



SOP for Monitoring Intertidal Bivalves in Mixed-Sediment Beaches — Version 2.0

Southwest Alaska Inventory and Monitoring Network

Natural Resource Report NPS/SWAN/NRR—2017/1443



ON THE COVER

Aerial photograph of a mixed-sediment sampling site at Kafia Bay in Katmai National Park and Preserve.
Ben Weitzman, USGS

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Contents

	Page
Figures.....	v
Tables.....	v
Appendices.....	v
Abstract.....	vi
Background and Objectives	1
Introduction	1
Rational for Monitoring Bivalves in Mixed-Sediment Beaches	2
Measurable Objective.....	3
Sampling Design.....	4
Rationale for Sampling Design Selection.....	4
Selecting Sampling Units	5
Sizes and number of sampling units per site	5
Vertical stratification.....	5
Number and location of sampling sites	6
Recommended Frequency and Timing of Sampling	6
Level of Change That Can Be Detected	6
Field Season.....	8
General methods.....	8
Field Season Preparation.....	8
Initial Site Layout.....	10
Biennial site visits	11
Collection of bivalves for determination of density and size distribution.....	11
Collection of sediments for sediment size distribution	13
Post collection processing of samples and data collected	13
After each field day, the following tasks are to be completed:	13
Laboratory methods for determination of sediment grain size.....	14
Data Handling, Analysis and Reporting	15
Metadata Procedures	15

Contents (continued)

	Page
Overview of Database Design.....	15
Data Entry, Verification and Editing.....	15
Routine Data Summaries and Statistical Analyses	15
Report Format	15
Methods for Trend Analyses	15
Data Archival Procedures.....	16
Reporting Schedule	16
Personnel Requirements and Training	17
Roles and Responsibilities.....	17
Qualifications	17
Training Procedures	17
Operational Requirements and Workloads	19
Operational Requirements.....	19
Annual Workload and Field Schedule	19
Facility and Equipment Needs	19
Procedures for Revising the Protocol.....	20
Literature Cited	21

Figures

	Page
Figure 1. Map of Intertidal Sampling Sites in the Gulf Watch Alaska Study region.....	2
Figure 2. Simplified mixed-sediment site layout. From start coordinate the 100 m transect is laid out to the right on the 0 m MLLW contour.	11
Figure 3. An excavated quadrat is ready for sieving. Left (A) – Image of a quadrat and sampled area, 10 mm mesh sieve, 3-5 gallon buckets for containing sediment, shovel, transect tape, and a labelled clam collection bag.. Right (B) – An observer carefully measures a large <i>Mya truncata</i> with other clams sorted in the background.	13

Tables

	Page
Table 1. Overview of the sampling designs used for soft sediment bivalves.....	5
Table 2. Frequency of sampling key metrics	6

Appendices

	Page
Appendix A.....	24
Appendix B.....	27
Appendix C.....	28
Appendix D.....	30
Appendix E	31
Appendix F.....	33

Abstract

Bivalve density and size are monitored because of their importance as prey for nearshore consumers, such as sea otters, sea stars, marine birds, including black oystercatchers and various sea ducks, and terrestrial consumers such as brown bears and humans. The macrofauna that inhabit mixed-sediment beaches can occur in very high-abundances and provide an important food source for nearshore consumers. However, mixed-sediment habitats are particularly sensitive to disturbance from environmental or anthropogenic sources, as witnessed in numerous studies in Prince William Sound following the Exxon Valdez Oil Spill and the Great Earthquake in 1964. These studies provide a baseline of information on bivalve density and size of focal species (identified in section 2 below) that this SOP intends to build upon, by following consistent methodology. The techniques described in this SOP will provide data that are comparable both within and beyond the scope of the Southwest Alaska Network (SWAN) and Gulf Watch Alaska (GWA) nearshore monitoring programs.

Background and Objectives

Introduction

Intertidal invertebrates on unconsolidated and mixed sediment substrate beaches are important components of nearshore marine habitats in the Gulf of Alaska (GOA). These habitats comprise approximately 25% of the intertidal zone in the GOA (Ford et al. 1996), and are a rich source of invertebrate production that includes clams, snails, polychaete worms, and small crustaceans. These, in turn, are primary food sources for a variety of vertebrate and invertebrate predators such as sea stars (Gage 1998, Gaymer et al. 2004) sea otters (Calkins 1978, Estes et al. 1981, Garshelis et al. 1986, Kvitek and Oliver 1988, Kvitek et al. 1992, Doroff and DeGange 1994), sea ducks (Goudie and Ankney 1986) and subsistence users (Fall and Field 1996). Intertidal mixed sediment communities are particularly vulnerable to both natural and human induced disturbance, and have been particularly vulnerable to earthquakes (Baxter 1971, Haven 1971), hydrocarbon contamination from the Exxon Valdez oil spill (Houghton et al. 1993, Armstrong et al. 1995, Driskell et al. 1996, Lees et al. 1996, Fukuyama et al. 2000), and changes in sediment composition as a result of spill related clean-up activity (Driskell et al. 1996, Lees et al. 1996).

The intertidal bivalve community on mixed sediment beaches in the GOA is comprised primarily of infaunal species that live within the upper layer of sediments and epibenthic mussels that attach to the substrate. Numerically dominant clams include *Macoma* spp., *Hiatella arctica*, *Leukoma staminea*, *Mya truncata* and *Saxidomus gigantea*. Mussels (*Mytilus trossulus*) also can be locally abundant. The community is spatially variable and species composition and relative abundance is dependent on a variety of factors, the most important of which are sediment grain size distributions, fresh water input, and degree of physical disturbance. Eelgrass (*Zostera marina*) is common at soft sediment sites in the lower intertidal and often extends into the subtidal zone. Species of particular importance are the large-bodied clams: *Leukoma*, *Clinocardium* spp., *Mya* spp., and *Saxidomus*, often the dominant organisms in terms of biomass and are critical prey for larger predators including octopus, sea otters, sea ducks, and bears. In addition, the more common hard-shell clams (*Leukoma*, *Clinocardium*, and *Saxidomus*) are harvested by subsistence users and are of commercial importance in a growing mariculture industry.

This protocol describes the methodology for assessing change in intertidal bivalve communities on mixed sediment beaches across the northern GOA. Sampling will be conducted in mixed-sediment intertidal habitats within four blocks across three regions (see Dean et al. 2014). These four blocks include two national parks, Kenai Fjords National Park (KEFJ) and Katmai National Park and Preserve (KATM), Kachemak Bay (KBAY) and Western Prince William Sound (WPWS). In total, nineteen sampling sites are monitored across these four blocks (Figure 1). Further explanation and justification for monitoring intertidal bivalves is summarized in the protocol narrative (Dean et al. 2014). Dean et al. refers to 6 sampling blocks however, beginning in 2014, the sampling universe was reduced. Those changes are reflected here.

