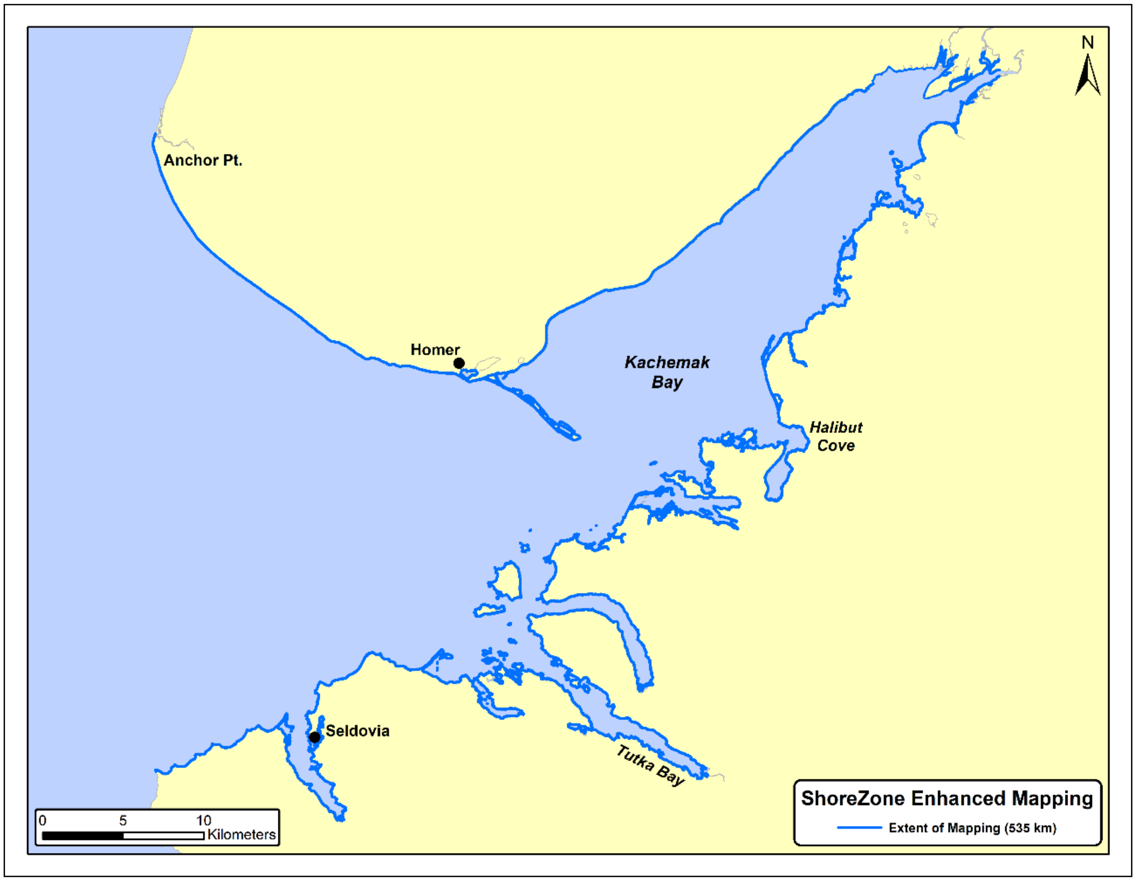
Coastal and Ocean Resources

MCORI Project: 16-20 **August 2018**

ShoreZone Enhanced Habitat Mapping Protocol and Kachemak Bay Pilot Project Summary Report



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The suggested citation for this report is:
Coastal and Ocean Resources, 2018. ShoreZone Enhanced Habitat Mapping Protocol and Kachemak Bay Pilot Project Summary Report. Produced for the NOAA National Marine Fisheries Service, Alaska Region, Juneau, Alaska, 76 p.

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Kachemak Bay Enhanced Mapping Summary

535 km of shoreline mapped

587 units of original ShoreZone mapping broken into **1859 subunits**

Spatial resolution increased three-fold (**911 m** average unit length to **288 m** subunit length**)**

32% of the intertidal substrate is classified as **Mixed Gravel and Sand** and **21%** is classed as **Sand**

80% of the shoreline has a high Oil Residence Index value (residence of months to years)

7% of the shoreline has a **Shoreline Modification** of some type

12 intertidal biobands were classified, with **Rockweed** and **Barnacle** being the most common (60% and 77% of units respectively)

8 supratidal biobands were classified, with **Black Lichen** being the most common (63% of units)

5 subtidal biobands were classified, with **Soft Brown Kelps** being the most common (67% of units)

Kachemak Bay

Bear Island

Glacier Spit, Kachemak Bay

Powder Island, Seldovia Bay

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1 INTRODUCTION

ShoreZone mapping has been completed over ~120,000 km of shoreline in the Pacific Northwest with the entire coastlines of Oregon, Washington State and British Columbia. The coastline of Alaska is over 85% imaged and mapped with only the central and western Aleutian Islands, part of the shoreline of St. Lawrence Island, the Pribilof Islands, and St. Matthew Island in the Bering Sea left to image and Glacier Bay National Park left to map (Figure 1). However, over 50% of that imaging was done over a decade ago with much of BC imaged close to 20 years ago. Given the pace of development on the coastline in BC, Washington State and Oregon and the pace of ice loss, sea level change and increase in storm intensity experienced in the Pacific and specifically in the Bering Sea, Chukchi Sea and Beaufort Sea in Alaska, a decade can make a huge difference in the physical and biological attributes of the coastal zone. Re-imaging of portions of Alaska (Cook Inlet) and BC (around the Ports of Prince Rupert and Vancouver) has already been accomplished and the question of how to re-map those areas has been posed. The main challenge in answering that question has been how to keep the existing ShoreZone habitat mapping relevant while enhancing and adding to it? Coastal and Ocean Resources has developed the ShoreZone Enhanced Mapping protocols to address that challenge.

ShoreZone Enhanced (SZE) mapping has been specifically developed for areas that have already been mapped using the ShoreZone Unit Level techniques detailed in previous ShoreZone protocols (Howes *et al*., 1994; Berry *et al*., 2000; Searing and Frith, 1995; Harper and Morris, 2004; Harney *et al*., 2008; Harper *et al*., 2013; Harper and Morris, 2014; Cook *et al*., 2017). This means there is already a digital shoreline delineated into units with physical and biological attributes attached to those units. For a section of shoreline to be appropriate for SZE mapping, there should either be updated imagery and/or an updated (more accurate) digital shoreline. Areas where there is new imagery and an updated CUSP shoreline would be good candidates. The principles the SZE mapping protocol was developed under were: 1) the attributes should be additive, meaning they should be adding new information to the ShoreZone dataset, either by providing new data or a new way of estimation, 2) the attributes should be complimentary to the existing ShoreZone dataset and 3) the Enhanced attributes should have high confidence when classified from ShoreZone aerial imagery. The spatial framework and physical and biological attributes for Enhanced ShoreZone mapping are described in the following sections.

Cook Inlet, including Kachemak Bay, was originally imaged in 2001 and was mapped from that imagery using the best available digital shoreline at the time, which was a composite of several sources including Coast63. Cook Inlet was re-imaged in June 2009 using upgraded video and digital still camera equipment. That imagery was not mapped. In recent years a portion of Cook Inlet, including Kachemak Bay, was updated with CUSP. This made Kachemak Bay a good fit for a pilot test of the SZE protocol. The purpose of this report is to provide details of the SZE protocols and results of selected attributes mapped over the 535 km of shoreline in the pilot area in Kachemak Bay (Figure 2). That shoreline was originally broken into 587 units with an average length of 911 m. The SZE mapping more than tripled the spatial resolution of that mapping by breaking those units into 1859 subunits with an average length of 288 m.

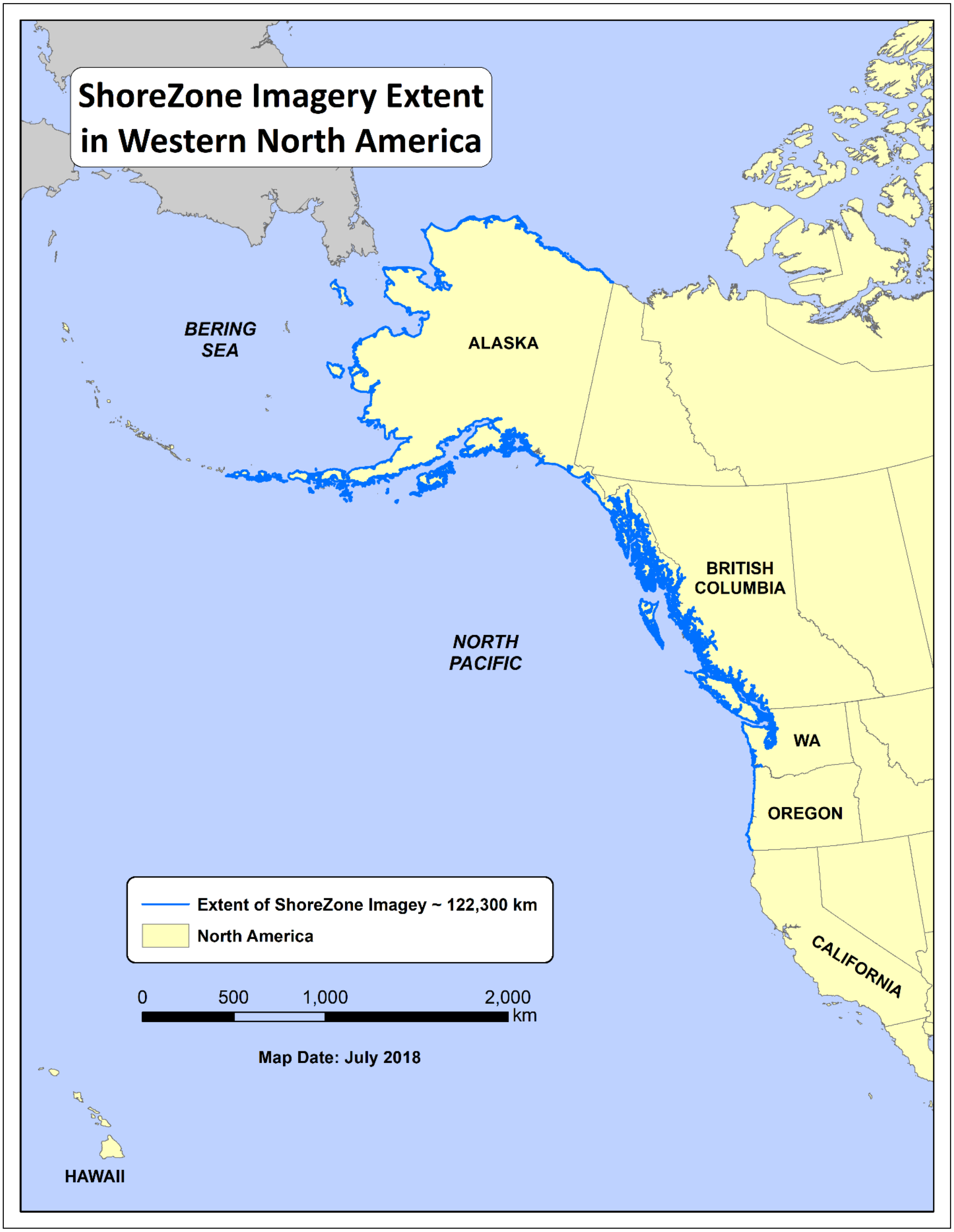


Figure 1. Extent of ShoreZone imagery in Alaska, British Columbia, Washington State and Oregon as of July 2018.

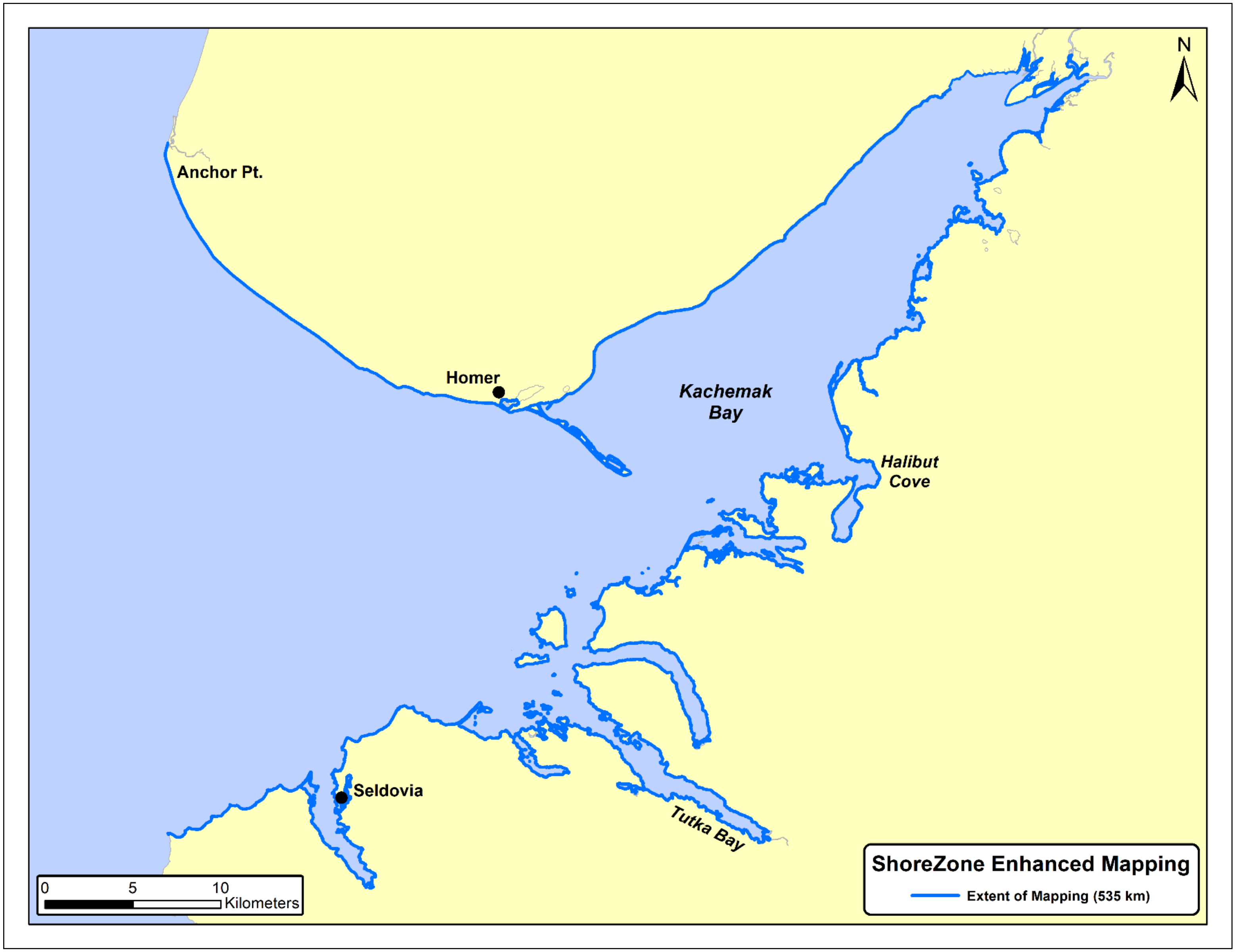


Figure 2. Extent of mapping in the Kachemak Bay ShoreZone Enhanced pilot project area.

1.1 Spatial Framework for ShoreZone Enhanced Mapping

The main spatial component of Enhanced ShoreZone Mapping is the subunit. Each subunit is defined as a relatively homogenous segment of the coast as defined from ShoreZone aerial imagery (video and photos) according to geomorphological forms, substrate and wave exposure. If any of those attributes changes by one or more categories for a significant portion of the intertidal zone then a new subunit will be created. Significant changes to supratidal forms and substrates should also be considered although these are given less weight than intertidal features. This breaking of subunits can still only be done to the resolution of the best available digital shoreline so if a feature cannot reasonably be resolved on the shoreline it should not be broken out as a subunit. No point features will be mapped as part of Enhanced ShoreZone mapping as all rivers and streams will be assumed to be part of the original ShoreZone unit level dataset.

The alongshore subunits will spatially 'nest' under the original ShoreZone units (see Figure 3 for an example) providing more explicitness in terms of the distribution of forms, substrates and biota, all of which have implications for coastal management including risk and oil spill response planning. This spatial nesting will ensure the original ShoreZone mapping will be connected to any re-mapping of an area. It should also make it potentially possible to compare change over time for some attributes.

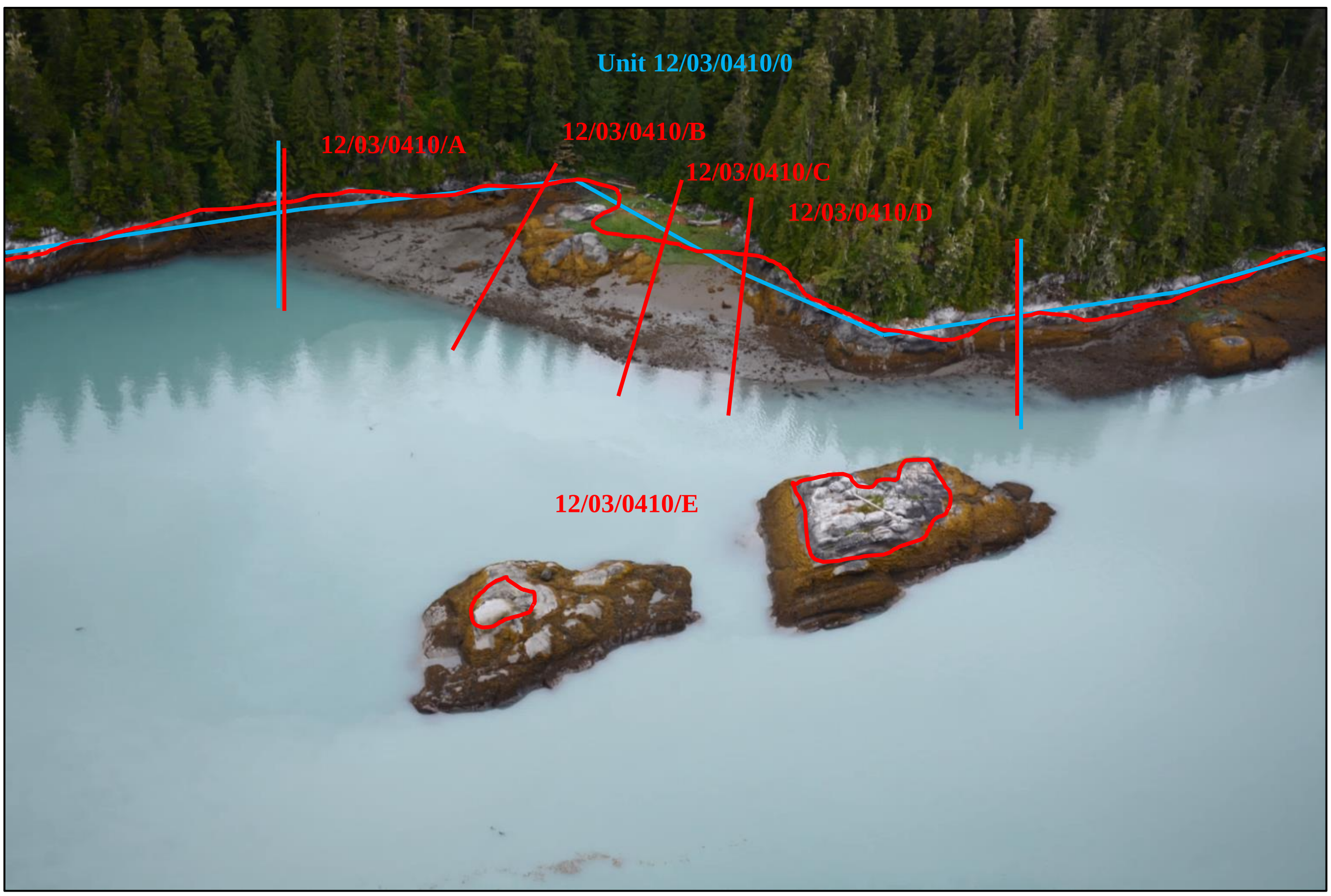


Figure 3. An example of a ShoreZone unit broken from the original 'best available' digital shoreline (blue) and the Enhanced subunits broken from the new digital shoreline (red). Note that the starting point of subunit A and the end of subunit D match the original unit boundaries.

Also note that the offshore islets were not reflected on the original digital shoreline but can be broken out as an explicit subunit on the new digital shoreline.

Each subunit is also subdivided into the three across-shore zones: supratidal (A), intertidal (B) and subtidal (C) (Figure 4). These zones are defined in the same way as for unit level ShoreZone mapping (see Cook *et al*. (2017) for the zone definitions in the 2017 ShoreZone protocol). The zones are not further subdivided into components in subunit mapping as they were in the original mapping.

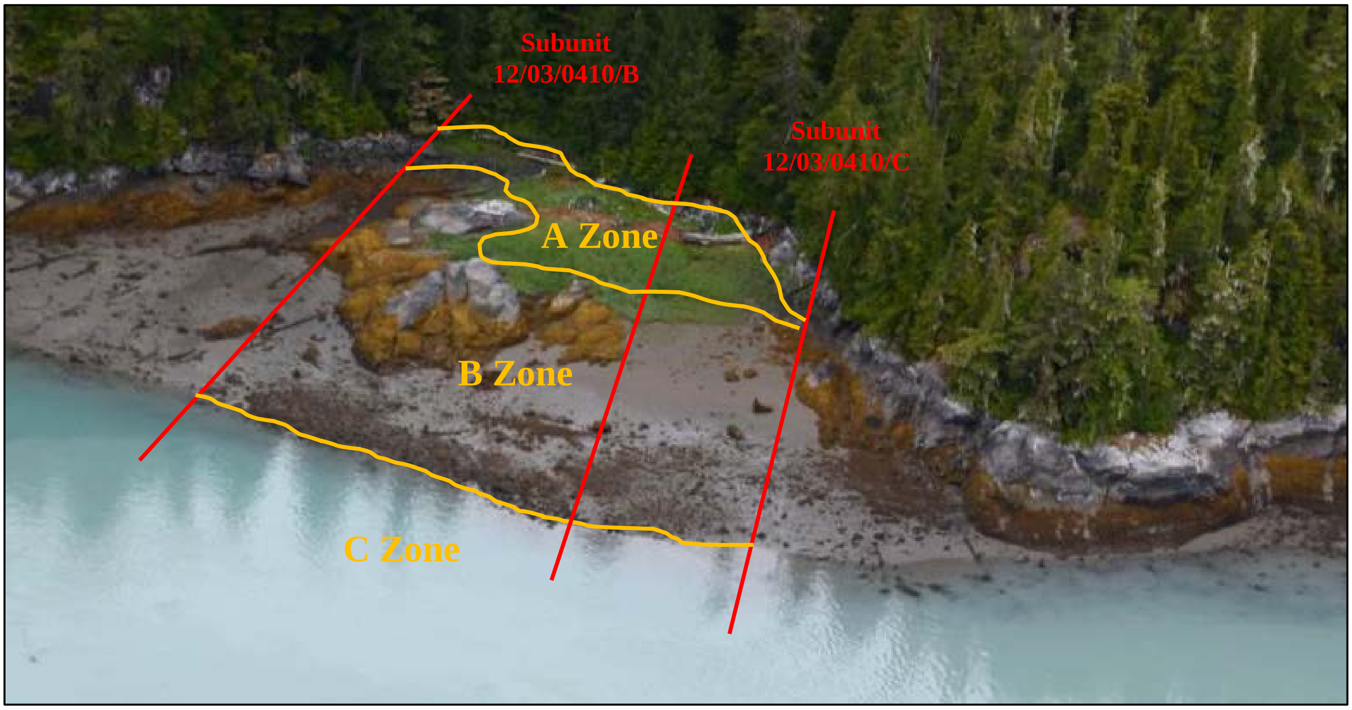


Figure 4. An illustration of the conceptual zone boundaries for two of the subunits shown in Figure 3.

