects and averages five seconds of GPS data for each point. Additional data were collected in the "continuous topo" mode to create surface models of the area near the site. The rovers were programmed to automatically collect one point every 10 cm.

2.4.3 GPS Field Methodology

Each of the two rovers were mounted on a fixed-height pole with an attached bipod and a 19" diameter rover wheel (Figure 5). The wheels allowed the GPS units to travel smoothly on uneven surfaces, collecting accurate surface elevational data. Points were recorded at the start and end of each transect, at visually estimated tidal stages such as mean sea level, and at the upper left corner of each quadrat.

During continuous topographic data collection, rovers walked a grid pattern that covered an area extending about 5 m from either side of the transect line. Both rovers worked in tandem to minimize coverage gaps, alternating between across-shore and along-shore direction of travel. Rovers deviated from the grid pattern to collect quadrat corner locations as needed (quadrat placement described below under Intertidal Sampling Methods). Continuous topographic points could be collected in the background even while a quadrat corner was recorded.

2.4.4 Data Download

Data were downloaded from the data loggers and base station daily and backed up each night. Each rover's daily data were imported into Trimble Business Center as a new job. Each new job was created in the same coordinate system that the data were collected: NAD 1983 (2011) State Plane Alaska Zone 5, vertical datum Geoid 12A (Alaska), meters.

2.4.5 Processing OPUS Solutions

To achieve a higher degree of accuracy, all base station data were submitted to NOAA's OPUS and corrected using National Geodetic Survey's Continuously Operating Reference Station (CORS) network. Once OPUS solutions were returned, the base station position was corrected within Trimble Business Center. This adjusted all survey points accordingly.

Figure 5. NPS biologist records a quadrat corner at Site 10 in Chinitna Bay, Lake Clark National Park and Preserve.

2.5 Intertidal Transect and Quadrat Sampling

The intertidal sampling methods were designed to address several concerns for best sampling the relatively unique rocky habitats found in Kamishak Bay. Prior ShoreZone habitat mapping and imaging showed that rocky habitat in much of western lower Cook Inlet is dominated by wide, low-angle rocky ramps and platforms. Sampling methods used in other Gulf of Alaska intertidal rocky habitat projects would not appropriately assess this habitat. Several factors were taken into consideration:

1. The sampling design needed to ensure that the entire tidal range on the day of sampling was represented in the total possible sampling area. This was accomplished by sampling along a transect swath that ran from mean high high water (MHHW) to the mean low low water line (MLLW), crossing the entire habitat including any beach face in the foreshore, the entire width of any rock ramp or platform, and including shallow subtidal habitat (below the 0 tide level which may or may not be part of the rock ramp or platform). To do so, the site transect was divided into obvious physical sections and random

sampling within the transect swath took place within each section. Thus, if there was a relatively short and steep beach face and a very wide rock ramp, sampling would take place within each of those sections.

2. Sampling of species was conducted using two common methods in order to assess the strengths and weaknesses of sampling approaches so that monitoring recommendations could be made to BOEM for these types of rocky habitats found in western Lower Cook Inlet and the results would inform the sampling design for assessments of additional habitats.

At each sampling location, a transect tape was stretched from MHHW to the water line at low tide. Major physical breaks were defined (e.g. significant change in slope or substrate) and zero tide was estimated with hand-held surveyor level and noted on the transect tape. The total tape distances between these breaks were used to determine how many random quadrats would be sampled within each of the sections along each transect. This was done to ensure that quadrats were sampled throughout the entire vertical tidal range because several sites are dominated by a mid-intertidal low-angle bench which might preclude quadrats landing in some of the other tidal range habitats (e.g. a short, steep beach face or shorter and steeper subtidal bench). For sections with tape distances < 10 m, 6 quadrats were sampled within the section. For sections with tape distances ≥10 m and < 30 m, 10 quadrats were sampled within the section. For sections with tape distances ≥ 30 m and < 100 m, 20 quadrats were sampled within the section. Finally, for sections with tape distances ≥ 100 m, 30 quadrats were sampled within the section.

The actual placement of the quadrats within each section were determined by haphazardly tossing a quadrat marker within a 5 m swatch to the right and left (making the possible sampling area a 10 m swatch centered on the transect tape). By dividing the tape distance by the appropriate number of quadrats for the length of the segment, quadrats were placed by standing at the randomly selected tape distances and haphazardly tossing a quadrat marker within a 5 m swath to the right and left of the transect. Where the marker landed became the upper left corner of the sampling quadrat. Figure 6 shows final quadrat placement for an example site (overlaid on RTK topography data that is described below). The purple squares indicate photo quadrats. Red arrows indicate which quadrats were also point-count data quadrats. Blue dotted lines show the section breaks for that particular site.

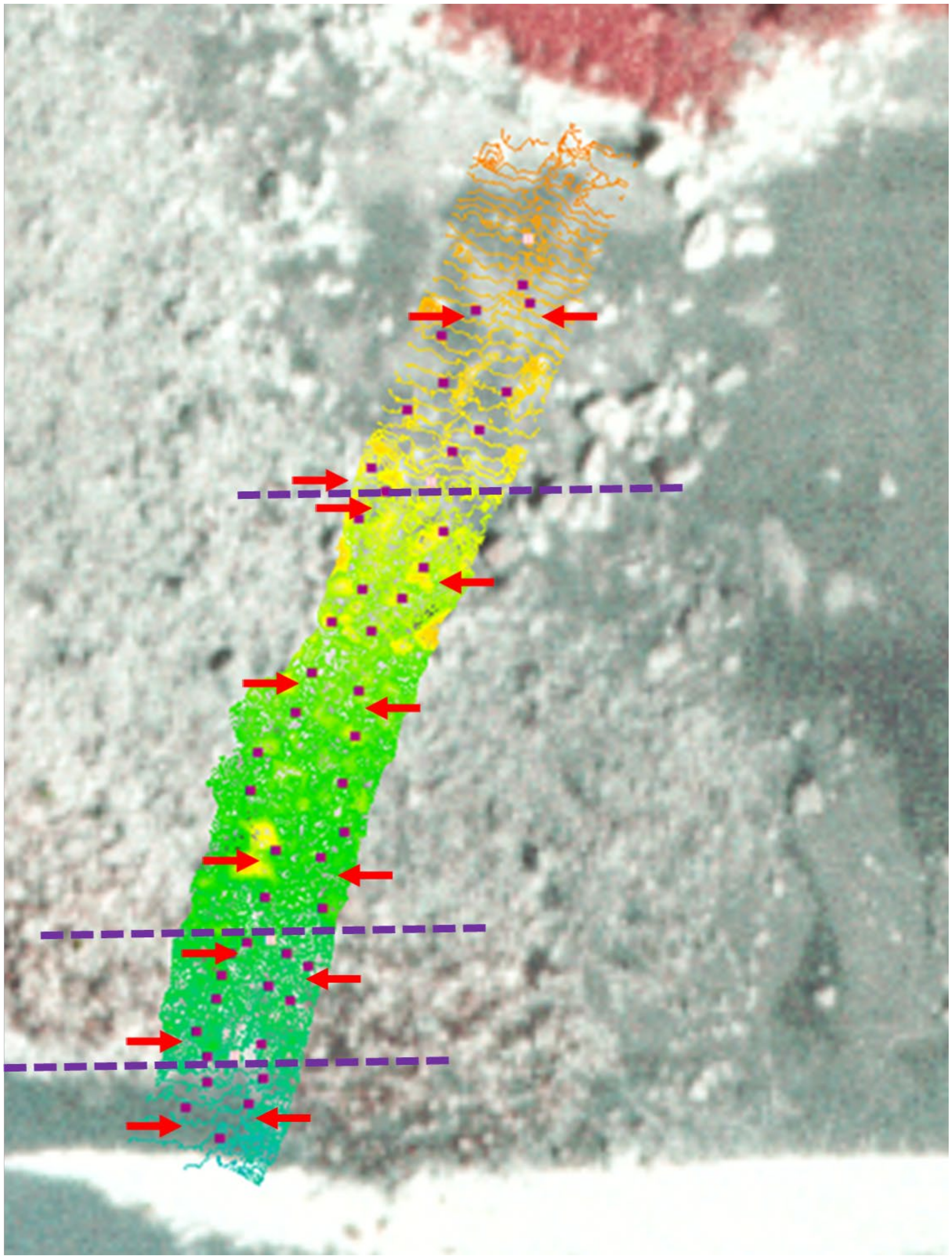

Figure 6. Example site intertidal sampling quadrat locations. Purple squares represent photo quadrats. Red arrows indicate which quadrats were also point-contact data quadrats. Dotted blue lines indicate transect breaks between transect sections based on physical profile.

Photo quadrats were taken at all of the quadrat locations. This was done by placing a placard with the quadrat name (reflecting site, team, and quadrat number) within the photo frame. Two photographs were taken that included the 0.5m x 0.5 m quadrat frame, taking care to minimize shadowing and reflections and zooming in so the quadrat filled the frame.

For every fourth quadrat within each section (from a randomly chosen starting quadrat), point-count quadrat data were collected by each team (left and right side of tape). When there were less than 4 random quadrats per team (e.g. sections < 10 m in length), one random quadrat per team was selected for point-counts in that section. For point-count data collection, a 0.5 m x 0.5 m quadrat was strung to create a 25 point grid. Beneath each intersecting point of the grid, all species were recorded that occurred through the layers of attached epifaunal invertebrates and seaweeds. Mobile invertebrates were counted within the quadrats. Species observed on the beach that did not land in quadrats were also recorded to provide more comprehensive taxa lists for each site.