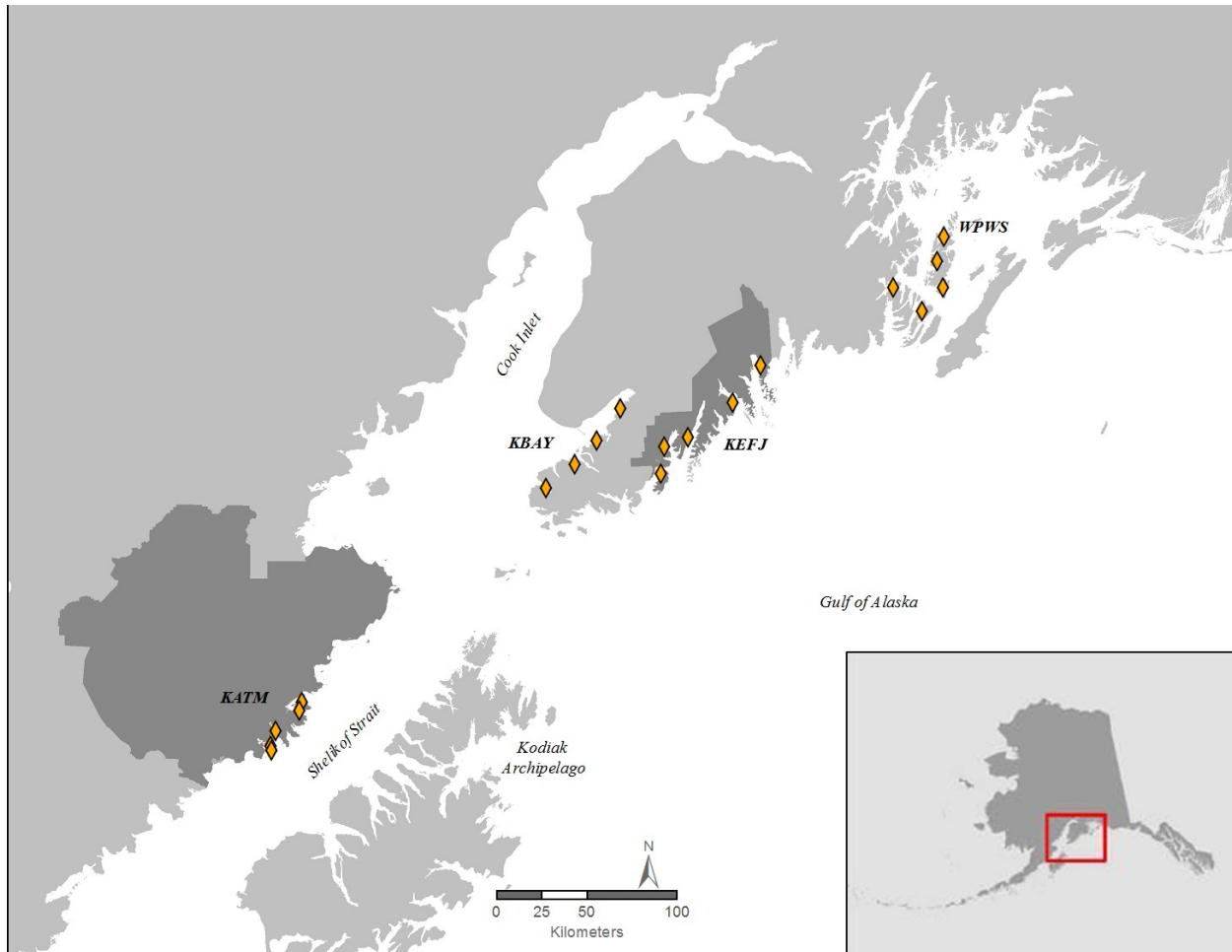


Figure 1. Map of Intertidal Sampling Sites in the Gulf Watch Alaska Study region.

Rational for Monitoring Bivalves in Mixed-Sediment Beaches

Bivalve density and size are monitored because of their importance as prey for nearshore consumers, such as sea otters, sea stars, marine birds, including black oystercatchers and various sea ducks, and terrestrial consumers such as brown bears and humans. The macrofauna that inhabit mixed-sediment beaches can occur in very high-abundances and provide an important food source for nearshore consumers. However, mixed-sediment habitats are particularly sensitive to disturbance from environmental or anthropogenic sources, as witnessed in numerous studies in Prince William Sound following the Exxon Valdez Oil Spill and the Great Earthquake in 1964. These studies provide a baseline of information on bivalve density and size of focal species (identified in section 2 below) that this SOP intends to build upon, by following consistent methodology. The techniques described in this SOP will provide data that are comparable both within and beyond the scope of the Southwest Alaska Network (SWAN) and Gulf Watch Alaska (GWA) nearshore monitoring programs. In addition to the metrics listed above, biomass can be derived using established size to biomass conversions (Ofstedal et al. 2007) allowing data from this SOP to be used in modelling aspects of nearshore ecosystem energetics.

Changes in intertidal communities on mixed sediment beaches will be assessed by examining changes in abundance, size distribution, and biomass of bivalves by species. Sampling will be conducted once every other year (biennially) due to the destructive sampling technique and to avoid oversampling over time. A stratified random sampling design will be employed, with sampling locations stratified by geographic location, geomorphologic shoreline type, and tidal elevation. Establishment and sampling of sites will be based on proximity to the stratified random sample of sites selected for the rocky intertidal algae and invertebrate sampling of sheltered rocky habitats (Dean and Bodkin 2011, Dean et al. 2014). Surveys will be conducted within each of the blocks that make up the GWA nearshore monitoring program, including the national parks that comprise the SWAN. Focal species, which are numerically dominant include: *Leukoma staminea*, *Clinocardium spp.*, *Hiatella arctica*, *Macoma spp.*, *Mya spp.*, *Mytilus trossulus*, and *Saxidomus gigantea*. These species are common across the GOA, provide an important source of food for consumers, and have been used as a fishery resource. In addition, there is an abundance of historical data on some of these species (*Leukoma*, *Saxidomus*, *Clinocardium*). These species can also be identified and enumerated with relative ease.

Measurable Objective

This protocol will accomplish three specific objectives, outlined below:

1. Assess changes in the bivalve assemblage diversity on intertidal, mixed-sediment beaches across the GOA
2. Assess changes in the relative abundance of bivalves (clams and mussels) on intertidal, mixed-sediment beaches across the GOA
3. Assess changes in the size distribution of numerically abundant bivalve species on intertidal, mixed-sediment beaches across the GOA

Sampling Design

Rationale for Sampling Design Selection

At each site, all bivalves > 14 mm in shell length will be recovered for identification and quantification of density and size. Size distributions will be generated for species whenever possible, dependent on the abundance of bivalves encountered (Table 1). Focal species, which are numerically dominant include: *Leukoma staminea*, *Clinocardium spp.*, *Hiatella arctica*, *Macoma spp.*, *Mya spp.*, *Mytilus trossulus*, and *Saxidomus gigantea*. Sediment grain size will be quantitatively measured at each site during initial site set up by taking core samples from each site. Proportions of grain size classes will be reported on from laboratory processing of sediment cores. On each visit, the percent cover of surface substrates will be qualitatively assessed using the Wentworth scale categories (silt, sand, granule, pebble, cobble, boulder; see Appendix E for details). We did not include more comprehensive sampling of the entire infaunal community (including smaller bivalves, gastropods, polychaete worms, and crustaceans) because of cost and time constraints. An evaluation of the complete infaunal community requires sampling using small cores, subsequent sorting of samples in the laboratory, and time consuming identification and enumeration of species. In addition, the small size of the sampling units and high variability among samples requires that a large number of units be sampled in order to provide reasonable power to detect changes in these communities. This, coupled with the high cost of sample sorting and counting, made a complete infaunal analysis impractical.

