

**Alaska - Yukon Arctic Ecoregional Assessment  
 Update #6: Coastal Ecosystem Model**



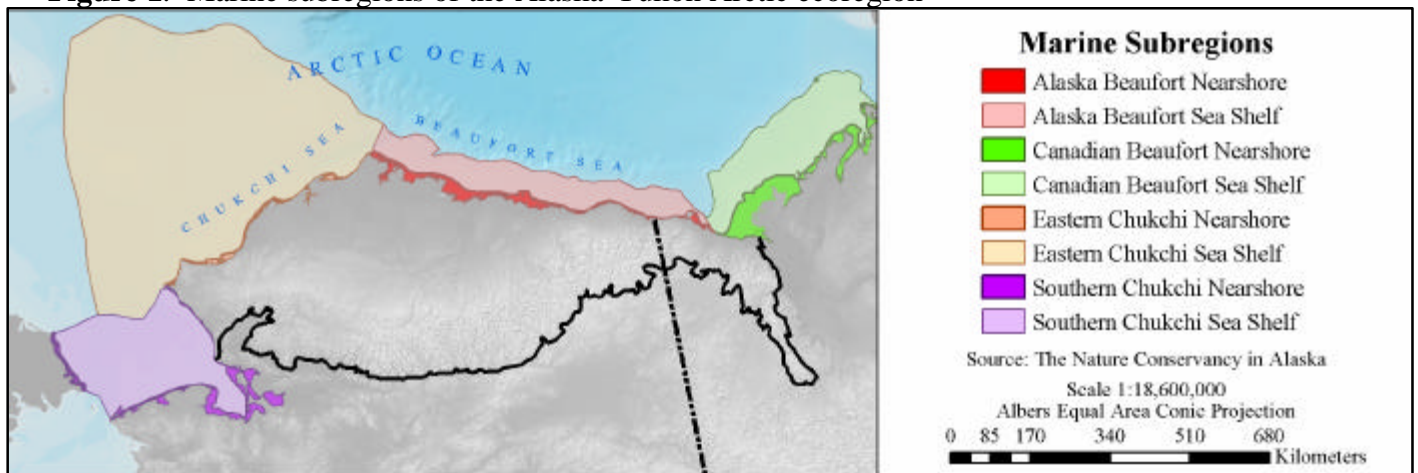
**Introduction**

This update describes the development of a coastal ecosystems model and a proposal for a bathymetry/habitat complexity<sup>1</sup> map for the Alaska-Yukon Arctic ecoregion. We developed these data sets to characterize the biodiversity of the nearshore environment for the ecoregional assessment. The coastal ecosystems classification is based largely on physical features, since we have only limited and incomprehensive knowledge about the biological components of the nearshore marine environment in this ecoregion.

**Describing the marine environment**

We partitioned the marine environment into two zones – nearshore and offshore. The nearshore generally extends to 10 meters in depth, while the offshore environment generally extends to 200 meters in depth in the Beaufort and Chukchi Seas. Deeper waters were not included in the assessment. In order to represent the targets of our conservation interest--species and ecosystems--across the environmental gradients of their distribution, we stratified these two zones into subregions, with two nearshore and two offshore subregions in both the Chukchi and Beaufort Seas, for a total of 8 marine subregions (Figure 1). Stratification was based primarily on bathymetry, ocean currents, sea ice, and salinity. See Appendix 1 for descriptions of the subregions.

**Figure 1.** Marine subregions of the Alaska-Yukon Arctic ecoregion



<sup>1</sup> Bathymetry is the measurement of the depth of the ocean floor from the water surface. It is the oceanic equivalent of topography.

## Coastal Ecosystem Classification

For conservation planning purposes, we need to understand broad patterns of habitat distribution. We developed a coastal ecosystem classification and map to compare habitats across the ecoregion in a consistent and comprehensive manner. Because we wanted our classification to reflect biodiversity, we made the assumption that different types of habitats were likely to harbor different aggregations of species. For example, we hypothesized that rocky shorelines likely have different species assemblages than sandy shorelines. Therefore, we built our classification using physical components of the shoreline that influence the distribution of nearshore biodiversity.