2 Physical ShoreZone Enhanced Mapping Attributes

The original ShoreZone unit/component level dataset provides a very detailed description of the coastal area visible in ShoreZone aerial imagery. That detail is valuable for some users; however, the detail and coding can be challenging to query out and analyze, especially for users less familiar with the ShoreZone protocols. The physical and biological attributes developed for SZE Mapping are meant to provide complimentary information to the original ShoreZone mapping while also being more 'user friendly' (i.e. more easily searchable for analysis). The attributes chosen are therefore either 1) modified versions of existing attributes (Modified Coastal Class, Oil Residence Index, Forms, Substrates), 2) attributes that have traditionally been challenging to interpret from aerial imagery and for which we have developed improved ways of estimating (Intertidal Zone Width, Wave Exposure, Biobands) or 3) attributes that have been added to ShoreZone unit level mapping in recent years that are considered valuable for managers and that would not have been part of the older ShoreZone datasets (the Coastal Vulnerability Module attributes, CMECS attributes).

2.1 Subunit Level Enhanced Mapping Attributes

2.1.1 Modified Coastal Class

As the name suggests Modified Coastal Class (MCC) is a simplified version of the unit level Coastal Class attribute (Cook *et al*. 2017). The MCC summarizes the dominant substrate, which is the major determining factor, along with Wave Exposure, of the biota that will be present on a shoreline, both in terms of the visible biobands as well as communities not visible from aerial imagery (i.e. infaunal communities). Width and slope were removed from the MCC because, while the width and slope breaks worked well for southern British Columbia (where they were initially developed), they were not always as relevant in different geographic areas such as the Bering Sea where the tide range was much smaller and different processes structured the shoreline. The MCC is designed to be useable and useful over the entire current range of ShoreZone as well as beyond. See Table 1 for definitions.

Table 1. Definitions of the shore types for the Modified Coastal Class attribute.

Dominant Substrate	Code
Rock (>90%)	1
Mixed Rock and Gravel	2
Mixed Rock and Gravel/Sand	3
Mixed Rock and Sand	4
Gravel (>90%)	5
Mixed Gravel and Sand	6
Sand (>90%)	7
Mixed Sand and Mud	8
Mud (>90%)	9
Mixed Substrate (any category) and Organics	10
Organics (>90%)	11
Anthropogenic Substrate (>50%)	12
Glacial Ice (>50%)	13
Other substrate (>50%)	14

In the Kachemak Bay pilot area Mixed Gravel & Sand shorelines (31.5%) and Sand shorelines (21.1%) dominated. Mixed Rock and Gravel/Sand shorelines were found along 13.7% of the shoreline while Mixed Sand & Mud shorelines were found along 9.8% of the coast (see Figures 5 and 6 for distribution of MCC values and summary statistics). The details for each MCC category in the survey area is given in Table 2. Photographic examples of the major MCC categories mapped Kachemak Bay are found in Appendix A, Table A-1.

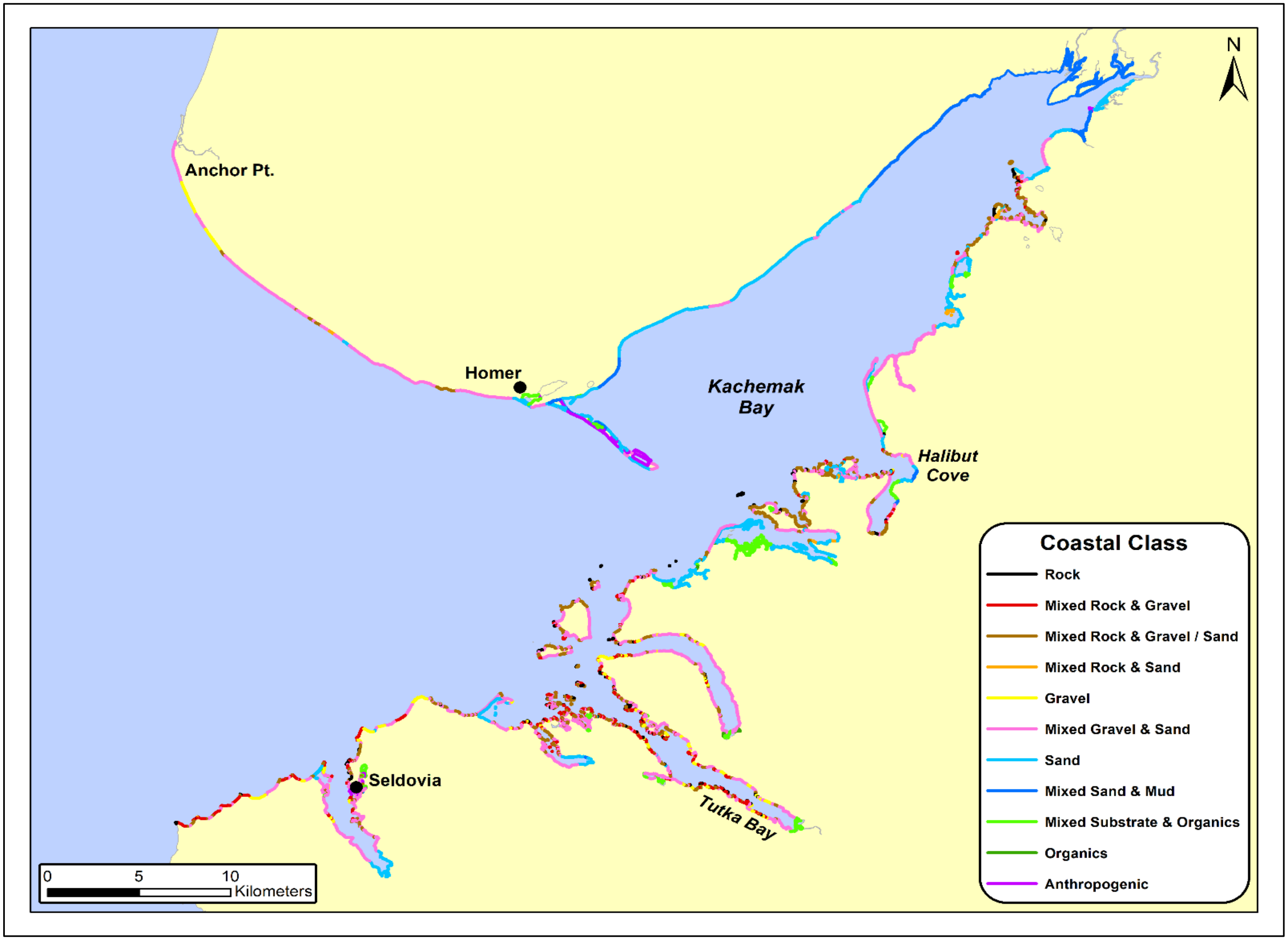


Figure 5. Map of the Modified Coastal Class categories in Kachemak Bay.

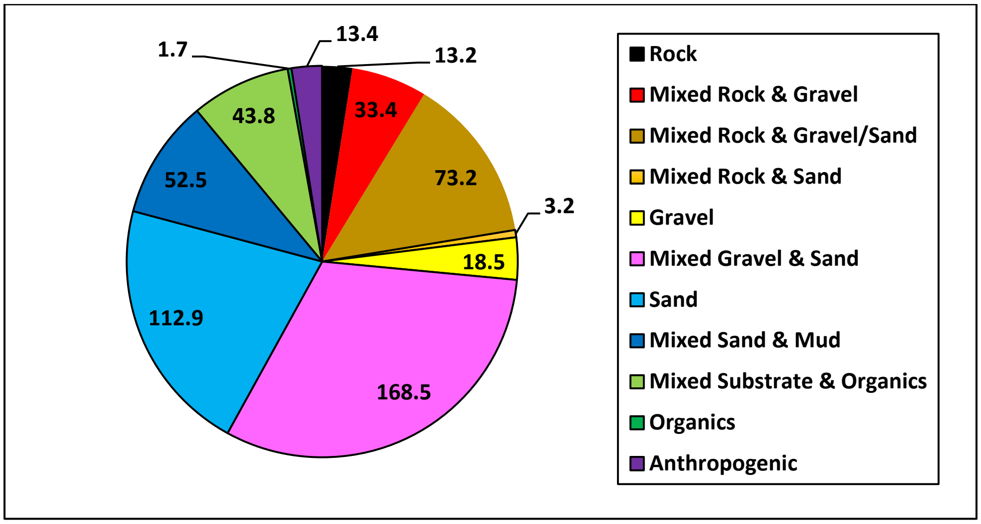


Figure 6. Modified Coastal Class categories by shoreline length (km).

Table 2. Summary of the Modified Coastal Class categories mapped in Kachemak Bay.

Shore Type		Sum of Unit Length (km)	# of Units	% Occurrence (by length)
No.	**Description**			
1	> 90% Rock	13	97	3
2	Mixed Rock & Gravel	33	254	6
3	Mixed Rock & Gravel/Sand	73	410	14
4	Mixed Rock & Sand	3	12	1
5	> 90% Gravel	19	85	4
6	Mixed Gravel & Sand	169	664	32
7	> 90% Sand	113	200	21
8	Mixed Sand & Mud	53	46	10
10	Mixed Substrate (any category) & Organics	44	54	8
11	> 90% Organics	2	4	<1
12	> 50% Anthropogenic Substrate	13	33	3
Totals:		***535***	***1859***	***100***

Note: This table only includes Coastal Classes observed in the Kachemak Bay survey area.

The original ShoreZone Coastal Class is one of the more commonly used ShoreZone attributes by end users as it provides a good summary of the habitat of the unit as a whole. Although the SZE Modified Coastal Class has been simplified down to only summarize the dominant substrate in order to make it relevant over larger geographic domains, it can be combined with other attributes such as Zone Slope, Zone Process and Dominant Form to provide data similar to the original Coastal Class attribute if desired. The SZE Modified Coastal Classes provides more certainty in the data at a better spatial resolution. Figures 7 and 8 show the comparison between the original ShoreZone Coastal Class and the Modified Coastal Class mapped in Kachemak Bay.

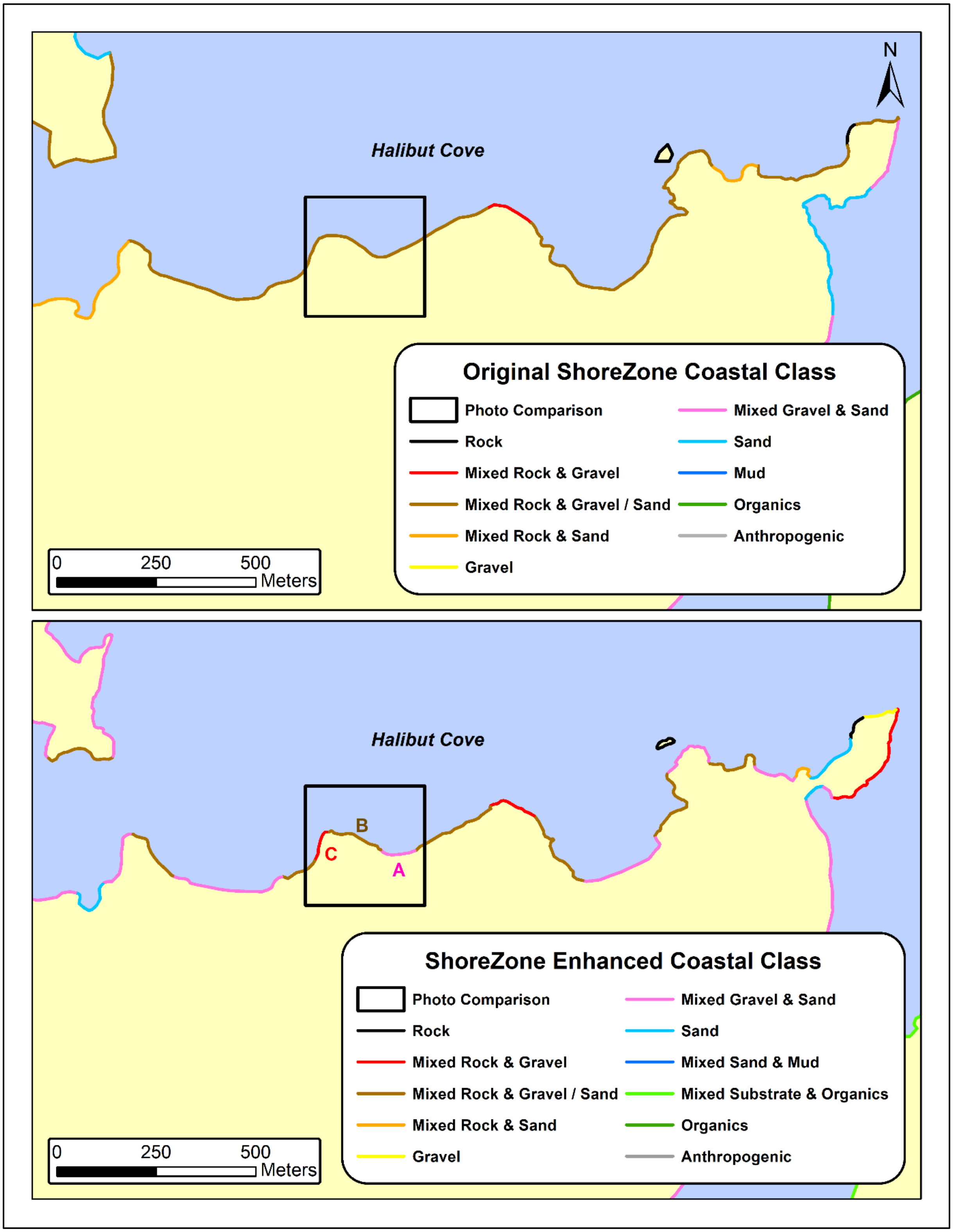


Figure 7. Comparison of original Coastal Class to Modified Coastal Class in Kachemak Bay (see Figure 8 for photographic comparison of the area inside the black box).

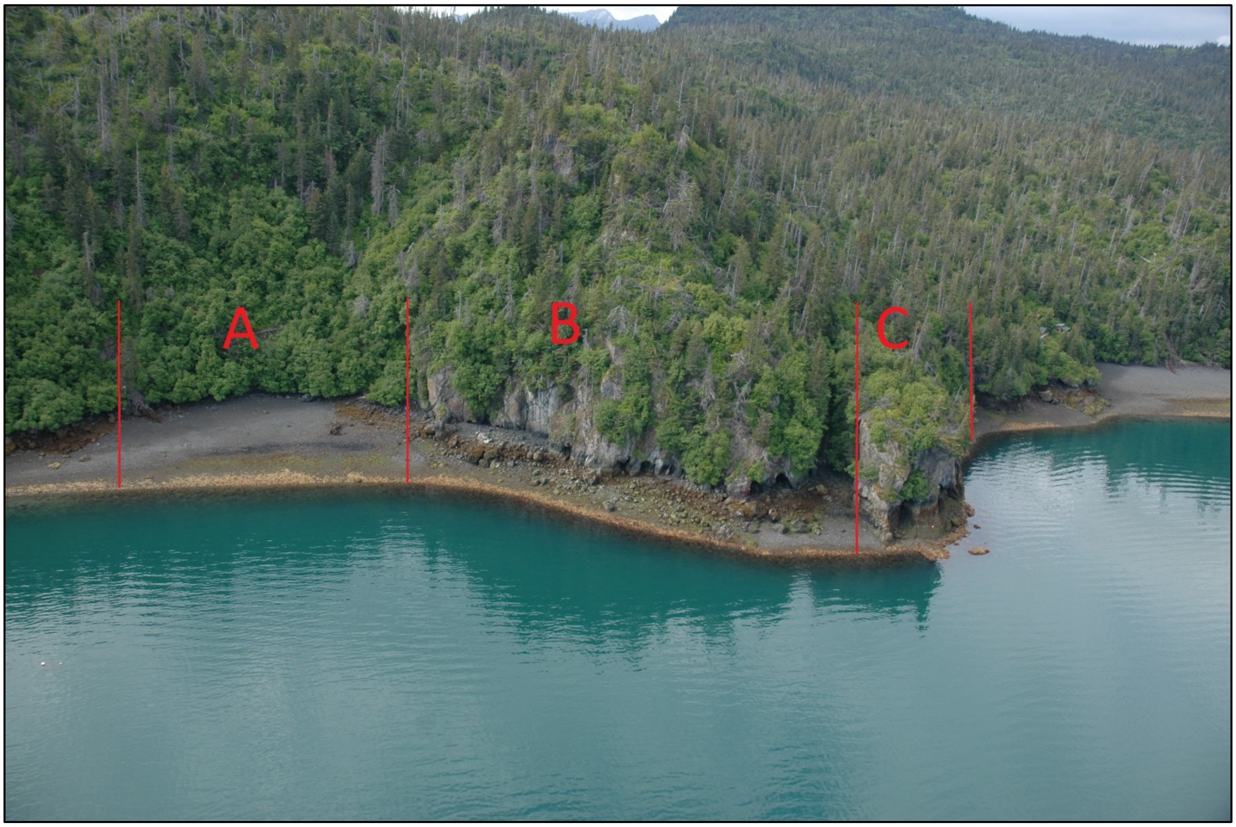


Figure 8. Photo ci09_hm_06135 showing the area in the black box in Figure 7. This shows how one larger unit original classified as 'Mixed Rock & Gravel/Sand' was broken into three units with three different SZE Modified Coastal Classes, providing improved spatial resolution to the ShoreZone data.

2.1.2 Environmental Sensitivity Index

The NOAA Environmental Sensitivity Index (ESI) is a shoreline classification system developed to characterize coastal regions based on sensitivity to potential oil spills (Petersen *et al*. 2002). The ESI system uses wave exposure and principal substrate type to assign a rank of 1 to 10 (with 10 being the most sensitive to oil) to alongshore units. Up to three ESI numbers can be assigned to each ShoreZone unit (high, mid and low intertidal) if applicable. The highest ESI number for each unit, which is the most sensitive, is used in this analysis. The NOAA ESI was not classified as part of older ShoreZone protocols (although a ShoreZone ESI was sometimes classified) so this attribute has been continued as part of the SZE protocols.

For the analysis of ESI values in Kachemak Bay we grouped them into categories ranked by sensitivity of the shoreline to oiling. The pilot area in Kachemak Bay is dominated by the grouped High and Very High ESI categories (65.1% of shoreline length). These sections of the shoreline have a potentially high sensitivity to oil. At the other end of the spectrum, only 20.1% of the shoreline was mapped with a potentially low sensitivity to oil (Figures 9 gives statistics and Figure 10 shows a map of the distribution). The summary of Shore Type by ESI class can be seen in Table 3.

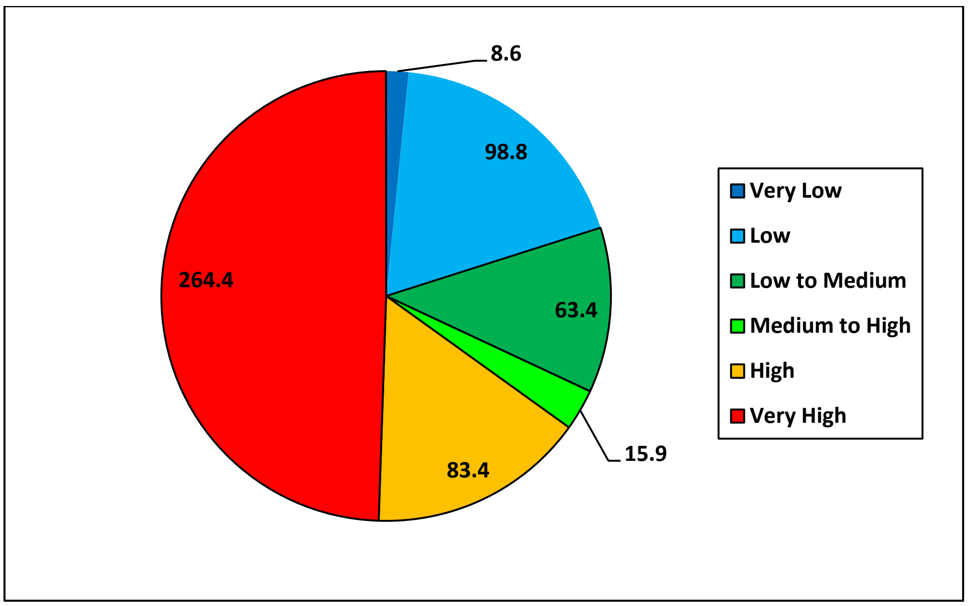


Figure 9. Grouped most sensitive ESI categories by shoreline length (km).

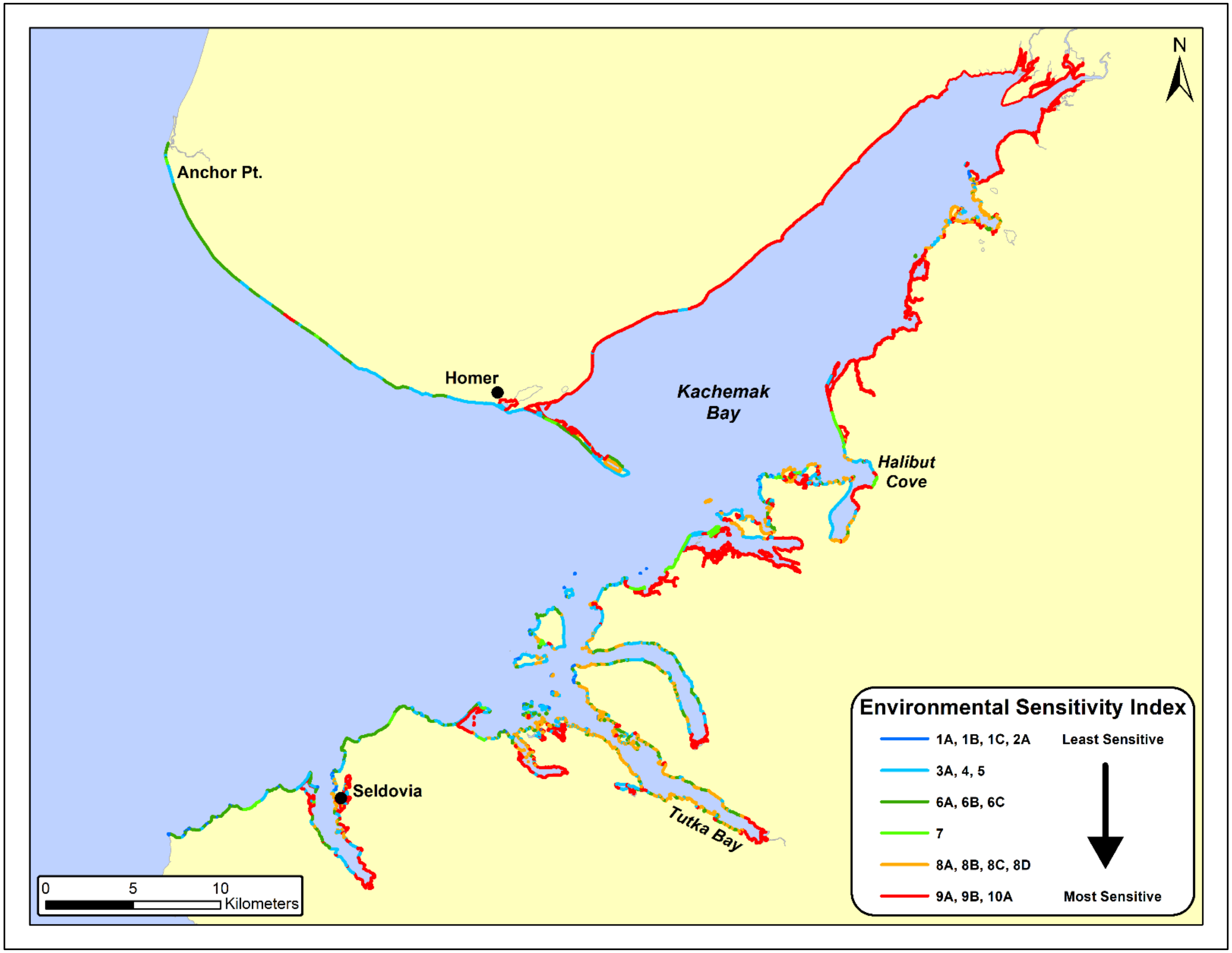


Figure 10. Distribution of the grouped ESI categories from least to most sensitive to oiling.