Initially, sampling will be conducted biennially. The number of quadrats sampled and frequency may be modified as justified following power analyses after five or more years of data collection. A stratified random sampling design will be used, with soft sediment sampling locations based on proximity to the stratified random sample of sites selected for the rocky intertidal algae and invertebrate sampling of sheltered rocky habitats (Dean et al. 2014).

The techniques used in this SOP are similar to those used in other associated research activities (Bodkin and Kloecker 1999, Weitzman 2013) and will provide data that are comparable both within and beyond the geographical scope of the Southwest Alaska Network (SWAN) and Gulf Watch Alaska Nearshore monitoring programs.

Table 1. Overview of the sampling designs used for soft sediment bivalves. Modified from Dean et al. 2014.

Vital Sign	Primary metric	Sampling unit	Size of sampling unit	# of sampling units & sampling period	Selection process for sample locations	Strata	Smallest spatial scale at which trends will be examined
Intertidal invertebrates – gravel/sand	Intertidal invertebrate abundance	Quadrat	0.25 m ²	12 quadrats per transect, 5 transects per block	Closest to rocky intertidal site, systematic with random start for quadrats	Blocks	Site
	Clam size, by species	Quadrat	0.25 m ²	Variable, dependent on the number of clams per site	Closest to rocky intertidal site, systematic with random start for quadrats.	Blocks	Site
	Changes in the bivalve assemblage diversity	Quadrat	0.25 m ²	Variable, dependent on the number of clams per site	Closest to rocky intertidal site, systematic with random start for quadrats.	Blocks	Site

Selecting Sampling Units

Mixed-sediment sampling sites are defined as 100 m stretches of coastline with contiguous beach of gravel or mixed sand and gravel habitat at the 0.0 m mean low low water (MLLW) tidal elevation. The approximate location of each site is pre-determined using the protocol described in Dean et al. (2014). However, there are known inaccuracies in the ESI shoreline classification data (Sundberg et al. 1996) due largely to the coarse scale at which the classifications were made. Therefore, on the initial visit to each pre-selected location, the sites will be evaluated and new sites substituted if the habitat classification proves to be incorrect.

Sizes and number of sampling units per site

The abundance of bivalves will be measured in twelve 0.25 sq. m. (0.5-m x 0.5-m wide by 25 cm deep) quadrats, spaced 8.33 m along a 100 m transect, at each site. The number of quadrats to be sampled per site was guided largely by logistical considerations (the estimated time required to sample a given site within one low- tide window). All living bivalves collected will be identified to the most specific taxa, counted, and measured to the nearest millimeter.

Vertical stratification

All sampling will be conducted at the 0.0 m MLLW tidal elevation. Tide height will be determined using the nearest tide station estimate of 0.0 MLLW. For locations with known tide delays, every effort shall be made to account for lag times to sample as close to 0.0 MLLW as possible.

Number and location of sampling sites

A total of five mixed-sediment bivalve monitoring sites will be sampled in KATM, KEFJ, and WPWS. Site selection for these blocks was based on the 1) proximity of appropriate habitat to rocky intertidal monitoring sites, and 2) presence of bivalves in the form of siphons, squirts at low tide, and fresh shell litter. In general, soft-sediment sites are less than 1 km from the rocky sites but can be upwards of 5 km. Details on focal site selection for rocky intertidal monitoring can be found in the rocky intertidal SOP (Dean and Bodkin 2011) and the Nearshore Protocol Narrative (Dean et al. 2014). A total of four mixed-sediment bivalve sites will be sampled in KBAY following similar criteria for selection. All sites are marked by a GPS waypoint for the start and end of the transect. Coordinates are maintained in the Gulf Watch Alaska master site table.

Recommended Frequency and Timing of Sampling

Visits will be made to each site biennially. Abundances of all bivalves and size distributions will be measured at each site during each visit. We elected not to visit each site annually because of the destructive nature of the sampling and its potential effect on the site. Sediment grain size is not expected to change appreciably over time except in cases of extreme disturbance. If such disturbances are noted, the frequency of sampling for sediment grain size will be increased. Sampling is to be conducted during spring tide series from May through July. Tidal series should be selected such that there are at least 7 consecutive days of minus tides occurring during daylight hours (Table 2.).

Table 2. Frequency of sampling key metrics

Metric	Sampling Frequency
Bivalve Abundance	2 years
Bivalve Size Distribution	2 years
Sediment Grain Size	8 years

Level of Change That Can Be Detected

From Dean et al. 2014: “In the Gulf of Alaska, there are relatively few data regarding the normal range of variability in clam assemblages on sand-gravel beaches or on levels of change that are ecologically important. Additionally, the sampling methods are by necessity destructive and preclude sampling at high frequency. As a result variation in mean density values within clam beds over time are generally high. Within clam beds sampled in multiple years in Glacier Bay, mean densities of dominant species varied by as little as 10% and as much as 300% (J. Bodkin, unpublished data). Similarly, Houghton et al. (1996) found relatively high inter-annual variability in clam densities in PWS (at sites unaffected by the Exxon Valdez oil spill). Because of the lack of data from many of our sampling sites (especially KATM and KEFJ) and the anticipated high spatial and temporal variance, we will use values for clam densities of 80% to represent changes that are deemed ecologically important. Reductions on the order of 80% or greater were observed at sites that were washed after the Exxon Valdez spill and were deemed ecologically important (Houghton et al. 1996). We also lack size data for dominant intertidal clams from KATM or KEFJ, but expect variation in

mean sizes to vary much less than density. As a consequence we expect a 50% change in mean size of dominant intertidal clams to be ecologically important.”

It is the goal of the sampling to detect an 80% decrease or increase of abundance of most abundant taxa within a 10 year period (5 sampling years) and a 50% change in the mean frequency in sizes of bivalves among seven size categories. As with other metrics, it is recommended that power analyses be conducted after the initial five years of sampling to assess efficacy of sampling intensity and frequency. Pending results of the power analysis, sampling effort may be adjusted accordingly to maximize power and sampling efficiency. Species selection was based on surveys conducted in KATM and KEFJ (Lees and Driskell 2006, Coletti et al. 2009) that focused on the abundance, size distribution, and diversity of clams. A total of over 25 species were found, most of which were rare (fewer than 10 individuals in 12 – 0.25 sq. m. quadrats per site) and offer little power to detect change in their abundance over time. As a result, we are limiting the number of taxa to the focal species listed in Section 1 of this SOP. While we will focus on these more abundant species at present, all larger bivalves are counted and measured and could be included in future analyses should their abundance increase over time.

Field Season

General methods

Sampling of invertebrates is to be conducted within quadrats placed within the appropriate vertical zone within each site. The positions of quadrats will be selected systematically with a random start point. The systematic placement of subsampling units will ensure relative equal distribution of sampling effort within the site. The location of the site will be fixed after the initial survey, but the start point for systematic placement of quadrats will be randomly selected prior to each sampling event. Random rather than fixed subsampling units are to be used because of the difficulty in ensuring that fixed sites could be relocated over extended periods of time, and because of the statistical design problems created if the location of a given fixed subsampling unit changed with time.

All bivalves ≥ 14 mm encountered in quadrats will be enumerated and measured to the nearest millimeter. Individuals smaller than 14mm will be excluded from the dataset due to sampling bias from the sieve mesh size. A 10mm mesh size has a diagonal of approximately 14mm so it is possible for clams smaller than that to fall through during the sieving process. Identifications will be made to the species level when possible. However, it is often difficult to distinguish congeneric species of *Macoma* without collecting organisms for later identification in the laboratory. Therefore, all *Macoma* clams will be aggregated by genus. Similarly, *Mya truncata* and *Mya arenaria* will be aggregated by genus.

