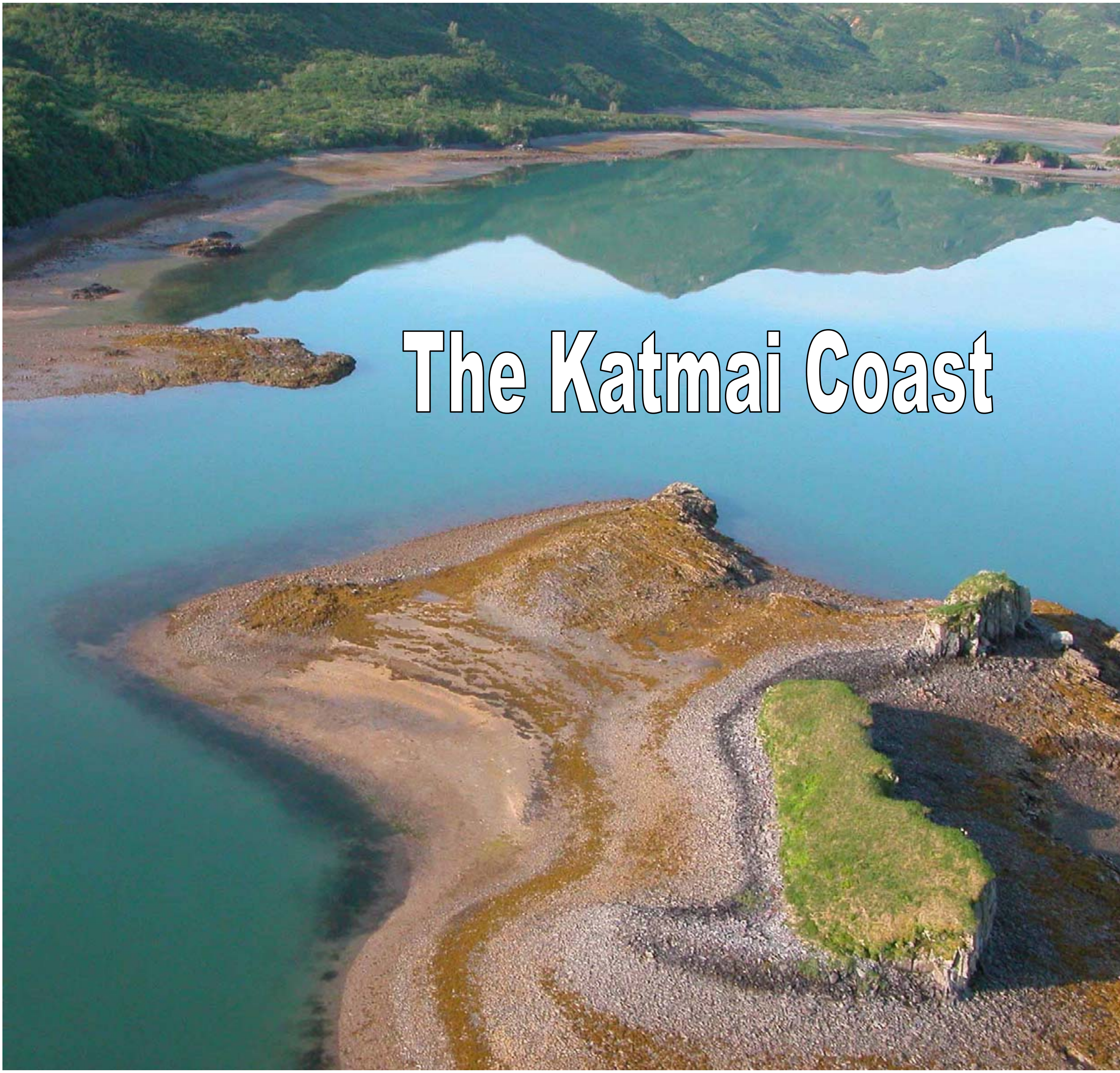

# The Katmai Coast

by

John Harper and

Mary Morris

# The Katmai Coast-
## *a guide to coastal biophysical features and ecological processes*

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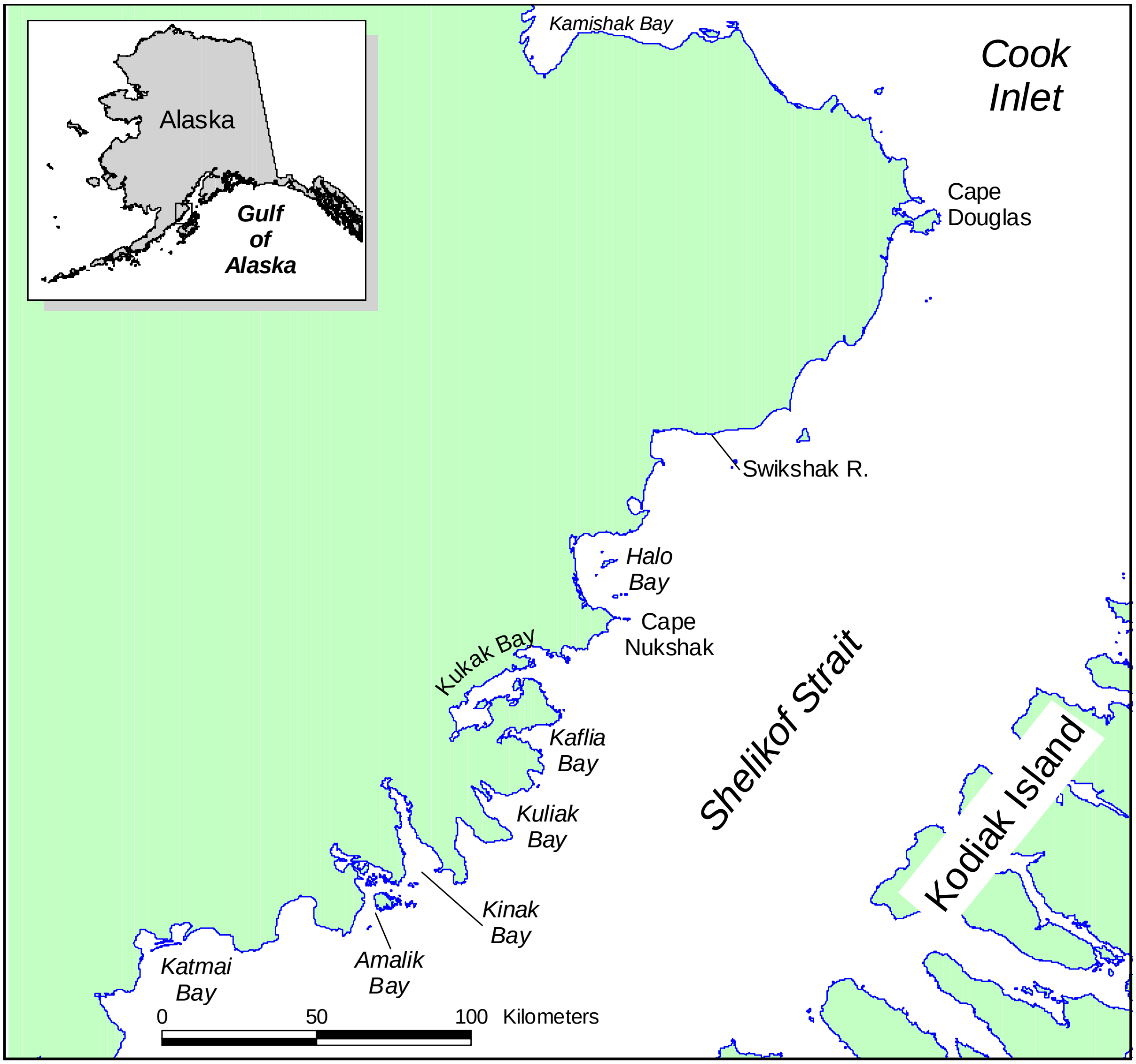



Figure 1. Location map of the Katmai National Park and Preserve and coastal locations.

# 1.0 INTRODUCTION

On March 24, 1989 the tanker Exxon Valdez grounded on Bligh Reef and discharged approximately 11 million gallons of Prudhoe Bay crude oil into Prince William Sound. Coastal winds and currents transported the oil slick southwest into Blying Sound and westward along the north shore of the Gulf of Alaska. The storm tossed crude oil degraded and weathered into an oil-and-water emulsion called mousse that stranded in various concentrations along the entire length of Katmai National Park and Preserve. This event highlighted the risk of anthropogenic disturbance on pristine coastal ecosystems even hundreds of miles from the origin. It also demonstrated the need for baseline information and how crucial it is to protecting and restoring coastal resources.

To address this need, the National Park Service initiated the Inventory and Monitoring Program to inform park managers about natural resources held in trust; natural processes that maintain those resources; and to create a base of information for effective, long-term monitoring and management of those resources. This guide is intended to provide an overview of the coastal processes in Katmai National Park and Preserve (Fig. 1). The guide was developed as part of a 2003 inventory of the coastal biophysical features within Katmai. It should give users and resources managers an understanding of the coastal features within the park, the processes that have shaped the features and the sensitivity of these features to both man-made and natural disturbances.

In 2003, aerial surveys were conducted during a period of extremely low tides and video imagery was collected of the entire shoreline of the Katmai National Park and Preserve. The video imagery provides a high resolution picture of the coastline and associated biota. Geologists and biologists then view and classify the imagery to create a habitat inventory of coastal morphology, coastal substrate types and biota that are visible from the air. The patterns of these features tell a story about the processes that have created them. For example, runoff from rivers reaches the coast, river-born sediments are deposited within a delta, and the sediment is redistributed by around the delta by wave action. Landforms and species occurrence are strongly related to these patterns.

In addition, 41 shore stations were visited from a vessel-based crew. These ground-based observations provide much more detail about the assemblages of intertidal species and their habitat.

In presenting this overview of the Katmai coast, it is important to recognize that the coastal ecosystem extends far beyond the few hundred meters of the shoreline. The coast is ultimately shaped by geological processes that create the surrounding terrain, by the watersheds that feed sediment and nutrients to the coastline and by the marine processes within Shelikof Strait. An understanding of the wind and wave climate are particularly important as this is the source of most of the energy that ultimately creates the coastal seascape. Tidal circulation and currents offshore are also important in that they strongly influence the supply of nutrients to the coast and in some cases, the distribution of larvae and pollutants. The landscape, the physical process and the biota are all elements of the coastal ecosystem.