When possible, voucher specimens of intertidal and subtidal algae were collected to build a collection of the algal taxa that were observed in the study area. These were sorted, identified, pressed, dried, and scanned. The original specimens are being held at the NOAA Auke Bay Laboratories in Juneau, Alaska, for distribution to museum and university herbariums collections. High resolution digital scans (examples in Figure 7) of each voucher can be made available on request (Mandy Lindeberg mandy.lindeberg@noaa.gov).

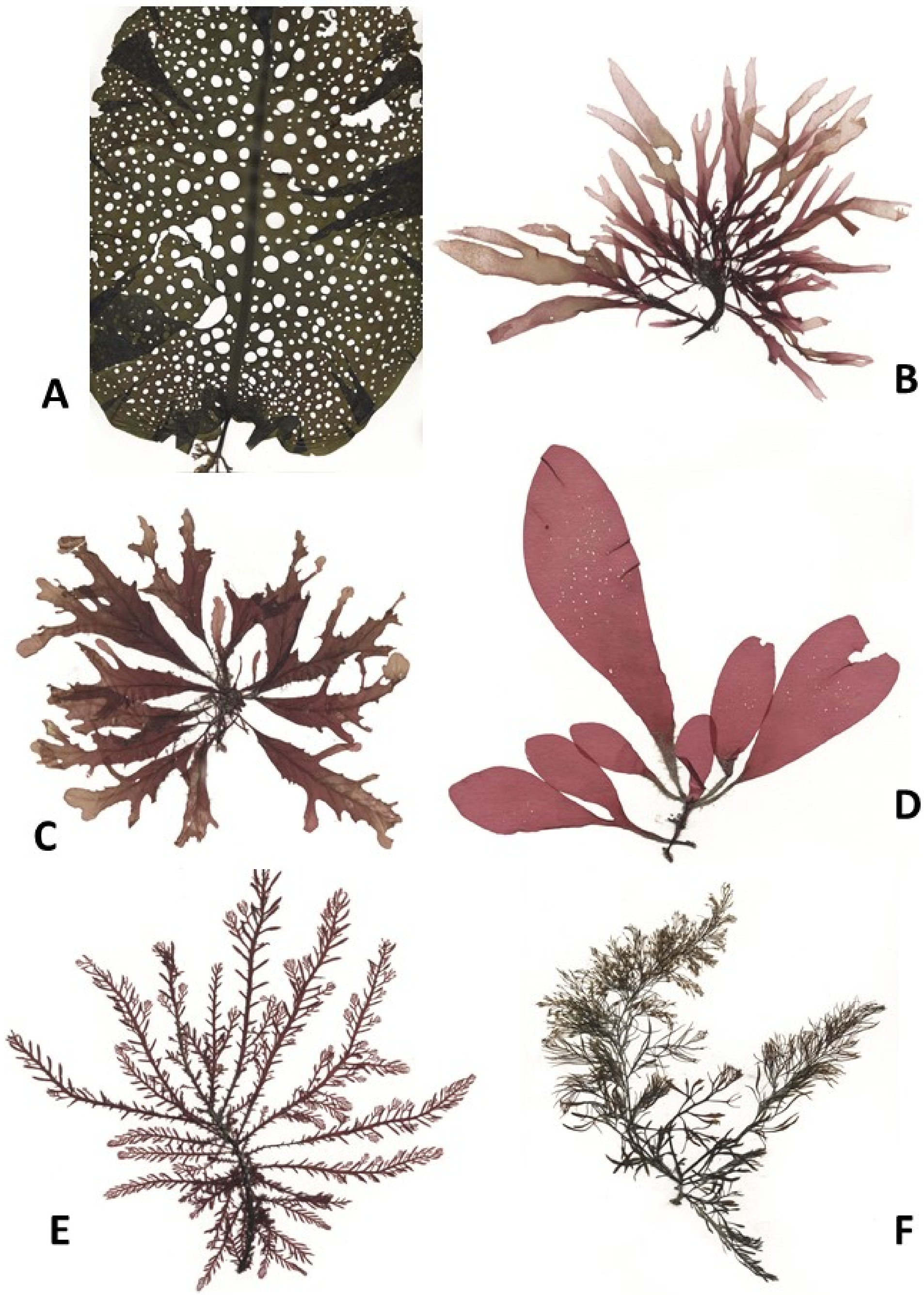

Figure 7. Example algal press scans from collections in June 2015. Taxa are Agarum clathratum (A), Palmaria callophylloides, atypical morphology (B), Phycodres fimbriata (C), Sparlingia pertusa (D), Neoptilota asplenoides (E), and Cystoseira geminata (F, recently renamed Stephanocystis geminata). (C) Was collected in the subtidal, all others were collected in the intertidal.

The photographs from the photo quadrats were interpreted by a trained taxonomist after returning from the field. Invertebrates and algae were identified to lowest possible taxonomic level possible from the photographs. This is to provide information on what quality of data can be obtained if non-taxonomists were to collect photo quadrat data in a future monitoring or assessment program for later interpretation by a taxonomist. For the point-count method, quadrat data were converted to percent cover by summing the number of points under which a taxa occurred and dividing by the total number of possible points in the quadrat (25).

2.6 Subtidal Sampling

The subtidal sampling protocols followed a modified version of the standardized sampling procedures originally developed within Census of Marine Life for hard bottom macroalgal communities (Rigby et al. 2007), which have also been used in subtidal studies during the Gulf Ecosystem Monitoring (GEM) phase in Cook Inlet. The target subtidal sites sampled were directly offshore from the randomly chosen intertidal sites. Our target depth was 5 m however, because of tides and available appropriate habitat, there was some variability in depth and location. In addition to our offshore site, we also attempted to sample a subtidal site on either side of the intertidal site at the most appropriate depth/habitat (i.e., rocky points where hard substrate could be found, limited by small boat distance, and typically 2-8 km from the target site). Lastly, we also attempted to sample sites where there were historical subtidal data.

For the sampling, ten haphazardly placed 1 x 1 m replicate quadrats were quantified for all macrophytes and conspicuous macrofauna (>2 cm length). For this, large solitary macroalgae (i.e., kelp stipes) and conspicuous fauna such as crabs, seastars, sea cucumbers, etc. were counted and an estimate of percent cover was made for other macroalgae and other colonial or encrusting organisms. In the percent cover data, we estimated overstory percent cover (kelps) separate from the rest of the community. In addition to the 1x1m quadrats, we sampled ten 50x50 cm replicate quadrats to determine macroalgal and invertebrate biomass. For this, all macrophytes and fauna within each quadrat were carefully and completely removed and placed into separate fine mesh bags. These quantitative samples were brought back to the vessel and sorted to the lowest possible taxa, wet weight determined (1 g accuracy), and a herbarium/invertebrate vouchers prepared if the specimen was unknown.

All data were assembled into an excel spread sheet and imported into the Primer-e software (Quest Research Limited) for analyses and visual presentation.

3. Results

3.1 Historical Database

A relational geodatabase was created to record relevant data. The database records the type of information gathered about each species in different studies and at different times; represents key pieces of information about all studies; and displays the data geospatially. Data are displayed as a point feature class.

The database contains a reference table, a site table, an algal occurrence table, and a bivalve occurrence table. Multiple sites are associated with each reference, and multiple references may be associated with each site. Each record in the bivalve and algal tables contains keyed fields referring to the reference and site tables. The data may be visually displayed from the site, algal or bivalve tables.

114 unique sites were identified in 31 references in the study area. Approximately 149 distinct algal species and 41 distinct bivalve species were identified in all studies. See Figure 8 for location of historic study sites.

The results of the data compilation will be displayed on the AOOS Cook Inlet Response Tool (CIRT) mapping portal. In the portal, records will be linked to PDFs of the source references. Eight datasets containing geomorphological data on the Lake Clark National Park and Preserve and Katmai National Park and Preserve coasts were also delivered to Axiom for inclusion in the AOOS CIRT portal.