Sampling will be conducted by crews of two to three people and are designed such that a single site can be surveyed within a single negative tide window during spring tide cycles.

Field Season Preparation

In preparation of data collection the following equipment and supplies should be compiled and tested for operation:

Skiff: The skiff and engines used to conduct surveys and access shorelines should be serviced and tested annually for operation. Equipment to carry on board include: an anchor, with chain, line, extra line, paddles or oars, a bilge pump or bailing device, spare parts for vessel and engine (e.g. valves, patch kit, spare prop, tools), fuel container and line, Emergency Position Indicating Radiobeacon (EPIRB), and VHF radio.

Prior to each field season, the following tasks are to be performed:

- Review the master field schedule and prepare a list of tasks to be performed and set the field schedule
- Review personnel requirements, train personnel as needed, and make personnel assignments
- Arrange for vessel charters
- Prepare an itinerary and emergency contact list

- Arrange for travel of personnel to the departure site
- Prepare smaller boats (inflatable and/or other skiffs) for use
- Review sampling procedures
- Gather equipment and supplies including:
 - o Laptop computer with data entry forms, databases, standard operating procedures, and needed software for data entry (Excel or similar) loaded
 - o GPS with local charts and site coordinates loaded
 - o 100 m tapes
 - o 50 m tapes
 - o Stadia rod
 - o Site level and/or laser levels
 - o Minimum of 12 - 5 gal. plastic buckets
 - o 2 - 0.25 sq. m sieves with 10 mm hardware cloth mesh
 - o 2 – Spade Shovels
 - o Sample bags (gallon closable freezer bags)
 - Suggested keys and reference material to invertebrates and bivalves
 - Nora Foster – Intertidal Bivalves: A guide to the Common Marine Bivalves of Alaska. Book
 - Rick Harbo – Shells and Shellfish of the Pacific Northwest. Book
 - Keller et al. - Guide for identifying select bivalve species common to southeast Alaska. NOAA Technical Memorandum
 - o Data sheets
 - o Sledge hammer
 - o Rebar, and tags for marking sites and transects
 - o Pencils, clipboards, permanent markers, scissors, and misc. office supplies
- Ensure that electronics have fresh batteries, spare batteries, and are in good working order

Miscellaneous supplies: Each observer should have appropriate safety equipment. Each observer should have a radio or other communication device to coordinate data collection activities among personnel.

Field personnel must be dressed appropriately for extended periods outdoors in wet and windy weather. Rain pants, jacket, and boots are recommended. Spare dry socks, gloves and a hat should be carried.

Safety equipment: Each observer should carry at a minimum the following safety equipment: a hand held radio with spare batteries, food and water for 3 days, a signaling device (e.g. mirror, flares), a flashlight, first aid kit, and a fire starting kit.

Bear-Safety Considerations: Operating in bear country requires knowledge, awareness, and training. Observers should always carry, and know how to use, bear spray, a noise maker, and/or flares. When working in areas of high bear density, such as KATM, observers should consider dedicating one team member to “bear watch”. In such instances, it is recommended that observers carry firearms (preferably a 12 gauge stainless steel shotgun with heavy weight slugs) for defense and be certified for non-LE firearm carry.

Initial Site Layout

The geographic coordinates for the approximate position of the site to be sampled will be determined using existing maps and habitat descriptions. On the initial visit to the site, a sampling team will go to these coordinates and evaluate the site to determine if the habitat is suitable for bivalves. It is determined a site if; 1) siphons or clam squirts are present or apparent, 2) bivalve shell debris is found around the area, and 3) obvious signs of non-human excavation or use of the beach for bivalve resources are witnessed. If necessary, alternative sites will be selected.

To locate the start position of the transect, the sampling team will go to shore before the 0.0 m MLLW tidal elevation is reached. The transect start at the 0.0 m MLLW tide elevation will be marked by consulting tide tables to determine the time of MLLW and marking the water’s height or level at that time. Then as if facing the shoreline from the water, the transect should be placed along the beach contour out to the end point at 100 m and marked (Figure 2). The vertical position of the transect must follow the beach’s contour and remain at the same elevation. The coordinates of the start and end positions are to be recorded using a GPS. To increase the likelihood of sampling at the same starting location, coordinates should be obtained using a point averaging technique (function during waypoint creation on a Garmin map 76 or 78) to increase accuracy as much as possible (~1.0 m).

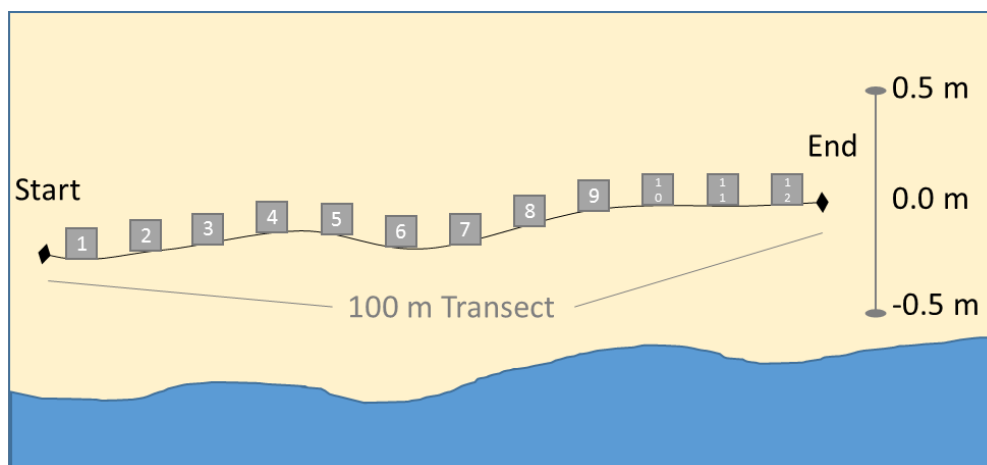


Figure 2. Simplified mixed-sediment site layout. From start coordinate the 100 m transect is laid out to the right on the 0 m MLLW contour. 12 quarter meter square quadrats are systematically placed from a random start point and excavated to 25 cm depth.

Biennial site visits

Collection of bivalves for determination of density and size distribution

On each site visit, teams will navigate to the established GPS coordinates of the start location at 0.0 m MLLW. Site information sheets, if created after site selection and maintained from prior years of sampling, provide reference information such as site photos and a drawn transect map from the previous sampling event. This information sheet should be used to validate the correct site start point, and upon completion of sampling, the sheets must be updated with the most current information and photos. Once the start location is confidently determined, run a 100 m transect tape from this location to the right, as if facing the shoreline from the water (Figure 2). One 0.25 sq. m. (50 cm X 50 cm) sampling quadrat is then to be placed at a random start point along the tapes and eleven more at evenly spaced intervals thereafter. The first quadrat is to be placed at a random start point between 0 and 7.33 m along the tape and at 8.33 m intervals thereafter. This will result in 12 evenly spaced quadrats being placed along the tape. The random start point must differ by greater than 0.5 m from prior years to ensure there is no overlap between quadrats. Quadrat frames should be positioned such that the lower left corner of the frame (as determined while looking from the water's edge towards the transect) is placed at the desired start point on the up-beach side of the transect tape (Figure 3a).