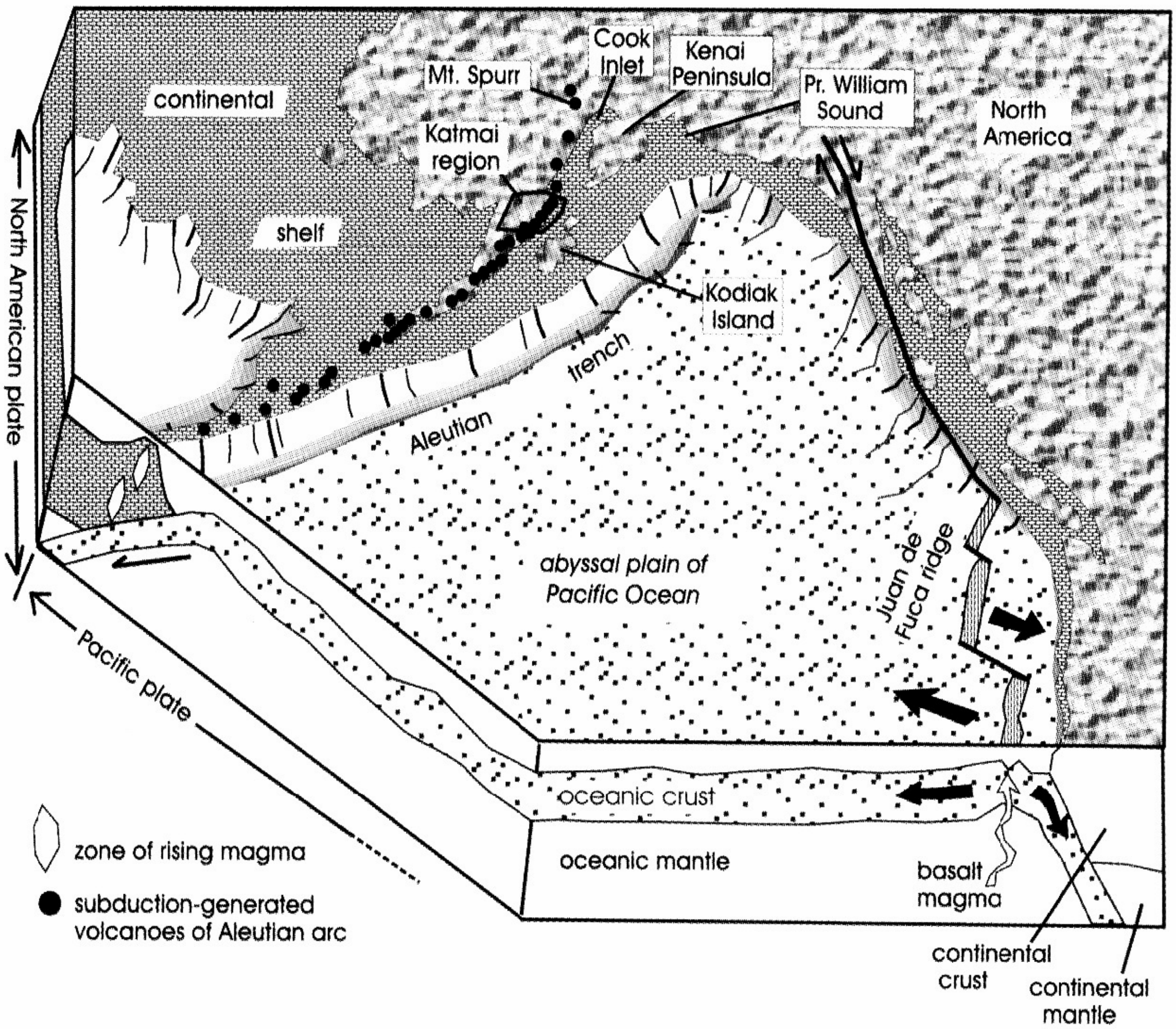



Figure 2. Schematic diagram of the North Pacific tectonics that strongly influence the coastal geology of Katmai National Park. The North Pacific Plate is moving northwestward and being pushed underneath the North American Plate. This plate interaction is responsible for creating the mountain ranges of Katmai and significant volcanic activity within the Park. The rugged, steep onshore topography has much to do with the high coastal relief along the shoreline and the presence of large alluvial deltas at the coast (from Riehle 2002; reproduced with permission of the author).

## Plate Tectonics

The overall physiography of Katmai National Park and Preserve is closely relate to the plate tectonics of the region. The collision of tectonic plates in the region has given rise to the coastal mountain and active volcanism. The oceanic Pacific Plate is being driven northwestward under the continental North American Plate (Fig. 2). The most prominent physical manifestation of this plate collision is the formation of the shore-parallel coastal mountain range – the Aleutian Range. This mountain range trends NE-SW with heights to 2,400 m ( Mt. Denison is a 2,318 m [7,600 ft] high stratavolcano) within a few tens of kilometers from the coast. Coastal relief is high (Fig. 2), especially o the south portion of the coastal park with elevations of hundreds of metres or more within a kilometer of the coast (Capes Ugyak, Gull, Kuliak, Atushagvik, Ilktugitak). The consequence of the high coastal relief, is the common occurrence of coastal cliffs within the park, especially in the southern portion..

Near the edge of a plate collision zone, it is common for deep-sea and shelf sediments to be scraped off the subducting oceanic plate and be plastered onto the continental margin – a process known as continental accretion. Such a process has occurred along the Katmai coast such that there is a complex mixture of sedimentary and volcanic rocks within the park. The additional injection of igneous rocks such as occur around Cape Douglas, further complicates the geological picture of the Park's coastline. Coastal erosion and weathering processes typically produce different shoreline landforms on different rock types. The development of wide, erosional rock platforms is most common on sedimentary rocks, whereas as granitic bedrock often weathers in a grain-by-grain fashion so that land forms tend to be well-rounded.

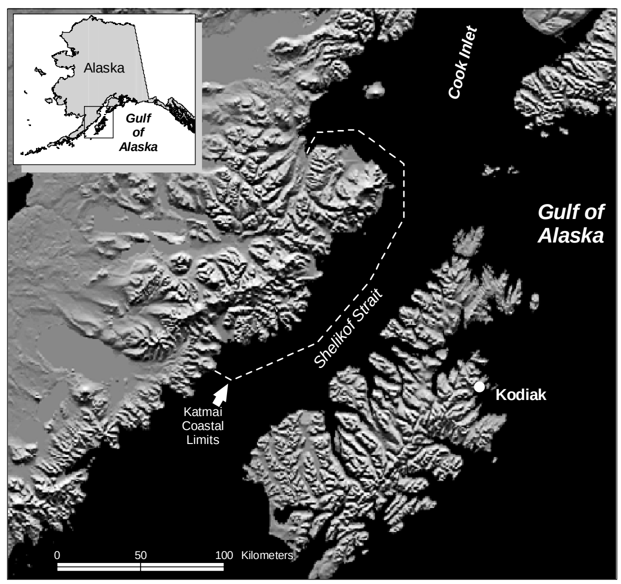



Figure 3. Coastal relief maps showing the extremely high coastal relief in close proximity to the shoreline within Katmai.

As the plates slip over each other, they generate earthquakes and also heat, which is manifested as volcanoes. The 1912 eruption of Novarupta was the largest of the 20$^{th}$ century, extruding an estimated 30 km$^3$ of ash (about 10 times the force of Mt. St. Helens eruption). A consequence of that eruption, is that blankets of ash, up to 200m (650 ft) thick, occur throughout the Park.

Another aspect of the plate tectonics that is relevant to the coastlines is uplift of the land, a common process at coasts at plate collision zones. That is, as the two plates collide, the continental plate is typically uplifted. The uplift may occur gradually, or in the case of the Great Alaskan Earthquake of 1964, as an individual event where some portions of the coast were uplifted over 8 m. The point is that coasts at an active plate-collision zone, such the Katmai shoreline, are not stable but are likely to in the process of change due to tectonic uplift (or in some cases down-warping).

**Glacial History**

Katmai National Park and Preserve was glaciated several times during the Quaternary (most recent 1.65 million years). There is evidence of several glacial advances; ice probably originated within Cook Inlet, and flowed southwestward through Shelikof Strait and spilled across the ranges through some of the valley passages (Riehle 2002). As such, there are discontinuous glacial features and deposits throughout much of the Katmai Park coastline. Glacial erratics and unconsolidated tills are occasionally evident along the shores. Active glaciers occur near the peaks of the Aleutian Range (Fig.4) and produce strongly seasonally discharges of melt-water and glacial outwash during the summer periods.

Glacial history is also important in understanding the sea level history of the coast. Continental glaciations, such as occurred in the Katmai area, add a huge weight to the land surface during the glaciation, essentially sinking the land. Following deglaciation, the land is typically depressed. As the glaciers melt, the melt waters contribute to sea level rise so that coastal areas are usually inundated by the sea immediately after glaciation. However, as the weight of the glaciers is removed, the land slowly rebounds, elevating submerged areas. This sequence of (a) glaciation, (b) flooding of the coastal areas immediately following deglaciation and (c) the subsequence emergence of land areas due to isostatic rebound, is common all along the coastline of the Pacific Northwest. The deposits associated with this sequence are not well documented within Katmai (Riehle 2002) but there are likely a combination of glacial and

Figure 4. Aerial photo of the Hallo Glacier, which extends to within 5 km of the coastline. Melt-water streams discharge a large volume of milky “glacial flour” (fine silts and clays) into Hallo Bay during summer months. The Bay is filled with sandflats and mudflats, on which wetlands have colonized. The barrier spit (foreground) is comprised of sand & gravel and created by wave action.

coastal and shallow-water marine deposits on land within the Park. Dating of archaeological sites and buried peat deposits indicates that sea level has been at or near its current level in Katmai National Park and Preserve for the past 7,000 years. Sea levels may have been higher in the interval from 7,000 to 10,000 years ago (Crowell and Mann 1996). In many areas, these sea level changes are heavily masked by pulses of volcanic and glacial sedimentation.

Some raised relict coastal landforms have been noted in the eastern-most portions of the park, near Cape Douglas (Fig. 5).

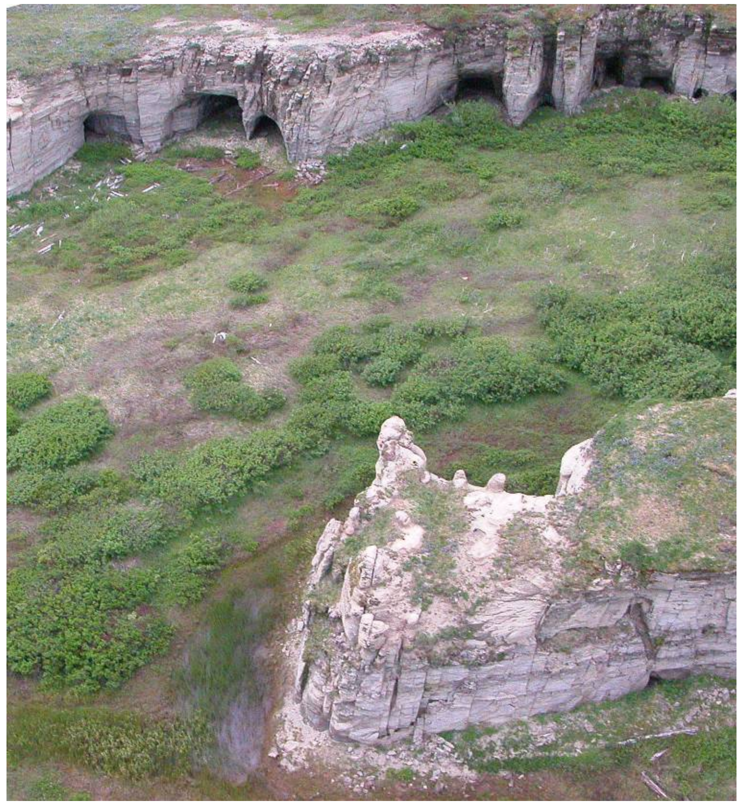


Figure 5. Relict sea caves and sea cliffs on an island within Kamishak Bay at the mouth of the Douglas River. It is believed that uplift of the wide, wave-cut rock platforms, resulted in the "stranding" sea caves above the level of present day wave activity. The age of these features is unknown but their fresh appearance suggests that they were formed within the last 1,000 years. Note shrubs lying seaward of the caves.

***Geology and the Coastal Landscape***

*The tectonic interaction of plates on a "collision" margin results in steep coastal relief within much of the south coast of Katmai. Coastal relief of hundred of meters results in steep, rocky cliffs along much of the coast.*

*Normally high coastal relief results in lots of coarse sediment delivered to the coast but the extensive blankets of ash within Katmai National Park and Preserve result in relatively fine, alluvia fans and deltas. For example, the extensive tidal flat shoreline at the abandoned settlement at Katmai (west end of the Park) is comprised largely of re-worked volcanic ash.*

*Tectonic activity and recent glaciations affect the land stability and relative sea levels. There is some evidence of raised coastal features (or higher sea levels) within the Park.*

*Large glaciers near the coast produce seasonal runoff and extensive alluvial fans in Kukak Bay, Hallo Bay and near Cape Douglas. These areas are associated with wide beaches and often extensive dune fields.*

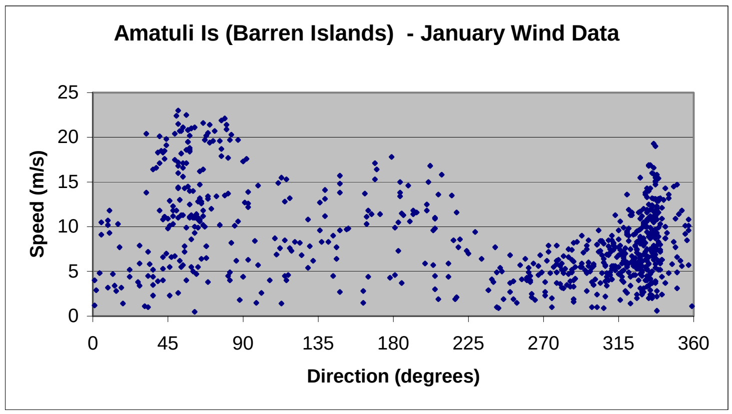
## Winds and Waves

Waves generated in Shelikof Strait provide the dominant energy source for shaping the coast. However, winds generate waves and the two processes are discussed together. That is, the wind energy is imparted to the water surface in the form of waves. The longer the winds blows or the harder the wind blows, the larger the resulting waves will become. Storm events, where wind speeds are very high, are extremely important in creating large, energetic waves.