Table 3. Summary of shore types by ESI Class for the Kachemak Bay survey area.

Environmental Sensitivity Index (ESI)		Sum of Unit Length (km)	# of Units	% of Total Shoreline Length
No.	Description			
1A	Exposed rocky shores; Exposed rocky banks	5	30	1
1B	Exposed, solid man-made structures	<1	1	<1
1C	Exposed rocky cliffs with boulder talus base	1	12	<1
2A	Exposed wave-cut platforms in bedrock, mud, or clay	3	21	1
3A	Fine- to medium-grained sand beaches	3	6	1
4	Coarse-grained sand beaches	4	15	1
5	Mixed sand and gravel beaches	92	401	17
6A	Gravel beaches (granules and pebbles)	17	62	3
6B	Gravel beaches (cobbles and boulders)	43	232	8
6C	Rip rap	4	7	1
7	Exposed tidal flats	16	34	3
8A	Sheltered scarps in bedrock, mud, or clay; sheltered rocky shores (impermeable)	35	197	6
8B	Sheltered, solid, man-made structures; sheltered rocky shores (permeable)	<1	3	<1
8C	Sheltered Rip Rap	5	17	1
8D	Sheltered rocky rubble shores	44	324	8
9A	Sheltered tidal flats	152	378	29
9B	Vegetated low banks	<1	1	<1
10A	Salt- and brackish-water marshes	112	118	21
	Totals:	***535***	***1859***	***100***

Note: ESI Classes not observed in this survey area were not included in the table.

2.1.3 Oil Residence Index

The ShoreZone Oil Residence Index (ORI) was developed by Dr. John Harper based on his many years of experience with cleaning up oiled shorelines, starting with the Exxon Valdez spill in Prince William Sound in Alaska (Cook *et al*. 2017). The SZE ORI has been modified from the original ORI and is calculated using the dominant intertidal zone Substrate and the subunit Wave Exposure. See Table 4 for the SZE ORI values and Table 5 for definitions of the ORI categories.

Table 4. The lookup table for the ShoreZone ORI attribute.

	Subunit Wave Exposure					
Intertidal Zone Primary Substrate	**VE**	**E**	**SE**	**SP**	**P**	**VP**
Rock	1	1	1	2	3	3
Any Anthropogenic, impermeable	1	1	1	2	2	2
Block						
Boulder	2	3	5	4	4	4
Cobble	2	3	5	4	4	4
Pebble	2	3	5	4	4	4
Sand or Silt (with Pebble, Cobble or Boulder as secondary or tertiary substrate)	1	2	3	4	5	5
Sand or Silt (without Pebble, Cobble or Boulder as secondary or tertiary substrate)	2	2	3	3	4	4
Mud	999	999	999	3	3	3
Peat/Obscured Vegetated	999	999	999	5	5	5
Any Anthropogenic, permeable	2	2	3	3	5	5
Shell	2	3	5	4	4	4
Wood	999	999	999	999	999	999

*'999' indicates this combination occurs rarely so is left to mapper discretion

Table 5. Definition of the categories for the ORI attribute.

Persistence	Oil Residence Index (ORI)	Estimated Persistence
Short	1	Days to Weeks
Short to Moderate	2	**Weeks** to Months
Moderate	3	Weeks to **Months**
Moderate to Long	4	**Months** to Years
Long	5	Months to **Years**

Lower wave exposures and unconsolidated sand and gravel sediments lead to high ORI values in 80.4% of the shore segments in Kachemak Bay, indicating oil residence times are on the order of months to years (see Figures 11 and 12 for distribution and summary statistics).

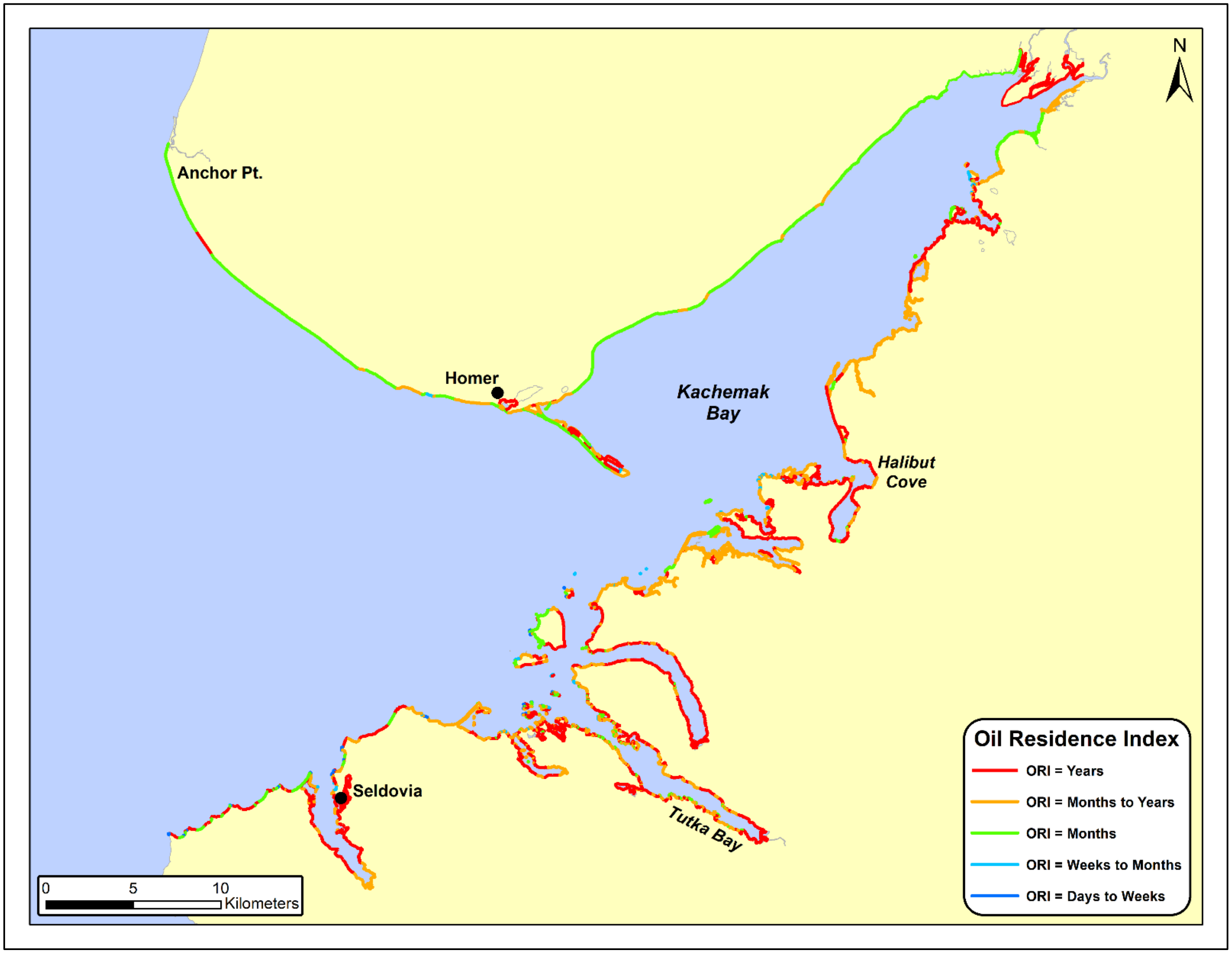


Figure 11. Distribution of the Oil Residence Index categories in Kachemak Bay.

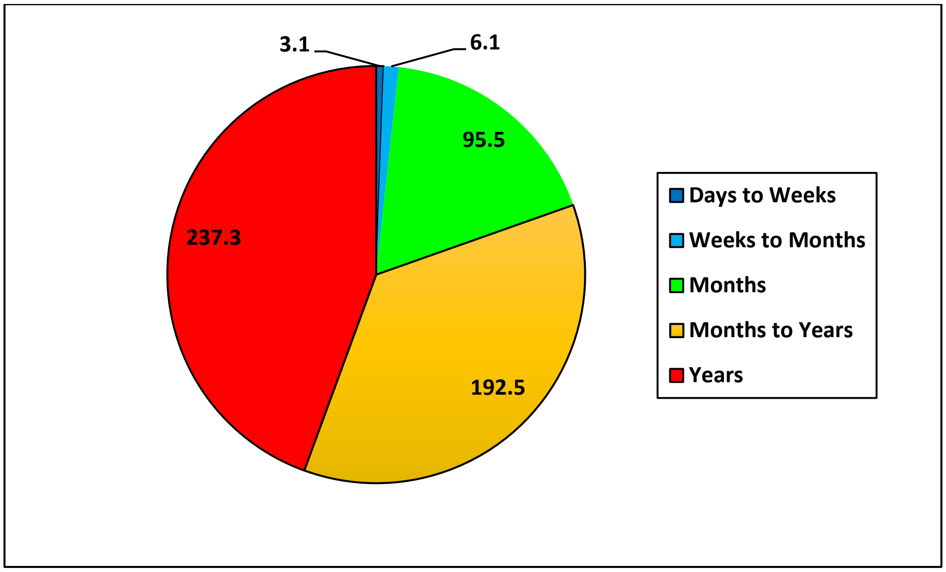


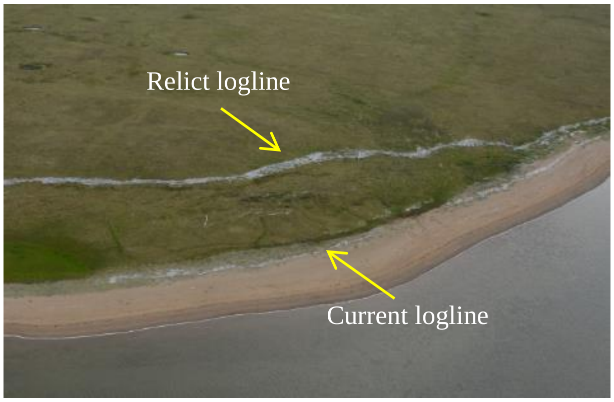
Figure 12. SZE Oil Residence Index (ORI) categories by shoreline length (km).

2.1.4 Coastal Vulnerability Module Attributes

A Coastal Vulnerability Module (CVM) was introduced to the ShoreZone program in 2012 to rank the shoreline in terms of potential sensitivity to coastal change, especially to rising sea levels. It was originally applied to permafrost dominated shorelines in the Beaufort and Chukchi Seas; however, sea level rise and the loss of sea ice in other areas covered by ShoreZone has been a growing concern so the CVM was adapted for non-permafrost shorelines as well. There are 4 attributes that make up the CVM: the Flood Zone Index, the Stability Index, Vulnerability Observations and the newly added Coastal Vulnerability Index (CVI). The CVM attributes were not classified for most of the original ShoreZone mapping so has been included in the SZE protocol. Each CVM attribute is defined below.

Flood Zone Index

The potential width of the flood zone adjacent to an alongshore unit is interpreted from aerial imagery. Indicators include relict loglines or storm berms above the active berms or loglines (Figure 13). The width of the flood zone is the metric used to assess vulnerability to flooding with wider areas being more vulnerable. The Flood Zone Width categories are: Very Low (1-5 m), Low (5-10 m), Moderate (10-50 m), High (50-100 m) and Very High (>100 m). A map of the distribution of the Flood Zone Index in the Kachemak Bay pilot area is presented in Figure 15.



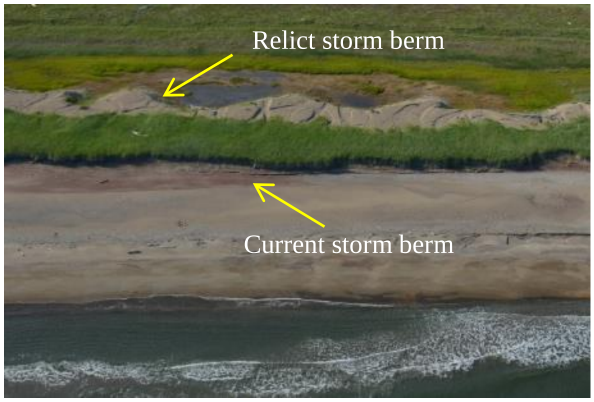


Figure 13. Examples of aerial images used to determine the flood zone width. The left image shows a relict log line on the tundra in northern Norton Sound and the image on the right shows a relict storm berm now vegetated by dune grass just south of Nome in Norton Sound.

Stability Index

The relative rate of shoreline erosion is estimated to assess shoreline stability. Erosional shorelines (showing evidence of volumetric loss) are considered more vulnerable than actively accreting shoreline (showing evidence of volumetric gain). Even though the ShoreZone images record one point in time and cannot therefore be used to measure rates directly, interpretation of shoreline features can provide an indicator for rates of change. For example, scarps or "cut banks" indicate actively eroding shorelines, rocky shorelines are relatively stable, and spits devoid of vegetation indicate active accretion (Figure 14). The erosion index categories are: 1= Very high (>2 m/yr, erosional), 2= High (1 to 2 m/yr, erosional), 3= Moderate (1 to -1 m/yr, stable), 4= Low (-1 to +1 m/yr, accretional), 5= Very low (>2 m/yr, accretional). A map of the distribution of the Stability Index in the Kachemak Bay pilot area is presented in Figure 16.

Figure 14. Examples of indicators for determining the rate of erosion or accretion. The image on the left shows an eroding peat bank on the exposed coast of the Yukon-Kuskokwim Delta near Angyoyaravak Bay and the image on the right shows an accretional spit by the city of Teller in Port Clarence, Norton Sound.

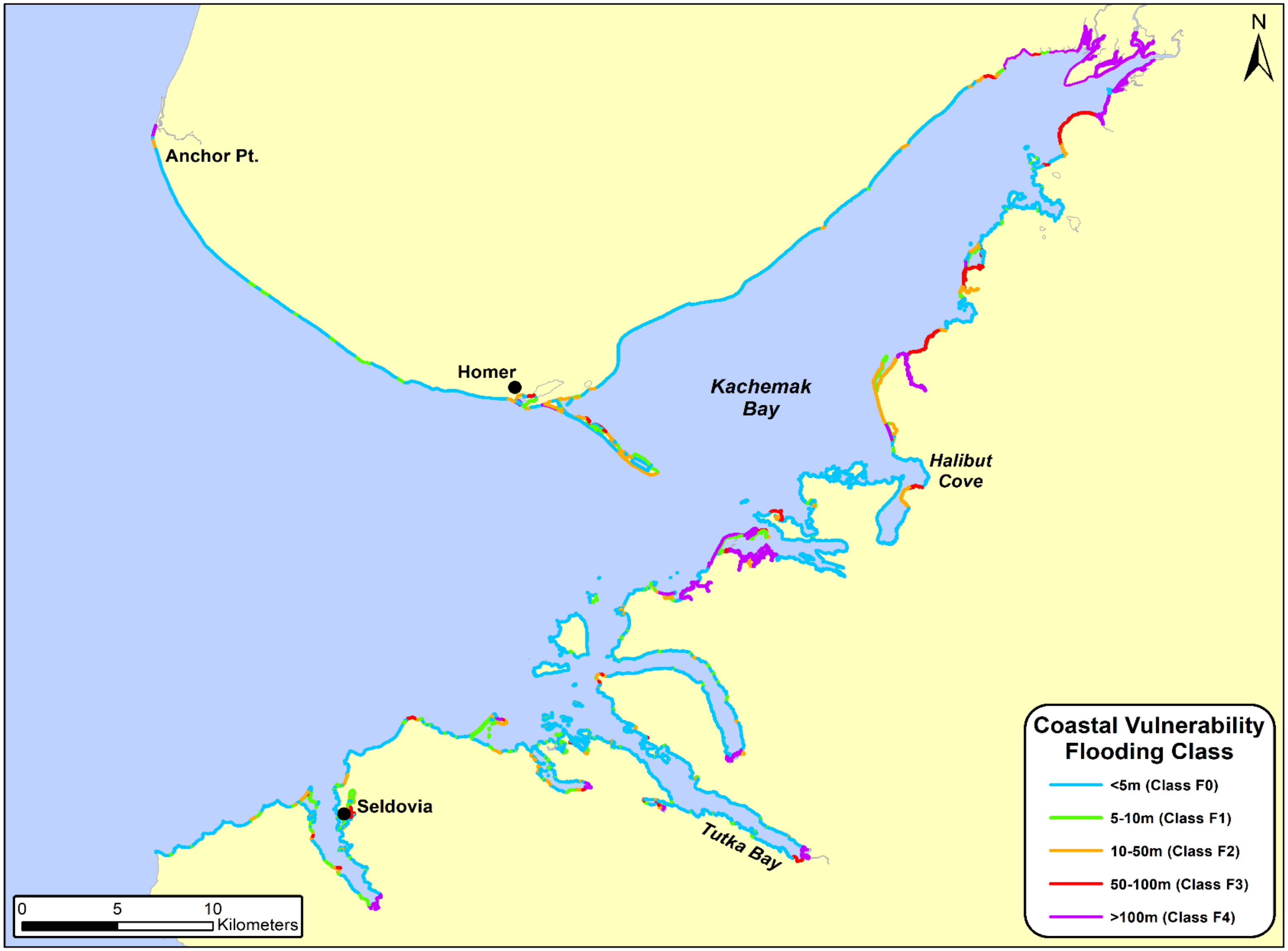


Figure 15. Distribution of the Coastal Vulnerability Flooding Class.

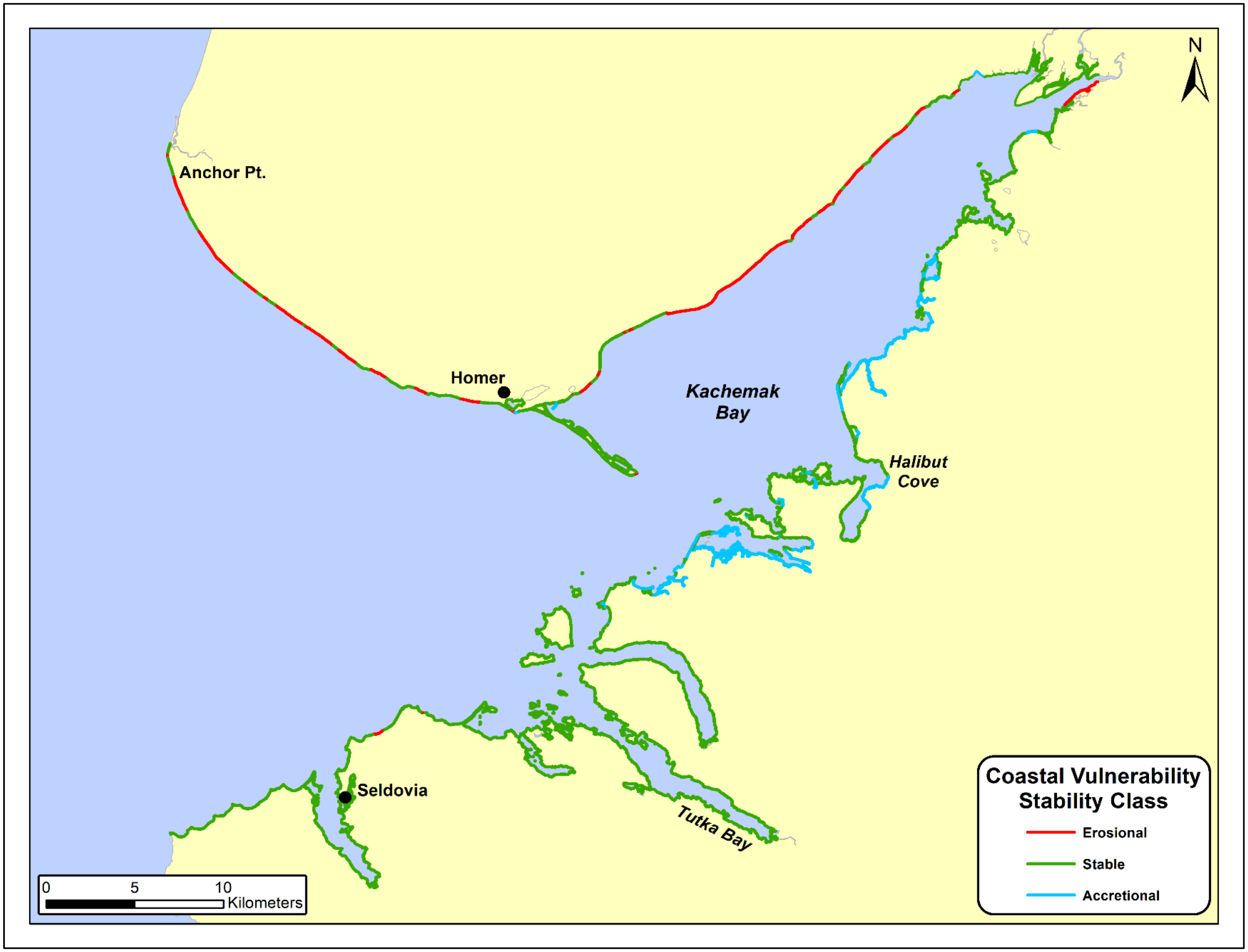


Figure 16. Distribution of the Coastal Vulnerability Shoreline Stability Class. The erosional and accretional categories were grouped for this map.

Vulnerability Observations

This CVM attribute classifies features that are potentially important to determination of the vulnerability of the coastline to sea level change. See Table 6 for a list of the feature codes.

Table 6. Features recorded for the Vulnerability Observations.