Our classification was built in three steps:

1. Describing the shoreline of the Alaska portion of the ecoregion
2. Simplifying shoreline types to representative landforms
3. Incorporating information about wave exposure

### **Step 1: Describing the Shoreline**

The most comprehensive data set for shoreline information was the Environmental Sensitivity Index (ESI) developed by the National Oceanic and Atmospheric Administration (NOAA). ESI maps provide information about the relative sensitivity of shoreline areas to oil contamination in the event of an oil spill.

ESI maps assemble data in standard formats. Along the 6,600-km Alaskan coastline of the ecoregion, ESI describes 20 major ESI shore types (Table 1).<sup>2</sup> In many cases on the ESI maps, shoreline segments are attributed with multiple codes to describe different parts of the intertidal zone (i.e., high, medium, and lower) along one segment of shoreline (e.g., 6B/3A). In the Alaska-Yukon Arctic, multiple codes produce 147 different ESI combinations across 7,043 shoreline segments.

**Table 1.** ESI shoreline types in the Alaska-Yukon Arctic ecoregion. Types are numbered in order from least sensitive to damage from spilled oil or chemicals to most sensitive.

ESI CODE	DESCRIPTION	ESI CODE	DESCRIPTION
1A	Exposed rocky shoreline	6B	Riprap
1B	Exposed, solid man-made structure	7	Exposed tidal flats
2A	Exposed wave-cut platforms in bedrock, mud, or clay	8A	Sheltered scarps in bedrock, mud or clay
2B	Exposed scarps and steep slopes in clay	8B	Sheltered, solid man-made structure
3A	Sand beaches (fine to medium)	8E	Peat shorelines
3B	Scarps and steep slopes in sand	9A	Sheltered tidal flats
3C	Tundra cliffs	9B	Vegetated low banks
4	Sand beaches (coarse)	10A	Salt and brackish water marshes
5	Mixed sand and gravel beaches	10E	Inundated low lying tundra
6A	Gravel beaches	U	Undefined

<sup>2</sup> Because ESI information does not exist for Canada, we were unable to include Canada in our classification.

## Step 2: Simplifying to Representative Landforms

Although ESI provides a good starting point for classification of the nearshore environment, we wished to reduce the 147 combinations of shoreline types to a more manageable number. We also wished to add explicit information about substrate to add dimension to the classification.

The ShoreZone classification was developed for coastal British Columbia in the 1990's (Howes et al, 1995; Searing and Frith, 1995). This classification has been applied to the entire coasts of British Columbia and Washington state, as well as portions of the Cook Inlet, Prince William Sound, and Alaska Peninsula. In addition, the ShoreZone classification has been cross-walked to ESI information developed for Southeast Alaska. We borrowed and modified<sup>3</sup> this crosswalk for the Alaska-Yukon Arctic. To apply the ShoreZone classification to the Alaska-Yukon Arctic, we re-assigned ESI information to 4 variables with a limited range of values:

variable	possible values
substrate	rock, rock/sediment, sediment, anthropogenic, channel
sediment	gravel, sand/gravel, sand, organics/fines, manmade
width	wide, narrow
slope	steep, inclined, flat

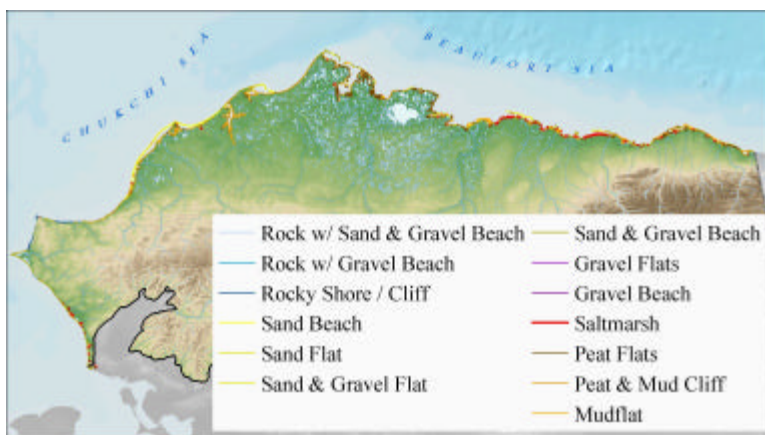
This resulted in 36 coastal classes in the ecoregion (Appendix 2). These 36 classes were aggregated to produce 13 representative landform types in the classification (Table 2, Figure 1):