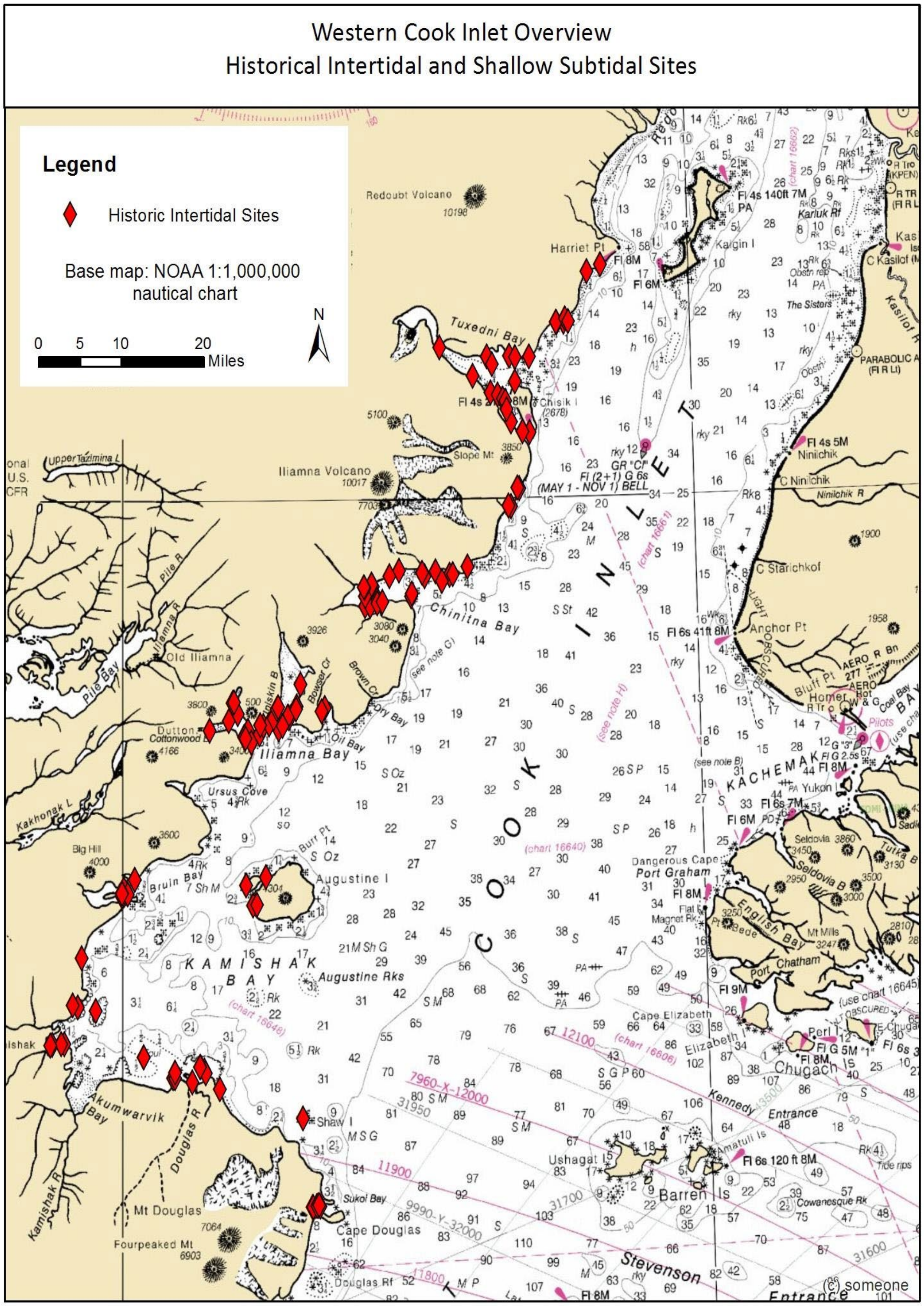

Figure 8. Map showing location and extent of historic intertidal study sites in western Lower Cook Inlet. Although the majority of the report specifications are listed in CSE, this section highlights the few areas where CSE is non-specific, where BOEM has specific preferences, or where the information in CSE is not easily located. Each sub-section lists the CSE section(s) (if any) relevant to that topic.

3.2 Real-Time Kinematic (RTK)

3.2.1 Topography

Between 20K and 30K positional (x,y,z) data points were collected with approximately 10 cm spacing at each site location and corrected with OPUS solutions for an estimated positional accuracy for each data point of ±5 cm. The corrected datasets were used to develop triangulated irregular networks (TINs) for each site over which a set of 0.1 m surface contours were laid, and where possible these overlays were examined with hi-resolution imagery for visual confirmation (Figure 9). All of the surface contours are relative to each other and based on the geoid surface of the earth with 0 m elevation being the geoid sea level (it is important to note that geoid sea level does not necessarily equal 0 tide from a NOAA tide table). Site contours generally included a small amount of the beach area above the start location of each transect to place the beach profile in relation to the intertidal zone and extended for 5 m – 10 m on either side of the transect. The total elevational range measured for all sites combined was 10.7 m with site 19 having the largest elevational difference (10.1 m) and site 2 having the smallest elevational difference (6.2) of any site (Table 2). Transects started considerably below the beach start at the upper edge of the identifiable intertidal zone. Total transect elevational range was 7.1 m for all sites combined with the largest transect elevational change at site 19 (6.5 m) and the smallest at site 6 (4.0 m). Within site elevational differences can be seen in Table 2.

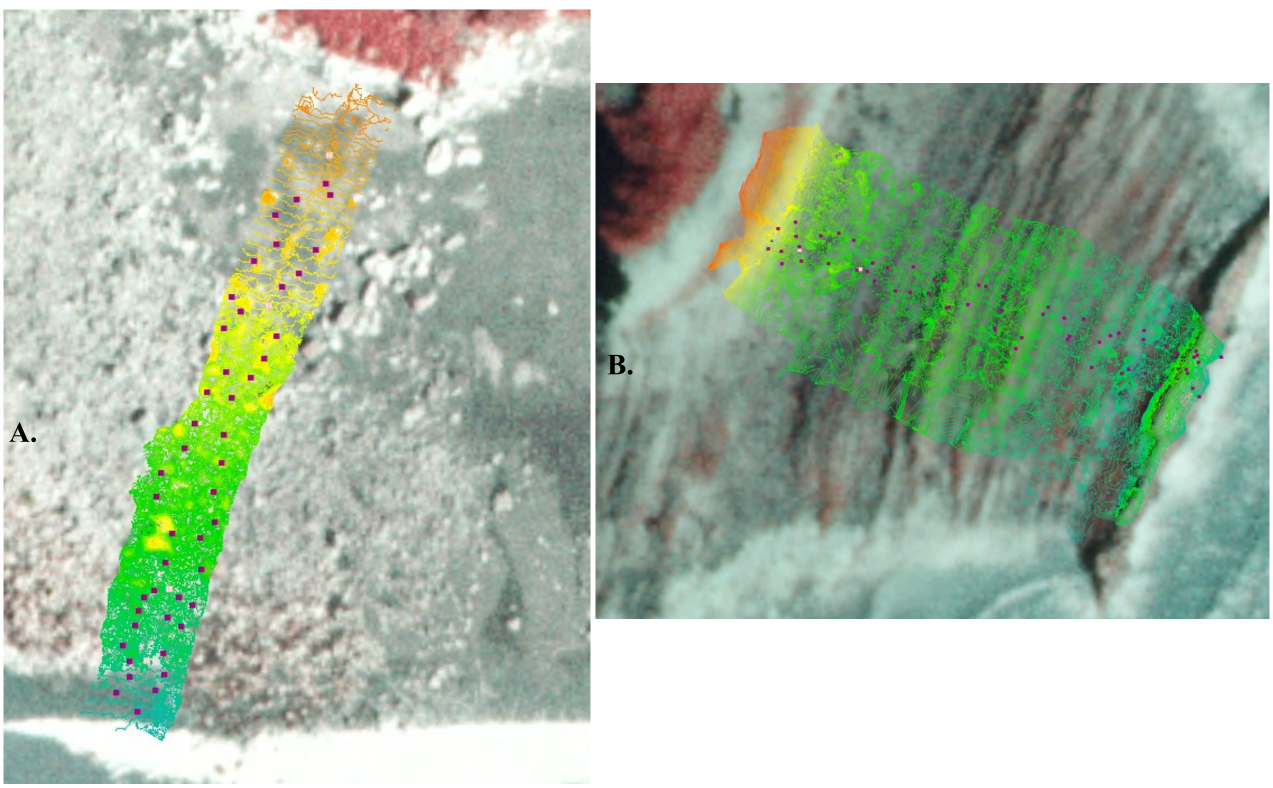

Figure 9. Site 10 (A) and Site 6 (B) hi-resolution coastal imagery with topography and quadrat location overlays. Gradient scale is identical with same elevations represented by the same colors. Purple squares indicate sampled quadrats.

Table 2. Total maximum elevational differences of surveyed site locations in meters. Beach start was the highest safe measurable location on the beach or the vegetation line. Transect start was the location of the identified intertidal zone. Edge of water is the lowest measured point of the water in the sampled tide series. Transect difference is measured from transect start to the edge of the water. Site difference is the total elevational difference from the start of beach to the edge of water.

	Site 2	Site 3	Site 4	Site 6	Site 10	Site 19	All Sites
Beach start (m)	3.8	4.8	3.2	5.8	4.8	7.6	7.6
Transect Start (m)	2.9	3.9	3.0	2.0	3.9	4.0	4.0
Edge of Water (m)	-2.4	-2.1	-3.1	-2.0	-1.9	-2.5	-3.1
Transect Difference (m)	5.3	6.0	6.1	4.0	5.8	6.5	7.1
Site Difference (m)	6.2	6.9	6.3	7.8	6.7	10.1	10.7

3.2.2 Slope

One significant benefit to using RTK to create contours is the ability to identify the slope of the intertidal zone. Because the upper beach was measured as well as the full transect line, slope was considered in two ways: the total slope of the entire beach and intertidal zone combined, as well as the transect slope of just the intertidal zone (Table 3). The transect slope represents the sampling area for this pilot study, with the total slope adding additional perspective to the site. The greatest overall transect slope was located at site 10 (-5.16%) while the smallest slope was seen at site 3 (1.35%). Several of these sites had extremely small slopes as indicated by the relatively small elevational changes over significant distances.

Table 3. Slopes and their vertical and horizontal change as measured in side profile.