Next, a series of digital photographs should be taken at the site. These are to be taken from the start point (0 m) of each transect and pointing toward the 100 m end of the transect, from the end of each transect pointing back toward the start, and from approximately 200 m offshore (far enough offshore to be able to see both ends of the tape) facing the beach. Stand a stadia rod or have a sampling team member stand at each end of the upper transect when taking the photos to provide perspective.

Samplers are to dig sediments from each quadrat to a depth of 25 cm using a spade-shovel and place the contents into 5 gallon bucket(s). After all sediments are collected they are to be sieved through a 10 mm square mesh screen and washed using a nearby source of water. It is advisable to sample with enough buckets that all quadrats can be excavated while the tide is below 0.0 MLLW since sieving can occur at any time, even after the site has been resubmerged if it is a short tide window.

Additionally, observers may be unable to sieve if the site is a broad tidal flat, precluding a source of water in close proximity, or for reasons that require vacation of the site such as severe weather or bear encounters. In those instances, having quadrats excavated and stored in buckets will still allow for the successful sampling of bivalves upon return to the site.

After sieving, all bivalves remaining on the screen are to be collected and placed in a plastic Ziploc bag, labeled with the site number and quadrat number. If possible, return sediments to the recently excavated sampling pit. During excavation of each quadrat, datasheets shall be filled in to document full site and quadrat level information fields. Datasheets allow for recording of qualitative substrate or unique circumstances by quadrat and provide a record of work completed during each sampling event. Qualitative substrate categories are used based on the Wentworth scale (Appendix E) and allow for detection of changes in the physical environment that may occur due to sedimentation, river outflows, or major disturbance.

Each living bivalve recovered is to be identified to species (or genus for *Macoma* spp.). Shell lengths are to be measured using dial or Vernier calipers. If the shell is crushed such that length cannot be determined, length is recorded as 'broken', allowing the bivalve to be included for abundance calculations even though it won't be useful for size-related data. Count and record the number of bivalves by species (Figure 3b).

In the event of uniformly dense mussel (*Mytilus trossulus*) cover on the surface of a quadrat, special rules may be followed to allow for subsampling. In situations where mussels occur uniformly over the entire quarter sq. m quadrat, a single subsample may be taken from within the quadrat using a standard clam gun (10.7 cm diameter). Center the cylinder with the lower edge midpoint of the quadrat such that the cylinder is touching the inside bottom edge of the quadrat. All mussels within the core will be collected and measured. All other mussels within the quadrat should be removed from the sample surface. Any clams collected within the core should be placed into the bivalve sample collection bag for that quadrat. Raw mussel densities from cores will be $\text{count}/0.008992 \text{ m}^2$, which shall be calculated post-hoc to match the scale of other species sampled at $\text{count}/0.25 \text{ m}^2$. In order to make mussel abundances comparable, the core count shall be multiplied by 27.802491. The calculated value ($\text{count}/0.25 \text{ m}^2$) should be recorded for total count of mussels by quadrat and a note made in the comments that this was calculated from a core sample. Only those mussels from within the core will be measured for sizing.



Figure 3. An excavated quadrat is ready for sieving. Left (A) – Image of a quadrat and sampled area, 10 mm mesh sieve, 3-5 gallon buckets for containing sediment, shovel, transect tape, and a labelled clam collection bag. Note that the water is to the left of the transect tape, such that the lower left corner of the quadrat lies on the meter mark. Right (B) – An observer carefully measures a large *Mya truncata* with other clams sorted in the background. All bivalves are identified, counted, and measured by quadrat.

Collection of sediments for sediment size distribution

Upon site establishment, sediments are to be collected from each site for the determination of sediment grain size distribution. A 15 cm diameter plastic core (PVC pipe) is placed at the upper left hand corner and just outside of each of 4 quadrats. Cores should be systematically sampled from every 3rd quadrat. Sediments are to be collected from each core to a depth of 10 cm. In the event that the core does not penetrate to depth, the core shall be moved to another corner of the quadrat and the initial sample discarded. Sediments from the four quadrats are to be composited and placed in a plastic container labeled with the site name, date, and sampler name. The sediments are to be stored in a freezer or maintained at temperatures of less than 4 degrees C.

Post collection processing of samples and data collected

After each field day, the following tasks are to be completed:

- Field personnel are to review data sheets and edit as necessary to improve legibility, update missing entries, and resolve any discrepancies.
- Make sure that samples collected for use in later analyses or species identification are appropriately labeled and stored. All samples of clams and sediment grain size analyses should be kept frozen.
- Enter data from data sheets into the data entry spreadsheet. Verify the data entry.
- Download files from digital cameras. Store these in the master photo directory and provide additional documentation as needed.
- Make a backup copy (onto a separate portable hard drive or other removable media) of all data collected.
- Check and replace batteries in electronic equipment as needed.
- Provide a summary of activities and observations for the day including any problems, suggestions for modifications in procedures, and unusual occurrences or observations.

- Prepare field sheets and equipment for the following day's use.

After each field trip or cruise, the following are to be completed:

- Catalogue and prepare to ship samples as required for analyses of sediment grain size or clam growth.
- Produce a summary of the cruise based on summaries of daily activities and observations.

After each field season the following are to be done:

- Clean and check all electronic equipment and field gear for needed repair and store appropriately.
- Make repairs or obtain replacements for damaged or lost equipment or supplies.

Laboratory methods for determination of sediment grain size

Sediment grain-size analyses are to be carried out using standard procedures as described in Poppe et al. 2000 (<http://pubs.usgs.gov/of/2000/of00-358/text/chapter1.htm>).

Data Handling, Analysis and Reporting

Metadata Procedures

FGDC compliant metadata will be created to document the spatial and tabular data. Within 12 months of data collection, the raw data in a machine readable format and accompanying metadata will be issued a DOI number and published on a publicly accessible site. These data will be published through USGS and the Gulf Watch Alaska Program.

Overview of Database Design

This database is currently under development. The intent is to build this database into a master Access database for the SWAN and Gulf Watch Alaska monitoring program (see Protocol Narrative, Dean et al. 2014).

Data Entry, Verification and Editing

Data currently are entered from field datasheets into Microsoft Excel spreadsheets. Data are entered as soon as possible upon returning from the sampling site. Raw data files are backed-up and the project manager verifies that data within the Excel spreadsheets matches the hardcopy recorded by the observer. The project manager edits data to correct discrepancies between the field datasheet and electronic data entry form. The project manager ensures consistency of corrections across data sheets and data entry platforms.

Routine Data Summaries and Statistical Analyses

The overall analytical approach is described in the SWAN Nearshore protocol (Dean et al. 2014). In preparation for providing data derived from this data collection to the synthetic analysis, biennial summaries should be completed.

Biennial data compilation will include the following:

- Provide a master list of all sites visited, dates of sampling, and sampling conducted.
- Produce a list of all samples that were collected for further analyses (i.e., clams for determination of growth) and the current status of those samples and analyses.
- Summarize each metric at the scales of site, block, and regions. Metrics to be included are the bivalve assemblage composition, mean densities of all bivalve species, and mean size of bivalves.
- Construct size frequency distributions for numerically abundant bivalves at each site.

Report Format

Reports will conform to specific guidelines set by the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/NRPM/index.cfm>). Reports will include maps, graphs, figures and other visuals to facilitate interpretation of findings.