### Winds

The combination of general storminess, significant windiness (and concomitant wave generation), have a strong influence on the variety and composition of the biota supported on exposed shorelines. Along the Katmai coast, terrain plays an important role in determining local weather. For example, a phenomenon specific to lower western Cook Inlet and Shelikof Strait is the interaction of terrain with synoptic and mesoscale pressure gradients that frequently produce gap and channel winds, often called low-level jets. These winds may at times be quite strong, with gusts occasionally exceeding 50 meters per second (Olsson 2004).

Wind data is always a challenge to illustrate but the scatter plot of wind direction and speed gives a good overview of the winds for Shelikof Strait (Fig. 6). The wind data is actually collected on the Barren Islands but probably provides the same picture as



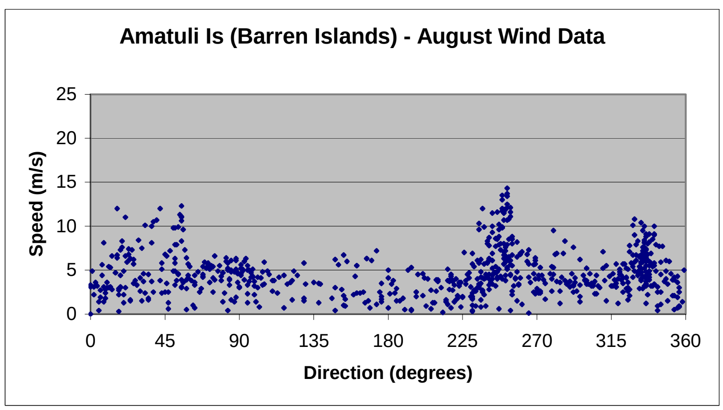




Figure 6. Scatter diagrams of wind speed versus direction from the Barren Islands at the mouth of Cook Inlet. Each point is an hourly average of wind peed and direction. The plots show that winds in January are stronger and more variable; there are two common directions: NE (045º)and NW (315-340º). Summer winds (August) are significantly weaker. [Source: NOAA, 2001-2002 data only]

occurs in Shelikof Strait and off the coast of the Katmai National Park and Preserve. The most notable feature is that wind strength is strongly seasonal with wind speeds during the winter commonly exceeding 10 m/s (~20 knots) whereas summer winds rarely exceed 5 m/s (10 knots). The strongest winter winds are most commonly from the NE (055º), even though the most common direction is from the NW (340º).

*The dominant wind directions in Shelikof Strait are from the east and west. Storms winds may come from either direction. Winds during winter months are much stronger than in summer months and storms are more frequent.*

Waves

There are no wave data records for Shelikof Strait. The nearest wave record is from the Barren Islands area (NOAA Buoy 46079) for a six month period (August 2001 to January 2002). A monthly wave height summary (Fig. 7) shows that mean wave heights in the summer are around 1m (3ft) and wave heights increase substantially to over 2 m (6 ft) in October with the advent of more frequent storms.

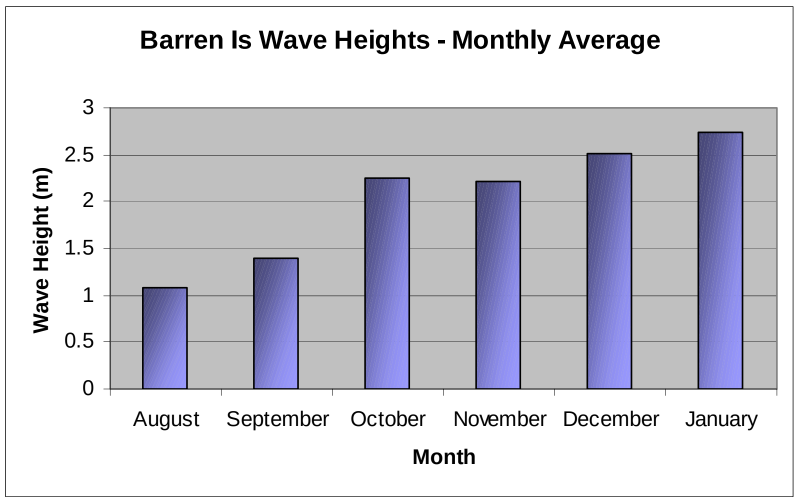



Figure 7. Monthly summary of wave heights for the Barren Islands area.

The importance of storms is more evident in the hourly measurements of wave height from the same station near the Barren Islands (Fig. 8). The largest wave heights, reaching 6.5m (21 ft), are associated with large storms. More typical storm wave heights are around 4m (13 ft). The storm events are typically at three day intervals.

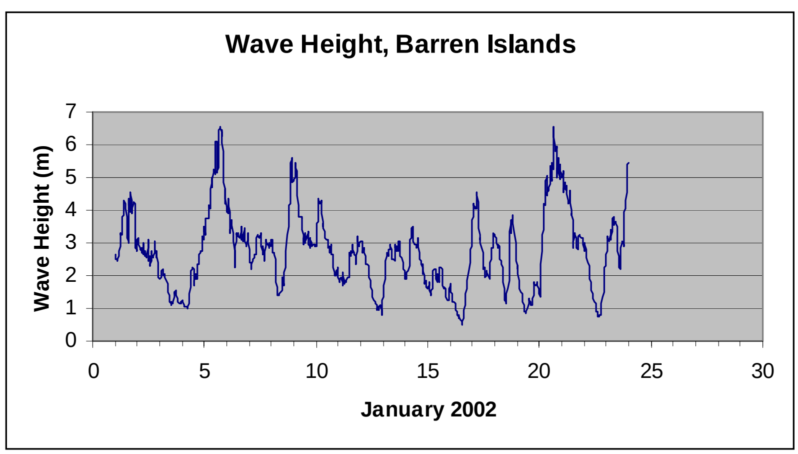



Figure 8. Hourly occurrence of wave heights for the Barren Islands area for January 2002 [source NOAA Buoy data 46079]

As previously mentioned, wind energy is transferred to the ocean surface in the form of waves. Most of the wave energy travels in the same direction as the wind and the general patterns of waves will follow that path of the winds. Waves will travel from north to south when generated by *northerly* winds, travel from east to west when generated by *easterly* winds and travel from west to east during *westerly* winds. For most of the Katmai coast that is west of Cape Douglas, the most important wave approach directions will be from the east and from the west as the fetch distances over which the waves can be generated are very limited during northerly wind events. The wind scatter plot (Fig. 6, top) suggests that storms waves in Shelikof Strait are most likely to originate during the winter easterlies.

Waves action is the dominant process that controls the distribution of biota along the coast – some shore organisms are well adapted to high wave exposures and some can only survive in lower exposures. For example, bull kelp (*Nereocystis*) occurs only in moderate to high exposure conditions whereas eelgrass (*Zostera*) occurs only in lower exposure conditions. By carefully noting the occurrence of biota along the coast and knowing that each species has certain exposure tolerances, wave exposure levels can be mapped. Figure 9 shows the variation in exposure levels, based on the observed occurrences of intertidal and shallow, sub tidal biota. Exposed headlands are associated with the highest wave energy levels, whereas protected bays and estuaries are associated with the lowest wave energy levels.

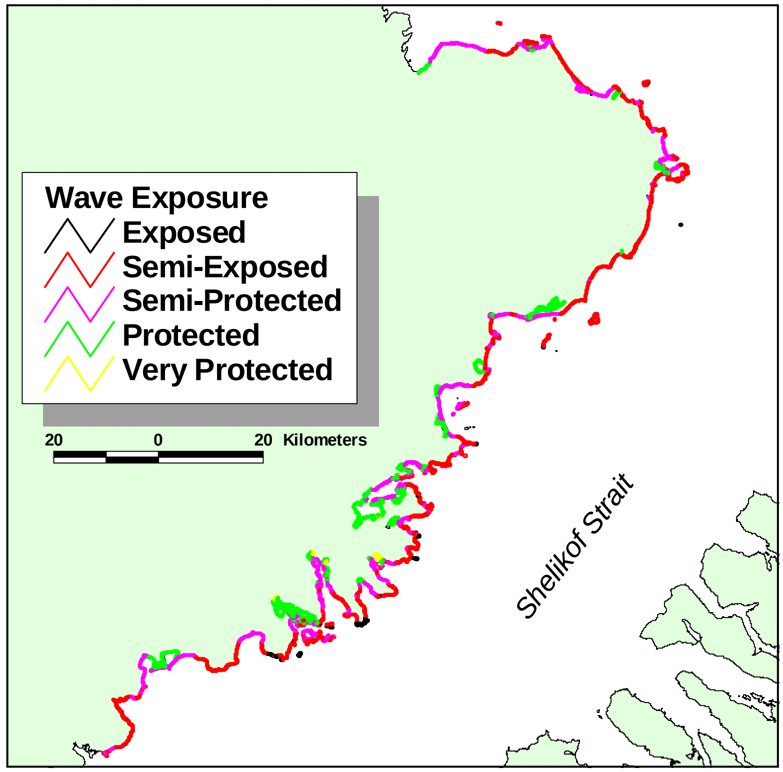



Figure 9. Wave exposure levels along the Katmai coast, based on observed assemblages of intertidal organisms. Most of the outer coast is sheltered by Kodiak Island from the high wave exposure environment of the Gulf of Alaska and is classified as *semi-exposed* shoreline.

*Because there is significantly more energy associated with high waves, most of energy that affects the Katmai Coast occurs in winter storm events. The largest storms are probably associated with easterly winds.*

*The general level of wave exposure is lower than the Gulf of Alaska because the Katmai coast is partially protected by Kodiak Islands from Gulf of Alaska storms.*

## Sediment Transport

Where coastal sediments of sand or gravel occur along the coast, breaking waves will suspend and transport the sediment. In that waves usually break at some angle to the shoreline, the breaking process generates alongshore currents which move sediment along the coast. Landforms such as spits and bars are created by this longshore transport and it is possible to "read" these landforms to map the dominant longshore transport directions (Fig. 10). A map of the most prominent features of longshore sediment transport and their associated direction is shown in Figure 11. While these features show the predominant direction of transport, reversals in transport direction may frequently occur and the spit patterns usually reflect *the dominant wave approach direction associated with storms*.

Figure 10. Aerial photograph of a recurved spit that was generated by longshore sediment transport. The dominant transport direction is from left to right (south to north) at this location near the mouth of Kuliak Bay. The spit is comprised primarily of cobble-sized material and the lagoon behind is comprised of sand-sized material.