Category	Feature
Mass Wasting	Ground ice slumps
	Block slumps
	Debris flows/solifluction
	Ice Wedges
Wetlands	Lagoonal complex
	Deltaic complex
	Tidal creek complex (multiple, branching channels)
	Marsh clones
	Associated mudflats
	Submerged morphology
	Relict river morphology
	Relict shoreline morphology
	Scrub/shrub wetland
Anthropogenic	Anthropogenic features that are potentially vulnerable to flooding
Other	Add description of relevant feature
None	Unit assessed, no relevant features (none of the above)

ShoreZone Enhanced Coastal Vulnerability Index

A ShoreZone Coastal Vulnerability Index (SCVI) was recently added that ranks five shoreline attributes according to how vulnerable the make the coast to sea level rise and uses an algorithm to combine them into a single value to estimate the overall vulnerability of a shoreline unit to coastal inundation due to sea level rise. The SCVI is intended to meet the growing need of coastal managers for information about the vulnerability of coastlines at the relevant spatial scales of coastal communities (100s m). The methods of Thieler and Hammer-Klose (1999, 2000a and 2000b) (http://woodshole.er.usgs.gov/project-pages/cvi/) are used to calculate the SCVI using coastal geomorphology (represented by Modified Coastal Class plus Intertidal Zone Slope in the SZE protocol), the maximum tide range, the erosion rate (using the Stability Index), the Flood Zone Index and significant wave height (Table 7). The attributes are either directly assessed from the imagery or are available from public data sources.

Table 7. The ranking matrix for the ShoreZone Enhanced Coastal Vulnerability Index attributes.

Variable	Ranking				
	Very Low	**Low**	**Moderate**	**High**	**Very High**
	1	**2**	**3**	**4**	**5**
Geomorphology (Description)	Rocky, cliffed coasts Fjords	Medium cliffs Indented coasts	Low cliffs Glacial drift Alluvial plains	Cobble beaches Estuaries Lagoons	Barrier beaches Sand beaches Marshes Mud flats Deltas
Geomorphology (Modified Coastal Class and Intertidal Slope) (a)	1,2,3,4 />45^o	1,2,3,4 /20^o-45^o	1,2,3,4 /<20^o	5,6,10,12	7,8,9,11
Flood Zone Index (m) (b)	1-5	5-10	10-50	50-100	>100
Stability Index (erosion/accretion (m/yr)) (c)	>2.0	1.0 - 2.0	1.0 - -1.0	-1.1 - -2.0	>-2.0
Max Tide Range (GT) (m) (d)	>6.0	4.1 - 6.0	2.0 - 4.0	1.0 - 1.9	<1.0
Significant Wave Height (m) (and corresponding Wave Exposure Category) (e)	<1 (VP, P)	1.0 - 2.0 (SP)	2.1 - 4.0 (SE)	4.1 - 6.0 (E)	>6.0 (VE)

The maximum tide range is the maximum mean annual value from the most appropriate local tide station as taken from the NOAA Tides and Currents website. This attribute is included because when we discuss the effects of sea level rise on the coastline, we are mainly concerned with inundation and erosion of the supratidal (the area above the daily tide cycle). That is because many coastal communities and coastal resources are found in the supratidal zone and the intertidal will not be as affected by rising sea levels since it is an ecosystem defined by changing water levels. Sea level rise will interact with the daily tidal cycles to create supratidal flooding at the highest tides. This effect will be swamped by the natural tide range in areas with large tide ranges while the effect will be more noticeable in areas with smaller tide ranges. For example, if relative sea level rise is predicted at 0.2 m over the next 50 years, an area with a 6 m tide range will see little time during the tide cycle when that 0.2 m rise will be able to cause supratidal flooding. This stands in contrast to a portion of the coast with a 0.3 m tide range, where that 0.2 m change becomes much more significant over the entire tidal cycle.

Much of the flooding that occurs along coastlines is associated with extreme events such as storms. The amount of damage that storm surge can cause is dependent on a combination of factors such as coastal geomorphology and local tide range (which are captured in the Coastal Class, Flood Zone Index and max tide range attributes). However, another factor that can exacerbate damage by storms is the height of the waves breaking at the coast. The height of the waves that reach the shoreline is in turn dependent on the exposure of that stretch of shoreline, which is dependent on factors such as the offshore fetch and aspect of the shoreline relative to the predominant wind direction as well as any occlusion by other landforms. For ShoreZone, the Wave Exposure category is used to derive the significant wave height using the U.S. Army Corps of Engineers wave prediction curves (Department of the Army 1984).

Once all five of the attributes have been ranked for each unit then an SCVI value must be calculated. We use the equation developed by Thieler and Hammer-Klose (1999, 2000a and 2000b):

$$SCVI = \sqrt{((a*b*c*d*e) / 5)}$$

The calculated SZCVI values can range from 0.447 to 25. The values are then ranked into four categories (Low, Moderate, High and Very High) using the criteria in Table 8.

Table 8. Criteria for defining the ShoreZone CVI rank categories.

CVI Rank	CVI Value Range	Cutoff Criteria
Low	<4.5	Maximum of three ‘Low’ ranked attributes and two ‘Moderate’ ranked attributes
Moderate	4.5 – 9.9	Maximum of three ‘Moderate’ ranked attributes and two ‘High ranked attributes
High	10 – 17	Maximum of three ‘High’ ranked attributes and two ‘Very High’ ranked attributes
Very High	>17	At least three ‘Very High’ ranked attributes and two ‘High’ ranked attributes

The distribution of Coastal Vulnerability Index ranks in the Kachemak Bay pilot area is shown in Figure 17. The majority of the coastline was in the Low category and there were no areas ranked as High or Very High likely due to the lower wave exposure in the areas with marshes and estuaries and high cliffs along the north shore of the Bay.

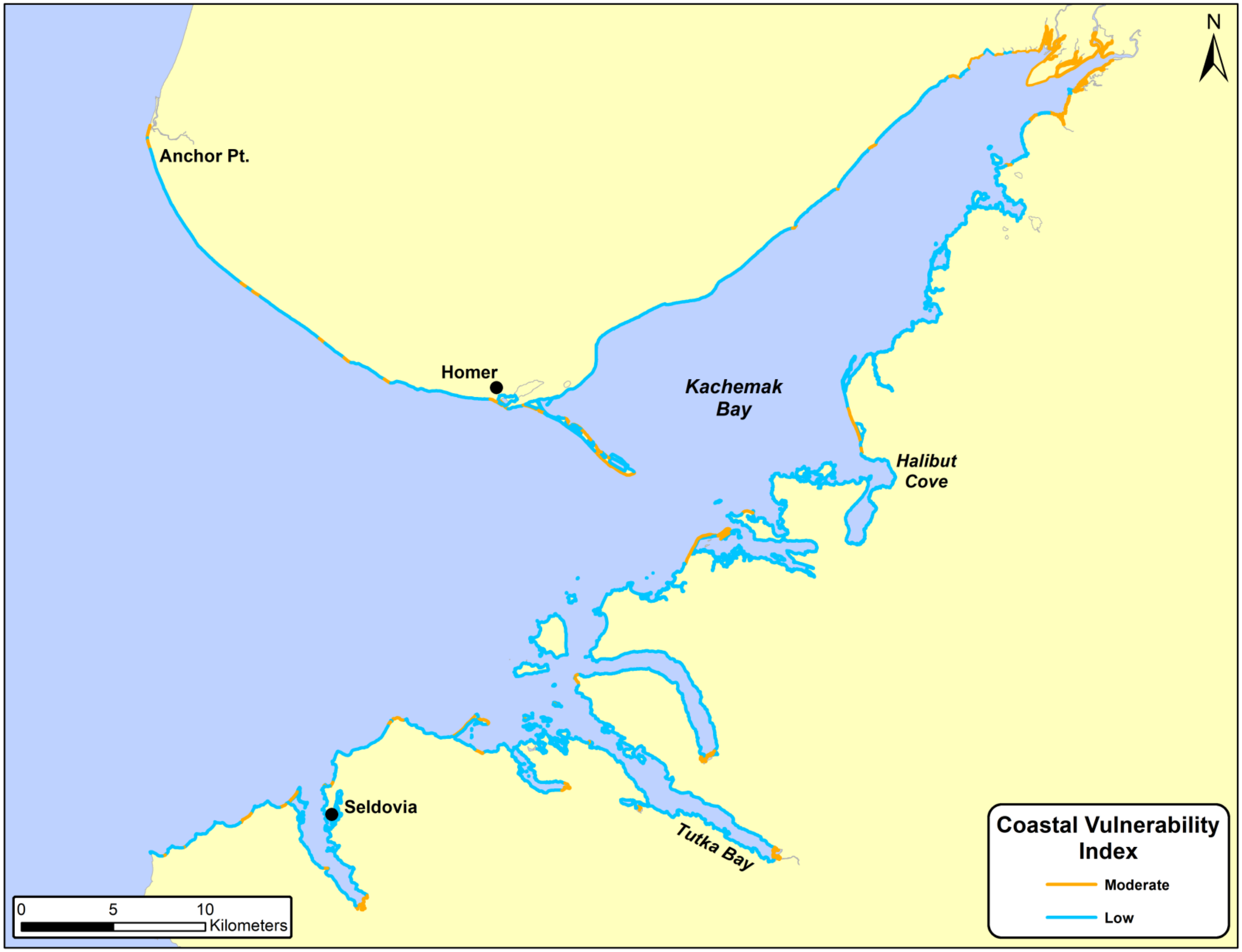


Figure 17. Distribution of the ShoreZone Enhanced Coastal Vulnerability Index ranks in Kachemak Bay.

2.1.5 Anthropogenic Shore Modifications

Enhanced ShoreZone Mapping will include cataloging anthropogenic modifications to the shoreline. The primary, secondary and tertiary Shoreline Modification code will be classified for each subunit as well as the percent of the alongshore length of the unit that modification is found along. See Table 9 for a list of the codes and what they describe. It was decided not to use the Anthropogenic Forms and Materials descriptions in the full ShoreZone protocol (Cook *et al.* 2017) as they are less repeatable between mappers. All the original mapping codes can also be translated to the new Shore Modification Codes so the datasets will still be comparable.

Pilings are not considered a shore modification unless they are driven in side-by-side to form a retaining wall, in which case the shore modification code for wooden bulkhead would be used. Floats also are not cataloged as part of the shore modification attributes. Fill and tailings placed deliberately at landings, industrial sites or around structures are cataloged as landfill. Domestic trash and debris around a house is not considered a landfill. The ‘Impacted’ code is meant to encompass evidence of human activities with no actual anthropogenic structures or materials, like ATV trails on the beach.

Table 9. Codes used for the Shore Modification Code attribute.

Code	Description
BR	Boat Ramp
CB	Concrete Bulkhead
LF	Landfill
SP	Sheet pile
RR	Rip Rap
WB	Wooden Bulkhead
PS	Pile-supported Wharf
AI	Impacted
FL	Marina/Floats
DS	Deep-sea Shipping
RS	Recreational Slips
UU	Undefined

The Shoreline Modification attribute can catalogue multiple modifications within a given unit. For example, if both riprap and a pile-supported wharf occur, both are catalogued in the appropriate zone of that unit with an estimate of the alongshore length of the unit that modification covers. A total of 6.6% of the shoreline (taking the estimated length of each modification within the unit into account) exhibits shore modifications in the Kachemak Bay study area (Figure 18). Landfill was the most commonly recorded observation (34.5% of observations) with Rip Rap and Impacted categories making up 25.6% and 21.2% of the observations, respectively. The associated map (Figure 19) shows the distribution of primary shore modifications though it should be noted that any given modification is necessarily along the entire length of the indicated shore unit. The Geodatabase delivered with this report displays each shore modification with a specific length category (meters) along the shoreline pertaining to each unit as well as the specific zone (supratidal or intertidal) the modification occurs in.

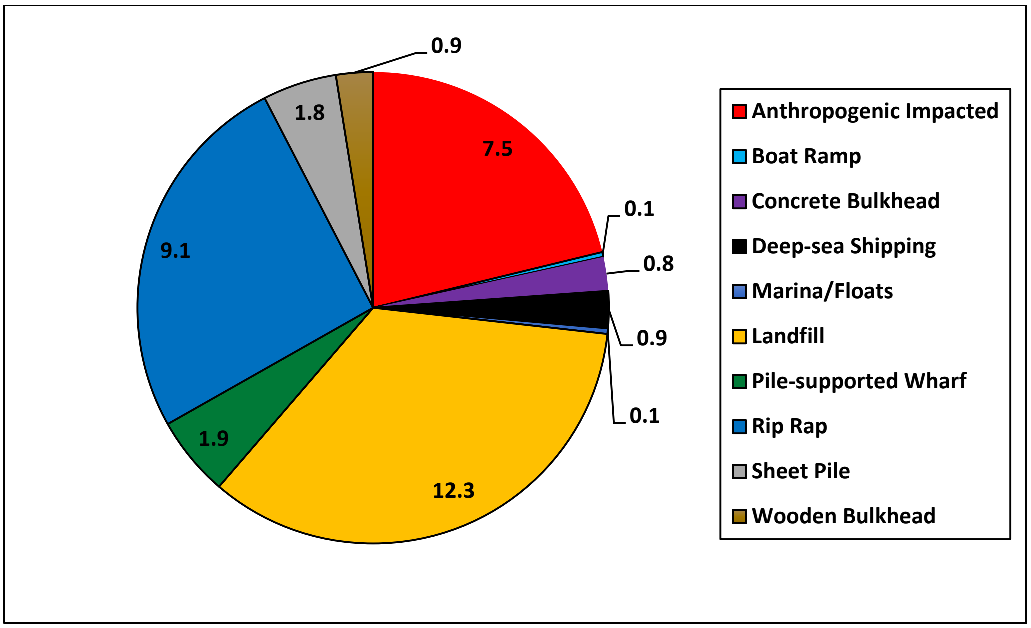


Figure 18. Shore Modifications by estimated shoreline length (km) of each modification type.

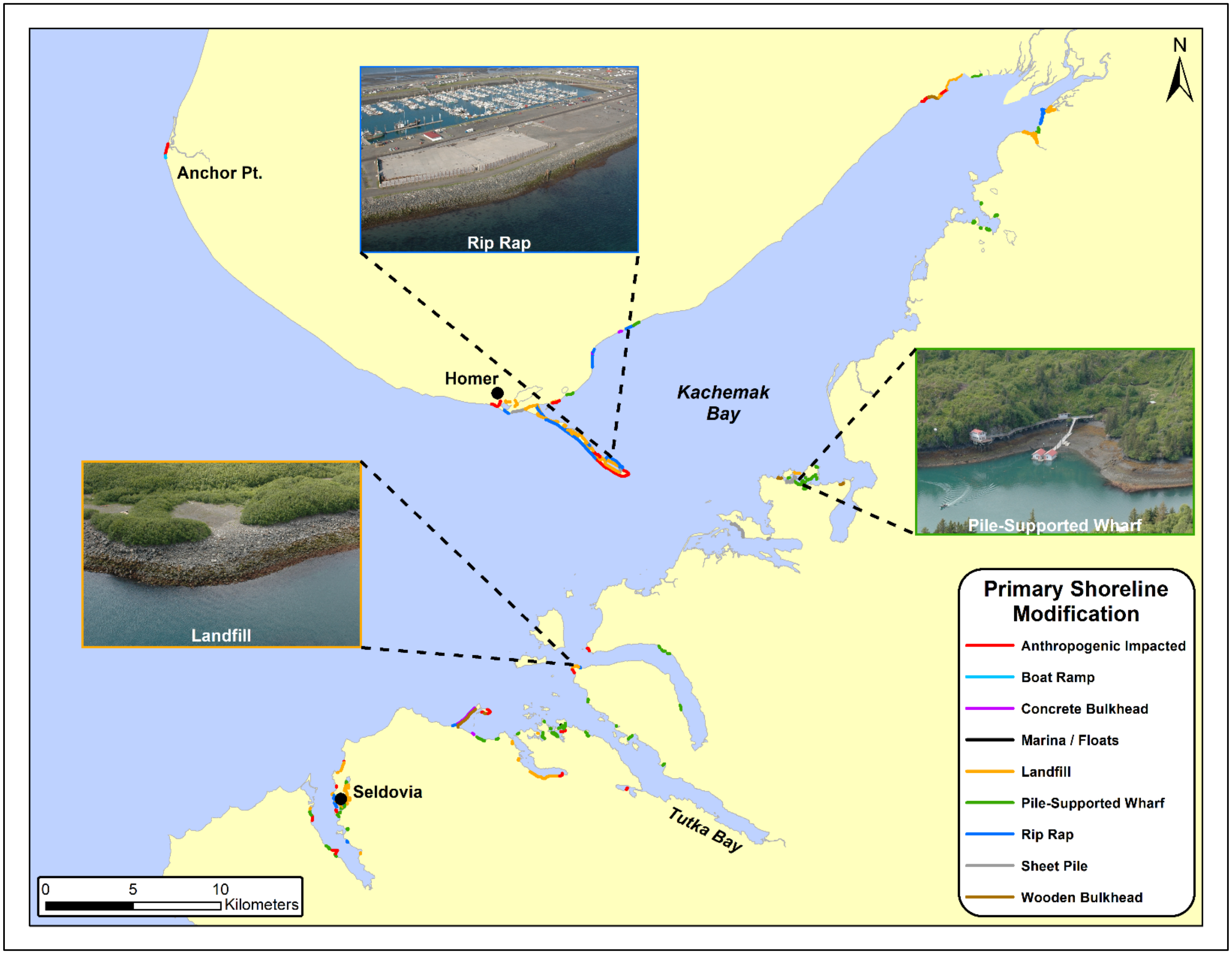


Figure 19. Distribution of types of the primary Shore Modifications. There may be other shore modifications in any given unit.

2.1.6 Forms and Substrate

The supratidal and intertidal zones of each subunit has a simplified description of the geomorphic forms and substrates that comprise those zones. The large numbers of codes and modifiers that are used to describe the geomorphic forms and material that comprise each form in the original ShoreZone mapping (Cook *et al*. 2017) made the description of each across-shore component more detailed but ultimately less repeatable between mappers and more challenging to analyze for the end users. It was therefore decided to just include the major form code in the SZE protocol. This change will also make it easier to crosswalk the SZE attributes with CMECS codes. The Primary, Secondary and Tertiary Forms and Substrates within the supratidal and intertidal are estimated. The Form codes are listed in Table 10 while the Substrate codes are listed in Table 11. The percent cover of each Form and Substrate is also estimated using the categories listed in Table 12. Please note that the Forms and Substrates for each zone are estimated independent of each other.

Table 10. Definitions of the codes for the ShoreZone Enhanced Form attribute.

Form	Description	Code
Dune	Vegetated sand ridges, built up by dry beach sand blown inland and trapped by plants and other obstructions	E
Marsh/Riparian	A wetland that is dominated by herbaceous rather than woody plant species	M
Tundra	A type of biome where the tree growth is hindered by low temperatures and short growing seasons	U
Beach	A landform along a body of water; it usually consists of loose particles, which are often composed of sediment, such as sand, gravel, pebbles, or cobbles	B
Delta	A landform that is created from deposition of sediment carried by a river or stream as the flow leaves its mouth and enters slower-moving or standing water such as the ocean; river deltas are ecologically important as they provide coastline defense, are home to many species, and can impact drinking water supply	D
Tidal Flat	A nearly flat coastal area, alternately covered and exposed by the tides, and consisting of mostly fine unconsolidated sediments	T
River Channel	A type of landform created by a river that consists of the outline of a path of relatively shallow and narrow body of fluid	R
Rock Cliff (>35^{o})	A high, steep or overhanging face of rock	C
Rock Ramp (5-35^{o})	A more gently sloping rock landform	O
Rock Platform (<5^{o})	A relatively flat rock landform	P
Reef	A ridge of rock separated from the main coastline by water even at the lowest low tide	F
Lagoon	A shallow, brackish body of water separated from the ocean by a constricted channel or wash over berm; can be open (flushes with each tidal cycle) or closed (only occasionally receives an input of ocean water during storms or extreme high tides); in ShoreZone the lagoon form should only be used for supratidal lagoons that are not part of the digital shoreline.	L
Anthropogenic	A landform composed of materials of anthropogenic origin; this can include natural sediments that have been moved from their original location (such as fill)	A
Ice	Glacial ice forms	I
Undefined/Other	A geomorphological coastal land form that is not described by any other ShoreZone form code	X

Table 11. Definitions of the codes for the ShoreZone Enhanced Substrate attributes. Sediment sizes are based on the Wentworth Scale.

Substrate Category	Substrate Name	Code
Lithogenic	Rock	1
	Block*	2
	Boulder*	3
	Cobble	4
	Pebble	5
	Coarse Sand	6
	Silt	7
Biogenic	Mud/Ooze	8
	Peat	9
	Shell	10
	Wood	11
	Other	12
Anthropogenic (Impermeable)	Metal	13
	Concrete	14
	Other	15
Anthropogenic (Permeable)	Rip Rap/Concrete Blocks	16
	Structural Wood	17
	Mixed Debris/Other	18
Obscured	Vegetated	19
	Ice	20
	Other	21

*modified from the Wentworth scale so Boulder (26.5cm-3m) and Block is >3m

Table 12. Percent cover categories for the Form and Substrate attributes.

Percent Cover Category Number	Percent Cover Category Value
1	<5%
2	5-25%
3	26-50%
4	51-75%
5	76-95%
6	>95%
NA	Not Assessed

A map of the Primary Intertidal Form for the subunits mapped in Seldovia Bay is shown in Figure 20. Focusing on the smaller Seldovia Bay, rather than the whole pilot Kachemak Bay area, demonstrates how detailed the SZE mapping can be and the ease with which that data cab be displayed and analyzed. We included the CMECS codes for each Form on the map to show how simplified that crosswalk is compared to the original ShoreZone Form codes. Figure 21 shows a map of the Primary Intertidal Substrate in Seldovia. The CMECS codes are also included on that map. This type of map would have been highly complicated to produce from the original ShoreZone mapping.