Methods for Trend Analyses

Refer to the SWAN Protocol Narrative for Marine Nearshore Ecosystem Monitoring (Dean et al. 2014) and the sampling design section of this SOP for more detail.

Data Archival Procedures

Refer to the SWAN Protocol Narrative for Marine Nearshore Ecosystem Monitoring (Dean et al. 2014).

Reporting Schedule

Summary reports and SWAN resource briefs should be produced biennially. More comprehensive reports should be produced after the first five years of sampling and five years thereafter. Also, refer to the SWAN Protocol Narrative for Marine Nearshore Ecosystem Monitoring (Dean et al. 2014).

Personnel Requirements and Training

Roles and Responsibilities

The roles and responsibilities of personnel are described here as responsibilities regarding the overall project, particular cruises, or particular field sampling teams at a given site. A single person may fill several of these roles. For example, a project leader may also serve as a cruise leader and field team leader or field assistant. The primary roles are as follows:

- Project Leader – Organizes the schedule and personnel assignments, takes part in field sampling, oversees all activities, and is responsible for preparation of reports.
- Trip Leader – Organizes daily schedules, makes sure all daily and cruise reports are completed, takes part in sampling, and reviews all data collected on a given cruise.
- Data Manager – Is responsible for on-site data management on a daily basis and for the review and entry of all data collected by that crew.
- Field assistant - Assists in site layout, data entry, and data collection at a site.

Qualifications

- Project Leader – Five or more years' experience in similar projects with a background and experience in project management, nearshore marine ecological field studies, data analysis, and report preparation.
- Team Leader – Experience in nearshore marine ecological field studies and leading field teams. Has expertise in sampling and taxonomy of marine algae and invertebrates.
- Data Manager – Expertise in data management practices, organization, and QA/QC processes.
- Field assistant – Competent boat handler and field crew member with ability to identify common marine invertebrates.

Training Procedures

- All personnel are to read this SOP and demonstrate knowledge and understanding of the specific procedures for sampling outlined here. See the Protocol Narrative (Dean et al. 2014) for more details on safety-related training, field emergency plans, etc.
- All field team members should be accompanied by personnel that have carried out sampling under this procedure in the past and must demonstrate proficiency by independently conducting site set up and duplicating counts of bivalves by an experienced sampler.
- Laboratory analyses of sediment grain size should be subcontracted to laboratories with experience in these analyses or done in house after a period of training and verification of competency.
- At a minimum, all personnel should have basic first aid and CPR training. Wilderness first aid and survival are strongly recommended for all personnel, but should be required of at least one-team member

- Training in small boat safety and cold-water survival are strongly encouraged for all participants. Completion of a government approved small motorboat operator course (MOCC) is required for any person operating skiffs.
- All participants should have basic bear safety and awareness skills. When working in high bear density areas, this training shall be required. Training in the handling and use of firearms for defense shall be required to carry firearms, and is good knowledge for participants to have when operating with and around firearms in bear country.
- It is advised that project leaders and trip leaders work together to address training needs of participants. Any special activities, new areas, or changes in logistics required an updated hazards assessment and training considerations.

Operational Requirements and Workloads

Operational Requirements

Operational requirements include transportation and access to each of the intensive intertidal invertebrate sampling sites within each block, access and use of required electronics (e.g., GPS) and access to taxonomic keys and guides to marine invertebrates common to the Gulf of Alaska. A vessel that accommodates at least six field crew members will be required. The vessel will be equipped with skiffs for accessing the beach. Two GPS units are required per each field crew. A team of six is required to sample all intertidal sites in a tide window, using three teams of two. To strictly sample mixed-sediment beaches, a minimum team size of two is required to complete a site.

Annual Workload and Field Schedule

Field surveys for intertidal bivalve monitoring are to be conducted in the summer of every other year (see Nearshore Protocol Dean et al. 2014). It is anticipated that field sampling will require 30 person days per each sampling year. Crews used for field sampling will share duties with those persons conducting yearly surveys at intensive rocky intertidal sites (including sea otter diet, summer bird and mammal surveys, and oystercatcher surveys). It is anticipated that a total of 30 days of vessel time per year will be required for these cruises. Approximately 1.5 months per year will be required for each of three staff (principal investigator, data analyst, and field assistant) in order to prepare for the field season, collect data and samples, prepare specimens for analysis, conduct analyses, and report the results.

Facility and Equipment Needs

Equipment requirements to successfully conduct intertidal invertebrate sampling on gravel mixed sand-gravel beaches includes a small skiff (holds 2-3 people), two to six persons to assist in field procedures, marine safety equipment (hand held radios, flares), binoculars and GPS units for data recording, home base computers (for data management, pre-season transect selection and mapping, and data analysis).

Procedures for Revising the Protocol

All edits and amendments made to this SOP should be recorded in the revision history log table at the beginning of this document. Users of this protocol should promptly notify the project leader of the marine nearshore monitoring program of recommended edits or changes. The project leader will review and incorporate suggested changes as necessary, record these changes in the revision history log, and modify the date and version number on the title page of this document to reflect these changes. It is anticipated that following at least five years of annual data collection it will be important to evaluate, in terms of power and sensitivity, the ability of the sampling design to detect change in the data derived from mussel bed sampling. Following such analyses it may be appropriate to consider revising sampling design or data collection protocols.

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Appendix A

Field Data Sheet

GWA Mixed-Sediment Sampling 20____ (ver 20170510)

Field Observer review, by whom: _____

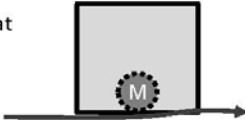
Date data entered up & by whom: _____

Write surface substrate (see Wentworth sheet) % cover on _____. Check boxes () should be filled a) once core is sampled, if a stream runs through the quadrat, or if a quadrat is not sampled. Mussel cores ONLY if mussel cover is uniform across 100% of quadrat.

Site Name: _____		Date: _____		0.0 Tide Time: _____		Start Time: _____	
Site ID: _____		Obs: _____		Photos: ☐ Start ☐ End ☐ Site ☐ Other			

Quad 1: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____				Quad 7: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____			
Quad 2: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____				Quad 8: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____			
Quad 3: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____				Quad 9: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____			
Quad 4: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____				Quad 10: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____			
Quad 5: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____				Quad 11: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____			
Quad 6: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____				Quad 12: _____ m ☐ NOT SAMPLED Surface Layer Silt Sand Gran Pebb Cobb Boul % cover _____ Cores? _____ ☐ Mussels ☐ Stream? % Undiggable: _____			

Notes:

Surface Layer	Before digging quadrat, visually determine the surface substrate % cover, by grain size, write in the % totalling 100 on the ____ provided. <table border="0"> <tr> <td>Silt</td> <td>< 62.5 μm</td> <td>Pebble</td> <td>4 mm - 64 mm</td> </tr> <tr> <td>Sand</td> <td>62.5 μm - 2 mm</td> <td>Cobble</td> <td>6.4 cm - 25.6 cm</td> </tr> <tr> <td>Granule</td> <td>2 mm - 4 mm</td> <td>Boulder</td> <td>0.256 m - 1.0 m</td> </tr> </table>	Silt	< 62.5 μm	Pebble	4 mm - 64 mm	Sand	62.5 μm - 2 mm	Cobble	6.4 cm - 25.6 cm	Granule	2 mm - 4 mm	Boulder	0.256 m - 1.0 m
Silt	< 62.5 μm	Pebble	4 mm - 64 mm										
Sand	62.5 μm - 2 mm	Cobble	6.4 cm - 25.6 cm										
Granule	2 mm - 4 mm	Boulder	0.256 m - 1.0 m										
Stream	If there is a stream flowing through your quadrat, check the Stream? Box. If it prevents you from sampling, check the NOT SAMPLED box.												
undiggable	If bedrock, a boulder, or concretion prevent you from excavating >50% of the quadrat, circle how much was not excavated and make a Note.												
<i>as needed</i> Mussel Cores mussel core at lower mid point 	Mussel cores are taken with a clam gun only when mussels are uniformly dense such that a subsample is required. All clams from the core shall be measured and counted in the quadrat total. All mussels recovered shall be measured, entered, and noted as "from core". Densities of mussels will be calculated post-hoc. Check the box if collected. These samples are field processed, not frozen.												