**Table 2.** ShoreZone landforms in the Alaska-Yukon Arctic

1. gravel beach	6. rock w/ gravel beach	11. sand & gravel flat
2. gravel flats	7. rock w/ sand & gravel beach	12. sand beach
3. mudflat	8. rocky shore/cliff	13. sand flat
4. peat & mud cliff	9. saltmarsh	
5. peat flats	10. sand & gravel beach	

Where the ESI to ShoreZone crosswalk was unclear, we selected for the ESI type that has greater influence from a conservation perspective. Thus, we biased selection in favor of peat shorelines, marshes, tundra, and tidal flats over rocky types with sediment (Jorgenson and Brown 2003). Our objective was to identify shoreline ecosystems that may function as surrogates for intertidal and shallow subtidal nearshore biodiversity.

**Figure 1.** ShoreZone landforms

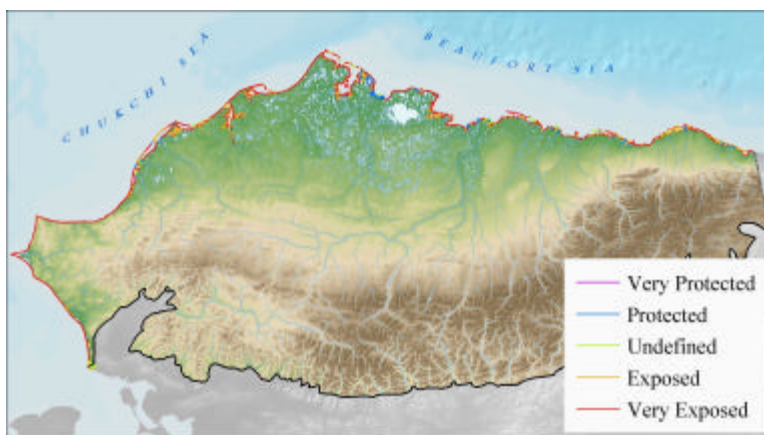


<sup>3</sup> We added 2 shoreline types to the dataset developed for Southeast Alaska from the crosswalk of ShoreZone with ESI: peat and mud cliff (tundra) and peat flats (inundated low-lying tundra and peat).

### Step 3: Incorporating Wave Exposure

To further enhance the classification, we added information about wave exposure to the 13 landform types. Note that the ‘exposed’ reference in some ESI shore types (see Table 1) means that the beach was bare upon observation, not that it is exposed from a wave energy standpoint. Therefore we removed the ‘sheltered’ and ‘exposed’ modifiers to the ESI shoreline types when we cross-walked the shore types to ShoreZone. We then added a measure of wave energy exposure to the ShoreZone classification to better partition the coastline in terms of habitats. Wave exposure (also known as fetch) was calculated as an estimate of the total area visible<sup>4</sup> over water from each point along the shore. We grouped exposure classes into 5 categories: *very exposed*, *exposed*, *very protected*, *protected*, and *undefined* (Figure 2).

Figure 2. Wave exposure



### Result: Coastal Ecosystem Types

Cross-walking the ESI information to the ShoreZone classification and adding exposure information resulted in a classification of 49 coastal ecosystems for the Alaskan Arctic coast. These ecosystems will be used as coarse filter conservation targets in the ecoregional assessment.<sup>5</sup>

Table 2 shows the coastal ecosystems as a matrix of ShoreZone landforms and exposure, with the percentage of each type in the ecoregion. The higher incidence of three ecosystems in the matrix (see boldface type in “total” column) can be traced to the ESI data. In the ESI, the *Mixed sand and gravel beaches* shoreline type occurs more frequently than any other shoreline type in the ecoregion, covering over 1,000 km, or 15% of the shoreline. The next two most frequent ESI types in the ecoregion are *Inundated low lying tundra* and *Sand beaches (fine to medium)*, each representing 10% of the shoreline. After crosswalking these types to the ShoreZone classification, the *Peat flats* ecosystem type dominates, comprising over 30% of the shoreline, followed by *Peat & mud cliffs* and *Sand & gravel beaches* (each 17%). Over 40% of the shoreline is *Very exposed* to waves, and over a quarter is *Exposed to Semi-exposed*.