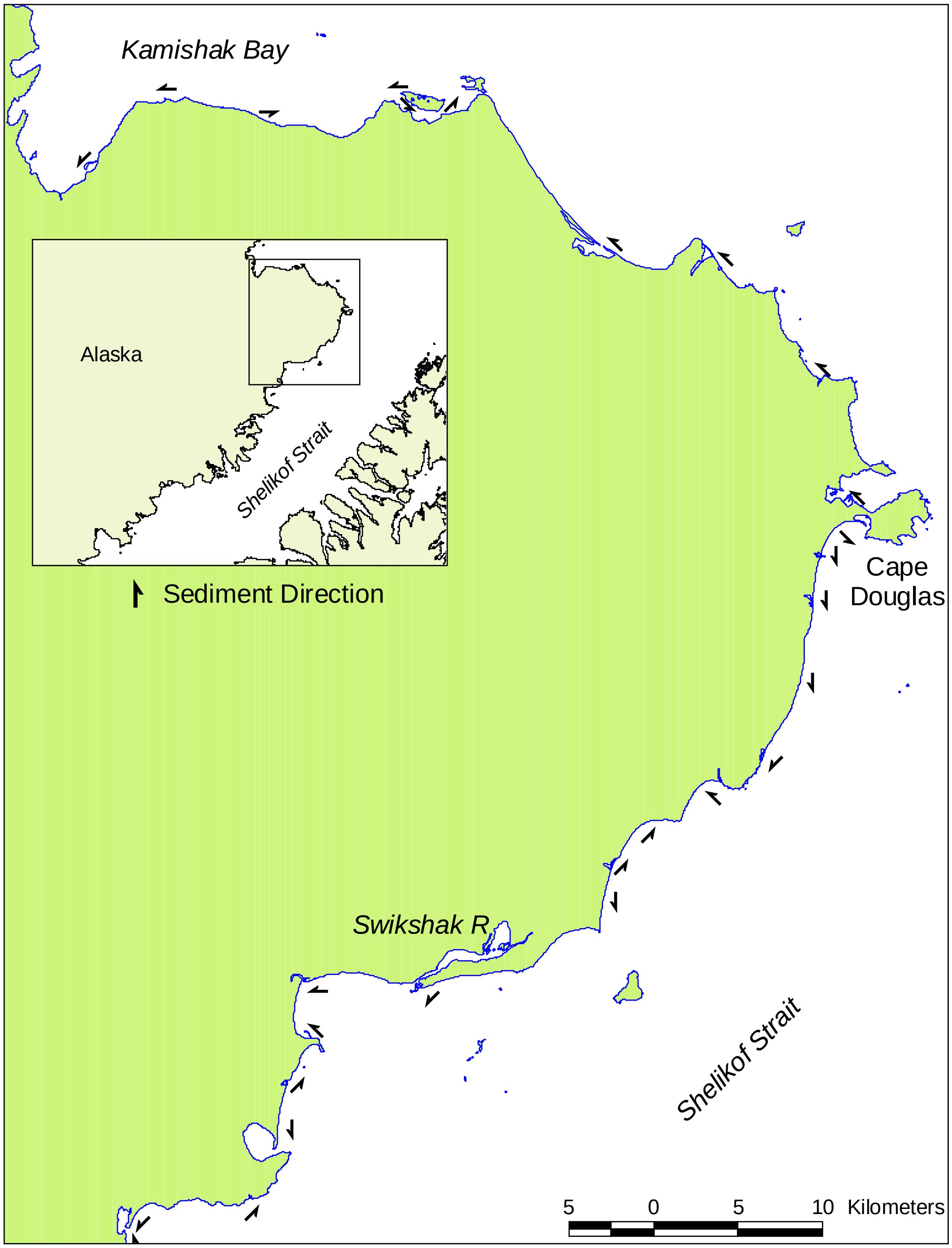



Figure 11a. Northern portion of Katmai National Parks and Preserve showing dominant longshore sediment transport directions. Dominant directions were interpreted from the coastal morphology such as beach ridges, recurve spits and deflected river outlets.

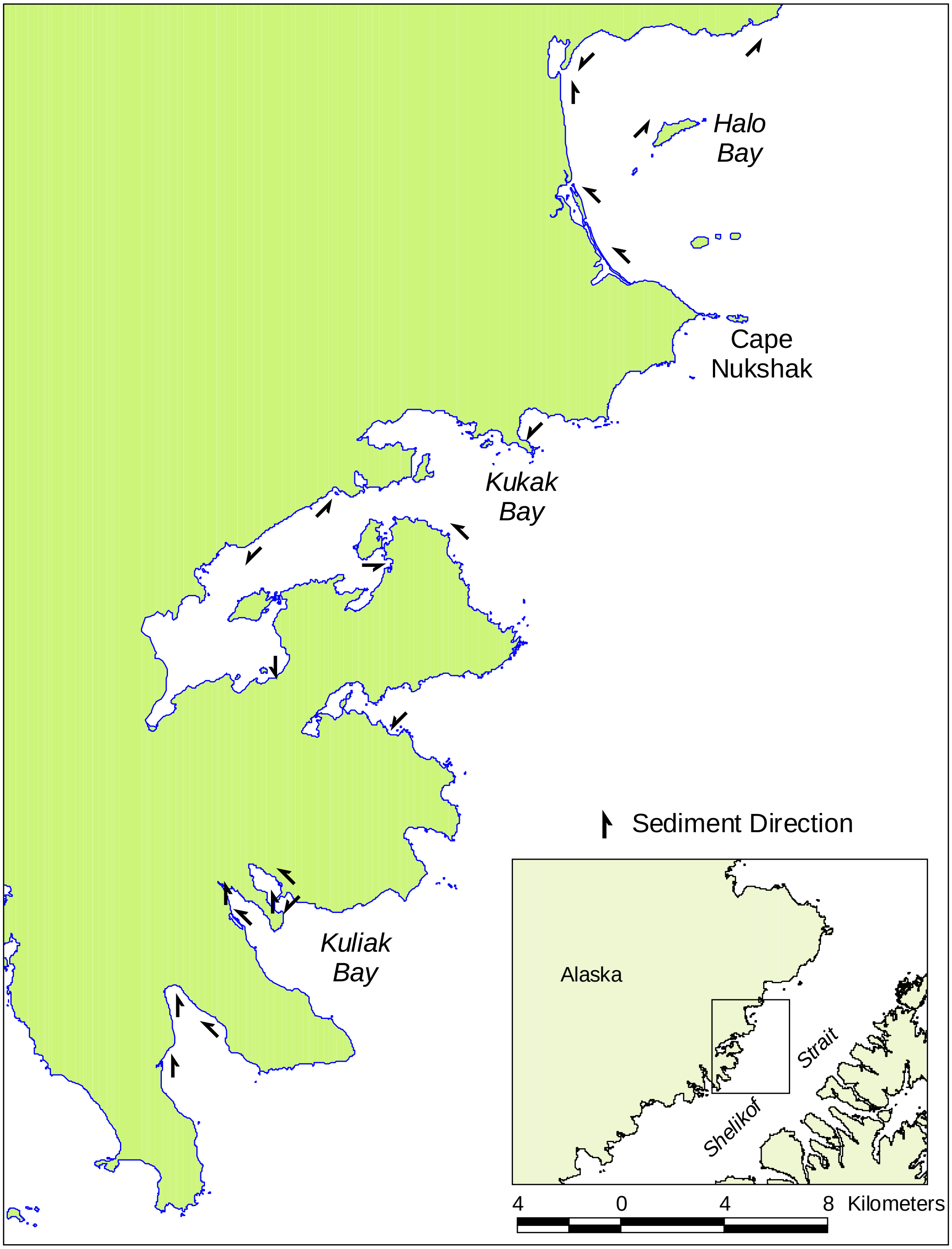



Figure 11b. Central portion of Katmai National Park and Preserve showing dominant longshore sediment transport directions. Dominant directions were interpreted from the coastal morphology such as beach ridges, recurve spits and deflected river outlets.

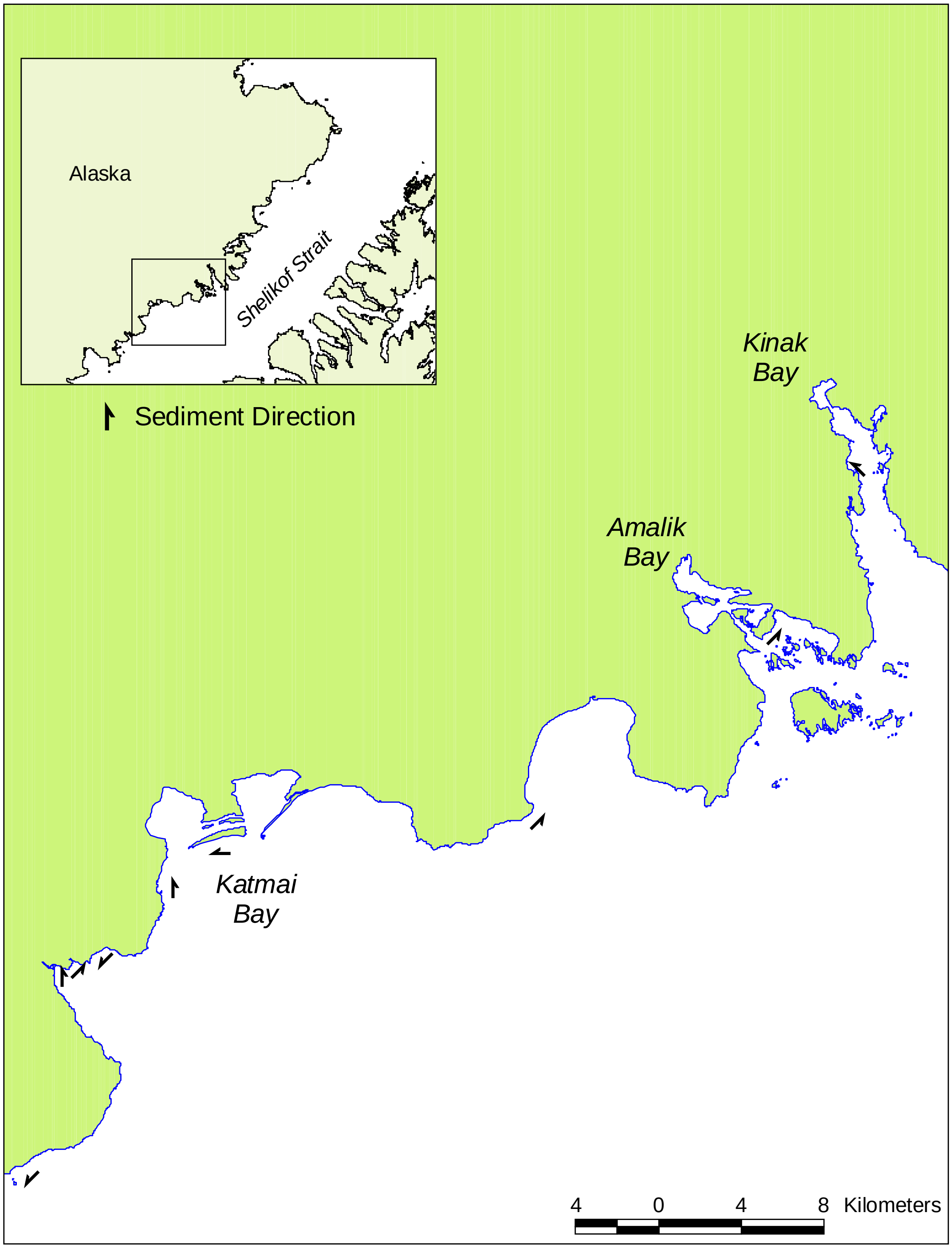



Figure 11c. Southern portion of Katmai National Park and Preserve showing dominant longshore sediment transport directions. Dominant directions were interpreted from the coastal morphology such as beach ridges, recurve spits and deflected river outlets.

## Tides

Tides are caused by gravitational effects of the sun and the moon on the worlds ocean. These forces create highly predictable waves in the world's oceans. In the North Pacific, there are two tides per day, although the two tides are typically unequal (*diurnal inequality*). The tidal range is up to 6m (~20ft) during spring tides and 4m (~13 ft) during neap tides (Fig. 12)

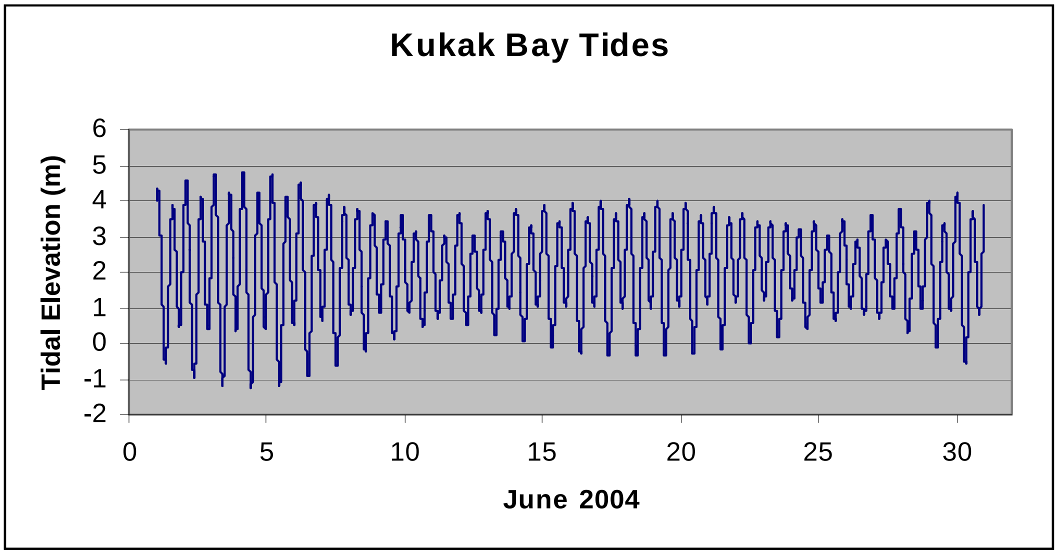



Figure 12. A monthly tidal curve from Kukak Bay showing the twice daily tides that affect the Katmai coast. June is typically the month with the largest tides of the year and the tidal range can be over 6m (4 June). The two daily tides are not equal.