Site	Total Slope	Transect Slope	Total Vertical Δ (m)	Transect Vertical Δ (m)	Transect Horizontal Δ (m)	Total Horizontal Δ (m)
2	-2.07%	-1.85%	-5.8	-5.0	273.0	279.7
3	-1.53%	-1.35%	-6.7	-5.8	427.9	438.1
4	-2.95%	-2.78%	-5.0	-4.8	173.3	169.5
6	-5.83%	-3.31%	-6.2	-3.3	98.8	107.2
10	-5.36%	-5.16%	-6.5	-5.6	108.8	121.3
19	-2.87%	-1.77%	-9.1	-5.3	298.7	316.3

3.2.3 Sampled elevational range

Because each quadrat at all sites were surveyed, the elevation of the upper left corner of every quadrat surveyed was recorded. The total elevational difference of all quadrats in all sites was 5.9 m (Table 4). However, individual variations in total intertidal site elevation sampled ranged from 3.4 m at Site 6 to 5.7 m at Site 19. A significant source of this variation relates to the total tide variation at the time of sampling, however, some of this variation is also related to the topography of the site and the location of the sampling quadrats.

Table 4. Maximum, minimum, and total elevational range of surveyed quadrat elevations at all sites in meters relative to geoid sea level. Max is the location of the highest recorded quadrat. Min is the elevational location of the lowest measured quadrat. Elevational range is the difference between the max and min measured for each site.

	Site 2	Site 3	Site 4	Site 6	Site 10	Site 19	All Sites
Max (m)	2.6	3.6	2.9	2.0	3.5	3.8	3.8
Min (m)	-2.1	-1.6	-1.8	-1.4	-1.7	-1.9	-2.1
Elevational Range (m)	4.7	5.2	4.7	3.4	5.2	5.7	5.9

3.3 Intertidal Quadrat Data

Species presence data from photo quadrat interpretation for each site are shown in Figure 10. These data do not reflect percent cover; only the percent of quadrats at each site that the taxa were identified as being present. The data show that there are relatively few dominant species observed in quadrat photos throughout the study area (e.g. the algae Fucus gardneri, and Neorhodomela aculeata, and invertebrate barnacles and littorine snails). Other species were relatively rare and identified as being present in the photographs at only one or two sites. From photographs alone, some observations are difficult to identify to species and were lumped (e.g. barnacles, Lottia sp.). In all cases, the photo quadrats were analyzed by a taxonomist who provided the best possible identification of species from the photographs. Sites 6 and 10, which were the two most northern sites had the lowest number of individual taxa (19 and 11, respectively) within the photo quadrats, whereas site 3 on Augustine Island had the most (41).

Point-count quadrat species data are shown in Figure 11. Compared to species data reported from photo quadrats, fewer taxa were reported in the point-count quadrats at each site. This may be a reflection of the number of quadrats where point-counts were conducted compared to the photo quadrats. Approximately one-quarter of the photo quads were also sampled using the point-count method. As with the photo quadrats, there were fewer numbers of taxa at the most northern sites (Sites 6 and 10 in Tuxedni and Chinitna Bays, respectively) compared to sites further south in Kamishak Bay.

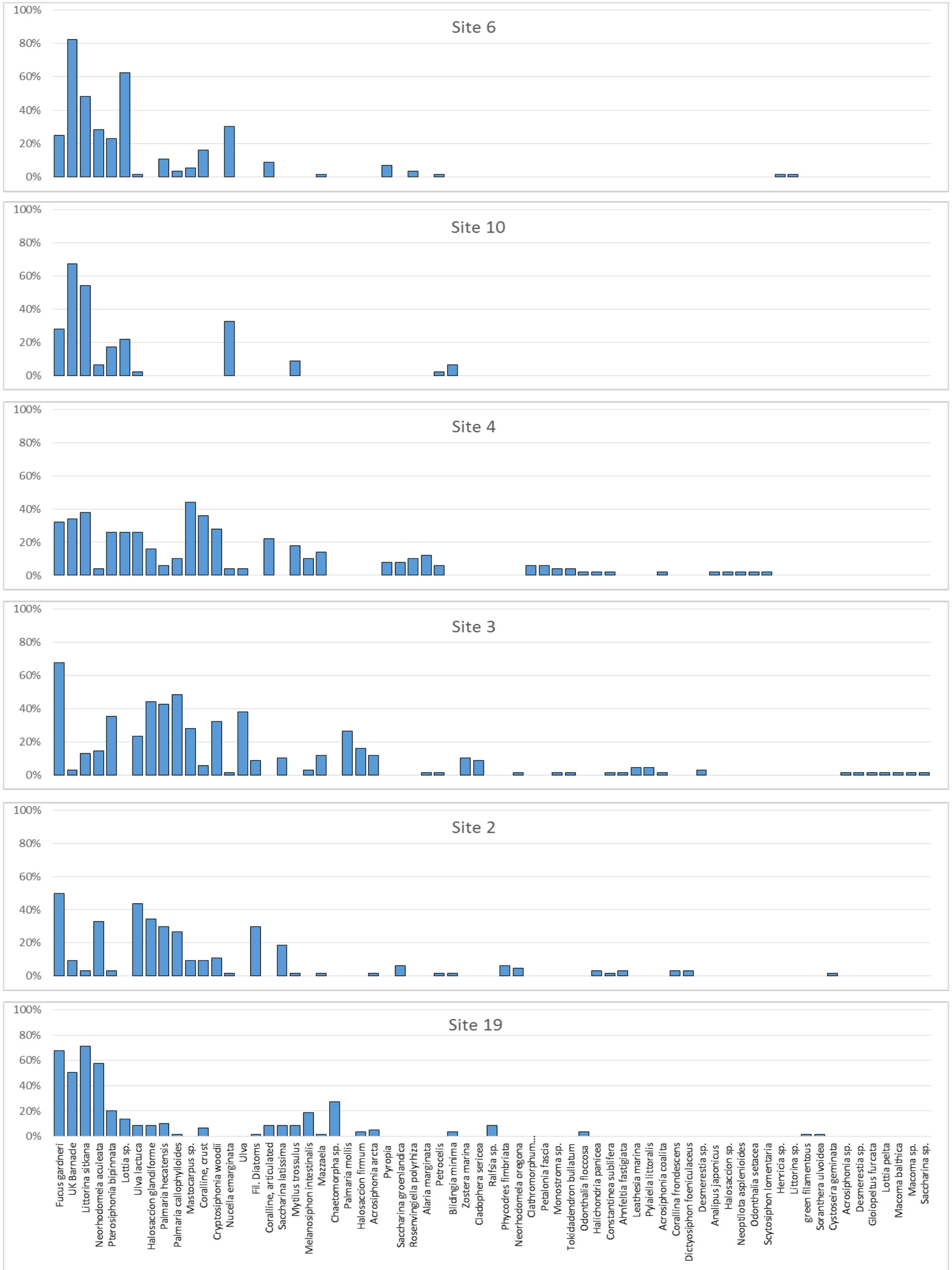

Figure 10. Species data from photo quadrats. The y-axis indicates the percent of total quadrats at that site that had the taxa present. The taxa are ordered from left to right in order of decreasing quadrat presence over all sites. Sites are stacked in general order of North (top) to south (bottom).