<sup>4</sup> Visible from a GIS model perspective (e.g. a straight line)

<sup>5</sup> See Update #5: Conservation Targets for more information about the coarse filter and targets.

**Table 2.** Percentage of coastal ecosystem types in the Alaska portion of the Alaska-Yukon Arctic ecoregion

LANDFORM	EXPOSURE (%)					Total (5 types)
	Very exposed	Exposed to Semi-exposed	Semi-protected to Protected	Very protected	Undefined	
Gravel Beach	0.17	0.09	0.03	0.01	0.19	0.50
Gravel Flats	0.00	0.00	0.02	0.00	0.00	0.02
Mudflat	1.79	2.71	6.34	0.16	5.01	16.01
Peat & Mud Cliff	10.36	5.92	0.28	0.27	0.59	<b>17.42</b>
Peat Flats	8.18	9.02	8.09	1.00	4.82	<b>31.11</b>
Rock w/ Gravel Beach	0.05	0.00	0.00	0.00	0.00	0.05
Rock w/ Sand & Gravel Beach	0.34	0.00	0.04	0.01	0.01	0.40
Rocky Shore/Cliff	0.95	0.00	0.19	0.00	0.05	1.19
Saltmarsh	1.73	1.41	0.72	0.08	0.32	4.26
Sand & Gravel Beach	10.43	4.17	0.27	0.08	1.70	<b>16.64</b>
Sand & Gravel Flat	0.00	0.00	0.07	0.00	0.11	0.18
Sand Beach	7.32	2.91	0.61	0.20	0.99	12.02
Sand Flat	0.00	0.00	0.12	0.00	0.07	0.18
<b>Total (13 types)</b>	<b>41.32%</b>	<b>26.22%</b>	16.80%	1.81%	13.85%	100.00%

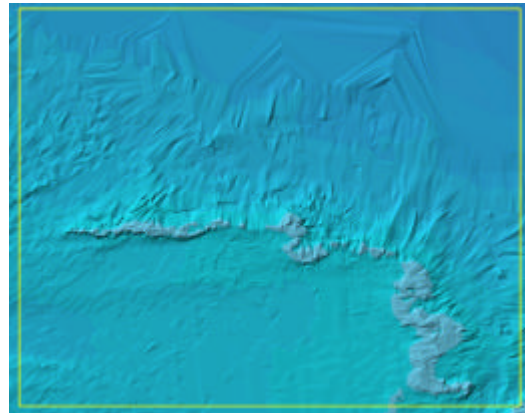
## Bathymetry Map

Bathymetric habitats are often influenced by physical or abiotic characteristics of the landscape or seascape. Bathymetric rugosity, or underwater structural complexity, is known to strongly correlate with habitat availability for different species at different scales (Beck 1998, Beck 2000). The Nature Conservancy is working to develop methods for capturing benthic habitat complexity in regional planning efforts. This research has included temperate, sub-tropical, and tropical oceans and could be applied to nearshore and offshore areas of the Beaufort and Chukchi Seas in future iterations of the ecoregional assessment.

A habitat complexity model in the Alaska-Yukon Arctic ecoregion would likely incorporate bathymetric sounding data in a TIN model (Triangular Irregular Network). In theory, TINs are better able to capture topographic complexity information than the currently-used raster method of interpolation. The TIN approach to interpreting bathymetric soundings creates triangles of different sizes, where the lengths of triangle sides represent the change in depth between soundings. More triangles are formed in areas with greater topographic complexity and the model does not lose information on fine scale habitat complexity in the interpolation process. For these reasons researchers engaged in modeling underwater habitats are experimenting with methods for assessing habitat complexity which include TIN processing as an early phase.