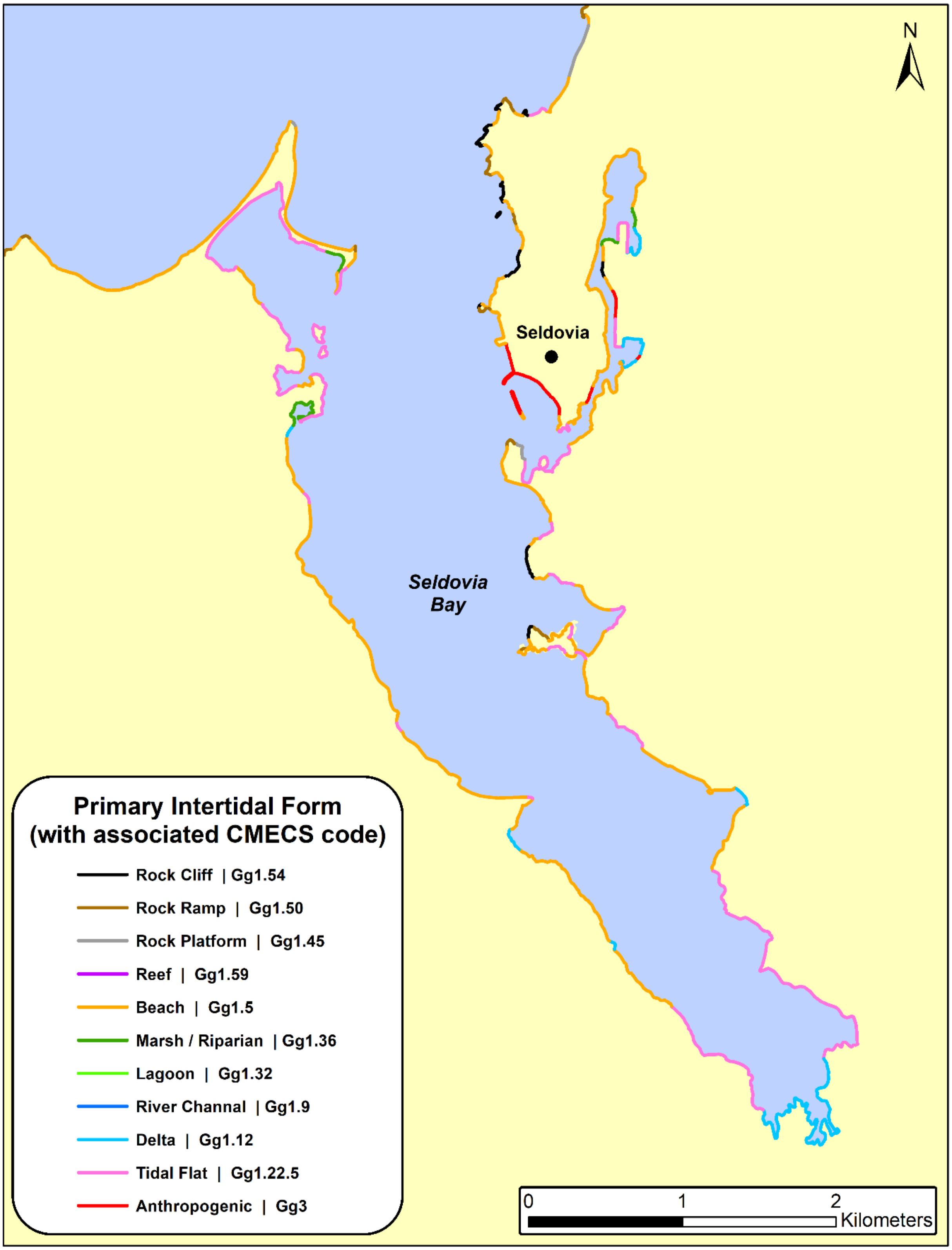


Figure 20. Distribution of the Primary Intertidal Forms in Seldovia Bay.

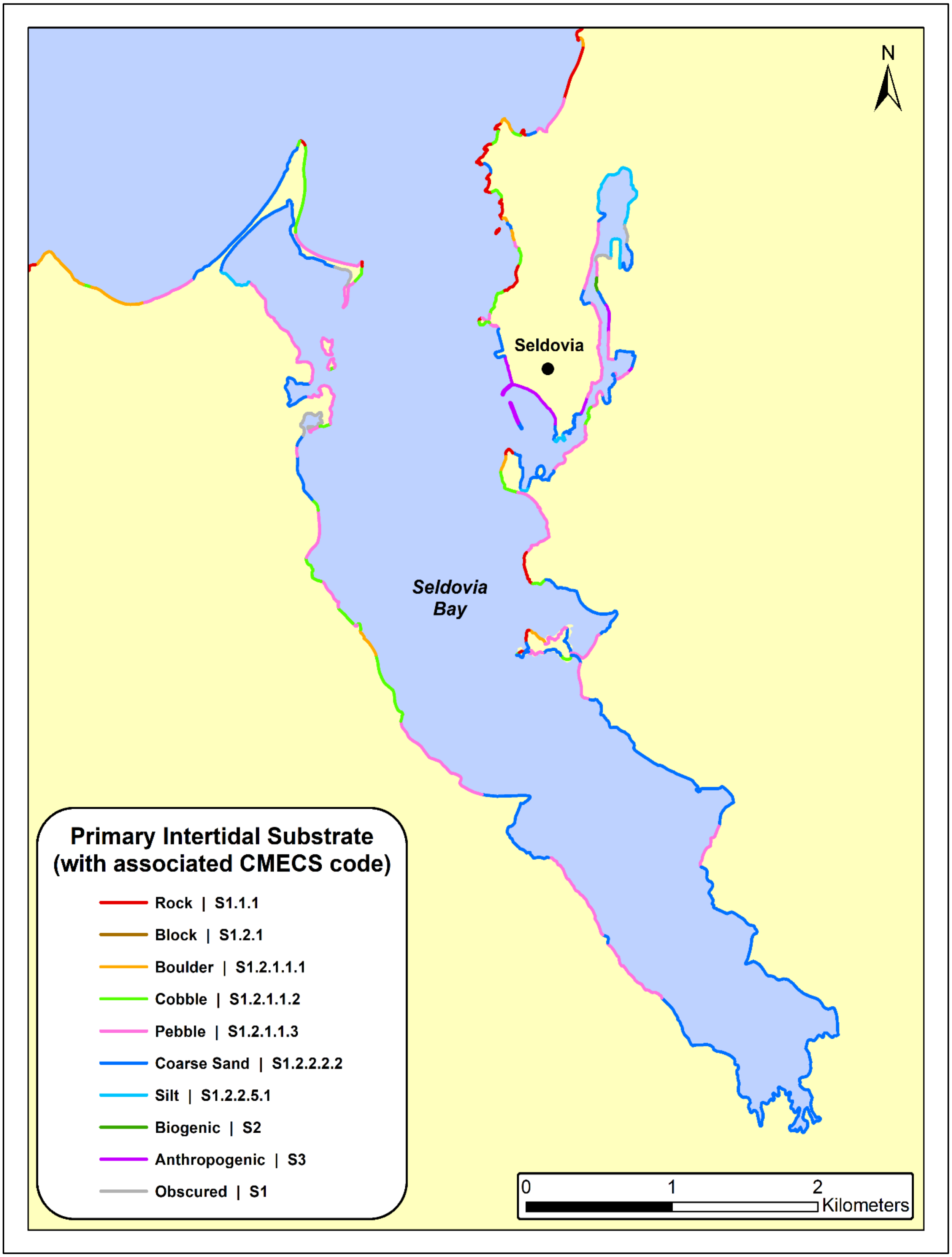


Figure 21. Distribution of the Primary Intertidal Substrate for Seldovia Bay.

2.1.7 Other ShoreZone Enhanced Physical Attributes

CMECS

The Coastal and Marine Ecological Classification Standard (CMECS) is “a catalog of terms that provides a means for classifying ecological units using a simple, standard format and common terminology” and was approved by the Federal Geographic Data Committee in 2012. CMECS is meant to allow scientists to analyze ecological data across different projects, collected using different methodologies, by providing a common terminology for that data. It has been adopted by NOAA and other agencies as the standard for ecological data in the U.S. It is therefore important that any federal datasets can be successfully cross-walked with CMECS. Coastal and Ocean Resources have been working with NOAA Coastal Services Center to successfully cross-walk the original ShoreZone attributes. This is not always a straight-forward process, so at the moment Coastal Class is the only attribute being delivered as a CMECS code, although we also place each original ShoreZone unit into the CMECS Biogeographic Regions which were originally developed by the CEC (Wilkinson *et al*. 2009). The original Forms, Materials and Biobands are also able to be cross-walked with some difficulty and that classification is currently under development with NOAA. The Enhanced ShoreZone attributes will also be cross-walked with CMECS and the simplified, more ‘user friendly’ nature of the subunit and zone attributes are designed to be more easily cross-walked with CMECS. SZE mapping will also have the Biogeographic Region.

Intertidal Zone Width

Coastal and Ocean Resources has adopted the use of Structure from Motion (SfM) with our oblique aerial imagery to measure width of the intertidal zone more accurately. SfM is a digital image processing technique for generating 3-D spatial data for use in mapping and GIS applications, and for indirect measurements of objects. SfM operates under the same principals as stereoscopic photogrammetry so that 3-D structure can be resolved from a series of overlapping, offset images (Figure 22) and requires at least 50% overlap between images.

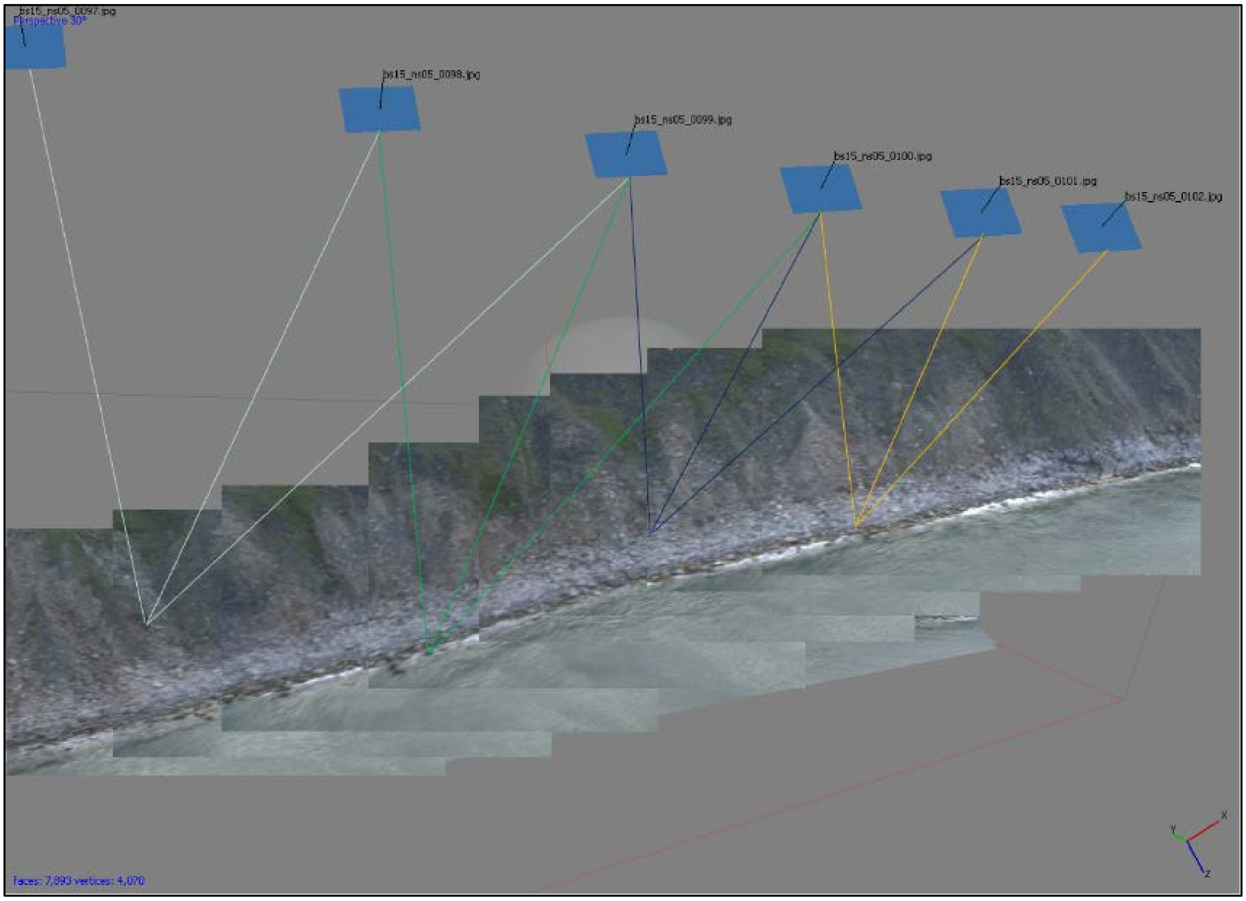


Figure 22. The Structure from Motion processing technique for video frames with 60% overlap.

The images for ShoreZone are acquired from a fast-moving helicopter but 1-second still imagery captures from the video still have at least 60% overlap provided the flight speed does not exceed 100 km/hr. The ShoreZone Enhanced workflow includes the creation of SfM orthophotos using those video captures which are imported into Google Earth or ArcGIS Earth. The programs GIS tools are then used to measure the width of the intertidal zone from the estimated Mean High Water line to the edge of the water in the imagery (Figure 23). This represents a technological improvement over past estimates of width, which was done purely from the imagery and whatever reference points could be found on the shoreline.

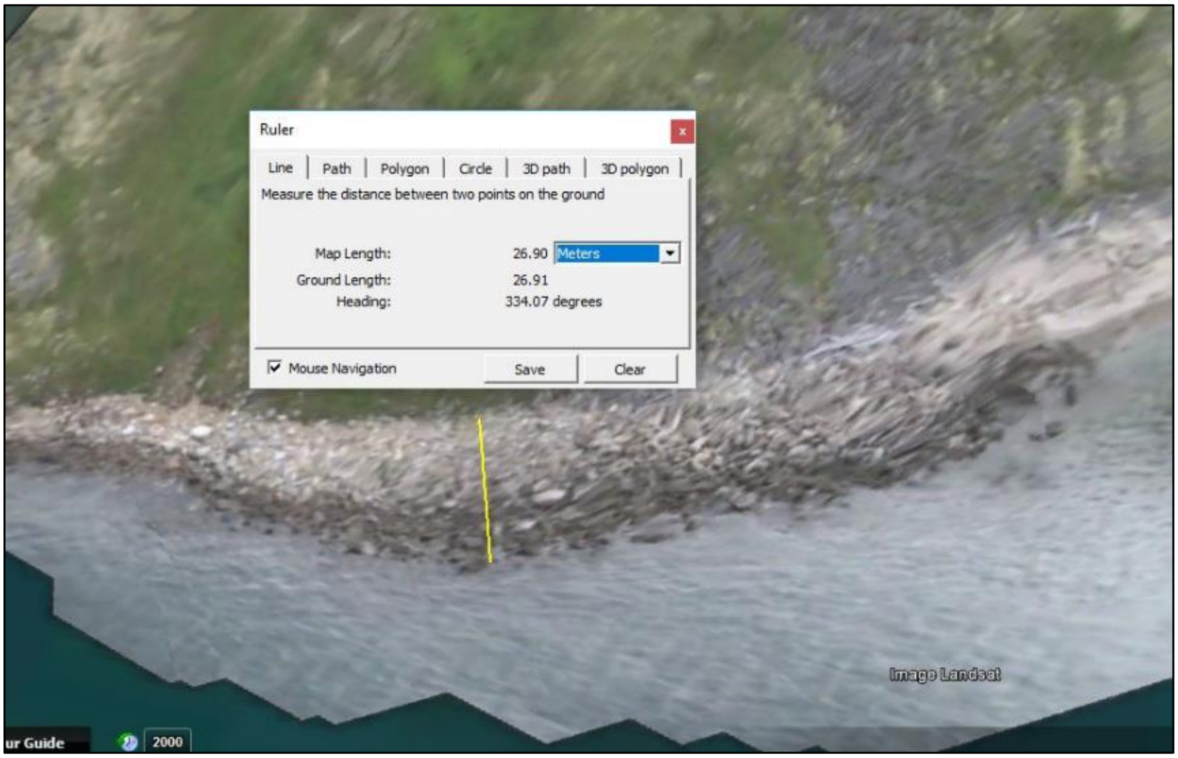


Figure 23. An Orthorectified image created using Structure from Motion with overlapping ShoreZone video captures. They are exported to Google Earth for width measurements of the intertidal shoreline.

This methodology (using the Structure from Motion orthophoto mosaic to measure the width in Google Earth) was only introduced the 2017 ShoreZone protocol (Cook *et al*. 2017) and is considered to be more accurate than previous methodology (estimation from the aerial image) which is why it is also included under the ShoreZone Enhanced protocol.

Intertidal Zone Area

The area of the unit intertidal zone (in m^2) is calculated using the Intertidal Zone Width multiplied by the Digital Shoreline Length which is calculated in ArcGIS using the best available digital shoreline. This method assumes that the digital shoreline length is relatively straight, as opposed to highly crenulated and that the width of the intertidal zone does not vary much along the length of the unit. The Intertidal Zone Area could potentially be used to calculate estimates of the amount of substrate in each unit or calculate biomass estimates for the Biobands when used in conjunction with the percent cover estimates.

Wave Exposure

Wave energy is generally the dominant structuring process of the intertidal and affects community structure through episodic disturbance events and by controlling substrate dynamics over short and long term periods. The lack of bare space is often the limiting factor governing community structure in the rocky intertidal. Thus, the most profound direct effect of waves on community structure is the creation of bare space allowing recruitment from the plankton. Denny *et al*. (2004) discusses the forces generated by waves on intertidal organisms in terms of patch dynamics, one of the most important processes by which rocky intertidal communities are structured. Unconsolidated substrates can be moved by the direct impact of waves, by wave run-up, and by wave generated currents. On beaches with mobile substrates, the particles can be rolled or entrained continually, seasonally, or episodically in high wave energy environments. Mobile substrates typically harbor fewer organisms than stable substrates, for example, rounded pebble and sand beaches are typically depauperate of macrobiota, while stable substrates such as bedrock, large boulders, and angular pebble beaches are relatively species rich. Intertidal fauna in heavy surf must have thick shells and strong muscular attachments (limpets and snails), permanent attachments (barnacles), or the ability to seek refuge in crevices or interstitial spaces (crabs and worms). The floral community must likewise adapt to the forces of the nearshore surf and swash zone, and in the absence of wave run-up, must also tolerate long hours of desiccation. The measurement of wave energy is therefore fundamental to understanding the structure of intertidal communities.

The Wave Exposure attribute is an estimate of the amount of wave energy that could potentially impact the intertidal zone of the unit. Howes *et al*. (1994) recommended that wave exposure be based on maximum fetch, where wave exposure increases with increasing fetch distance; therefore, the Wave Exposure attribute in ShoreZone is assumed to be a function of the fetch window of the unit. The standard definition of fetch is the length of water over which a given wind can be blown. However, that maximum fetch can be modified by several factors. Changes in coastal orientation, presence of offshore islands, or the proximity to shoaling bathymetry will attenuate the height and wavelength of open ocean waves. Protection may also be provided by a short sea fetch resulting from the distribution of land masses surrounding the unit. Thus, ShoreZone uses this attenuated or modified *effective* wave exposure to characterize the wave climate for alongshore units (Table 13).

Table 13. Definitions for the Wave Exposure attribute.

Effective Fetch Range (km)	Wave Exposure Category
<1	Very Protected
1-10	Protected
10–50	Semi-Protected
50–500	Semi-Exposed
500–1000	Exposed
>1000	Very Exposed

It is a rare to have the exposure change directly from the Exposed category to the Protected category in adjacent units, although it does occasionally occur. In most cases, there will be a transition zone that includes a few units of Semi-Exposed to Semi-Protected or both. For example, the entrance to a bay will tend to have a slightly higher exposure than the head of the bay due to its location and processes such as wave refraction.

Wave Exposure is another attribute that has been estimated for unit level mapping across the extent of ShoreZone. However, the method and the tools used to measure the maximum and effective fetch range have improved over the years including the addition of readily available satellite imagery via Google Earth and Arc GIS Earth, which also has GIS measuring tools. Given that improvement, it was decided to include an estimate of the Wave Exposure in SZE mapping.

Intertidal Zone Slope

This subunit attribute is the slope of the intertidal (B Zone), calculated using the equation: Slope = $\tan^{-1}$(Tidal Height/Intertidal Zone Width). Tidal Height is the projected (modelled) tide height or sea level elevation (in meters) of each unit on the day and time the imagery was taken. This estimate is taken from the nearest or most relevant tide station (from the NOAA Tides and Currents website). It should be noted that this estimate is only as accurate as the tide station information (which can be problematic along remote areas of the Alaska coast) and the width estimation using Structure from Motion. To account for that potential uncertainty, we created categories (Table 14) for the slope attribute to alleviate some of the potential sources of error as well as reduce inter-mapper variability. The slopes for the supratidal and intertidal zones are recorded as a slope category in the Zone table while the original calculated intertidal zone slope is recorded as an absolute number in the subunit table. This attribute was introduced in the most recent ShoreZone protocol (Cook *et al*. 2017) and has been carried over into the SZE protocol.

Table 14. ShoreZone Enhanced Slope Category definitions.

Slope Category	Degree Range
Flat	<2
Low Incline	2-4
Moderate Incline	5-10
High Incline	11-20
Steep	21-45
Very Steep	>45

Iribarren Category

Wave Exposure provides a good estimate of the total energy acting on a Unit; however, the morphology of the wave that results from the interaction of that energy with the slope of the beach face can also be an important factor in structuring the biotic community.

Wave morphology can be modelled for each unit by calculating how the slope and wave energy might interact using an algorithm called the Iribarren number (Battjes 1974). Table 15 shows the calculated Iribarren values for each Intertidal Slope Category/Wave Exposure category combination in the ShoreZone classification. This calculation also requires the wave height, period and interval for each Wave Exposure category. This information was taken from the U.S. Army Corps of Engineers wave prediction curves (Department of the Army 1984). These values are then rolled into four categories: Spilling, Plunging, Collapsing and Surging (see Figure 24 for illustration). The Plunging and Collapsing categories generally represent highly dynamic shorelines if the substrate is unconsolidated (Komar 1998). This attribute was introduced in the most recent ShoreZone protocol (Cook *et al*. 2017) and has been carried over into the SZE protocol.

Table 15. Iribarren Number value table for each Wave Exposure and Slope Category combination.

		Wave Exposure Category					
		Very Protected	Protected	Semi-Protected	Semi-Exposed	Exposed	Very Exposed
Slope Category	Flat	0.03	0.05	0.06	0.10	0.10	0.10
	Low Incline	0.15	0.27	0.32	0.49	0.48	0.52
	Moderate Incline	0.31	0.55	0.64	0.99	0.97	1.05
	High Incline	0.64	1.14	1.31	2.04	2.01	2.16
	Steep	1.77	3.13	3.61	5.59	5.53	5.93
	Very Steep	3.06	5.41	6.25	9.69	9.57	10.27
		Iribarren Number					

Iribarren Categories: Blue = Spilling, Green = Plunging, Yellow = Collapsing, Orange = Surging

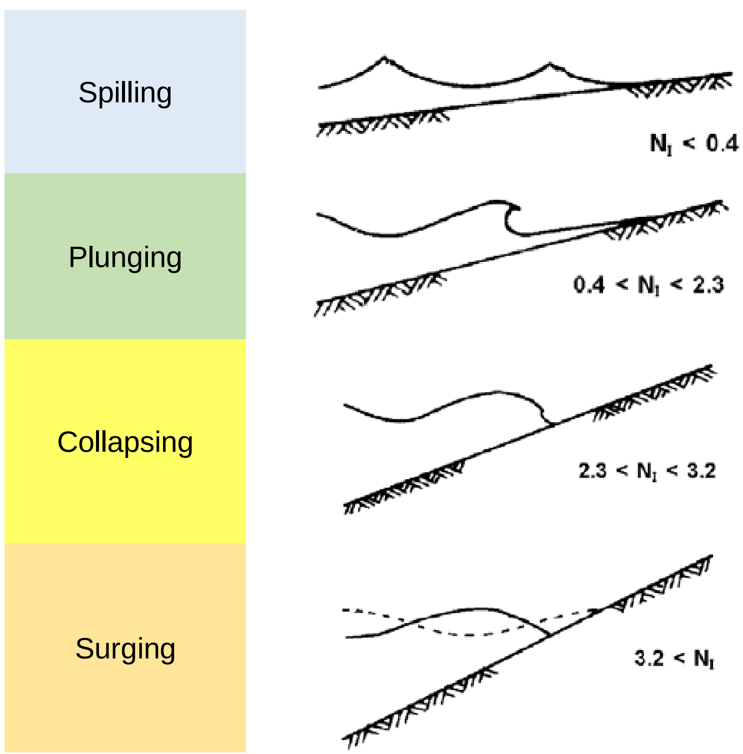


Figure 24. Illustration of the type of wave morphology represented by each Iribarren Category (after Komar 1998).