The tides are very important in controlling the zonation of intertidal biota along the coast. Some organisms are capable of surviving long periods of emergence and occupy the upper intertidal zone, which is submerged only few hours per day. Barnacles are an example of this type of organism. Other organisms require almost total submergence and occupy the lower intertidal zone, which is submerged nearly all the time. Urchins, kelps and seagrasses are examples of these types of organisms.

The daily tidal emergence/submergence is the dominant process controlling the vertical variation of biota on the coast. And because the shoreline is sloping, there is a distinct across-shore variation in biota, which often appear as distinct bands when seen from the air or on the ground (Fig. 13). Variation in wetlands are also strongly related to tides, where some wetland assemblages are tolerant of saltwater submergence and some are not. (Fig. 14) Wetlands tend to be very elevation sensitive and in the numerous bays and estuaries along the Katmai coast, show considerable complexity in their spatial occurrence (Fig. 15).

*Tides are extremely important in controlling the occurrence of biota within the intertidal zone. Most organism are highly sensitive to the duration of emergence/submergence due to tides and occur at very specific elevations.*

Figure 13. An example of intertidal banding on a small islet in Kukak Bay during low tide, when the entire intertidal zone is exposed. The black band in the upper intertidal zone is lichen and grows primarily in the supratidal splash zone. The golden-brown banding in the middle intertidal zone is rockweed (*Fucus*). The dark band in the shallow subtidal is eelgrass. These biota always occur around the same elevation within the intertidal zone.

Figure 14. Aerial photo looking south across the wetlands within Hallo Bay. The subtle color differences indicate different wetland plant assemblages. These assemblages are strongly controlled by tidal elevation. A detailed map of the wetland assemblages is shown in Figure 15.

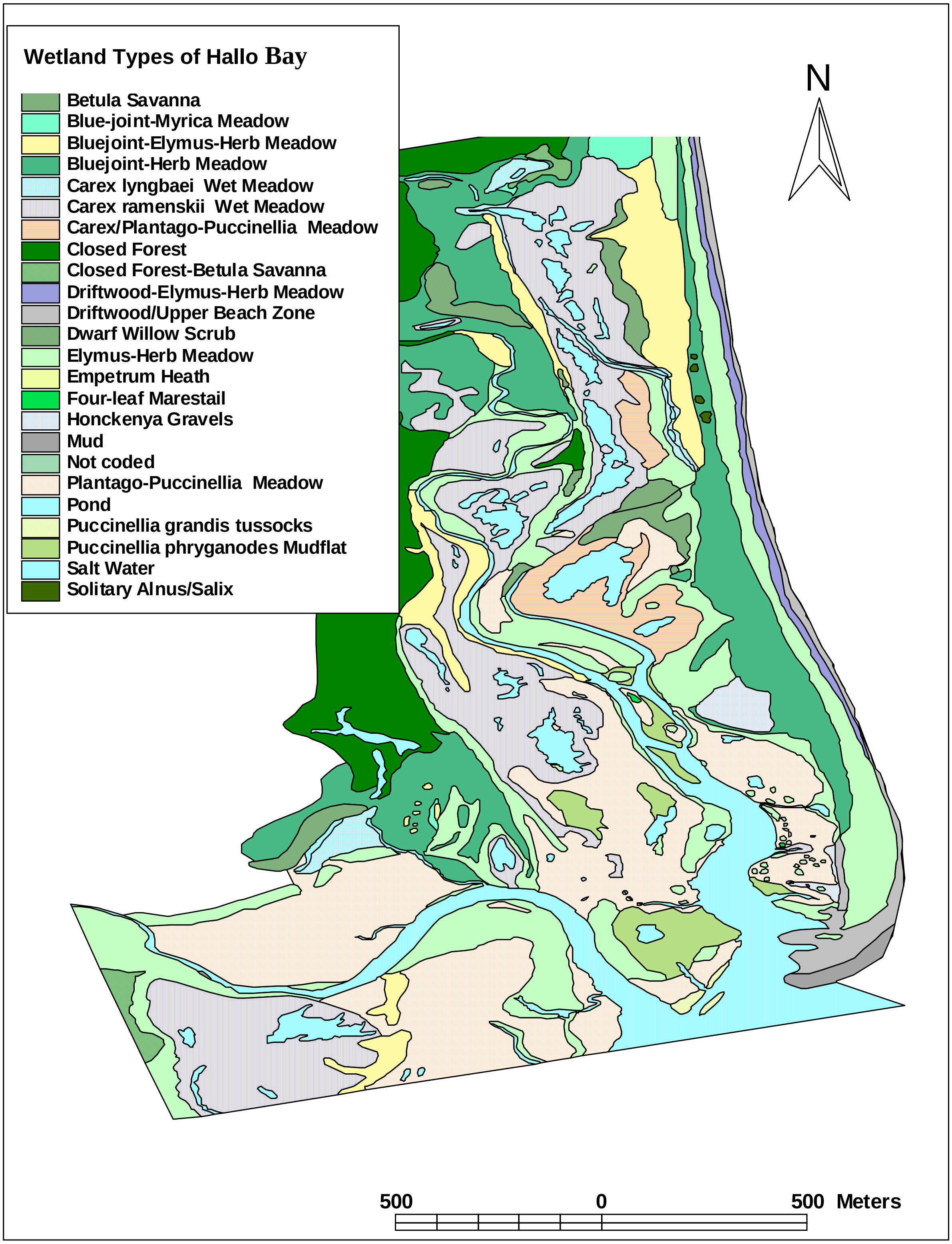



Figure 15 Map of wetland types in northeastern Hallo Bay (unpublished map by G.F. Tande for the National Park Service, Anchorage). The complex spatial pattern of wetland types is due to small variations in elevation within the estuary.

## Ocean Circulation

Ocean currents are not as an important energy source in shaping the shoreline but do play an extremely important role in providing nutrients and larvae dispersal. In the northern Gulf of Alaska, the Alaska Coastal Current is the major driving force (Fig. 16). This current flows from east-to-west and has been shown to be closely related to nutrient fluxes along the coast. Upwelling events that are associated with the current. Although the pattern is generally one of east-to west flow, there are large clockwise gyres that occur within the current system that cause significant variation in local current directions and speeds.

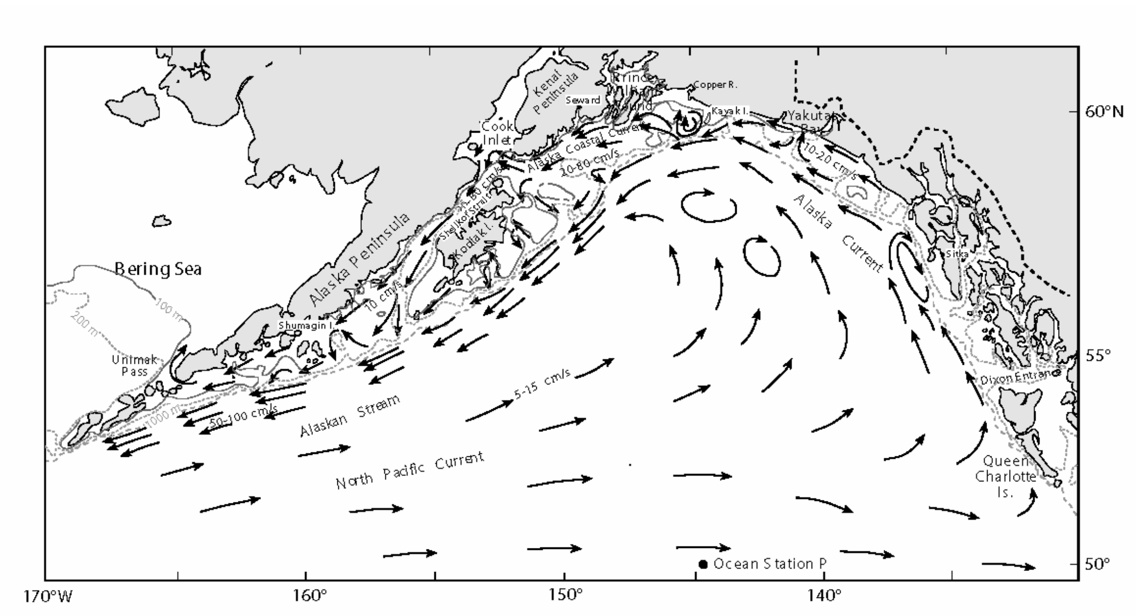



Figure 16. General circulation of the northern Gulf of Alaska showing the westward flowing Alaska Coastal Current along the shore. The Alaska Coastal Current flows westerly through Shelikof Strait and along the shore of Katmai National Park and Preserve.

The dominant current through Shelikof Strait is nearly always east to west but some reversals occur, particularly during the late spring, early summer period. A circulation model of the Shelikof Strait circulation (Fig. 17; http://www.pmel.noaa.gov/sciapp/spem/shelikof.html) also shows that freshwater runoff near the coast creates low-salinity water along much of the Katmai shoreline in late summer-early fall.

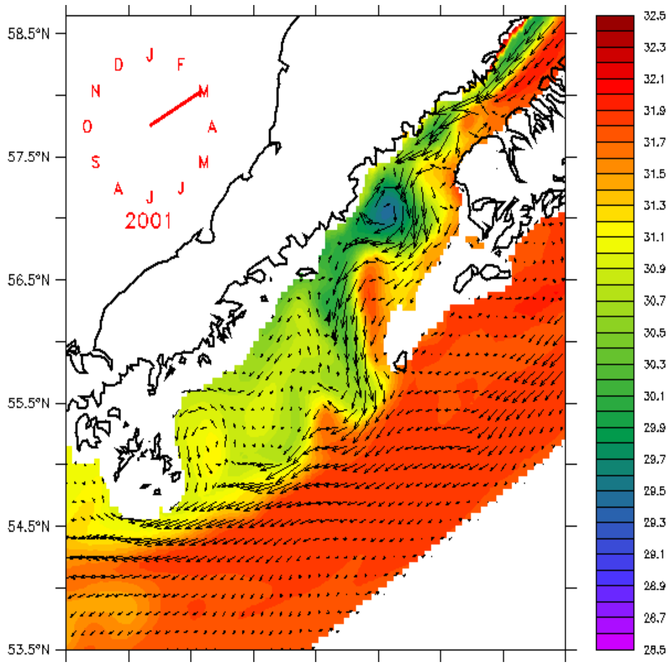



Figure 17. Results from a model of the Shelikof Strait circulation pattern (arrows) and salinity pattern (color: red is salty, blue is fresh; scale is in parts per thousand) for March 2001. (Source: NOAA website: http://www.pmel.noaa.gov/sciapp/spem/shelikof.html)

*Ocean currents (the Alaska Coastal Current) generally flow from east to west along the Katmai coast. The current is important in dispersing organisms along the coast and also was responsible for spreading oil from the Exxon Valdez spill to the Katmai coast.*

**Runoff**

Runoff from rivers delivers sediment to the shoreline where it can be redistributed by waves. There are typically large areas of accretional landforms associated with the major rivers on the Katmai coast. The steep terrain, common occurrence of glacial runoff, and the abundance of unconsolidated sediments within the watersheds of the Park result in high rates of sediment supply to many sections of the shoreline. This sediment supply is part of the coastal sediment budget and has resulted in prograding shoreline on many sections of shoreline. For examples, the former village of Katmai, originally located on the shoreline of Shelikof Strait prior to the 1912 eruption, is now several kilometers from the shore, primarily due to coastal progradation from river runoff.