**Figure 3.** Preliminary Bathymetric Model for the Alaska-Yukon Arctic Nearshore Marine Environment.

Little is known about the ecology of submerged habitats in the Arctic and more research is imperative if we are to understand and protect this natural resource. We hope to continue to develop the bathymetric/habitat complexity model of the Alaska – Yukon Arctic shelf (Figure 3) and to employ it as a guide for directing areas of future research.



## Limitations of Coastal Ecosystem Classification and Model

As a result of employing multiple classification schemes to construct the coastal ecosystems model, we faced several data challenges. First, since the coast of the Alaska-Yukon Arctic has not yet been inventoried using ShoreZone<sup>6</sup>, the existing ShoreZone summary classification has not been adapted to represent Arctic systems. To overcome this limitation, we included Arctic-specific types by assigning a sediment type to original ESI types. Thus, *Tundra cliffs* and *Inundated low-lying tundra & peat* became *Peat and mud cliff* and *Peat flats* and *Tidal flats* became *Mudflats*.

Another issue we faced relates to the large number of unique combinations in ESI as a result of its classification of different parts of the intertidal zone (high, medium, and lower intertidal zones). To simplify the classification we had to decide how much, for example, *Mudflats* and *Intertidal saltmarshes* should override *Rocky coasts* and *Sand and gravel beaches* when assigning a single type to a shoreline segment. We erred toward assigning the category that best represents biological diversity and affects nearshore processes (e.g., *Tidal flats* often took precedence because they strongly affect wave energy and provide substrate for invertebrates). Our choices in terminology resulted in generalization in some cases (where the original classification was more descriptive), and at other times a finer level of detail than the original data set included (e.g., changing *Tidal flat* to *Mudflat*).

The fetch calculation used to augment geomorphic types presented another limitation to our ability to build robust coastal ecosystem classes. Due to calculation limitations, exposure for many of the shoreline segments was undetermined. This is significant in that the combination of geomorphic type and wave energy is among the best indicators of biotic assemblages along the coast (latitude is another significant indicator). Not being able to determine wave energy everywhere limited our ability to identify shoreline types that represent the potential intertidal biodiversity of the Arctic.

---

<sup>6</sup> Aerial footage of the ecoregion's coastline was actually shot in the 1980s by John Harper, a leading user of the ShoreZone methodology, but it has not been mapped.

Another limitation was not incorporating sea ice into the fetch calculation. Given its temporal nature, we were unable to compile the necessary images to determine maximum extent of summer sea ice. Certainly the summer extent of sea ice is a useful factor for determining where coastal stretches experience lower wave energy. It has been recommended that averaging sea ice extent during the last four years may be appropriate if we are looking toward the future. More work needs to be done to both enhance the fetch calculation and evaluate the existing data set for accuracy of results.

## **Application of this Nearshore Characterization**

The coastal ecosystem model adds to the existing available nearshore data for the Alaska portion of the Arctic by consistently mapping physical components of the shoreline that influence the distribution of nearshore biodiversity, and by including the addition of wave exposure. Despite its limitations, the model represents a step forward in our understanding of the ecological systems of the ecoregion at a large scale.

We will use the coastal ecosystem model in the ecoregional assessment as a surrogate for fine-scale information that does not comprehensively exist for marine species and habitats across the ecoregion. We hypothesize that the model will capture the variety and variability of marine species and habitats. In the future, we would like to incorporate others' work on coastline typology (Jorgensen and Brown 2003) and include a representation of major types (e.g. inlets, deltas, and lagoons) in the ecoregional assessment.

Development of the coastal ecosystem model and the bathymetry map highlight how much is not known about the marine environments of the Arctic, especially in terms of bathymetry and explicit locations of intertidal and shallow subtidal vegetation. We hope that the work The Nature Conservancy has already done in describing the nearshore and offshore environment will provide a platform for others to add to the existing data about the Arctic marine environment.

## Contacts

The model and classification descriptions are available upon request. Please contact The Nature Conservancy for further information or to offer feedback on the Alaska-Yukon Arctic ecoregional assessment project:

Amalie Couvillion                      [acouvillion@tnc.org](mailto:acouvillion@tnc.org)                      (907) 276-3133 x103  
Corinne Smith                              [corinne\\_smith@tnc.org](mailto:corinne_smith@tnc.org)                      (907) 276-3133 x121

## Acknowledgements

The Nature Conservancy would like to acknowledge the generous support of the Bureau of Land Management, U.S. Fish and Wildlife Service, National Park Service, BP, and ConocoPhillips.