Backup Data Entry Sheet

Below is a sample table to be used in the event of a computer/database failure to record bivalve count and sizes.

Observers:

Date:

[illegible]

Appendix B

Websites

Poppe website for sediment grain size:

<http://pubs.usgs.gov/of/2000/of00-358/text/contents.htm>

Gulf Watch Alaska Data Portal:

<http://www.gulfwatchalaska.org/>

<http://portal.aos.org/gulf-of-alaska.php>

SWAN Information & Data Portal:

<http://science.nature.nps.gov/im/units/swan/monitor/nearshore.cfm?tab=0>

Appendix C

Unique Circumstances When Sampling

At times when sampling, it may not be possible to excavate a quadrat at its prescribed location along the meter tape. Several examples of these situations are outlined below, along with the decisions made on how to handle the problem. It is ultimately up to the sampler to exercise proper judgment in how to sample, inquiring with the trip leader when necessary. As these unique circumstances arise it is important to note what the problem was, how it was handled, and properly document the decision tree in the appendix of the SOP to ensure consistency over time.

- Boulder or Bedrock taking up a significant portion of the quadrat
 - If you lay down your quadrat is mostly boulder or bedrock substrate, continue to sample normally excavating all sediments within the quarter meter area. Make a note of this quadrat on the data sheet estimating the amount of space taken up by the consolidated substrate.
- Boulder or Bedrock filling 100% of the quadrat
 - If you lay down your quadrat and 100% is covered by a boulder or bedrock, you will consider this quadrat empty, and it should be checked on the data sheet as 100% boulder/bedrock. This quadrat will count as sampled with 0 bivalves.
- Freshwater output or stream directly over the quadrat.
 - If you have water gently flowing over your quadrat in a way that you can properly excavate the quarter meter area, then you must do so. However,
 - If you have significant water flow over your quadrat that prevents a confident sample, make a note of this on your data sheet by marking the quadrat not sampled due to stream/water flow. This quadrat will be considered missing (non-zero).
- Obvious signs of previous sampling.
 - If you lay out your meter tape and notice obvious, evenly placed pits. Ensure that this observation is documented. If your quadrat falls within one of these pits, ensure that it is noted on the data sheet.
 - You must check with the trip leader about quadrat placement along the transect to avoid resampling previous quadrats.
- Obvious signs that the transect tape was placed at an elevation different from 0.0 MLLW
 - Transects are laid at an estimated 0.0 MLLW tidal elevation with many sources of variation in the estimate. Therefore it is assumed 0.0 MLLW, but in some cases it becomes apparent that the tape was placed higher or lower.
 - If you observe this change, make a note on the data sheet and estimate the actual elevation sampled using a stadia rod.
- Rebar at site is different from actual sampling location

- o As of 2015, rebar stakes initially used to make the start and end of a transect have been lost or removed at some sites, but remain at others. At some sites where they remain they may not indicate the intended location to due to potential movement of the stake.
- o For this reason, make note of the rebar but only use the GPS start/end coordinates and tidal elevation to determine transect location at the site.

Appendix D

Mixed-Sediment Site Locations

Block	Site Code	Site Name	Longitude	Latitude
KATM	AKP_B10_SI_01	Kukak Bay	-154.195280	58.304090
KATM	AKP_B10_SI_02	Kafli Bay	-154.215480	58.260910
KATM	AKP_B10_SI_03	Kinak Bay	-154.437880	58.160240
KATM	AKP_B10_SI_04	Amalik Bay	-154.487010	58.084630
KATM	AKP_B10_SI_05	Takli Island	-154.480567	58.062317
LACL*	AKP_B12_SI_01	Chinitna Bay	-152.927586	59.875902
LACL*	AKP_B12_SI_02	Tukendni Bay	-152.550853	60.225920
LACL*	AKP_B12_SI_03	Chisik Island	-152.593689	60.174123
LACL*	AKP_B12_SI_04	Johnson Creek	-152.623964	60.000127
LACL*	AKP_B12_SI_05	Polly Creek	-152.404880	60.291554
KEFJ	KEP_B05_SI_01	Aialik Bay	-149.640370	59.897900
KEFJ	KEP_B05_SI_02	McCarty Fjord	-150.405930	59.564330
KEFJ	KEP_B05_SI_03	Nuka Bay	-150.639190	59.524260
KEFJ	KEP_B05_SI_04	Nuka Passage	-150.687520	59.392400
KEFJ	KEP_B05_SI_05	Harris Bay	-149.941070	59.723340
WPWS	PWS_B08_SI_01	Hogan Bay	-147.766358	60.207080
WPWS	PWS_B08_SI_02	Iktua Bay	-148.005280	60.099500
WPWS	PWS_B08_SI_03	Whale Bay	-148.261890	60.232460
WPWS	PWS_B08_SI_04	Johnson Bay	-147.807210	60.338830
WPWS	PWS_B08_SI_05	Herring Bay	-147.711640	60.456470
WPWS*	PWS_B08_SS_02	Herring Bay- Southwest	-147.719629	60.449013
WPWS*	PWS_B08_SS_04	Disk Island	-147.661510	60.498120
WPWS*	PWS_B08_SS_05	Northwest Bay	-147.579210	60.550730
KBAY	BC	Bear Cove	-151.052700	59.721900
KBAY	CP	China Poot Bay	-151.301733	59.568800
KBAY	JB	Jakalof Bay	-151.527400	59.457383
KBAY	PG	Port Graham	-151.816900	59.343450
EPWS*	PWS_B09_SE_01	Galena Bay	-146.64136	60.95308
EPWS*	PWS_B09_SE_02	Port Fidalgo	-146.271900	60.853560
EPWS*	PWS_B09_SE_03	Olsen Bay	-146.19296	60.74636
EPWS*	PWS_B09_SE_04	Simpson Bay	-145.883990	60.672120
EPWS*	PWS_B09_SE_05	Observation Island	-145.735840	60.594820
NPWS*	PWS_B07_SE_01	Cedar Bay	-147.38977	60.96042
NPWS*	PWS_B07_SE_02	Esther Passage	-148.03279	60.93349
NPWS*	PWS_B07_SE_03	Bettles Bay	-148.31696	60.94865
NPWS*	PWS_B07_SE_04	Perry Island	-147.88872	60.67899
NPWS*	PWS_B07_SE_05	Unakwik Inlet	-147.60268	60.94949