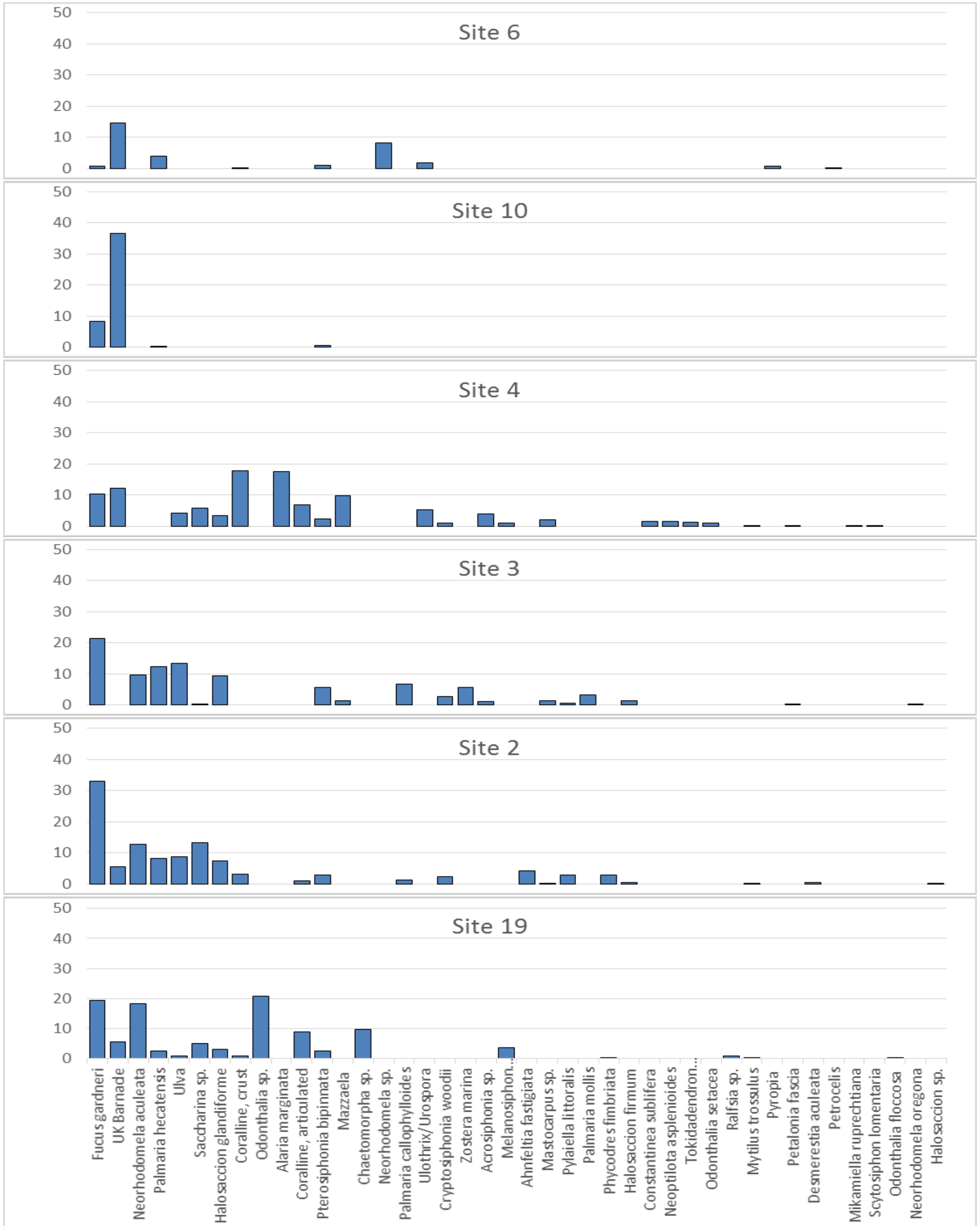

Figure 11. Species data for point-count quadrats. The y-axis indicates the average percent cover in all quadrats at that site. The taxa are ordered from left to right in order of decreasing quadrat presence over all sites. Sites are stacked in general order of North (top) to south (bottom).

Using the non-metric multidimensional scaling (MDS) routine of the statistical program PRIMER, which is software for interpreting multivariate community data (Clarke and Warwick 2001, Murray et al. 2006), a preliminary analysis of intertidal community structure by site was conducted from the point-count data. The MDS plot visualizes differences in community assemblages between sites based on percent cover site data (Figure 12). Each symbol represents the multivariate species assemblage in one quadrat; and the relative distance between any two symbols indicates the degree of community similarity between those samples. Symbol colors differentiate sites. Comparisons are based on Bray-Curtis similarity matrix. For this preliminary look at community assemblage data, we allowed for comparisons of blank samples (where no taxa were recorded at any plot) by using a ‘dummy value’ of 1% cover class (0.01) added to all samples in the similarity matrix. Other data transforms were not performed. Symbols that are closest together in the MDS plot represent quadrats that have more similar communities than do those represented by symbols that are further apart. Sites 2 and 3 overlap strongly and relatively close to most quadrats at site 19. These three sites are the furthest south in the overall study area. Sites 4, 10, and 6 further to the north do not strongly ordinate with each other or with sites 2, 3, or 19.

Tests for differences in assemblages between sites using an analysis of similarity (ANOSIM) routine show that community assemblages were somewhat different from each other by site (Global $R = 0.207$ $p < 0.001$) with the most difference in pairwise tests shown between Sites 3 and 10 ($R = 0.421$ $p < 0.001$) and between Site 3 and 6 ($R = 0.471$ $p < 0.001$).

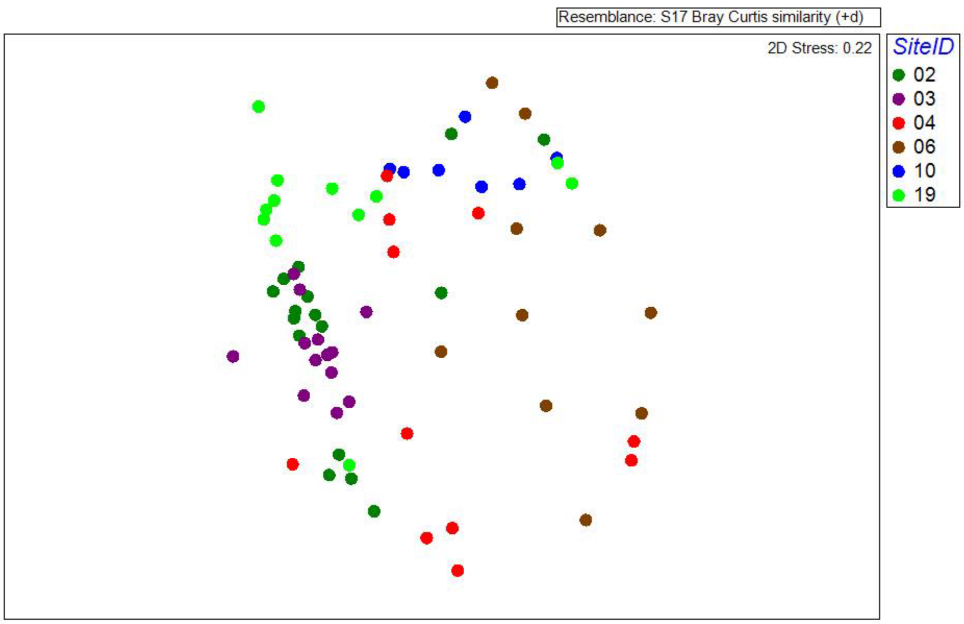

Figure 12. Non-metric MDS showing similarity of sites based on percent cover in point-contact quadrats.

3.4 Intertidal Quadrat Data by Elevation

The RTK position data point that was collected for each quadrat allows individual taxa and community assemblage data to be evaluated by elevation. Cumulative frequency distribution of tidal heights for all quadrats sampled during the June 2015 survey was plotted (Figure 13). The data indicate that the method used for placing quadrats ensured that sampling was conducted across the entire tidal range, with a relatively stable slope throughout the tidal range. The steeper slope of the right portion of the graph (Figure 13) represents the higher elevation quadrats, which were often on a foreshore gravel beach that was shorter and steeper than the mid-intertidal habitat. The cumulative frequency data for quadrat tidal heights also show that the low intertidal zone (below “0” tide) was well-represented, though fewer quadrats were sampled at the very lowest tide levels (indicated by the slightly steeper slope to the left of the graph). This reflects that not all sites could be sampled on the day(s) with the very lowest of tides during the 6-day minus-tide window).

Because each quadrat is tied to an elevation within the intertidal zone, all species identified within the quadrat can be assigned an elevation. These elevations can be used to correlate the species presence within a quadrat across multiple sites to examine the elevational range of species in the intertidal zone. Using the RTK data and data acquired from the photo quadrats, simple intertidal elevational graphs were made for a variety of species comparing their elevation ranges at each site (Figure 14). The taxa shown here were chosen to reflect examples of species that were most ubiquitous throughout the study area, those that cover a wide tidal elevation range, and to illustrate that species are known to typically occur at narrow and more specific tidal elevations.

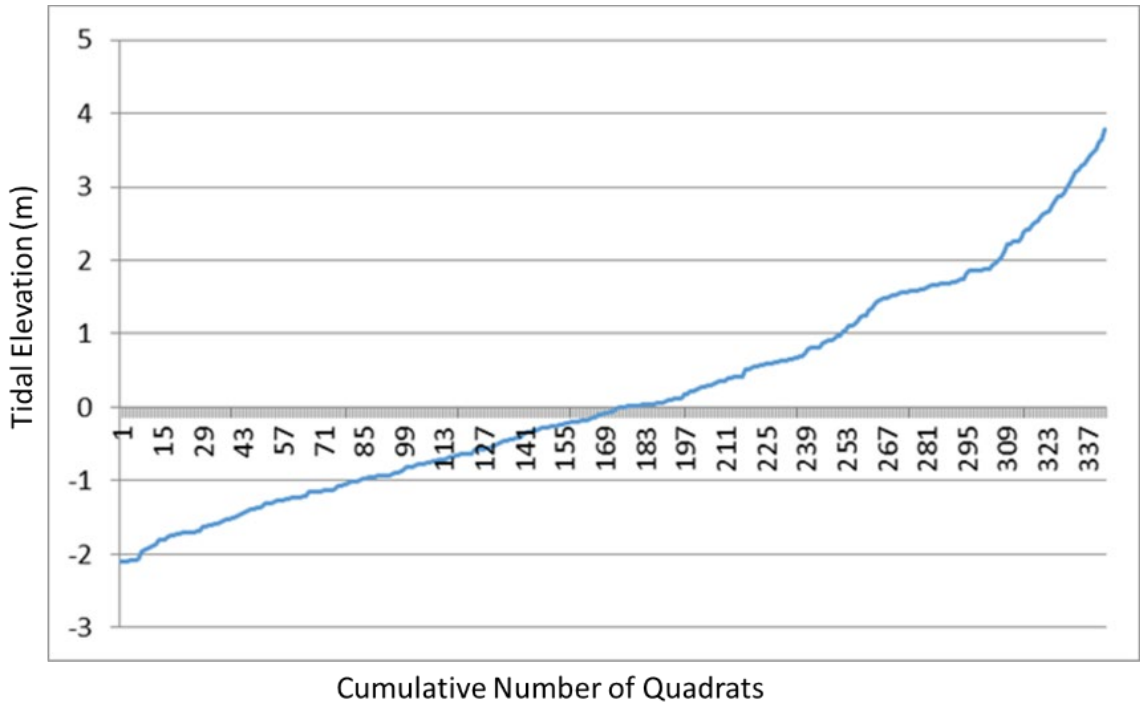

Figure 13. Distribution of quadrat sampling heights for all quadrats sampled at all sites.