River runoff is also important in diluting the salty, marine waters near the coast and creating estuarine conditions in many of the bays. Some intertidal species prefer brackish water habitats (for example, wetland grasses) whereas other intertidal species are quite sensitive to freshwater (for example, seastars) so the occurrence of fresh or brackish water has an important influence on coastal biota. Some species are considered as indicators of *estuarine conditions* whereas other species are seen as indicators of *marine conditions*. The coastal mapping program uses *wetlands* as an important indicator of estuarine water quality (see discussion of wetland/estuaries in Katmai on page 43).

There are no gauged rivers within Katmai National Park and Preserve but the Johnson River from Lake Clark National Park to the north has similar watershed characteristics and its annual runoff curve is presented in Figure 18. The rivers generally have very low flows during the winter months when precipitation is in the form of snow. The onset of spring freshet is very abrupt in the late spring with peak discharges in June-July. Late summer peaks are may also occur as a result of precipitation events. The rivers return to low flow conditions in September where they remain for the duration of the winter.

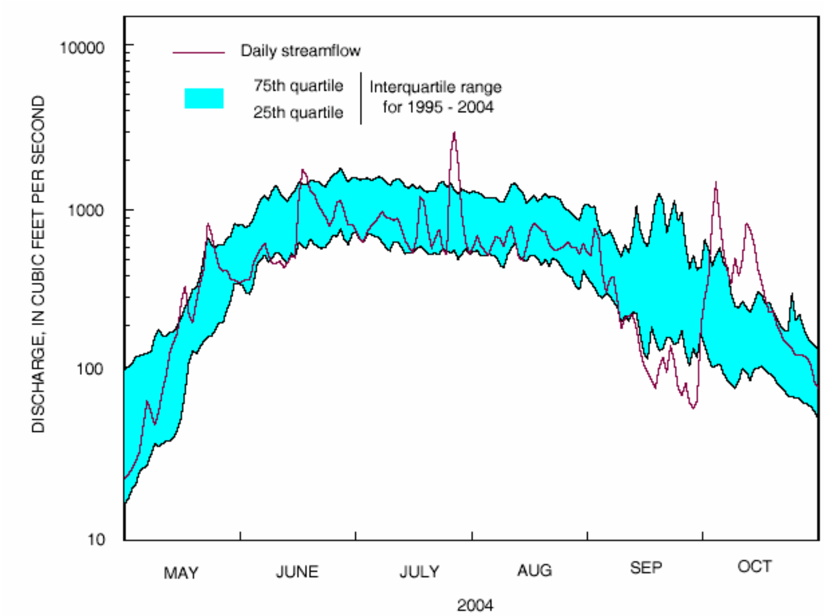



Figure 18. Example of stream flow data from the Johnson River in Lake Clark National Park. Discharge scale (left) is logarithmic.

## Ice

Sea ice does not form in Shelikof Strait. However, freshwater from river runoff into the small bays along the coast does freeze locally. While this ice cover is not permanent and may shift around within the bays, it can affect the occurrence of intertidal organisms where the ice scrapes against the shore. Such ice formation may also limit the seaward extent of wetlands.

*Flows in coastal rivers are very low during winter months but climb rapidly during the summer melt season. Freshet occurs in June-July and as a result the waters of coastal embayments are likely to be very fresh during the summer months.*

*Ice is probably not very important in controlling ecological processes on the Katmai coast.*

It is helpful to think of the shoreline as divided up into a limited number shore types such as sand beaches, rock cliffs, mudflats, etc. In fact this is the fundamental principal of the coastal habitat mapping program. There are repeatable and recognizable coastal features that can be mapped and in the case of the coastal geomorphology, these repeatable features are called *shore types*. As part of the mapping program, thirty-four separate shore types were mapped along the 837 km of the Katmai coast. It is important to remember, however, that in the natural environment, there are few well-defined boundaries - there is really a continuum of coastal morphologies and almost an infinite number of unique combinations of coastal features and substrates.

The mapping procedure that was used as part of this project has been applied to over 50,000 km along the shoreline in the northeast Pacific Ocean. Shoreline features are mapped from coastal videography that is flown during the lowest tides of the year. Features as small as cobbles can be identified on the imagery. Coastal morphology, coastal substrate and coastal biota are systematically recorded by mapping their distribution as alongshore segments of shoreline and by recording information in a linked database (see www.CoastAlaska.net for more information). A general picture of the coastline is built from the detailed observations and mapping.

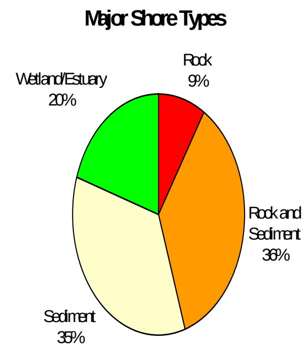
## Classification and Occurrence

For this overview, only the most generalized information is presented. The most general level of coastal morphology is usually considered in terms of hard, immobile substrate termed rock shorelines and "soft", mobile substrates termed sediment shorelines. Although it is helpful to think of shorelines in these two general classes, there are many place where *both* substrates occur together – rock *and* sediment shorelines - and these are mapped separately. A fourth shore type is that of wetland/estuaries, where wetlands, which can be mapped and are used as an indicator of estuarine or brackish water conditions. The occurrence of these major shore types along the Katmai coast is shown in Figure 19. A map of these major shore types is included as Figure 20.

**Table 1 Shore Type Classification**

| Major Substrate | Shore Type |
|---|---|
| *Rock* | rock cliffs and platforms |
| *Rock + Sediment* | rock with gravel |
| | rock with sand & gravel |
| | rock with sand |
| *Sediment* | gravel beaches |
| | sand & gravel beaches |
| | sand beaches |
| | mud flats |
| *Wetland/Estuary* | wetland (over sand) flats |
| *Man-made* | does not occur in Katmai |

Figure 19. Occurrence of major shore types within Katmai National Park. This distribution is shown in Figure 20.



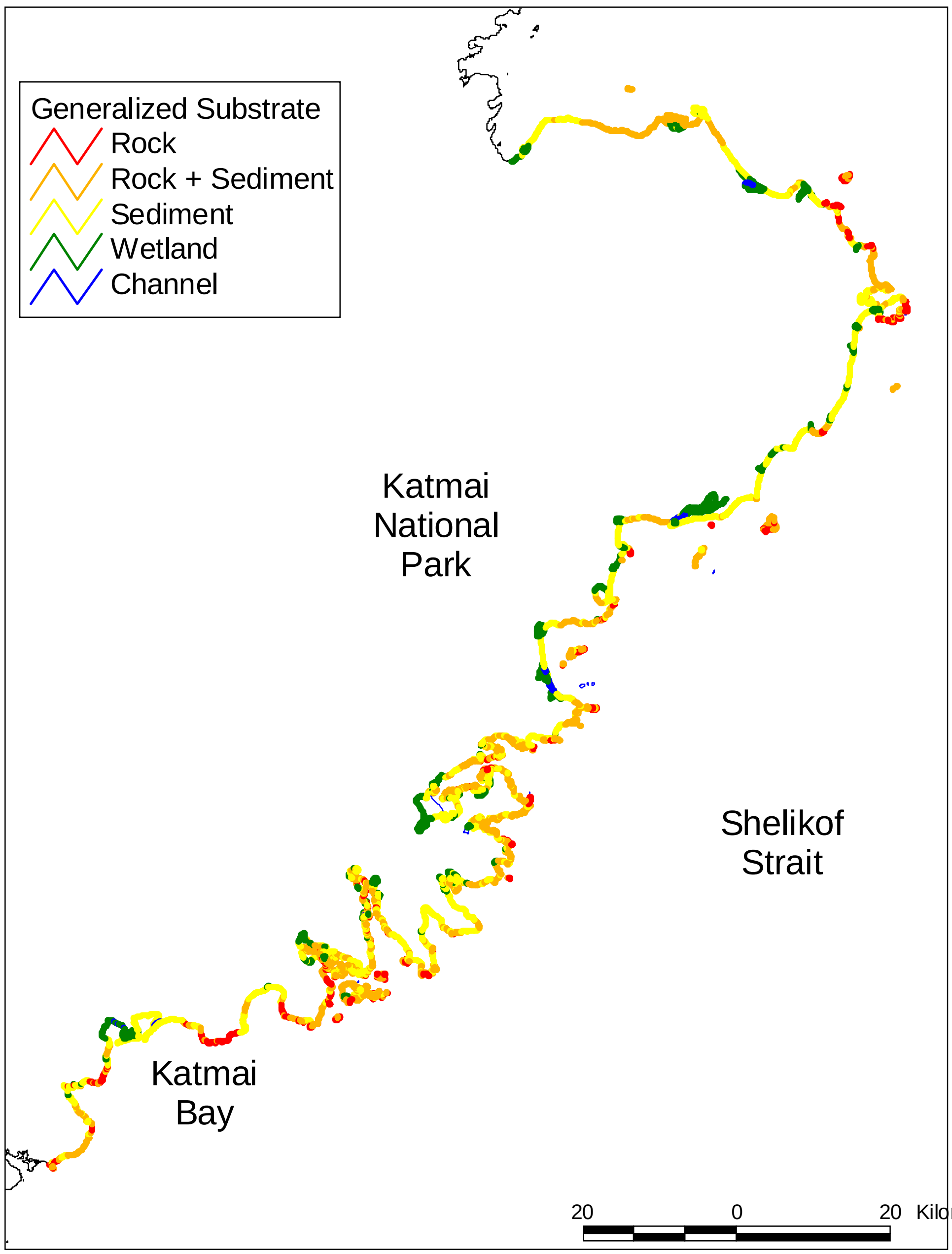




Figure 20 Distribution of general substrate types in Katmai National Park. The dominant orange-yellow coloring reflects the high proportion of the coast with sediment cover (~71%). Only 9% of the coast is rock without sediment.

**Examples and Descriptions of Shore Types**

Rock

Rock shores, which make up less than 10% of the Katmai coast, include steep rock cliffs (Fig. 21), rock ramps and rock platforms (Fig. 22). On outer exposed shorelines, wide rock platforms, particularly where sedimentary bedrock is found. Eroding cliffs cut into columnar basalt occur frequently.

Figure 21. Rock cliff shoreline cut into columnar basalts on Takli Island at the mouth of Amalik Bay. Cliff heights are 20-30m.

Rock & Sediment

Combinations of rock and sediment are the most common shore type (36%). These may be rock cliffs with gravel (boulder-cobble) beaches at their base, rocky ramp shorelines surrounded by beaches (Fig. 23), or wide rock platforms with sediment veneers of boulder cobble-sized sediment. Depending on the exposure that is associated with a particular rock-sediment shoreline, the sediment constituent may be mobile and move under the influence of wave action or it may be sufficiently large to be stable. Even large boulders may be transported on high exposure shorelines whereas small cobbles and pebbles may be stable on low exposure shorelines.

Figure 22. Rock cliff with wide, wave-cut platforms cut into sedimentary rocks at Cape Nukshak (south end of Hallo Bay). Platform width is about 50-70m.