## Previous Updates on the Alaska-Yukon Arctic Ecoregional Assessment

Update #1: Project Description  
Update #2: Predictive Terrestrial Ecosystem Model  
Update #3: Gap Analysis of Terrestrial Ecosystems  
Update #4: Freshwater Ecosystem Model  
Update #5: Conservation Targets

## References

- Beck, Michael. 1998. Comparison of the Measurement and Effects of Habitat Structure on Gastropods in Rocky Intertidal and Mangrove Habitats. *Marine Ecology Progress Series*. Vol. 169: 165-178.
- Beck, Michael. 2000. Separating the Elements of Habitat Structure: Independent Effects of Habitat Complexity and Structural Components on Rocky Intertidal Gastropods. *Journal of Experimental Marine Biology and Ecology*. Vol. 249: 29-49.
- Berry, H.D., J.R. Harper, T.F. Mumford Jr., B.E. Bookheim, A.T. Sewell, and L.J. Tamayo. 2001. The Washington state shorezone inventory user's manual. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA.
- Howes, D.E., P. Wainwright, J. Haggarty, J. Harper, E. Owens, D. Reimer, K. Summers, J. Cooper, L. Berg and R. Baird. 1995. Coastal resources and oil spill response atlas for the southern Strait of Georgia. BC Ministry of Environment, Lands and Parks, Environmental Emergencies Coordination office. 317 pp. Victoria, B.C.
- Joregenson, T, and Brown, J. Submitted 2003. Classification of the Alaskan Beaufort Sea Coast and Estimation of Carbon and Sediment Inputs from Coastal Erosion. ABR, Inc. Fairbanks, Alaska.
- NOAA, 1996. Environmental Sensitivity Index Guidelines. Version 2.0. NOAA Technical Memorandum.

Searing, G.F. and H.R. Frith. 1995. British Columbia shore-zone mapping system, contract report by LGL, Ltd., Sidney, B.C. for the Land Use Coordination Office, B.C. Ministry of Environment. 46pp. Victoria, B.C.

Weiss, Andrew. 2004. Topographic Position Index and Landform Classification. Working draft. Jan. 2004. Indus Corp. EPA Region 10.

## **Input Data**

National Oceanic and Atmospheric Administration (NOAA). 1999. North Slope, Alaska ESI: Environmentally Sensitive Areas. NOAA, National Ocean Service, Office of Response and Restoration, Hazardous Materials Response Division, Seattle, Washington and the Alaska Department of Environmental Conservation.

## **The Nature Conservancy**

The Nature Conservancy is an international non-profit conservation organization that seeks to preserve the plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. Ecoregional assessments employ a science-based approach to evaluate the biodiversity significance of landscapes. For the Alaska-Yukon Arctic, our goal is to gather sufficient information to identify areas of biological significance, evaluate current and potential stresses to biodiversity, and develop appropriate and constructive conservation strategies to ameliorate threats in special areas.