Aspect

Aspect is the shore normal compass direction the unit faces (Figure 25) and is useful to estimate the amount of insolation a unit receives. Shore unit Aspect can also affect the volume of debris accumulation, wave energy input, and wind and sun-induced desiccation. South-facing shorelines receive more sunlight which can cause evaporation from organisms directly exposed to its rays; therefore, some flora and fauna are more common on north facing beaches (or on north facing boulders) than on south facing aspects. The Aspect is recorded as one of the 8 cardinal compass points (i.e. N, NE, E, SE, S, SW, W, NW). This attribute was introduced in the most recent ShoreZone protocol (Cook *et al*. 2017) and has been carried over into the SZE protocol.

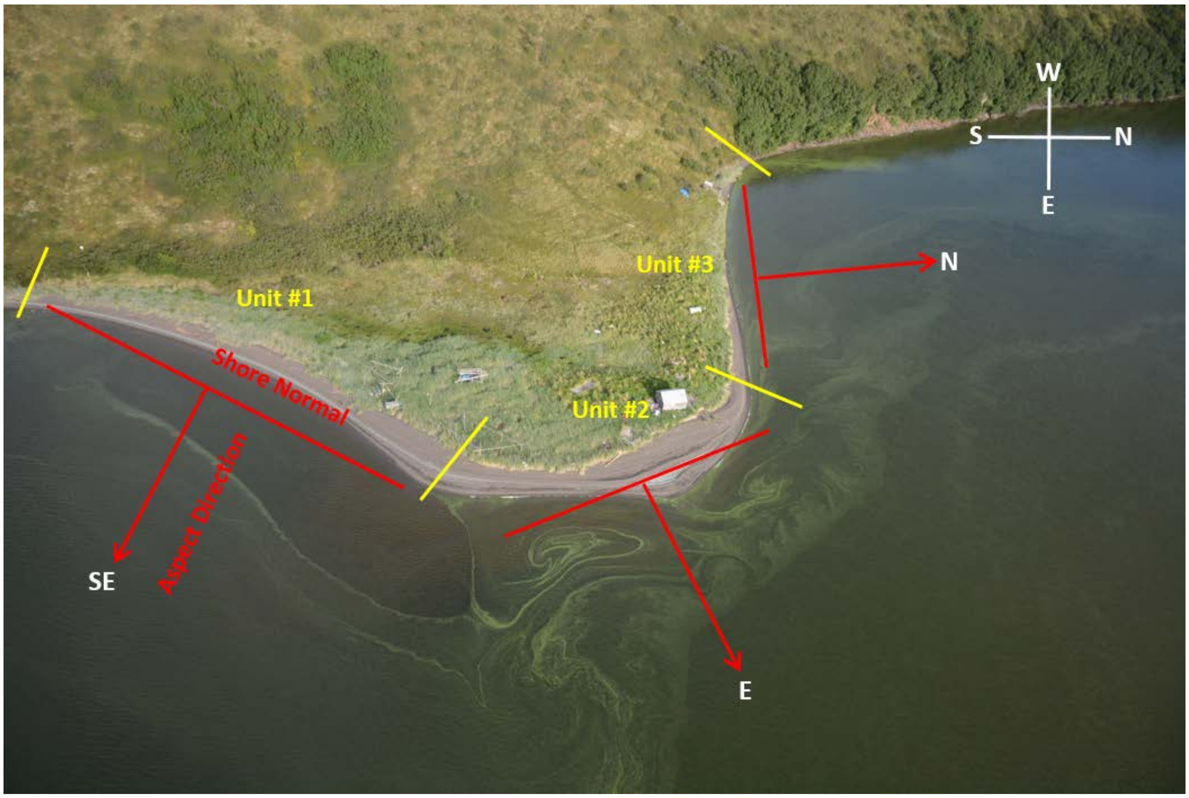


Figure 25. Determining the Aspect attribute of each ShoreZone Enhanced subunit.

Zone Process

The dominant structuring process (wave energy, glacial, current dominated etc.) for the supratidal and intertidal zones are estimated from clues present in the imagery. For example, a rip rap wall in the supratidal is structured by anthropogenic processes while a gravel and sand beach below it would be structured by across-shore waves. Therefore, each component in the supratidal and intertidal zones is given a process from the categories listed in Table 16. The subtidal zone Component is not given a process because it cannot be determined from the imagery.

Table 16. Categories and codes for the ShoreZone Enhanced Process attribute.

Process Category	Process Code
Anthropogenic (Impacted)	A
Eolian Transport (wind)	E
Gravity (mass-wasting)	M
Hydrologic (Across-shore Waves)	W
Hydrologic (Fluvial Current)	Cf
Hydrologic (Tidal Current)	Ct
Hydrologic (Alongshore Current)	Cx
Hydrologic Ice (Glacier)	Ig
Hydrologic Ice (Sea)	Is
Hydrologic Ice (River)	If
Hydrologic (Ponded)	Hr
Hydrologic Groundwater (Karst)	Hk
Hydrologic Groundwater (Seeps)	Hs
Periglacial (Slumping/Eroding)	Pe
Undefined/Other	X

3 BIOLOGICAL SHOREZONE ENHANCED MAPPING ATTRIBUTES

Biobands represent assemblages of coastal biota found on the shoreline at typical wave exposures, substrate conditions and across-shore elevations. Biobands are spatially distinct, with alongshore and across-shore patterns of color and texture that are visible in aerial imagery. Biobands are generally named for the dominant species or group that best describes the entire assemblage. Some Biobands are named for a single indicator species (such as the Blue Mussel Bioband), while others represent an assemblage of co-occurring species (such as the Red Algae Bioband). The indicator species listed for each Bioband are those which best describe the overall appearance and assemblage present for the band. The full Bioband list with associated color, texture and elevation can be found in Appendix B, Table B-1, B-2 and B-3.

A new nested Bioband classification scheme was developed and applied to all ShoreZone mapping completed after January 1st, 2015. Part of this scheme was the application of a new four-digit code for each Bioband with a consistent naming convention. Another part was the creation of Primary, Secondary and Tertiary Biobands which nest under each other with increasing specificity in terms of the biotic assemblage described. In addition, some of the original Biobands were split to better describe observed biota as ShoreZone continues to move into new areas and imaging resolution continues to improve. Some new Biobands were also added in response to ShoreZone surveys being conducted in Arctic areas that are fundamentally different from other coasts previously described by ShoreZone. The nested organization of the new scheme gives new options for analysis for Biobands that serve a similar ecological function, or those that can't be identified with high confidence, as they can now be rolled up into a well-defined 'higher level' Bioband for analysis. This facilitates regional comparisons within the ShoreZone dataset as Bioband names and descriptions have been added over time and over different regions. For example, there are five Tertiary Biobands described under the Secondary Bioband level of Wetland Vegetation, including three salt marsh Biobands from three different regions; however, all five Biobands look similar in the aerial imagery and serve similar ecological functions. By rolling them up into the Wetland Vegetation Bioband they could be analyzed with more confidence over a larger area of coastline.

Some Biobands are generally observed with higher confidence than others and may be visible as discrete patches at lower density than more obvious Biobands. For example, the Red Algae Bioband is usually low turf and mixed with kelp bands and therefore can be hidden by larger seaweeds. Often the Eelgrass and Surfgrass Biobands are easier to see, even if present as scattered patches, as they are usually a color contrast to the lower intertidal seaweed (often the large browns of the Soft-brown Kelps or the Dark Brown Kelps). The nearshore canopy kelps (Bull Kelp, Dragon Kelp and Giant Kelp) are also generally observed with higher confidence, as they all have large sized individuals and are easier to see even when the band is patchy.

Each Bioband observed in a unit is described using several metrics, which are outlined in Table 17. The metrics used to describe the Biobands have been simplified for the Enhanced mapping protocol to percent length, percent cover for the intertidal zone and a width category for the supratidal and subtidal Biobands. This links the Bioband occurrence to the spatial framework of ShoreZone, which is primarily based on the linear digital shoreline. An illustration of these metrics is found in Figure 26.

Table 17. Bioband metrics for the ShoreZone Enhanced Bioband attribute.

<table>
<tr><th>Zone</th><th>Bioband Length (% of unit)</th><th>Bioband Width Category</th><th>Percent Cover of Zone</th></tr>
<tr><td>Supratidal and Subtidal</td><td rowspan="2"><5%
5-25%
26-50%
51-75%
76-95%
>95%
Not Assessed</td><td>Narrow (<10 m),
Medium (10-30 m),
Wide (>30 m),
Not Assessed</td><td></td></tr>
<tr><td>Intertidal</td><td></td><td><5%
5-25%
26-50%
51-75%
76-95%
>95%
Not Assessed</td></tr>
</table>

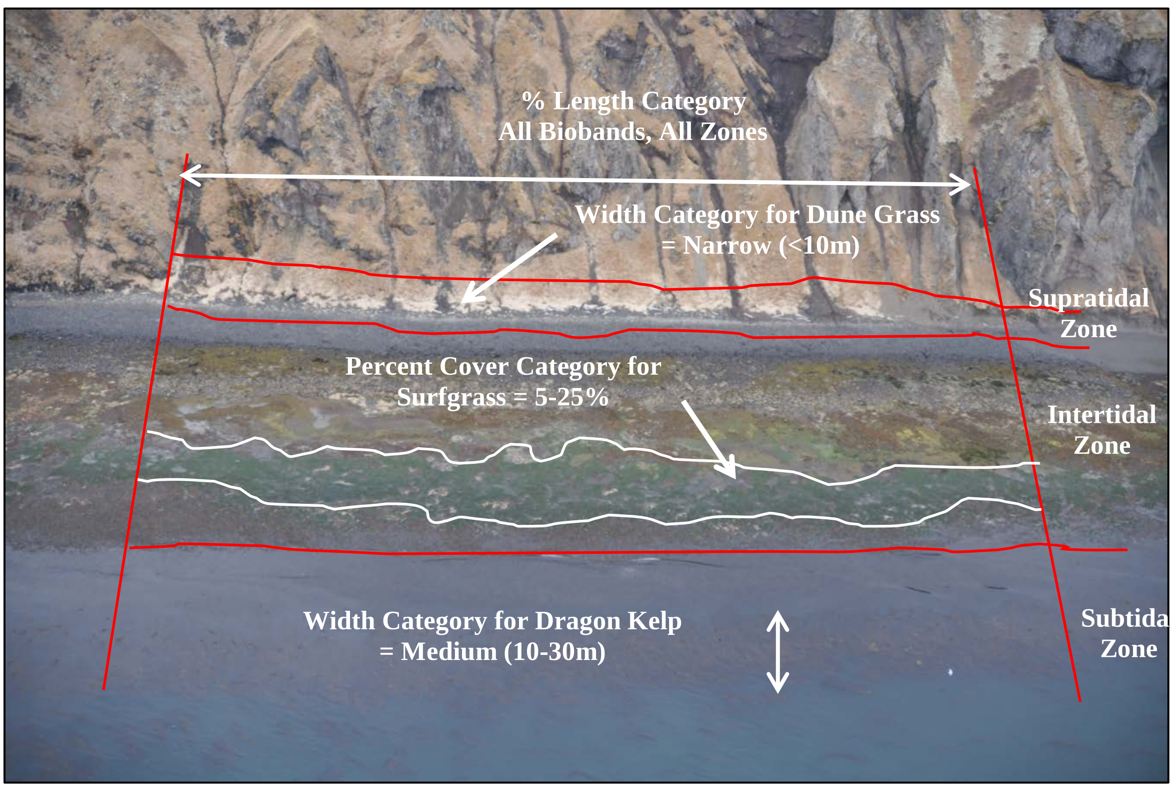


Figure 26. Illustration of the width metric for the supratidal Biobands not under the Splash Zone (SPZO) primary category and the subtidal Biobands, and the percent cover metric for intertidal Biobands.

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The 21 individual biobands mapped in Kachemak Bay are summarized in Tables 18 and 19 (see Appendix A, Table A-2 for photographic examples from the Kachemak Bay survey area). The survey area had more sediment beaches along the northern shore while the southern shore had more rocky inlets interspersed with estuaries and marshes. The most common intertidal biobands were Rockweed, Barnacle and Green Algae with Rockweed in more than 75% of the units and both Barnacle and Green Algae in over 50% of the units. The most common supratidal biobands were Dune Grass and Salt Marsh in 24% and 16% of the units, respectively (see Figures 27 and 28 for maps of the distribution of these biobands). Kelps were the most common subtidal vegetation observed, with two biobands recorded, Bladed Brown Algae and Soft Brown Kelps. Combined, these biobands are found in just over 70% of units. Eelgrass was not common overall (fewer than 10% of units) (see Figure 29 for distribution) nor were canopy kelps with Bull Kelp in only 2% of units and Dragon Kelp in 6% of units (see Figure 30 for distribution of both).

ShoreZone Enhanced mapping provides more detail on the distribution of the biobands in Kachemak compared to the original mapping. Figure 31 shows a comparison of the Rockweed bioband distribution between an original unit and the 4 subunits it was divided into. This represents an increase in resolution over the original ShoreZone data and an increase in the ability to spatially represent that data on a more detailed digital shoreline.

Table 18. Percent cover category for the intertidal biobands in the Kachemak Bay survey area.

Bioband Name	Bioband Code	Zone	Number of Units – Percent Cover Category (Intertidal Zone): <5%	5-25%	26-50%	51-75%	76-95%	>95%	Bioband Present, Percent Cover Not Assessed	Total Number of Units With Bioband Present*	% of Total Units with Bioband Present
Salt Marsh	SAMA	Upper to Mid-Intertidal (B)	10	67	22	11	3	0	0	113	6.0
Barnacle	BARN		105	897	105	9	2	0	2	1120	59.9
Rockweed	ROCK		62	1130	207	15	6	0	10	1430	76.5
Blue Mussel	BLMU		158	297	6	0	0	0	0	461	24.7
Green Algae	GRAL		157	808	53	1	0	0	2	1021	54.6
Bleached Red Algae	BRAL		3	10	0	0	0	0	0	13	<1
Filamentous and Foliose Red Algae	FFRA	Mid- to Lower Intertidal (B)	51	618	60	0	0	0	2	731	39.1
Surfgrass	SURF		2	1	0	0	0	0	0	3	<1
Eelgrass	EELG		3	106	41	6	1	0	1	158	8.5
Brown Bladed Algae	BRBA		2	55	4	0	0	0	0	61	3.3
Soft Brown Kelps	SOBK		67	662	18	2	0	0	14	763	40.8
Coralline Red Algae	CORA		0	8	0	0	0	0	0	8	<1

*Please note that Total Number of Units is used to describe the distribution of biobands rather than length (in kilometers) because biobands are usually not continuous along the entire length of a unit. A calculation could be performed to estimate length of a bioband over a region using the percent length metric in the dataset.

Table 19. Width category of supratidal and subtidal biobands in the Kachemak Bay survey area.

Bioband Name	Code	Zone	<1 m	1-5 m	>5 m	Bioband Present, Width Category Not Assessed	Total Number of Units With Bioband Present*	% of Total Units with Bioband Present
Splash Zone	SPZO	Splash Zone (A)	206	189	1	1	397	21.4
Black Lichen	BLLI	Splash Zone (A)	484	670	17	5	1176	63.3
White Lichen	WHLI	Splash Zone (A)	3	4	0	0	7	<1
Yellow Lichen	YELI	Splash Zone (A)	3	3	0	0	6	<1
			<10 m	**10-30 m**	**>30 m**	**Bioband Present, Width Category Not Assessed**		
Trees and Shrubs	TRSH	Supratidal (A)	6	27	86	0	119	6.4
Grasses	GRAS	Supratidal (A)	34	29	1	0	64	3.4
Dune Grass	DUGR	Supratidal (A)	364	74	5	1	444	23.9
Salt Marsh	SAMA	Supratidal (A)	192	46	61	2	301	16.2
Eelgrass	EELG	Subtidal (C)	39	49	12	16	116	6.2
Soft Brown Kelp	SOBK	Subtidal (C)	476	128	124	520	1248	67.1
Brown Bladed Algae	BRBA	Subtidal (C)	13	0	7	65	85	4.6
Bull Kelp	BUKE	Subtidal (C)	23	19	2	1	45	2.4
Dragon Kelp	DRKE	Subtidal (C)	70	23	12	2	107	5.8

*Please note that Total Number of Units is used to describe the distribution of biobands rather than length (in kilometers) because biobands are usually not continuous along the entire length of a unit. A calculation could be performed to estimate length of a bioband over a region using the percent length metric in the dataset.

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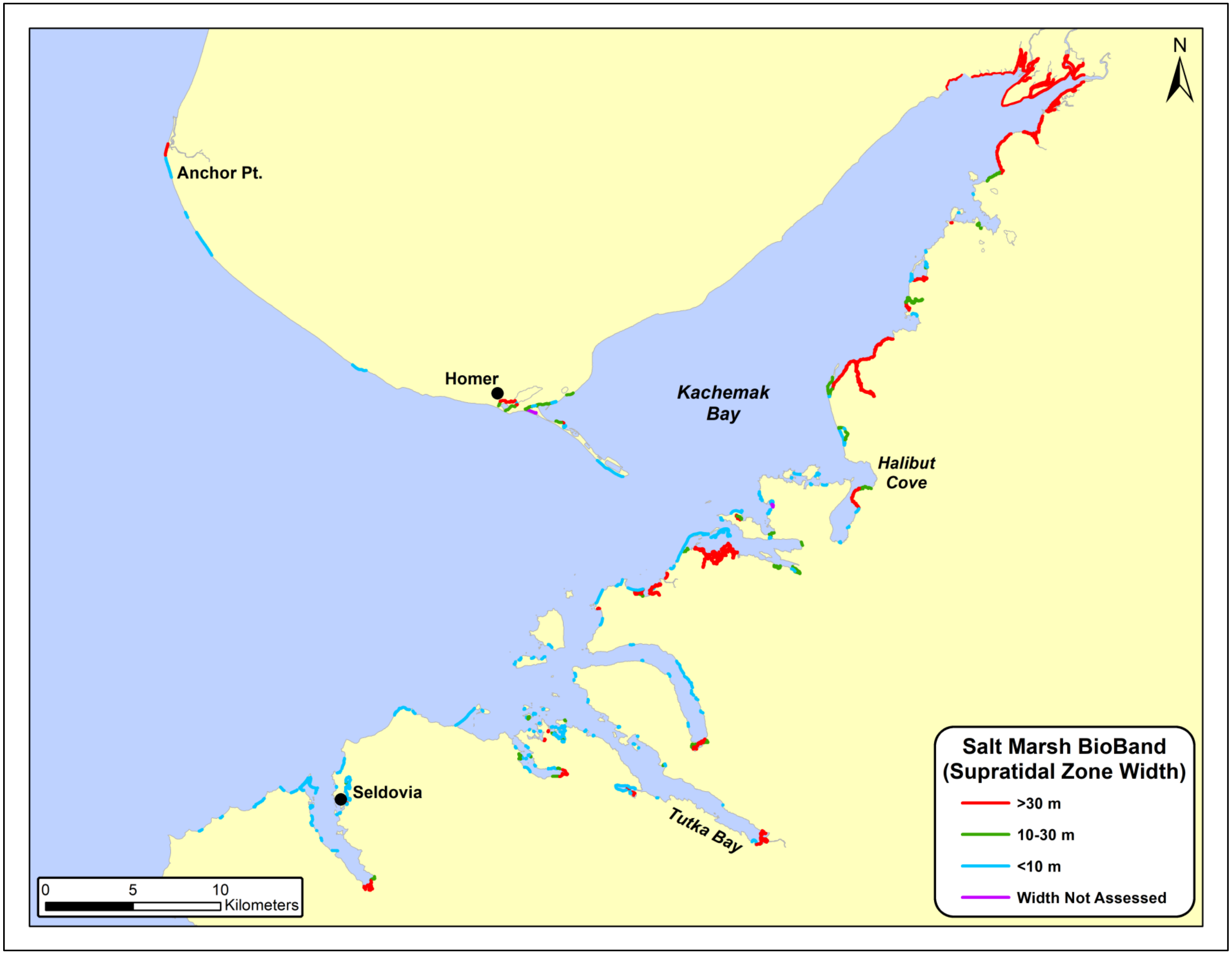

Figure 27. Distribution of the Salt Marsh bioband by Width Category in the supratidal zone of the Kachemak Bay survey area.

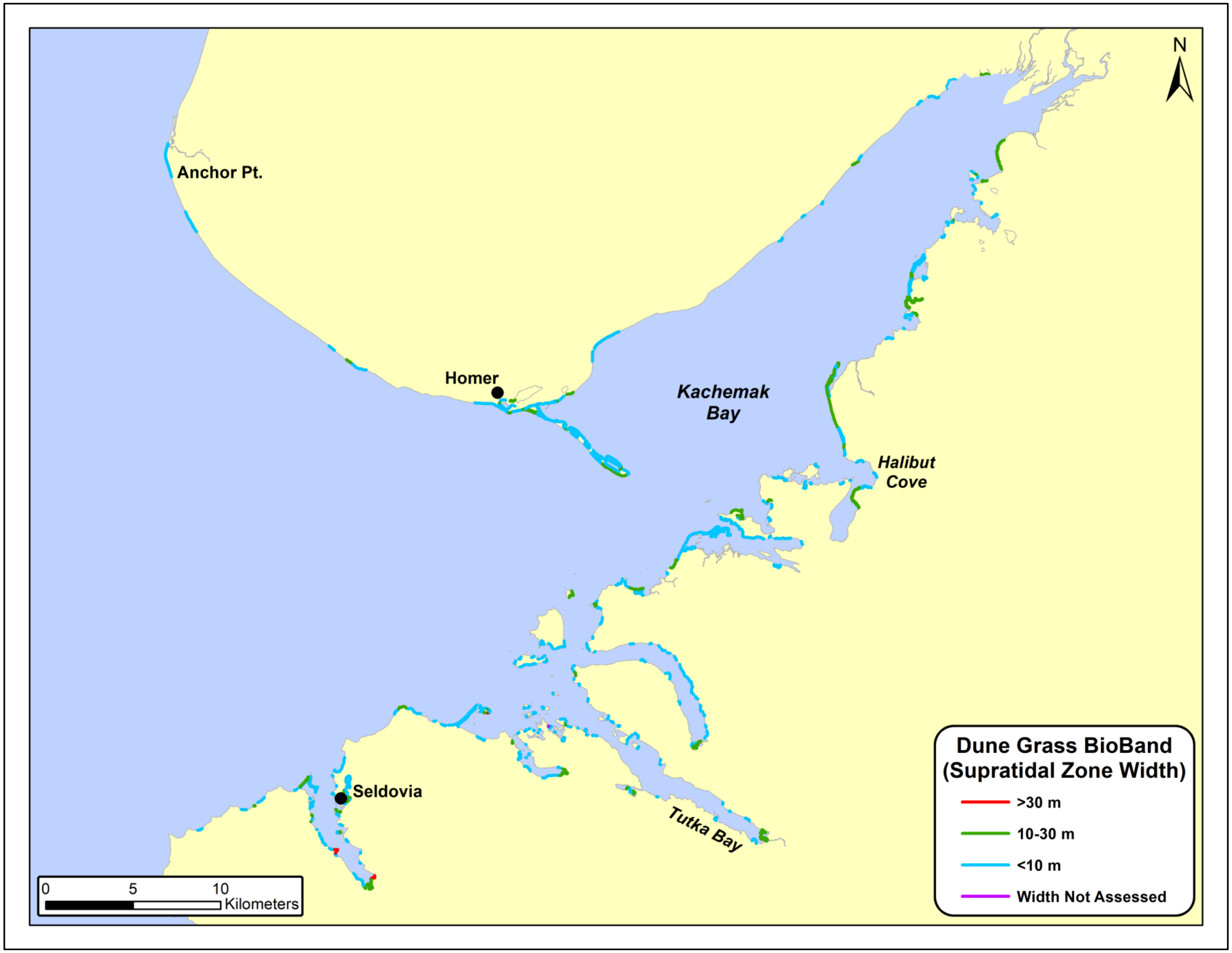

Figure 28. Distribution of the Dune Grass bioband by Width Category in the supratidal zone of the Kachemak Bay survey area.