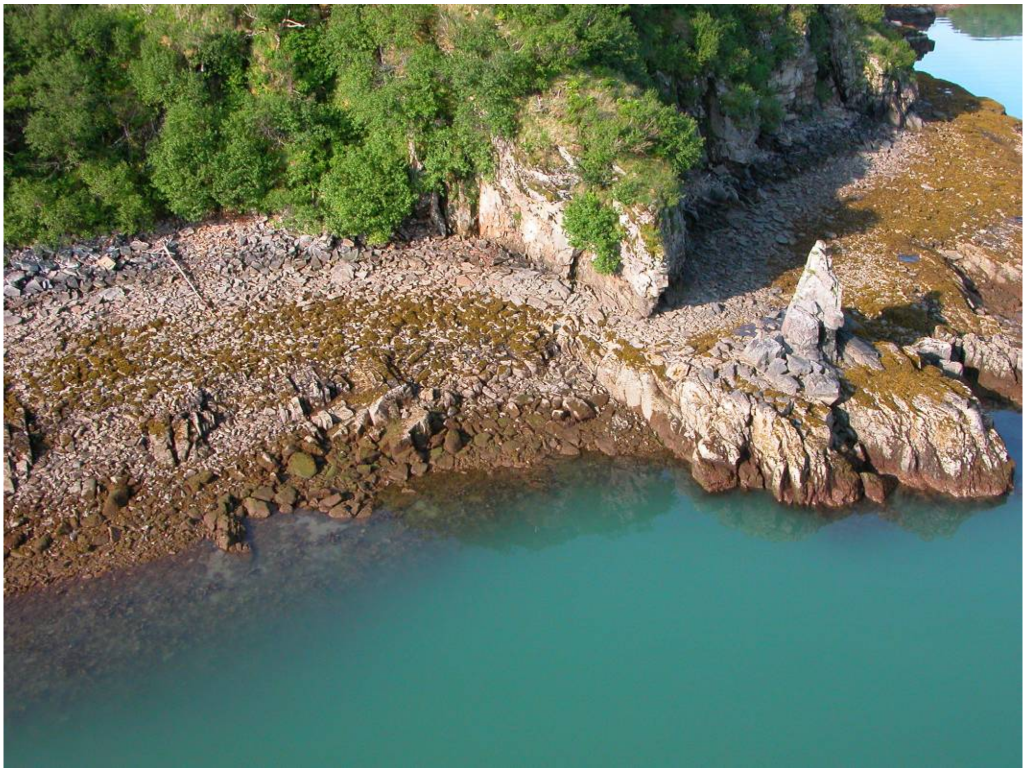


Figure 23. A complex area of shoreline with a combination of rock and sediment shore types within Kukak Bay. The predominate shore type in this photo is a rock platform with a veneer of cobble and boulder. Energy levels at the site are low and the cobble-boulder sediment is stable so there is a well-established algae cover in the mid to lower intertidal (especially near the waterline) . There is a sea stack on the narrow rock platform (right side of photo).

Sediment

All sediment shorelines, primarily gravel (Fig. 24), sand & gravel (Fig. 25) and sand beaches (Fig. 26) are common (35%; Fig. 19) within Katmai National Park and Preserve. There is also sediment on the rock-sediment shoreline; the total occurrence of sediments on shorelines is summarized in Table 2. Most of the shorelines on the outer, exposed coastline have highly mobile sediments. Longshore sediment transport may transport sediment along the coast for many kilometers from its source, such as a river mouth or an eroding cliff. On gravel shorelines within low-energy bays, sediments are typically too large to be reworked by the small waves that occur in these environments.

**Table 2 Occurrence of Beach Types**
**(includes sediment, rock & sediment)**

| Type | Occurrence |
|---|---|
| *gravel* (boulder, cobble or pebble) | 22% |
| *sand & gravel* | 26% |
| *sand* | 22% |
| *mud* | 2% |

Mudflats are relatively rare and form in places of low wave energy where there is a large sediment source. Glacial runoff streams typically carry large silt and clay loads and mudflats with Katmai National Park and Preserve are strongly associated with these features.

Figure 24. A boulder beach at the base of a rock cliff near Cape Nukshak. Although this boulder beach is on an exposed coastline, the boulders are stable and support lush algae growth from the middle to lower intertidal zone. The beach width is approximately 40 m.

Figure 25. The beach at the base of this cliff at the mouth of Kinak Bay includes both sand (brownish in color, especially at lower left and in the subtidal) and gravel (gray colour is mostly pebble-cobble although individual boulders are visible at right). A small berm of pebble-sized sediment occurs along the base of the cliff. Sediment finer than boulders is mobile and does not support epibiota but the boulders at right are large enough that they are stable and algae is attached.

Figure 26. A wide sand flat near the mouth of Kukak Bay (in background). Although there is a cliff in the backshore, the sand flat is nearly a kilometer in width with a series of shore-parallel sand ridges formed by wave action (ridge and runnel system).

Wetland/Estuary

Wetlands are very common with Katmai National Park and Preserve (20%of the coastal length; Fig. 19) and are indicators of estuarine water conditions, where water is typically brackish throughout most of the year. there are a wide-variety of wetland/estuary shores in Katmai National Park and Preserve, ranging from the broad embayments estuary that occurs in Hallo Bay (Fig. 14, 15), wetland/estuaries at the alluvial fans of glacial melt-water streams (Fig. 27), lagoon wetland/estuaries (Fig. 28) and small pocket wetland estuaries (Fig. 29).

Figure 27. A wetland/estuary on an alluvial fan at the head of Missak Bay

Figure 28. A lagoon wetland/estuary on the exposed coast southwest of Douglas Reef (near Cape Douglas). A barrier spit protects the lagoon. There is no permanent opening but runoff from the backshore and occasional storm washover of the barrier spit create a brackish water environment conducive to wetland development.

Figure 29. A small pocket wetland/estuary in Missak Bay. The barrier spit is progading to the north (from top to bottom of the photo). Older, relict barrier spits are evident within the estuary. Logs are accumulating in the storm berm and are occasionally washed into the estuary during storms; the logs are deposited on top of the wetlands (center right).

Coastal habitats are described by the observations of the biota together with the physical attributes of the shoreline. The geomorphology, that is, the substrate type and its form, together with the energy at the shoreline are the primary determinants of the biological community. Coastal substrate that is stable, such as bedrock coasts, has different biological communities than mobile, dynamic beaches. Stable shorelines support attached epibiota (sessile plants and animals that live on the bottom), whereas shifting, mobile sediments cannot support attached epibiota.

The combination of substrate, energy or exposure, salinity regime, tidal submergence and the biota itself are elements that define coastal habitat. It is the wonderfully complex mixture of biotic and abiotic features that determine the suitability for a variety of coastal wildlife.

Understanding how these factors influence the spatial variability of coastal habitat along the Katmai coast will help to identify sensitive habitats and can assist in managing resources associated with different habitats.

## Aerial Biology

As with the coastal geomorphology that is discussed in the previous chapter, it is possible to make systematic observations of the biology during the aerial surveys. Biological features such as wetlands, mussel beds, eelgrass beds or kelp beds are visible from the air and are systematically mapped throughout the Katmai National Park and Preserve. The recognizable assemblages of biota that are visible from the air are called *biobands* because they resemble painted bands along the shoreline (Fig. 30). A *bioband* is a repeatable assemblage of biota that (a) has a characteristic color and texture, (b) is recognizable from the air, (c) typically occurs at a specific elevation in the intertidal zone and (d) is usually named after the dominant species in the band. A detailed description of the biobands that have been mapped in Katmai is included in Appendix A.

Figure 30. Biobands on a rocky islet at moderate wave exposure. Each band is an assemblage of biota, named for the dominant species. The combination of biobands observed on the shoreline are used to indicate the intertidal wave exposure and habitats. This islet is near Cape Gull, south Kaflia Bay.

The presence or absence of these biobands provides considerable information about the ecological processes on the shoreline. The occurrences of indicator species in biobands are used as an guide to the known physical tolerances of those species, and by recording these biobands' occurrence in a spatial dataset, coastal habitats can be classified and mapped.

For example, the *eelgrass bioband* is always found in lower wave exposures and in sediment-dominated locations. In contrast, the presence of the *dark brown kelps bioband* always indicates higher wave exposures and stable substrate. It is the combination of bands (presence and/or absence) that is used to classify the unit's wave exposure category and habitat class category.

The lower intertidal biobands are diagnostic in determining the wave exposure and habitat categories. Upper intertidal biobands (e.g., *rockweed, barnacle*) can occur at almost all energies, on stable shorelines. The presence or absences of the lower intertidal bands (e.g., *red algae, soft brown kelp, dark brown kelp, alaria, eelgrass, surfgrass* and the nearshore subtidal canopy kelps *bull kelp* and *dragon kelp*) are the bands used to categorize the exposure and habitat classes.

Examples of five habitats defined by the 'biological bar-coding' or bioband assemblages are illustrated in Table 3. Not every wave exposure/substrate combination will show exactly these assemblages of biobands, but rather, these are 'typical' combinations at these example habitats.

**Table 3 Examples of Habitats Defined by Bioband Occurrence**

| Zone | Bioband Name | high exposure sand beach | high exposure rock | moderate exposure rock & sediment | low exposure rock | low exposure estuary |
|---|---|---|---|---|---|---|
| Supra-tidal | Salt marsh grasses & herbs | | | | | ■ |
| | *dune grass* | ■ | | | | ■ |
| | *sedges* | | | | | ■ |
| Intertidal | *rockweed* | | | ■ | ■ | |
| | *barnacle* | | ■ | ■ | ■ | |
| | *green algae* | | | | ■ | |
| | *blue mussel* | | ■ | ■ | ■ | ■ |
| | *bleached red algae* | | | ■ | | |
| | *red algae* | | ■ | ■ | | |
| | *surfgrass* | | | ■ | | |
| | *alaria* | | ■ | ■ | | |
| | *soft brown kelps* | | | ■ | ■ | |
| | *dark brown kelps* | | ■ | ■ | | |
| Subtidal | *eelgrass* | | | | | ■ |
| | *dragon kelp* | | | ■ | | |
| | *bull kelp* | | ■ | ■ | | |

**Stable Substrates**

The assemblages of fixed biota generally vary in predictable patterns on stable substrates, according to the combined influence of wave energy, tidal submergence and freshwater occurrence. Bedrock shorelines are always immobile (Fig. 31, 32) and are the shorelines where the 'typical' assemblage of biobands is the clearest index of the site's wave exposure. At lower wave energies, boulder or even cobble-sized beaches can have attached biota because the wave energy is not sufficient to move the substrate.

Figure 31. Stable substrate shorelines (rock cliff) at moderate to high exposure occur on about 8% of the Katmai shoreline. Indicator biobands for this class include: the upper intertidal wide *splashzone*, *rockweed*, *blue mussels*, *barnacles* and, the lower intertidal lush *red algae* and *alaria biobands*. This islet is at the southwest entrance Kinak Bay.

Figure 32. Stable bedrock cliff, at lower wave exposure. These shorelines are not common in Katmai and are found on less than 5% of the coastline. Indicator biobands of this habitat are: narrow *splashzone*, which is the black lichen in the upper intertidal, with *barnacle, rockweed; filamentous reds biobands* at the waterline. There is also a *soft brown kelps bioband* in the nearshore. This example is from Hidden Harbor, at the head of Kinak Bay.

**Partially Stable Substrates**

At moderate wave exposures, shorelines that are a mixture of stable and mobile substrates will include some of the exposure indicator biobands but may be missing others on mobile portions of the shore. For example, at a moderate wave energy site, a rock platform can have a lush biota, while the nearby, mobile pebble beach will be bare. These mixed habitats are termed *partially mobile* habitats.

Partially mobile habitats are seen at all wave exposures, depending on sediment size. That is, at the high wave energies, boulders can be mobile and have less attached epibiota, while at lower wave energies, finer materials will be mobile and appear bare of epibiota. Finer sediments are often well populated with benthic infauna.

Figure 33. The partially-mobile, moderate wave-exposure habitats account for about 15% of the Katmai shoreline. The beach, at Cape Gull south of Kaflia Bay, is ‘armoured’ by boulders. On the upper beach, only the largest sediment sizes are stable. Indicator biobands in this example are: patchy *barnacle* and *rockweed biobands* on the stable upper beach boulders, with lower intertidal showing *red algae, alaria* and *dark brown kelps biobands*.

Figure 34. Low-energy partially mobile habitats are also common in Katmai, and account for about 16% of the shoreline length. Mobile sediment is seen as bare beach on the right half of this example, while larger material on the left half of the beach has patchy *barnacle*, *rockweed* and *blue mussel biobands* in the upper beach. There is a nearshore subtidal bioband of *soft brown kelps bioband*. This example is in Geographic Harbor.

## Mobile Substrates

Examples of mobile substrates are bare sand, pebble or cobble beaches (Fig. 35-37). Mobile habitat classes can also appear at all wave exposures but are most common in moderate or high wave energies. At high-energy shorelines, any sediment size may be mobile (e.g., large boulders to sand-sized sediment) whereas at lower energies, only the finest sand and silt will be mobile. Much of the Katmai coast is in the bare, mobile sediment habitat classes, with about 36% of the Katmai classified as bare beaches.