## Appendix 1. Descriptions of northern Alaska marine ecoregions

<i>Ecoregions and subcoregions</i>	<i>Descriptions</i>
<b>Chukchi Sea Ecoregion</b>	
Southern Chukchi Sea Shelf	Moderately deep (10–50 m) offshore water on the continental shelf of the portion of the Chukchi Sea south of Point Hope. The area is affected by southerly input of water from the Alaska Coastal Current, which generally has lower salinity from freshwater input from the Yukon and Kuskokwim rivers. The area has high primary productivity and productive fisheries. The area is ice-free from mid-June through mid-October.
Kotzebue Sound Nearshore Water	Shallow (<10 m) nearshore water in the southern portion of the Chukchi Sea near Kotzebue Sound. The area includes estuarine water associated with lagoons, deltas, and protected portions of the Sound. Water generally has lower salinity due to freshwater input from the Noatak and Kobuk rivers.
Eastern Chukchi Sea Shelf	Moderately deep (10–80 m) water on the continental shelf of the eastern portion of the Chukchi Sea. The area is affected by southerly input of water from the Alaska Coastal Current. The area is less productive than the Southern Chukchi Sea. The area has minor ice coverage during summer.
Eastern Chukchi Nearshore Water	Shallow (<10 m) nearshore water in the eastern portion of the Chukchi Sea. Most of the coast is exposed to high-energy wave action, but also includes estuarine water associated with lagoons and deep embayments.
<b>Beaufort Sea Ecoregion</b>	
Alaska Beaufort Sea Shelf	Moderately deep (10–80 m) water on the continental shelf in the western Beaufort Sea from Barrow to Herschel Island. The area is affected by westerly flow of water from the Beaufort Gyre. The ice-free period is short and ice coverage can be high even during summer.
Alaska Beaufort Nearshore Water	Shallow (<10 m) nearshore water in the western portion of the Beaufort Sea. The area includes estuarine water associated with lagoons and deep embayments. Most of the coast is protected by barrier islands.
Canadian Beaufort Sea Shelf	Moderately deep (10–80 m) water on the continental shelf in the eastern Beaufort Sea from Herschel Island to Amundsen Gulf. The area is affected by westerly flow of water from the Beaufort Gyre and is affected by inputs of freshwater and nutrients from the Mackenzie River. The ice-free period is longer than for the Alaskan Beaufort Sea Shelf.
Canadian Beaufort Nearshore Water	Shallow (<10 m) nearshore water in the western portion of the Beaufort Sea. The area includes estuarine water associated with lagoons and deep embayments. Salinity is greatly affected by freshwater input from the Mackenzie river. Most of the coast is exposed to high-energy waves.

## Appendix 2. ShoreZone classes in Alaska-Yukon Arctic ecoregion

Substrate	Sediment	Width	Slope	Coastal Class	No.	
Rock	NA	Wide	Steep	n/a		
			Inclined	Rock Ramp, wide	1	
			Flat	Rock Platform, wide	2	
		Narrow	Steep	Rock Cliff	3	
			Inclined	Rock Ramp, narrow	4	
		Flat	Rock Platform, narrow	5		
Mixed Rock & Sediment	Gravel	Wide	Steep	n/a		
			Inclined	Ramp with gravel beach, wide	6	
			Flat	Platform with gravel beach, wide	7	
		Narrow	Steep	Cliff with gravel beach	8	
			Inclined	Ramp with gravel beach	9	
			Flat	Platform with gravel beach	10	
		Sand & Gravel	Wide	Steep	Cliff with gravel / sand beach, wide	11
				Inclined	Ramp with gravel / sand beach, wide	12
				Flat	Platform with gravel / sand beach, wide	13
			Narrow	Steep	Cliff with gravel / sand beach	14
	Inclined			Ramp with gravel / sand beach	15	
	Flat			Platform with gravel / sand beach	16	
	Sand	Wide	Steep	n/a		
			Inclined	Ramp with sand beach, wide	17	
			Flat	Platform with sand beach, wide	18	
		Narrow	Steep	Cliff with sand beach	19	
			Inclined	Ramp with sand beach	20	
			Flat	Platform with sand beach, wide	21	
	Sediment	Gravel	Wide	Flat	Gravel flat, wide	22
			Narrow	Steep	na	
				Inclined	Gravel beach, narrow	23
Flat				Gravel flat or fan	24	
Sand & Gravel		Wide	Steep	na		
			Inclined	na		
			Flat	Sand & gravel flat or fan	25	
		Narrow	Steep	na		
			Inclined	Sand & gravel beach, narrow	26	
			Flat	Sand & gravel flat or fan	27	
Sand / Mud		Wide	Steep	n/a		
			Inclined	Sand beach	28	
			Flat	Sand flat	29	
			Flat	Mud flat	30	
	Narrow	Steep	n/a			
		Inclined	Sand beach	31		
		Flat	n/a			
	<u>Organics / Fines</u>	Wide	Flat	<u>Estuaries &amp; tidal flats</u>	32	
		Narrow	Steep	Tundra cliff	33	
Anthropogenic	Man-made			Man-made, permeable	34	
				Man-made, impermeable	35	
Current				Channel	36	

**Total = 36**