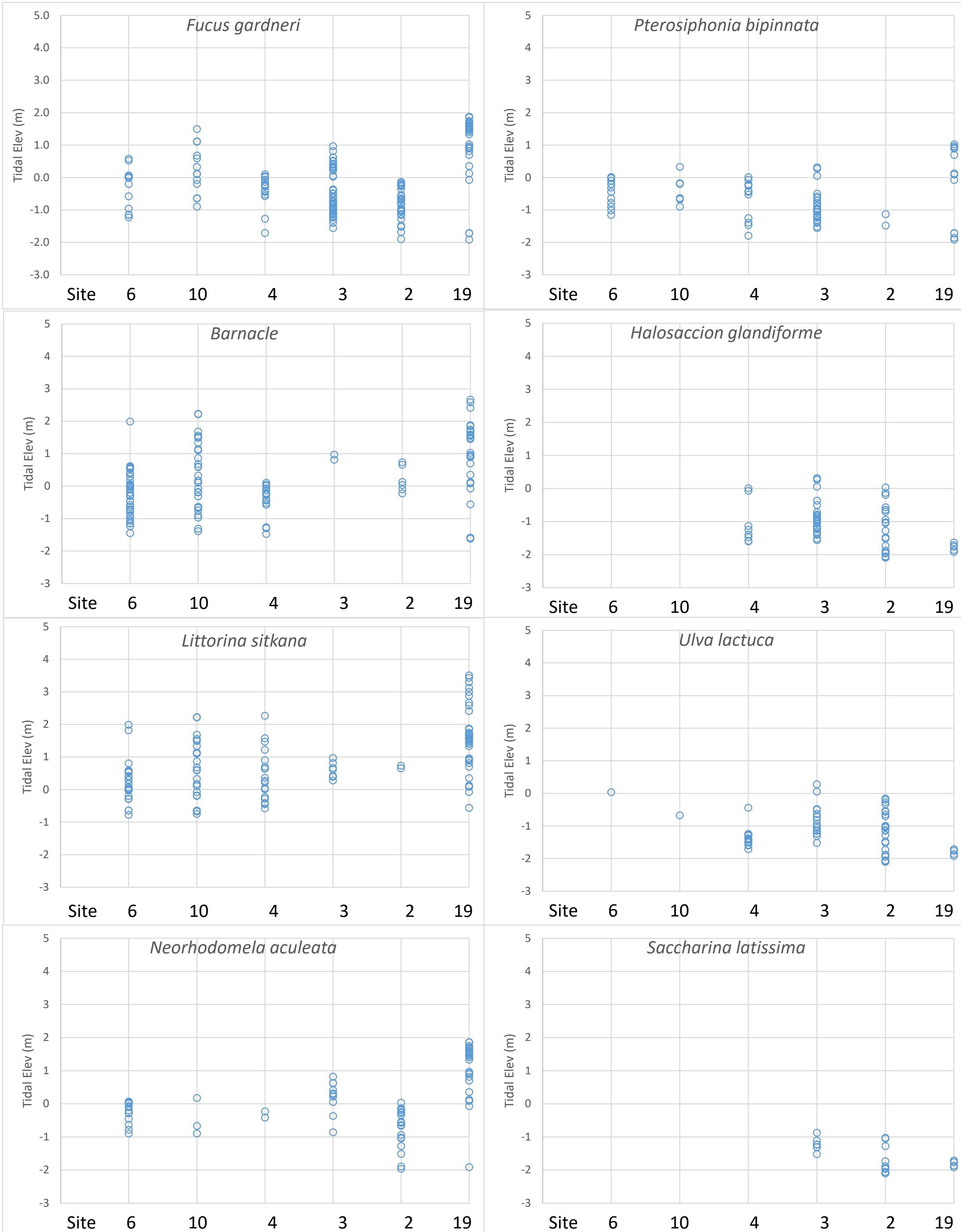

Figure 14. Elevational occurrences of various taxa observed in photo quadrats at each site. Each blue circle represents a quadrat where that taxa was observed. The y-axis is the elevation range relative to the geoid sea level as measured by RTK.

Influences of tidal elevation on the similarity of community assemblages among sites were examined. The MDS ordination plot was created for percent cover quadrat data from all sites by binned elevations (Figure 15). For this preliminary analysis, elevations were binned in 0.5 m increments. When viewed with the earlier MDS showing ordination by site, this ordination plot shows that lower elevation quadrats are more similar to each other than higher elevation quadrats, regardless of site. Assessing the significance of the clustering using ANOSIM, there is a small but significant clustering by elevation ($R = 0.239$, $p < 0.001$).

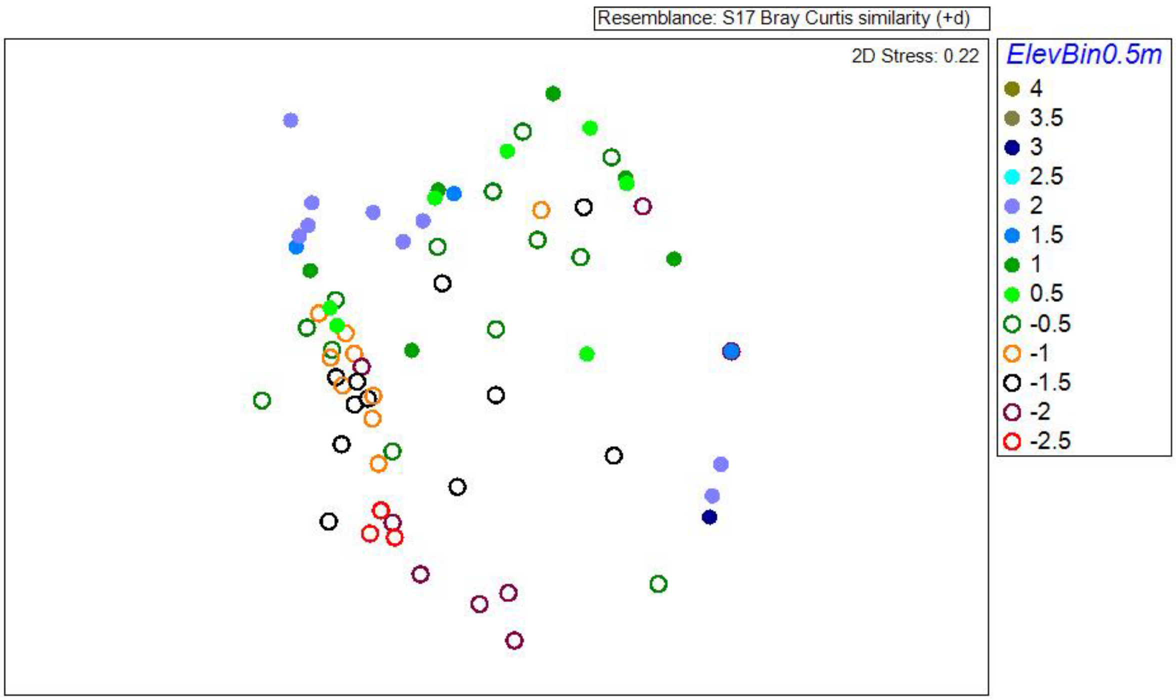

Figure 15. Non-metric MDS showing similarity of sites based on percent cover in point-contact quadrat across all sites. Each symbol is a quadrat and colors represent tidal elevation binned in 0.5 m increments.

3.5 Subtidal

Twenty-one sites were sampled for rocky subtidal community structure between 6/14/2015 and 6/19/2015 (Figure 16). Water depth of these sites varied between 2.5 m to 7 m. Sites were either ones with historical data or ones that were associated with an intertidal site that was sampled as part of this assessment. For the ones associated with the intertidal sites, we sampled directly offshore of the site, and along the beach (to a suitable rocky outcropping) on either side of the site (2-8 km distance to main site), or additionally at an offshore island/outcropping reachable by small boat operations. With this design, we attempted to get reasonable spatial coverage throughout the study area.