*No longer sampled

Appendix E

Species List

Scientific Name	Common Name
<i>Axinopsida serricata</i>	Northern, silky, Axinopsid
UNIDENTIFIED BIVALVE	bivalve
UNIDENTIFIED CLAM	clam
<i>Clinocardium nuttallii</i>	Nuttall cockle
<i>Diplodonta impolita</i>	
<i>Entodesma navicula</i>	Ugly clam
<i>Ennucula tenuis</i>	smooth nutclam
<i>Gari californica</i>	California sunset clam
<i>Hiatella arctica</i>	Arctic Hiatella
<i>Humilaria kennerleyi</i>	Kennerley's Venus
<i>Lucinoma annulatum</i>	western ringed lucine
<i>Macoma balthica</i>	pink macoma, baltic macoma
<i>Macoma calcarea</i>	chalky macoma
<i>Macoma inquinata</i>	pointed, stained, macoma
<i>Macoma nasuta</i>	bent nose macoma
<i>Macoma obliqua</i>	oblique macoma
<i>Mactromeris polynyma</i>	Arctic surf clam
<i>Macoma spp.</i>	MacomaDec
<i>Modiolus</i>	Horse mussel
<i>Mactridae species</i>	
<i>Mytilus trossulus</i>	Blue mussel
UNIDENTIFIED MUSSEL	mussel
<i>Mya arenaria</i>	soft shell clam
<i>Mya spp.</i>	soft shell clam
<i>Mya truncata</i>	truncate soft shell clam
<i>Panomya ampla</i>	ample roughmya (hiatellidae, not mya)
<i>Parvalucina tenuisculpta</i>	
<i>Pododesmus macrochisma</i>	Rock jingle, Alaska jingle
<i>Leukoma staminea</i>	Pacific littleneck clam
<i>Neaeromya compressa</i>	fuzzy clam
<i>Neaeromya rugifera</i>	wrinkled montacutid, mud shrimp clam
<i>Rochefortia tumida</i>	robust mysella
<i>Saxidomus gigantea</i>	Butter clam
ANY SCALLOP	scallop
<i>Serripes groenlandicus</i>	Greenland cockle
<i>Siliqua patula</i>	Pacific razor clam
<i>Solen sicarius</i>	Jackknife clam
<i>Tellina bodegensis</i>	Tellina
<i>Tellina modesta</i>	Tellina
<i>Tellina sp.</i>	Tellina

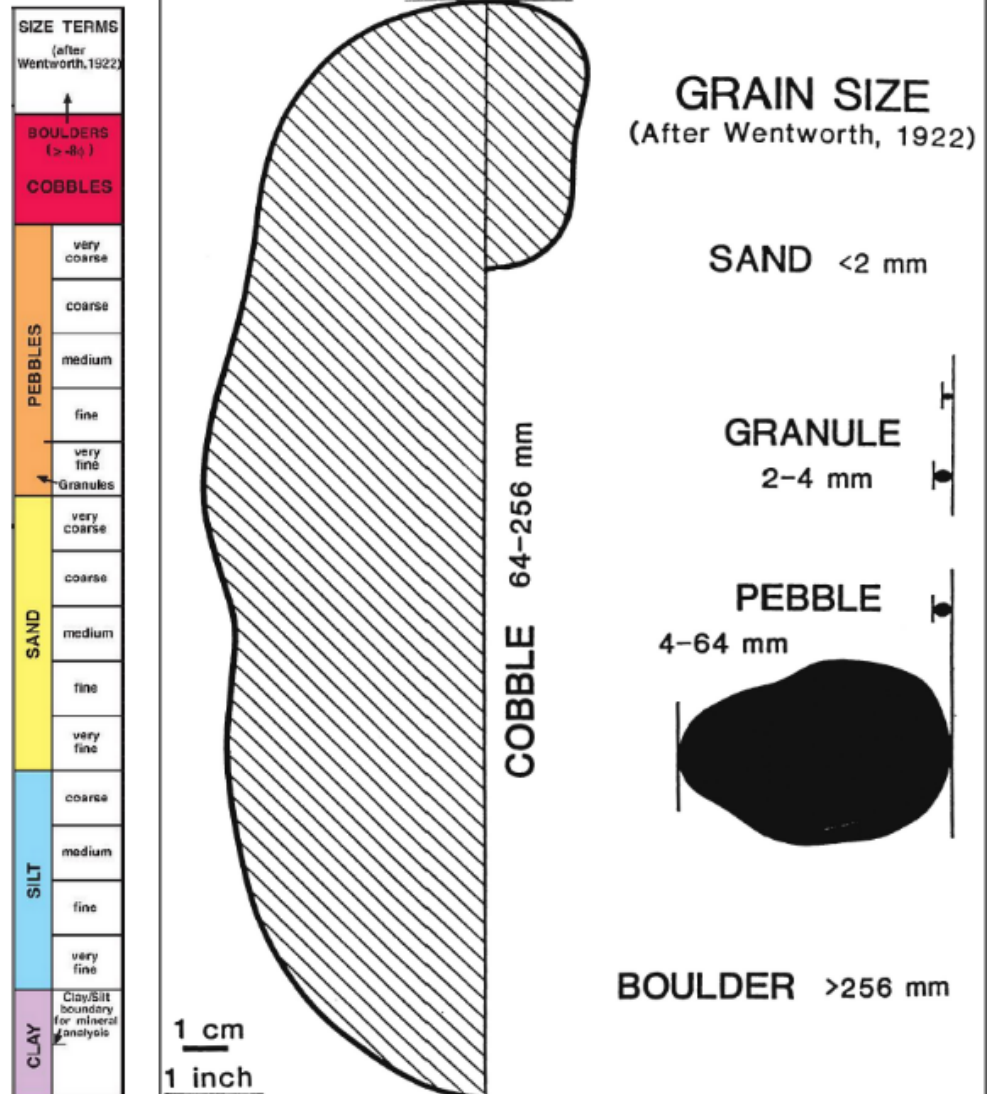
Scientific Name	Common Name
<i>Tresus capax</i>	fat Gaper clam
<i>Turtonia minuta</i>	little mullet shell
<i>Yoldia spp.</i>	Yoldia

Appendix F

Wentworth Scale

ϕ scale	Size range (metric)	Size range (approx. inches)	Aggregate name (Wentworth Class)	Other names
-8 <	256 mm <	10.1 in <	Boulder	
-6 to -8	64–256 mm	2.5–10.1 in	Cobble	
-5 to -6	32–64 mm	1.26–2.5 in	Very coarse gravel	Pebble
-4 to -5	16–32 mm	0.63–1.26 in	Coarse gravel	Pebble
-3 to -4	8–16 mm	0.31–0.63 in	Medium gravel	Pebble
-2 to -3	4–8 mm	0.157–0.31 in	Fine gravel	Pebble
-1 to -2	2–4 mm	0.079–0.157 in	Very fine gravel	Granule
0 to -1	1–2 mm	0.039–0.079 in	Very coarse sand	
1 to 0	½–1 mm	0.020–0.039 in	Coarse sand	
2 to 1	¼–½ mm	0.010–0.020 in	Medium sand	
3 to 2	125–250 μ m	0.0049–0.010 in	Fine sand	
4 to 3	62.5–125 μ m	0.0025–0.0049 in	Very fine sand	
8 to 4	3.90625–62.5 μ m	0.00015–0.0025 in	Silt	Mud
> 8	< 3.90625 μ m	< 0.00015 in	Clay	Mud
> 10	< 1 μ m	< 0.000039 in	Colloid	Mud

In some schemes, gravel is anything larger than sand (comprising granule, pebble, cobble, and boulder in the table above).



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