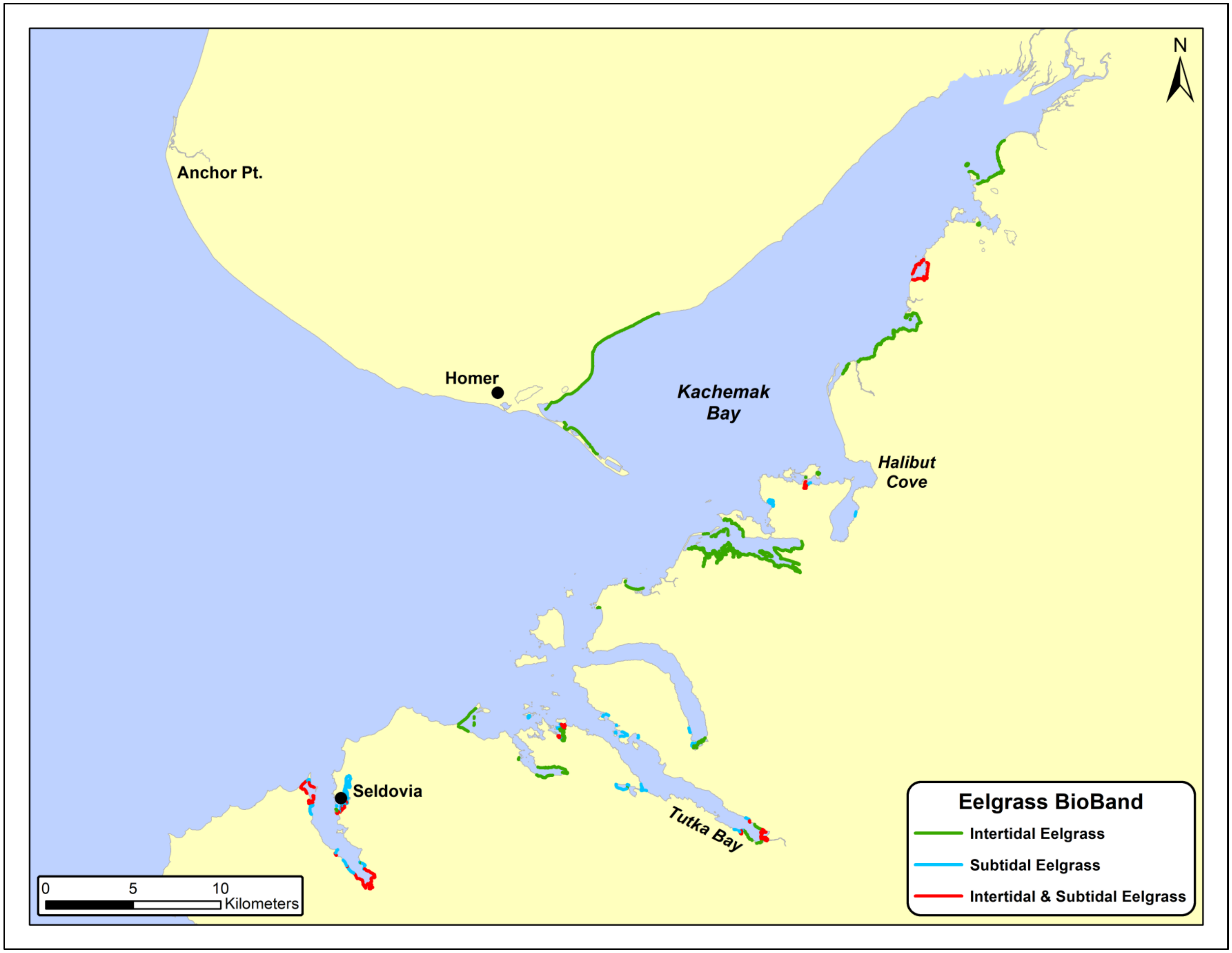

Figure 29. Distribution of the Eelgrass bioband by Width Category in the subtidal zone of the Kachemak Bay survey area.

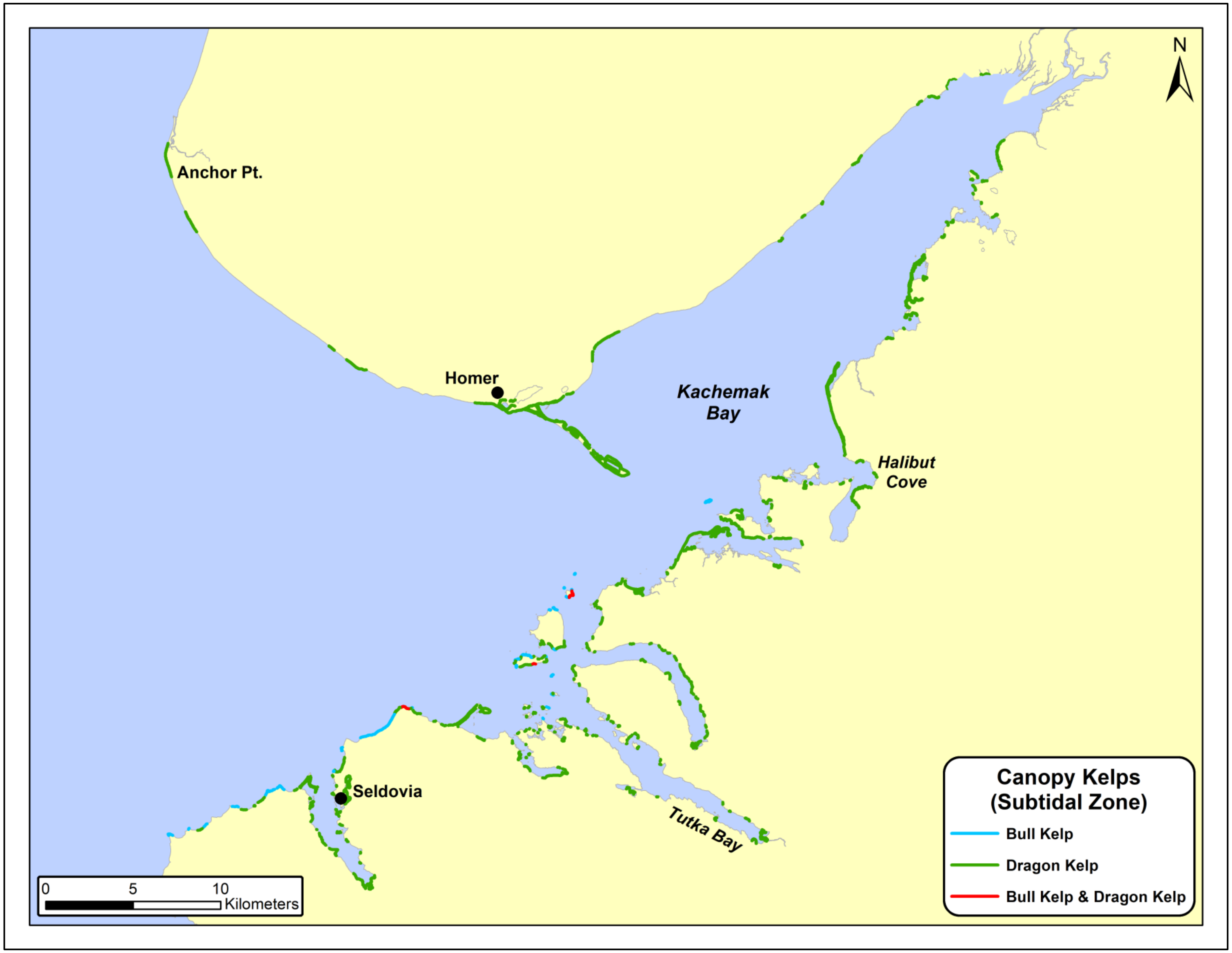

Figure 30. Distribution of the Bull Kelp and Dragon Kelp biobands by Width Category in the subtidal zone of the Kachemak Bay survey area.

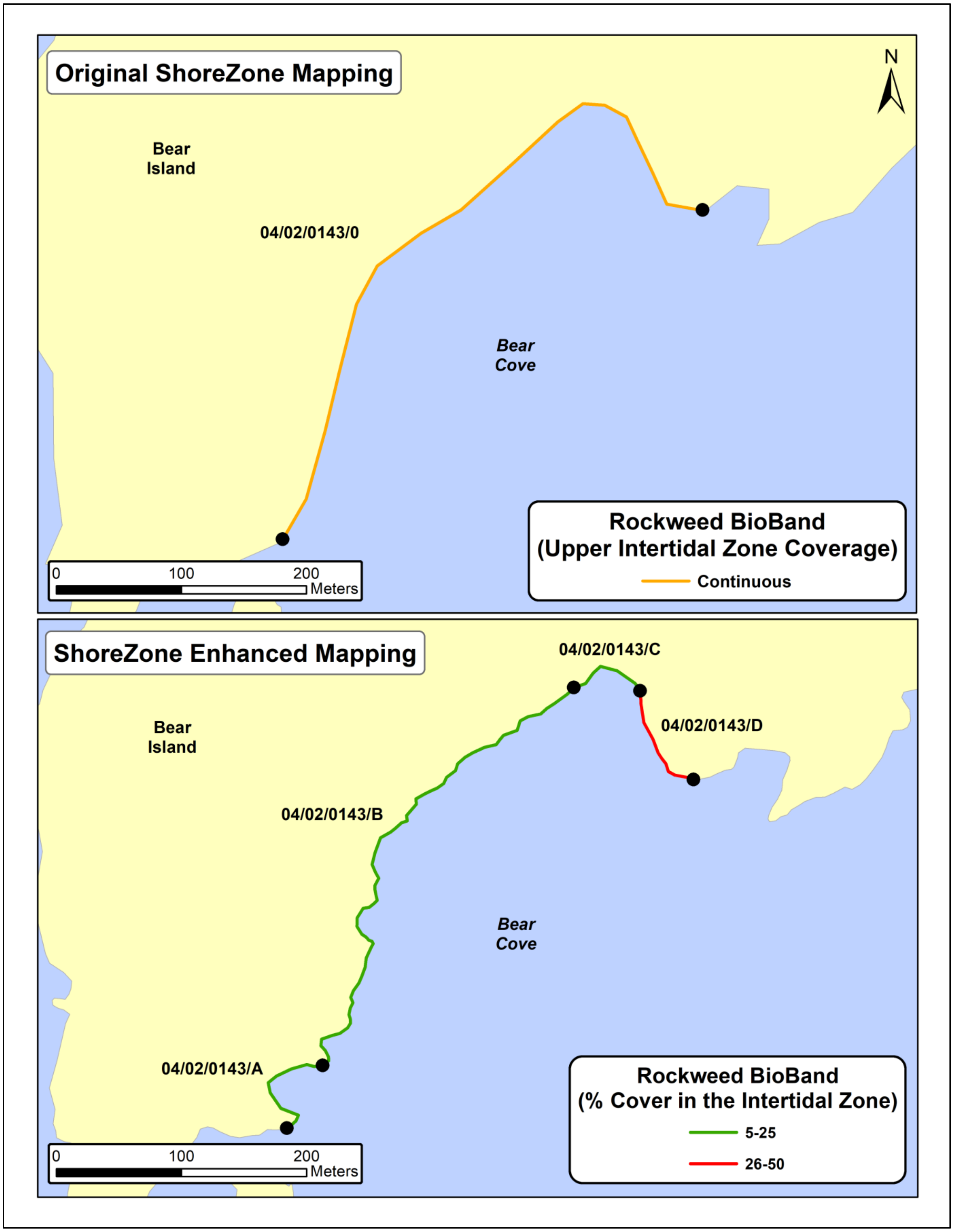

Figure 31. A comparison of the distribution of the Rockweed bioband in the original ShoreZone mapping (top) and percent cover of the Rockweed bioband from the Enhanced ShoreZone mapping (bottom). The original unit was split into 4 subunits which were each mapped separately providing more detail in the distribution of the biota.

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5 ACKNOWLEDGMENTS

We would like to thank the NOAA National Marine Fisheries Service for funding the imaging and mapping represented in this summary report. The ShoreZone program is a partnership of scientists, GIS specialists, web specialists, non-profit organizations and governmental agencies. We gratefully acknowledge the support of organizations working in partnership for the Alaska ShoreZone effort including: Alaska Department of Fish and Game, Alaska Department of Natural Resources, Archipelago Marine Research Ltd., Cook Inlet Regional Citizens' Advisory Council, Exxon Valdez Oil Spill Trustee Council, National Park Service, NOAA National Marine Fisheries Service, Prince William Sound Regional Citizens' Advisory Council, The Nature Conservancy, United States Fish and Wildlife Service, the University of Alaska and the US Forest Service.

Protocols for data access and distribution are established by the program partner agencies. Please see www.ShoreZone.org for a list of partner agencies and related web sites. Video imagery can be viewed, and digital stills downloaded online at www.ShoreZone.org. Any hardcopies or published data sets utilizing ShoreZone products shall clearly indicate their source. For questions regarding the protocols or information in this report, please contact Sarah Cook, General Manager of Coastal and Ocean Resources at Sarah@coastalandoceans.com (Tel: 250-658-4050). For data requests or analytical support contact Kalen Morrow at Kalen@coastalandoceans.com.

APPENDIX A

Photographic Examples of ShoreZone Enhanced Modified Coastal Classes and Biobands in Kachemak Bay

Table A-1. Examples of the Modified Coastal Classes in Kachemak Bay.

Photo ci09_hm_05715: Example of Modified Coastal Class 1; Rock.
Chugachik Island.

Photo ci09_hm_06535: Example of Modified Coastal Class 2; Mixed Rock and Gravel.
Kachemak Bay.

Photo ci09_hm_06179: Example of Modified Coastal Class 3; Mixed Rock and Gravel/Sand.
Ismailof Island.

Photo ci09_hm_05790: Example of Modified Coastal Class 4; Mixed Rock and Sand.
Bear Island, Bear Cove.

Photo ci09_hm_07356: Example of Modified Coastal Class 5; Gravel.
Tutka Bay.

Photo ci09_hm_07183: Example of Modified Coastal Class 6; Mixed Gravel and Sand.
Sadie Cove.

Photo ci09_hm_05190: Example of Modified Coastal Class 7; Sand.
Homer, AK.

Photo ci00_hm_05299: Example of Modified Coastal Class 8; Mixed Sand and Mud.
Homer, AK.

Photo ci09_hm_05872: Example of Modified Coastal Class 10; Mixed Substrate and Organics. Aurora Lagoon.

Photo ci09_hm_07235: Example of Modified Coastal Class 11; Organics. Sadie Cove.

Photo ci09_hm_05278: Example of Modified Coastal Class 12; Anthropogenic Substrate. Homer Harbor.

Table A-2. Examples of the most common biobands in Kachemak Bay.

Photo ci09_hm_05847: Good example of the Black Lichen (BLLI) bioband which is a black band in the supratidal zone, usually caused by the lichen *Verrucaria* sp. Near Bear Cove.

Photo ci09_hm_05098: Good example of the Splash Zone (SPZO) bioband which is recorded when the supratidal is too mobile for other biobands to occur. Near Bluff Point

Photo ci09_hm_05549: Good example of the Dune Grass (DUGR) bioband as a narrow blue-green strip at the top of the beach. North side Kachemak Bay.

Photo ci09_hm_05640: Good example of the Salt Marsh (SAMA) bioband which appears as a light green strip at the top of the beach and extending onto the flats of the delta. Fox River estuary.

Photo ci09_hm_06171: Good example of the Barnacle (BARN) bioband in the high intertidal. It appears white and beige on hard substrate. Near Ismailof island.

Photo ci09_hm_05152: Good example of the Rockweed (ROCK) bioband in the upper intertidal. Near Bluff Point.

Photo ci09_hm_05853: Good example of the black, velvety Blue Mussel (BLMU) bioband in the mid- to lower intertidal. Near Peterson Bay.

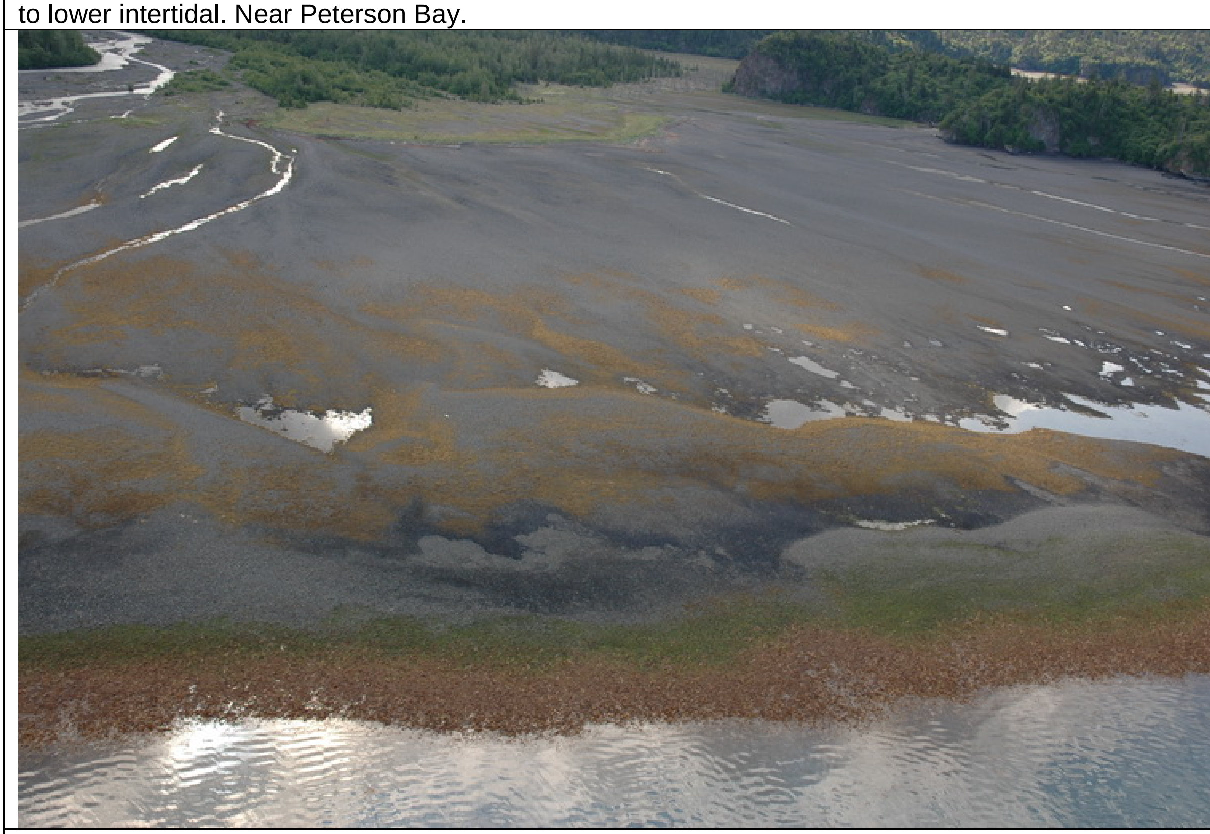

Photo ci09_hm_05919: Good example of the Green Algae (GRAL) bioband in the mid- to lower intertidal. Near Tutka Bay.

Photo ci09_hm_11612: Example of the Filamentous and Foliose Red Algae (FFRA) bioband in the lower intertidal, mixed with Bladed Brown Algae. Near Port Graham.

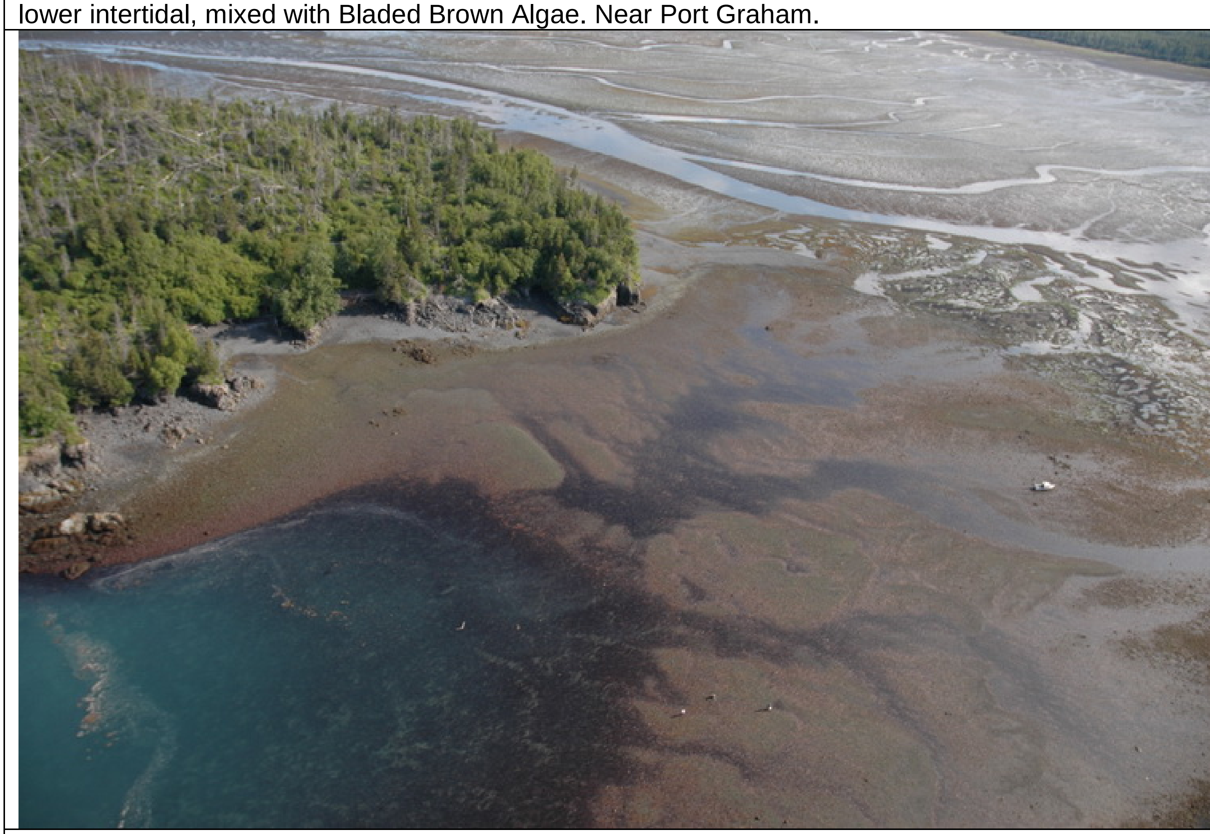

Photo ci09_hm_05721: Good example of the Soft Brown Bladed Kelps (SOBK) bioband in the lower intertidal, right at the waterline. Bear Island.