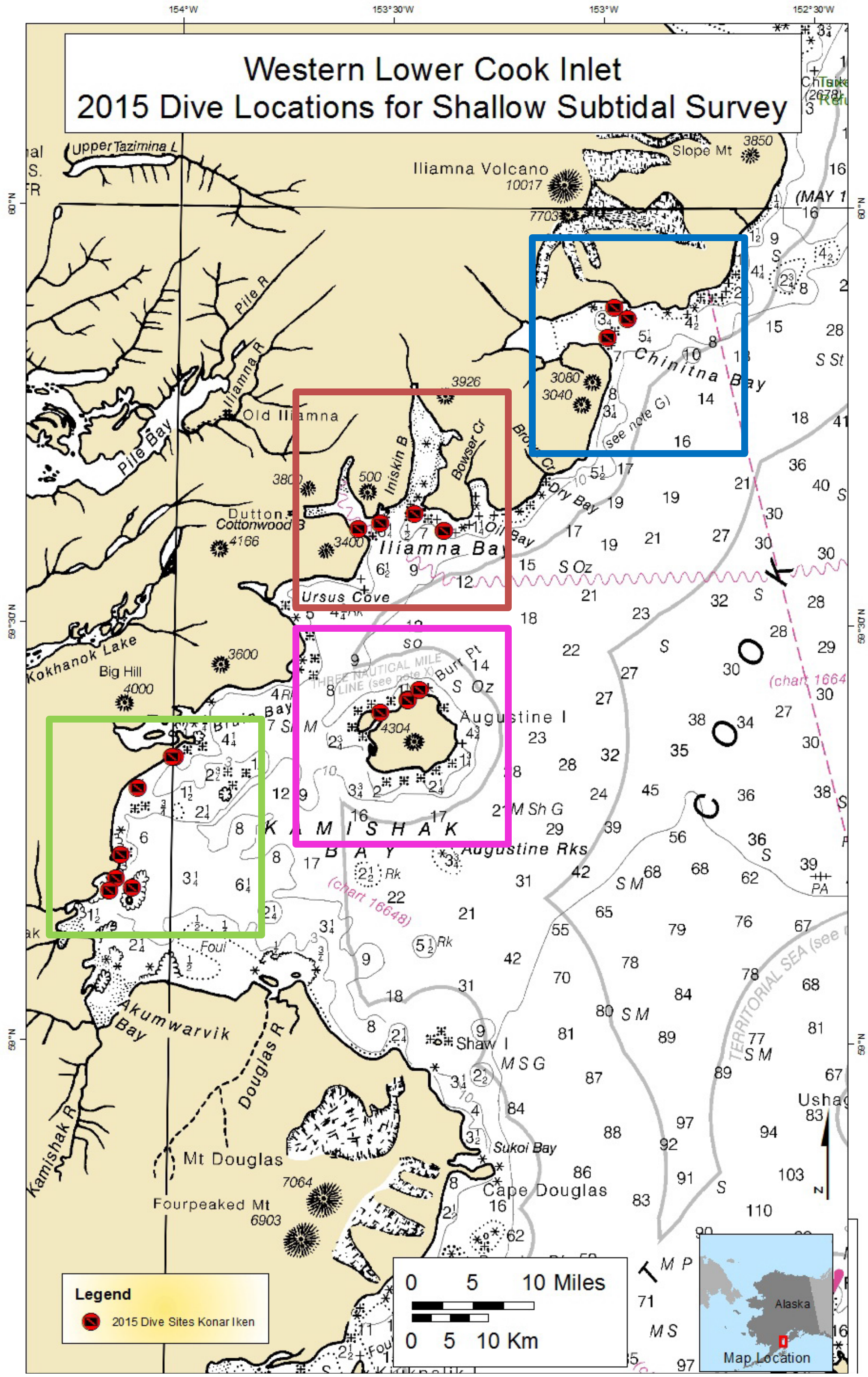

Figure 16. Sites sampled for subtidal community structure. For preliminary analyses, sites were grouped into four regions (Chinitna Bay (Blue), Iliamna Bay (Red), Augustine Island (Pink), and Kamishak Bay (Green)).

In the subtidal biomass surveys from the scrapes of the 50 x 50 cm quadrats, 55 algal and 92 invertebrate taxa were identified. Preliminary analyses of the community structure based on these biomass estimates indicate that regions and sites were significantly different from one another (Figure 17; PERMANOVA pseudo-F=2.033, P(perm)=0.003 and pseudo-F=4.059, P(perm)=0.001 for region and site nested in region, respectively). Subtidal communities in the two southern regions, Kamishak Bay and Augustine, were not significantly different (post-hoc comparison P(perm) = 0.182) but most other regional comparisons were.

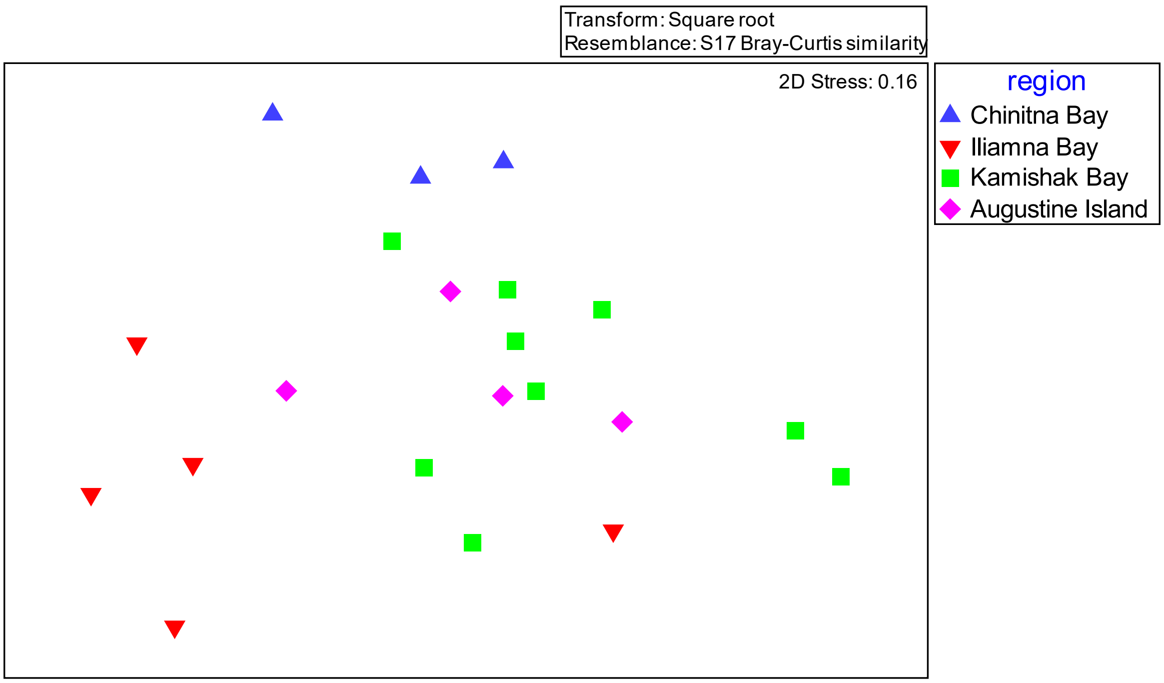

Figure 17. Non-metric MDS showing similarity of sites and regions based on biomass from ten 50x50 cm quadrats per site.

The community assessments conducted from the 1 x 1 m visual quadrats (organism counts and percent cover estimates) had similar regional and site results to the above biomass assessment (based on organism counts: Figure 18; PERMANOVA pseudo-F=3.938, P(perm)=0.001 and pseudo-F=1.808, P(perm)=0.001 for region and site nested in region, respectively. Based on understory percent cover: Figure 19; PERMANOVA pseudo-F=4.841, P(perm)=0.001 and pseudo-F=4.618, P(perm)=0.001 for region and site nested in region, respectively). All region comparisons (post-hoc comparisons) were significantly different both based on counts as well as on percent cover. The number of taxa recorded from the counts included seven kelps and 24 invertebrate taxa. The number of taxa recorded from the percent cover estimates included 41 algal and 19 invertebrate taxa and three substrate categories (bare rock, cobble and sand).

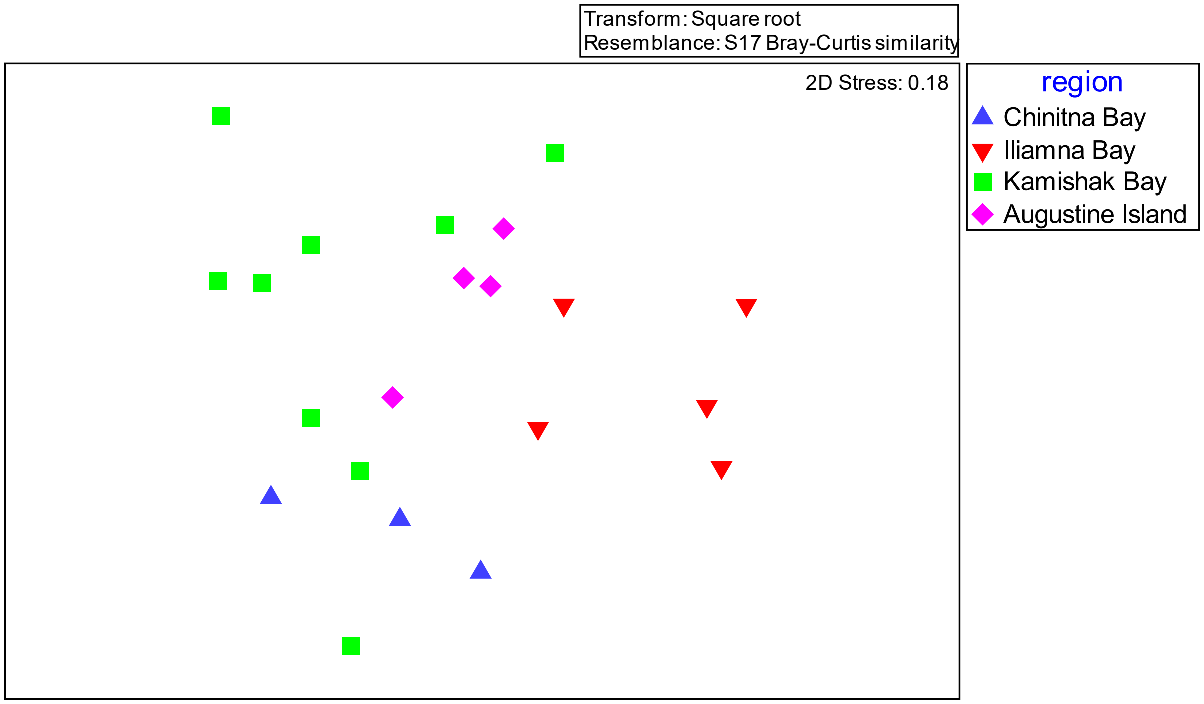

Figure 18. Non-metric MDS showing similarity of sites and regions based on counts of kelp stipes and macroinvertebrates from ten 1 x 1 m quadrats per site.

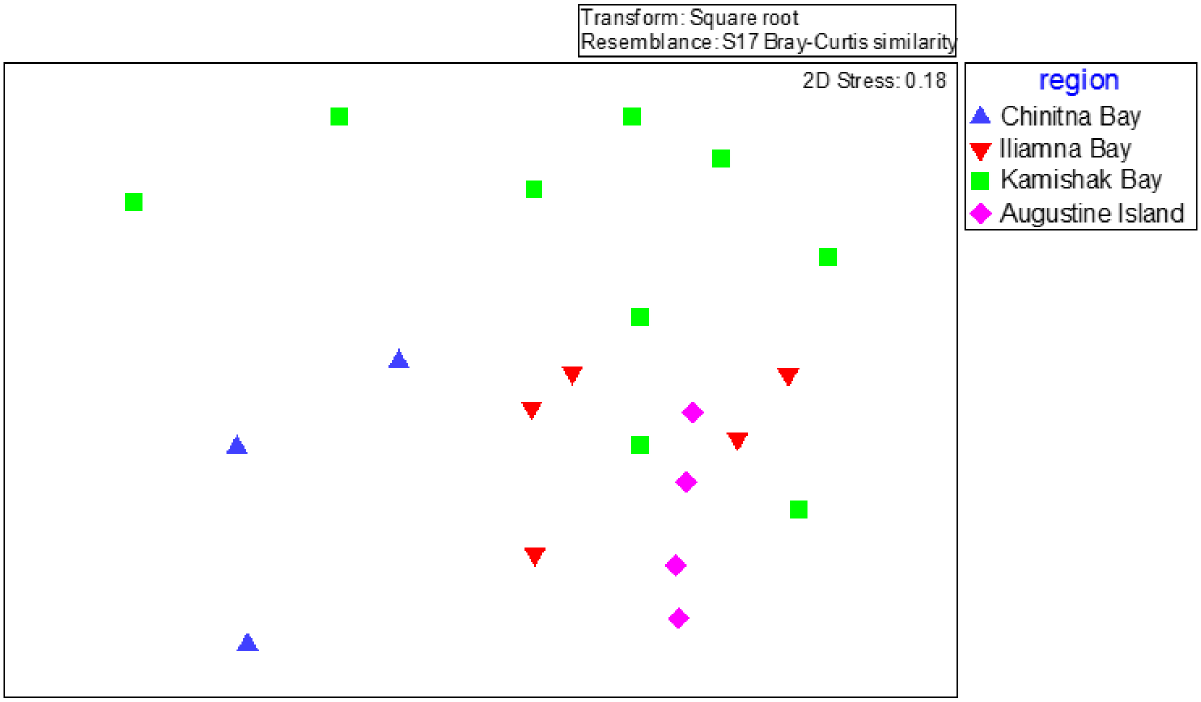

Figure 19. Non-metric MDS showing similarity of sites and regions based on algal and encrusting/colonial invertebrate percent cover of from ten 1 x 1 m quadrats per site.

4. DISCUSSION

Our preliminary work in 2015 has laid the foundation for continued efforts, which will further our understanding of biological communities in Lower Cook Inlet. A study entitled: Subtidal and Intertidal Habitats and Invertebrate Biota in Lower Cook Inlet, Alaska (M15PG00037), began in June 2016 and builds on the data base and field results of this current project. To date, we have completed the historical data compilation and completed one season of pilot field testing.

Intertidal quadrat sampling captured community differences among sites, as well as regional differences (e.g. northern vs. southern sites within the study area). Our site layout methods ensured sampling throughout the tidal range at each site. By combining photo quadrats and point-count quadrats, we were able to obtain data from a high number of quadrats (from photo quadrats) and percent cover data (from point-count quadrats). Some combination of these methods will continue for future rocky site sampling, though several factors should be taken into consideration in developing future sampling programs. A significant amount of time on each site was required to lay out the transect, measure the sections, and place quadrats. The sites sampled in 2015 were up to hundreds of meters from MHHW to the low water line. However, in southern Kamishak Bay, the rocky platforms and reefs are often several kilometers in length. The site layout employed during this pilot study would not be possible for sampling southern Kamishak Bay sites. Consideration should be given to developing a sampling plan that will ensure sampling throughout the tidal range in these unique.

A higher number of species were found on each site from the photo quadrats compared to the point-count quadrats, likely due to the much larger number of photo quadrats collected. However, interpretation of photo quadrats provides data for only those species on the surface. Species that are typically understory taxa would be under-represented in any percent cover estimates from the photos and might be missed altogether if photo quads are the only source of data.

We recommend that a nested design be developed whereby the focus would be on collecting as many photo quadrats as possible in addition to the collection of a subset of point-count or percent cover estimate quadrats should be sampled in the field. When interpreting the photo quadrats after returning from the field, the data recorded should include percent cover estimates for all taxa identified in the quadrats. It is important that taxonomists or field crew experienced in identifying Alaskan marine algae and invertebrates be available on the field teams to provide detailed species lists for each site. However, if taxonomists are unavailable for field efforts, we have seen from the 2015 field season that trends in species distributions across the study area (north vs. south) and by elevation can be seen from presence/absence data interpreted from photo quadrats. Thus, it should be recognized that opportunistic sampling by field crews untrained in taxonomy can obtain the high-resolution photographs that can be later interpreted by taxonomists to provide species-level information.

Elevation information collected with quadrats is an important piece of environmental information allowing correlation of elevation with species presence and abundance, and it allows for calculation of inundation times at elevation correlated to species. RTK collection of elevational data at quadrats is recommended to continue for habitat assessments. The high-resolution tidal elevation data may be critical for any future assessments of intertidal ecosystem changes due to sea-level rise and may even be able to detect shifts in topography and beach elevations resulting from earthquakes such as the recent (January 2016) 7.2 magnitude earthquake centered within a few kilometers of our Site 4 and approximately 100 km deep.

Topography is important in considering the physical constraints of the habitat. RTK provides very high-resolution point location information and tidal elevation data. However, it is time consuming and hazardous when used to conduct topographic surveys over very large areas comprised of complex and highly rugose intertidal substrate. Hazards include slippery surfaces on cobble/bolder substrates, poor visibility for safe footing, and unstable rocky conditions. It is recommended that RTK continue to provide the high-resolution quadrat point location and tidal elevation data, while also looking towards using LIDAR or Photogrammetry to provide the large aerial context in which to place the RTK data. This will allow expansion of the topographic information to even larger areas and enhance the interpretability of the fine detail data collected at the site level.

The sampling that was performed in the subtidal seemed to capture community differences and similarities so it is recommended that these protocols be continued into the new project (M15PG00037) with field work in 2016. Subtidal site recommendations for 2016 are to re-sample some of the sites that were sampled in 2015 so that the temporal variability that exists between years can be examined. In addition to these re-sampled sites, we recommend that some new sites are sampled (particularly in the southern part of the study area) to increase the spatial resolution of the data.

Total number of taxa recorded was higher in the biomass collections than in the visual assessments. Conversely, data collection and processing of visual data is much faster than for biomass collections. However, overall community patterns among regions were quite similar among the various methods. Which methods are used in future assessment and monitoring depends on the main goals: If greater spatial coverage is desirable, then more sites could be surveyed in the available time by just using the visual techniques. If a detailed species record and the potential of rare (or even invasive) species is of interest, the biodiversity collections should be continued. Alternatively, a combination of methods could be applied where one central site (e.g., the subtidal site corresponding to the intertidal site) could be sampled for biomass and all other (satellite) sites could be sampled only visually.

5. REFERENCES

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Rigby P. R., K. Iken, Y. Shirayama. 2007. Sampling Diversity in Coastal Communities. NaGISA Protocols for Seagrass and Macroalgal Habitats. Kyoto University Press. 145 pp.

Online Resources:
Alaska ShoreZone Program Partnership website (www.shorezone.org)
AlgaeBase (http://www.algaebase.org/)
NOAA Fisheries Alaska ShoreZone Coastal Mapping and Imagery website (https://alaskafisheries.noaa.gov/mapping/szflex/)
The Seaweeds of Alaska website (http://www.seaweedsofalaska.com)
The World Register of Marine Species (http://www.marinespecies.org/index.php)

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under US administration.

The Bureau of Ocean Energy Management

As a bureau of the Department of the Interior, the Bureau of Ocean Energy (BOEM) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS) in an environmentally sound and safe manner.

The BOEM Environmental Studies Program

The mission of the Environmental Studies Program (ESP) is to provide the information needed to predict, assess, and manage impacts from offshore energy and marine mineral exploration, development, and production activities on human, marine, and coastal environments.