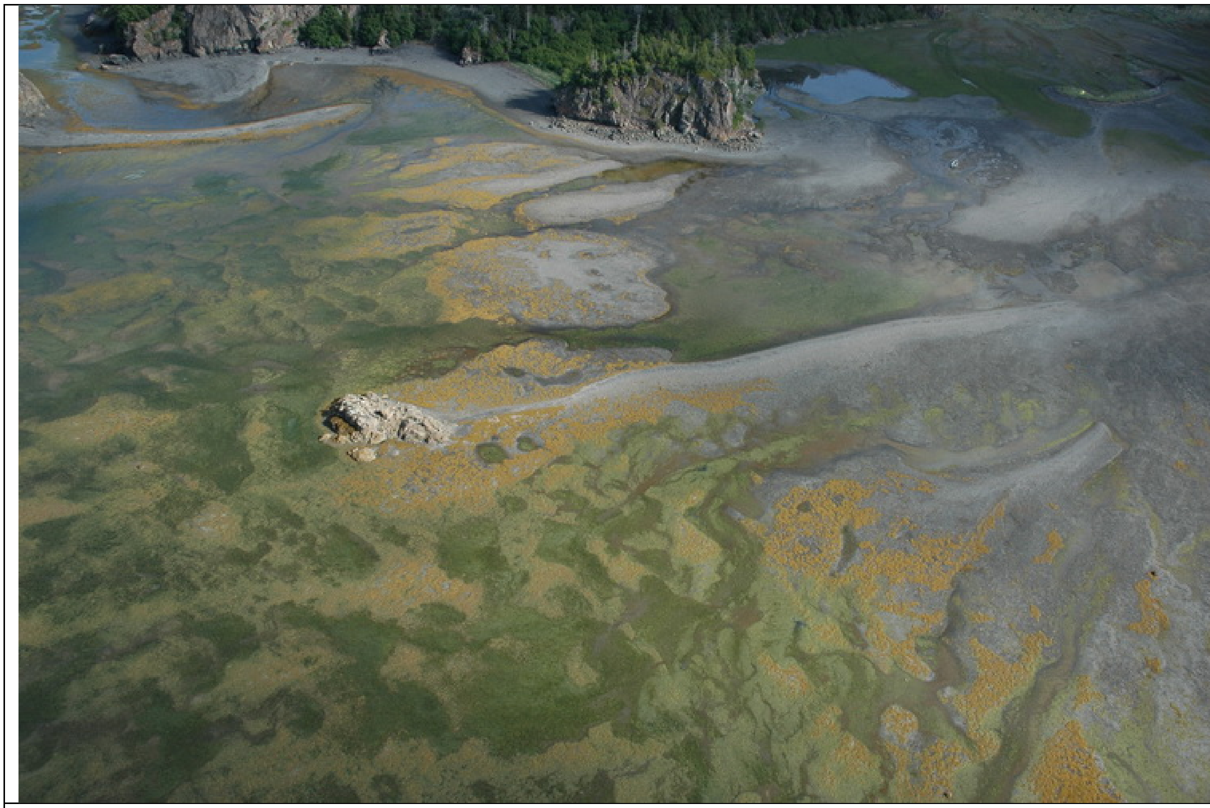

Photo ci09_hm_05932: Good example of the Eelgrass (EELG) bioband, mixed with Rockweed. Near Peterson Bay.

Photo ci09_hm_11690: Good example of the Dragon Kelp (DRKE) bioband as a narrow strip of canopy kelp in the subtidal. Near Port Graham.

Photo ci09_hm_12184: Example of the Bull Kelp (BUKE) bioband in shallow subtidal, on the outside of the Dragon kelp bioband. Near Nanwalek.

APPENDIX B

Full Bioband Tables for the ShoreZone Enhanced Mapping Protocol

Table B-1. Definitions for the supratidal Biobands. This combines Biobands used in Oregon State, Washington State, British Columbia and Alaska. Not all Biobands are applicable to all areas so it is noted in the Bioband description if it is specific to a certain region.

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Terrestrial Vegetation				**TEVE**	A	N/A	N/A	Non-specific vegetation existing in the supratidal zone that does not fit into any other more specific supratidal bioband or cannot be clearly identified from the imagery.	All
	Tundra		TUN	**TUND**	A	Green to Grey-green	*Salix* spp. *Vaccinium* spp. *Dupontia fisheri*	Low turf of dwarf shrubs, herbs, grasses, sedges with lichens and mosses, in uppermost supratidal and splash zone. May be inundated in storm surge.	All
	Trees & Shrubs			**TRSH**	A	Greens and browns	N/A	Non-specific trees and shrubs in the supratidal zone that do not fit into any other more specific tree/shrub bioband or cannot be clearly identified from the imagery.	All
		Deciduous Trees		**DETR**	A	Greens and browns, white-grey	*Alnus* spp. *Betula* spp.	This bioband consists mostly of stands of alder and birch trees mixed with understory shrubs in the supratidal zone. Mostly confined to river banks.	All
		Coniferous Trees		**COTR**	A	Greens and browns	*Picea* spp. *Pinus* spp.	This bioband consists mostly of stands of pine and spruce trees mixed with understory shrubs in the supratidal zone. Mostly confined to river banks.	All
		Shrub Meadow	MSH	**SHME**	A	Pale green	*Deschampsia caespitosa* *Picea sitchensis*	A narrow strip at the uppermost marsh edge, next to the tree line; usually a transition to spruce forest, including small spruce, shrubs and mixed grasses, sedges and herbs. Created for Oregon SZ.	VP to P
	Grasses			**GRAS**	A	Green to blue-green to beige	N/A	Non-specific grass in the supratidal zone that does not fit into any more specific grass bioband or cannot be clearly identified from the imagery.	All
		High Grass Meadow	MAG	**HIGM**	A	Pale grassy green or beige	*Deschampsia caespitosa* *Trifolium wormskjoldii*	Mixed grassy meadow, on uppermost salt marsh, interfingers with Salt Marsh (TRI) or Sedge (SED) at lower elevation transition. Specific to Oregon SZ	VP to P
		European Beach Grass	AMM	**EUBG**	A	Beige-green	*Ammophila* spp.	Outer coastal sand dunes, forming clumps and stabilizing active dunes. Non-native species which is displacing native dune grass species. Specific to Oregon.SZ.	SE to E
		Dune Grass	GRA	**DUGR**	A	Pale blue-green	*Leymus mollis*	Found in the upper intertidal zone, tall grasses observed as clumps continuous on dunes, in logline or on beach berms. This band may be the only band present on high-energy beaches.	VP to E

Table B-1. Con't

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Splash Zone			VER†	**SPZO**	A	Black, white or bare rock	N/A	Non-specific band marking the upper limit of the intertidal zone that does not fit into any more specific splash zone bioband. All bands in the splash zone are recorded by width: Narrow (<1m), Medium (1m-5m) or Wide (>5m)	All
	Lichen			**LICH**	A	Black, white to yellow/ green white	N/A	Non-specific lichen band in the supratidal zone that does not fit into any more specific splash zone bioband.	All
		Black Lichen		**BLLI**	A	Black to grey-black	*Verrucaria* sp. Encrusting black lichens	Visible as a dark stripe on bare rock marking the upper limit of the intertidal zone.	All
		White Lichen		**WHLI**	A	Creamy white to pinkish-grey	*Coccotrema maritimum* Encrusting white lichens	Visible as a bright white stripe on bare rock marking the upper limit of the intertidal zone. When present, this band usually occurs above the Black Lichen band.	All
		Yellow Lichen		**YELI**	A	Bright to dark yellow or orange	*Caloplaca* spp. *Xanthoria* spp.	Visible as bright yellow to dark orange blotches, sometimes forming a stripe, on bare rock. Usually co-occurs with the Black Lichen bioband.	SE to VE

†The previous Splash Zone Bioband (VER) has been split into several current Bioband codes (LICH, BLLI, WHLI, YELI) so these bands would need to be rolled together for comparison with the VER Bioband.

Table B-2. Definitions for the invertebrate Biobands. This combines Biobands used in Oregon State, Washington State, British Columbia and Alaska. Not all Biobands are applicable to all areas so it is noted in the Bioband description if it is specific to a certain region.

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	Secondary Level	Tertiary Level							
Invertebrate				**INVE**	B & C	N/A	N/A	Non-specific band of invertebrates that does not fit into any more specific invertebrate bioband or cannot be clearly identified from the imagery.	All
	Crustaceans			**CRUS**	B	N/A	N/A	Non-specific band of crustaceans that does not fit into any more specific bioband or cannot be clearly identified from the imagery.	All
		Barnacle	BAR‡	**BARN**	B	Grey-white to pale yellow	*Balanus glandula* *Semibalanus cariosus*	Visible on bedrock or large boulders. Can form an extensive band in higher exposures where algae have been grazed away.	P to VE
		Mud Flat Shrimp	CAL	**MUFS**	B	Mottling on sand flats, burrows	*Neotrypaea californiensis* *Upogebia pugettensis*	On sand/mud flats in larger estuaries, where textured surface indicates presence of infauna. Specific to Oregon and Washington State SZ.	VP to P
	Molluscs			**MOLL**	B	N/A	N/A	Non-specific band of molluscs that does not fit into any more specific bioband or cannot be clearly identified from the imagery.	All
		Blue Mussels	BMU	**BLMU**	B	Black or blue-black	*Mytilus trossulus*	Visible on bedrock and on boulder, cobble or gravel beaches. Appears in dense clusters that form distinct black patches or bands, either above or below the barnacle band.	P to VE
		California Mussels	MUS	**CAMU**	B	Grey-blue	*Mytilus californianus*	Dominated by a complex of California mussels (*Mytilus californianus*) and thatched barnacles (*Semibalanus cariosus*) with gooseneck barnacles (*Pollicipes polymerus*) seen at higher exposures.	SE to VE
		Oyster	OYS	**OYST**	B	Dark beige to brown	*Crassotrea gigas*	Generally inconspicuous and of limited extent in BC. Includes areas of oyster aquaculture on mudflats in Oregon and Washington State, in particular in Coos Bay and Yaquina Bay. Specific to Oregon, BC and Washington State SZ.	VP to P

‡ The previous Barnacle (BAR) bioband has been split into BARN and WILA (described in Table 27) so these would have to be rolled together to be equal to the previous BAR band.

Table B-2. Con`t

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Invertebrate	Sponges			**SPON**	B & C	Commonly yellow, purple or red	N/A	Encrusting sponges usually occur as brightly colored patches at the waterline or in the shallow subtidal. Associated with high wave energy or current-dominated habitats.	SP to E
	Cnidarians			**CNID**	B & C	N/A	N/A	Non-specific band of cnidarians that does not fit into any more specific bioband or cannot be clearly identified from the imagery.	All
		Anemones		**ANEM**	B & C	Usually white to yellow and red	N/A	Anemones usually appear as small circular dots of colour in the low intertidal and shallow subtidal. It is usually associated with high wave energy or current-dominated habitats. Could include *Metridium* spp. and *Urticina* spp.	SP to E
	Echinoderms			**ECHI**	B & C	N/A	N/A	Non-specific band of echinoderms that does not fit into any more specific bioband or cannot be clearly identified from the imagery.	All
		Urchin Barrens	URC	**URBA**	C	Coralline pink/white	*Strongylocentrotus franciscanus*	Shows rocky substrate clear of macroalgae. Often has a pink-white color of encrusting coralline red algae. May or may not see urchins.	SP to E
		Sand Dollars	DEN	**SAND**	Lower B & Upper C	Black spots within beige sand matrix	*Dendraster excentricus*	Beds of sand dollars, usually on sand beaches. Specific to Washington State SZ.	P to SE

Table B-3. Definitions for the intertidal/subtidal vegetation Biobands. This combines Biobands used in Oregon State, Washington State, British Columbia and Alaska. Not all Biobands are applicable to all areas therefore it is noted in the Bioband description if it is specific to a certain region.

Bioband Name			**Prior Code**	**Current Code**	**Zone**	**Typical Color**	**Indicator Species**	**Description**	**Biological Wave Exposure**
Primary Level	**Secondary Level**	**Tertiary Level**							
Intertidal/ Subtidal Vegetation				**INSV**	B & C	N/A	N/A	Non-specific intertidal or subtidal vegetation that does not fit into a more specific bioband or cannot be clearly identified from the imagery.	All
	Wetland Vegetation			**WEVE**	A & upper B	Greens and browns	N/A	Non-specific wetland vegetation in the supratidal zone that does not fit into any more specific wetland bioband or cannot be clearly identified from the imagery.	VP to E
		Sedges	SED	**SEDG**	A & upper B	Bright green to yellow-green	*Carex lyngbyei*	In wetlands around lagoons and estuaries. Usually associated with freshwater. This band can exist as a wide flat pure stand or be intermingled with dune grass. Often the SAMA band forms a fringe below.	VP to SE
		Spartina	SPA	**SPAR**	Upper & mid B	Bright green	*Spartina* spp.	*Spartina*-invaded and *Spartina*-dominated salt marshes and mudflats. Specific to Washington State.	P to SP
		Salt Marsh	PUC	**SAMA**	A & upper B	Light, bright or dark green with red-brown	*Puccinellia* spp. *Plantago maritima* *Glaux maritime* *Deschampsia* spp.	Appears around estuaries, marshes, and lagoons and is usually associated with freshwater. In some areas, it can be sparse plants on coarse sediment or a wetter, peaty meadow with associated herbs and sedges.	VP to SE
		Salt Marsh (Oregon & Washington State)	TRI	**SAMO**	A & upper B	Light, bright or dark green with red-brown	*Triglochin maritima* *Distichlis spicata* *Deschampsia caespitosa*. *Scirpus americanus* *Salicornia virginica*	Appears around estuaries, marshes, and lagoons, associated with fresh water. Separated as 'high marsh' and 'low marsh' according to elevation/salt water inundation in Oregon, but describes only a 'high marsh' in Washington State. Can be sparse vegetation on coarse sediment or a wetter, peaty meadow with an assemblage of herbs, grasses and sedges. Specific to Oregon and Washington State SZ.	VP to SE
		Salt Marsh (BC & Washington State)	SAL	**SAMB**	A & upper B	Light, bright, or dusty green	*Salicornia virginica*	Salt-tolerant herbs and grasses associated with freshwater. This band is often associated with estuaries, marshes, and lagoons although it is not uncommon as a fringing meadow in the supratidal. Used to describe a 'low marsh' in Washington State and generally lacking associated grass species in that classification. Specific to BC and Washington State.	SE to VP

Table B-3. Con't

Bioband Name			Prior Code	Curren t Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Intertidal/ Subtidal Vegetation	Biofilm		BFM	**BIOF**	B	Rusty orange-beige or dark green-black	Bacterial or diatom mat, blue-green algal mat	Low turf or stain on sediment. Includes moss-like turf of blue-green algal mat. Usually seen in pools of washover bars and river deltas.	P to SE
		Diatom	DIA	**DIAT**	B	Beige or bleached white	Diatoms	This band describes bare-looking lower intertidal areas in the coastal fjords of BC where a low turf of encrusting filamentous diatoms may be present. Specific to BC SZ.	P to SP
	Green Algae		ULV	**GRAL**	B	Various shades of green	*Ulva* sp. *Monostroma* sp. *Cladophora* sp. *Acrosiphonia* sp.	Found on a variety of substrates. The band consists of filamentous and/or foliose green algae. Filamentous species often form a low turf of dark green.	VP to E
	Red Algae		RED†	**REAL**	B	Various shades of red, pink, gold	N/A	Non-specific band of red algae that does not fit into a more specific red algae bioband or cannot be clearly identified from the imagery.	P to VE
		Coralline Red Algae		**CORA**	B	Pink to whitish-pink	*Corallina* sp. *Lithothamnion* sp.	A combination of foliose and encrusting coralline algae occurring in the low intertidal. Lush coralline red algae indicate highest wave exposures.	SE to VE
		Filamentous and Foliose Red Algae		**FFRA**	B	Dark to bright red and red-brown	*Odonthalia* sp. *Neorhodomela* sp. *Palmaria* sp. *Neoptilota sp.* *Mazzaella* sp.	Diversity of foliose red algae indicates medium to high exposures, with filamentous species, often mixed with green algae, occurring at medium and lower exposures.	P to E
		Winter Laver	BAR‡	**WILA**	Upper B	Pale green to greenish-gold	*Porphyra pseudolanceolata* *Porphyra hiberna*	These species of *Porphyra* grow in the high intertidal of more exposed coasts in the winter season (sometimes seen in spring or summer in colder climes). *P. hiberna* replaces *P. psuedolanceolata* south of Sitka Sound. It is associated with the Barnacle bioband.	SE to E
		Bleached Red Algae	HAL	**BRAL**	B	Olive, golden or yellow-brown	Bleached foliose/ filamentous red algae	Common on bedrock platforms, and cobble or gravel beaches. Distinguished from the FFRA band by color, although may be similar species. The bleached color usually indicates lower wave exposure.	P to SP
		Graceful Red Weed	GCA	**GRRW**	B	Dark reddish brown	*Gracilaria* spp.	Usually present as patches in the mid-intertidal on sandy and muddy tidal flats. Specific to Washington State SZ.	P to SP

Table A-18. Con't

Bioband Name			Prior Code	Current Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Intertidal/ Subtidal Vegetation	Rooted Vegetation			**ROVE**	B & C	Green to green-grey	N/A	Non-specific rooted vegetation in the lower intertidal and/or shallow subtidal that do not fit in any more specific intertidal/subtidal bioband or cannot be clearly identified from the imagery.	VP to SE
		Surfgrass	SUR	**SURF**	B & C	Bright to dark green	*Phyllospadix* sp.	Appears in tide pools on rock platforms, often forming extensive beds. This species has a clearly defined upper exposure limit of Semi-Exposed and its presence in units of Exposed wave energy indicates a wide across-shore profile, where wave energy is dissipated by wave run-up across the broad intertidal zone.	SP to SE
		Eelgrass	ZOS	**EELG**	B & C	Bright to dark green	*Zostera marina*	Commonly visible in estuaries, lagoons or channels, generally in areas with fine sediments. Eelgrass can occur in sparse patches or thick dense meadows.	VP to SP
	Brown Bladed Algae			**BRBA**	B & C	Various shades of brown	N/A	Non-specific bladed brown algae in the lower intertidal and/or shallow subtidal that do not fit in any more specific kelp bioband or cannot be clearly identified from the imagery.	All
		Alaria	ALA	**ALAR**	B & C	Dark brown to red-brown	*Alaria marginata*	Common on bedrock cliffs and platforms, and on boulder/cobble beaches. This band has a distinct ribbon-like texture, and may appear iridescent..	SP to E
		Soft Brown Kelps	SBR	**SOBK**	B & C	Brown to yellow-brown to olive	*Saccharina latissima* *Cystoseira sp.* *Sargassum muticum*	This band is defined by non-floating large browns and can form lush bands in semi-protected areas. The kelp fronds have a ruffled appearance and can be encrusted with diatoms and bryozoans giving the blades a 'dusty' appearance.	VP to SE
		Dark Brown Kelps	CHB	**DABK**	B & C	Dark brown	*Laminaria setchelli* *Lessoniopsis littoralis* *Laminaria longipes* *Laminaria yeozensis*	Found at higher wave exposures, these stalked kelps grow in the lower intertidal. Blades are leathery, shiny, and smooth. A mixture of species occurs at the moderate wave exposures, while single-species stands of *Lessoniopsis* occur at high exposures.	SE to VE

Table A-18. Con't

Bioband Name			Prior Code	Curren t Code	Zone	Typical Color	Indicator Species	Description	Biological Wave Exposure
Primary Level	**Secondary Level**	**Tertiary Level**							
Intertidal/ Subtidal Vegetation	Brown Non-Bladed Algae			**BRNA**	B & C	Various shades of brown	N/A	Non-specific non-bladed brown algae that does not fit into a more specific algal bioband or cannot be clearly identified from the imagery.	All
		Rockweed	FUC	**ROCK**	B	Golden-brown to brown	*Fucus distichus*	Appears on bedrock cliffs and boulder, cobble or gravel beaches. Commonly occurs at the same elevation as the barnacle band.	VP to E
		Sargassum	SAR	**SARG**	Lower B & C	Golden-brown to brown	*Saragssum muticum*	This bioband descrbes continuous stands of Sargassum in the lower intertidal and nearshore subtidal. It is often 'fuzzy' looking and golden-brown in colour. Specific to Washington State SZ.	P to SP
	Brown Canopy-Forming Algae			**BRCA**	C	Dark brown	N/A	Non-specific canopy kelp that does not fit into any more specific canopy kelp bioband or cannot be clearly identified from the imagery.	P to VE
		Dragon Kelp	ALF	**DRKE**	C	Dark brown to golden-brown	*Eularia fistulosa*	Canopy-forming kelp, with winged blades on gas-filled center midrib. Usually associated with silty, cold waters near glacial outflow rivers. Range: southern Southeast AK to Aleutian Islands, AK.	SP to SE
		Giant Kelp	MAC	**GIKE**	C	Dark brown to golden-brown	*Macrocystis pyrifera*	Canopy-forming giant kelp, long stipes with multiple floats and fronds. If associated with NER, it occurs inshore of the bull kelp. Range: Baja California, Mexico to Kodiak Islands, AK.	P to SE
		Bull Kelp	NER	**BUKE**	C	Dark brown	*Nereocystis luetkeana*	Distinctive canopy-forming kelp with many long strap-like blades growing from a single floating bulb atop a long stipe. Can form an extensive canopy in nearshore habitats, usually further offshore than *Eularia fistulosa* and *Macrocystis pyrifera*. Often indicates higher current areas if observed at lower wave exposures. Range: Point Conception, CA to Unimak Island, AK.	SP to VE

[†] The previous Red Algae (RED) bioband has been split into CORA and FFRA. These need to be combined to be equal to the old RED band (NOT including WILA, GRRW or BRAL).

[‡] WILA used to be an associate species for the old Barnacle (BAR) band and was not mapped as a separate band as the surveys were often completed in the summer months when WILA is not present.