Figure 35. Wide, bare-looking sand beaches occur at many of the larger river mouths in Katmai. This beach, in Dakavak Bay, just east of Katmai Bay has no attached epibiota, and is classified as a moderate energy, mobile habitat. A benthic infaunal community is likely present, buried in the dynamic, shifting sand.

Figure 36. Higher energy bare beaches, like this example from near Cape Douglas, show mobile boulder and cobble sediment. Infauna on this type of beach is different than on bare sand or mud beaches.

Figure 37. Numerous bare pocket beaches are mapped in Katmai. This example is from a low wave exposure shore in Geographic Harbor, with attached biota on the stable substrate at either side of the beach. Smaller bare beaches seemed to be favorite foraging areas for brown bear and red fox, as many animals were observed digging in the intertidal zone.

There are some coastal features that are recognized as having special habitat value. These may be areas vulnerable or sensitive to man-made disturbance or habitats of special significance for other management values. Several coastal habitats in Katmai identified for discussion are: dunes, wetlands, seagrasses, canopy kelp beds, soft sediment beaches, and higher-energy bedrock habitats.

## Dunes

Sand dunes occur in many locations within the Park and may be distinguished by distinctive morphology and a near continuous cover of dune grass. About 70 km of dunes have been mapped along the Katmai coastline (Fig. 38).

There are several different dune types in Katmai. One feature that is commonly confused with dunes are the prograding beach ridges areas (Fig. 39); these wide beach ridge plains are typically associated with larger river mouths on the outer coast. The morphology of these ridges is inherited from storm berm deposits, which are then capped by dune grasses that trap some wind-blown sand. However, the prograding beach ridges are typically colonized by dune grasses (Fig. 40), which is the dominant vegetation of the dunes.

Small dunes exist locally within the Park (Fig. 38), and the area north of Cape Douglas near the mouth of the Douglas River has extensive dune fields (Fig. 41).

Dunes are listed as a special habitat because they are sensitive to damage by trampling. Dunes in blowout areas (see Fig. 41) are of particular concern as dunes are highly susceptible to re-activation and even a small loss of vegetation could produce some relatively large effects.

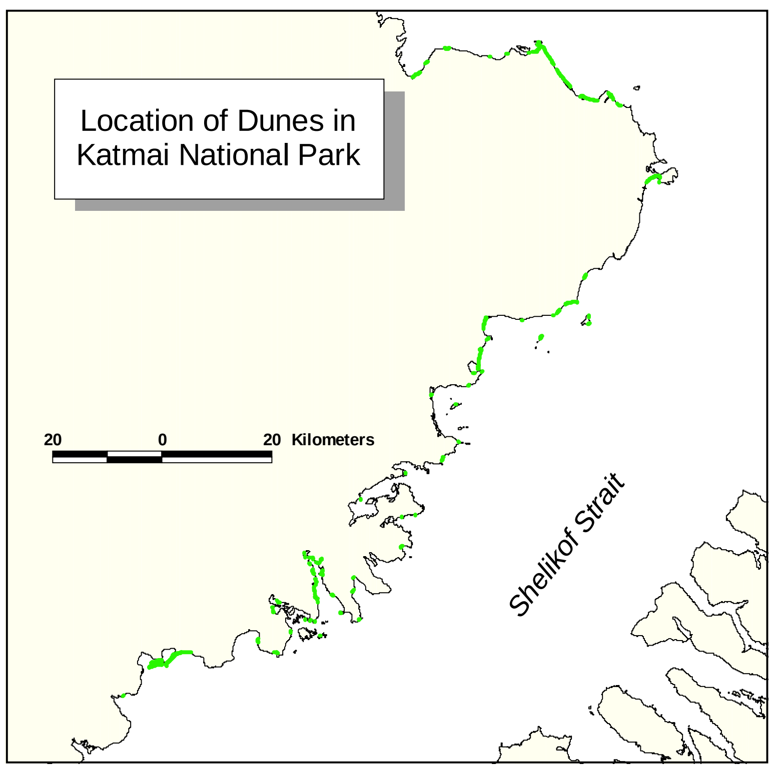



Figure 38. Occurrence of dunes along the Katmai shoreline. Approximately 70 km of shoreline was mapped with dunes.

Figure 39. Wide beach ridge plain at the mouth of the Swikshak River, north of Hallo Bay. Gravel storm berms (unvegetated storms berms are visible in the lower part of the frame) are vegetated by dune grass and small shrubs. Longshore sediment transport is from right to left (to the west).

Figure 40. Dune grass (*Leymus mollis*) on upper intertidal beach berm in Geographic Harbor.

Figure 41. Dune field near the mouth of the Douglas River showing blowout dunes cut into the established dune vegetation.

**Wetlands**

Wetlands in Katmai are nearly all associated with estuaries, and most estuarine habitats in Katmai are large areas of alluvial delta, with glacial outwash rivers and abundant sediment supply (Fig. 4, 10, 14, 27, 28 and 29 show examples of wetlands and estuaries). Figure 42 shows an example of a small estuary.

These wetlands have spatially complex vegetation communities, with combinations of grasses, salt-tolerant herbs and sedges stratified by elevations (Fig. 15). In the Hallo Bay vegetation map (Fig. 15) the most salt-tolerant and drought-tolerant assemblage of dune grass (*Leymus mollis*) is mapped in a narrow strip along the driftwood line along the beach berm. Dune grass is also a component of the next two higher vegetation types: the '*Leymus* – Herb Meadow' and the 'Bluejoint (grass) – *Leymus* – Herb Meadow'. The '*Puccinellia'* (alkali grass) types are also tolerant of brackish water conditions and will flourish at elevations between the open coast and the more riverine salinities. The '*Carex'* (sedge species) communities are found at slightly higher, more riverine conditions than the alkali grass types, and the highest elevations in the estuary meadows are the least salt-tolerant, as soil conditions become more terrestrial. These highest elevations in the estuary have 'birch forest' or 'shrub willow' communities (*Betula* – Scrub Willow – *Empetrum* vegetation types).

Figure 42. Small estuary in Kukak Bay associated with small river and watershed. Most of the Katmai shoreline that was classified as estuary habitat is found in the large estuaries; however, smaller estuaries are important contributors to habitat complexity in the landscape.

Smaller estuaries in Katmai show similar patterns of vegetation communities but with a lesser area of extent (Fig. 42). Because estuaries are highly productive and highly valued areas, understanding the distribution of small estuaries within Katmai is important for regional planning. Several, scattered small estuaries will have a different cumulative ecological function in the area than one large estuary equivalent to the same combined area.

Estuaries and wetlands are highly sensitive to oil spills. Because of the fine and organic sediment and the low wave exposure environments, oil persistence in these areas can be lengthy. Cleanup is also difficult and can result in long-term, damage if not conducted properly..

## Seagrass Beds

Seagrasses that occur within Katmai National Park and Preserve include eelgrass (*Zostera marina*) and surfgrass (*Phyllospadix*). Their appearance is very similar but they occur in different habitats that rarely overlap. Both are vascular plants that are adapted to the marine environment. Seagrasses are identified as a "special habitat" because they are regarded as having high value as a juvenile fish habitat. Juvenile salmonids, juvenile bottom fish and forage fish are known to use eelgrass beds for cover and foraging. Seagrasses are also an important spawning habitat for herring.

The primary anthropogenic threats to seagrasses on the Katmai coast are probably oil spills and man-induced climate change. Studies have suggested that fauna within eelgrass beds are more likely to be effected by an oil spill than the plants themselves[1]. Even where oil comes into contact with the leaves, damage appears to be transitory. The potential impacts of climate change on eelgrass are highly speculative but could include changes in precipitation that would change nearshore salinity or turbidity regimes, changes in frequency of storms that might alter the existing energy balance of the nearshore and changes of ambient water temperature that could affect plant growth rates or even the formation of nearshore ice.

### Eelgrass

Eelgrass occurs in lower wave-exposure environments than surfgrass. Eelgrass is most commonly found in *semi-protected* or *protected* exposure areas and is rooted in soft-sediment bottoms of sand or muddy sand.

Eelgrass is mapped as *continuous* on about 7% of the coast and *patchy* on an additional 15% of the coast for a total occurrence within the Park of 128 km (Fig. 43). The eelgrass within Katmai National Park and Preserve occurs almost exclusively as narrow fringing beds (Fig. 44, 45 and 46). The turbid glacial melt-water that is common within many of the Katmai bays may limit eelgrass to the shallow shore areas because of the light attenuation (the seaward limit of eelgrass is commonly limited by the amount of sunlight).

### Surfgrass

Surfgrass is a more robust plant and is found in *semi-exposed* areas and attaches to hard, immobile substrate (Fig. 47 and Fig. 48).

[1] http://www.ukmarinesac.org.uk/communities/zostera/z5_2.htmi

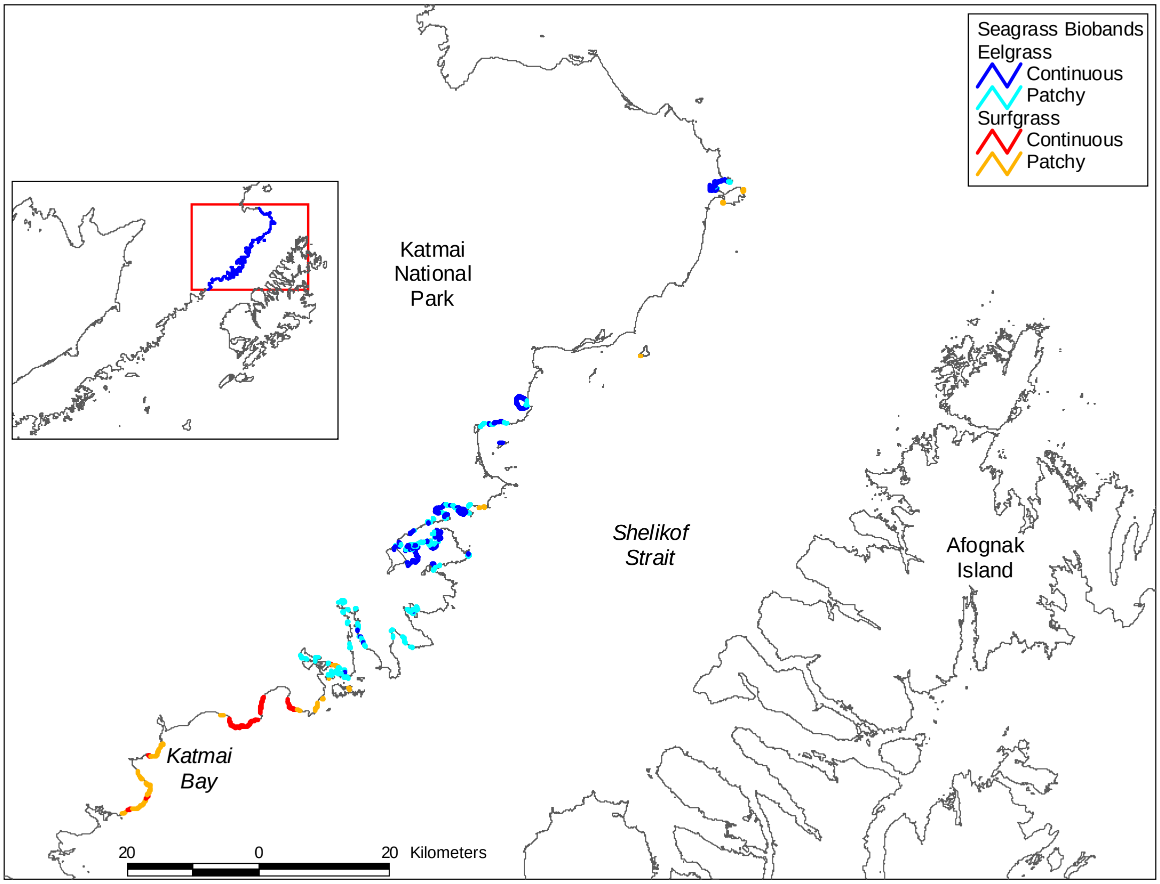



Figure 43. The occurrence of seagrasses within Katmai National Park shoreline. Eelgrass is typically limited to protected bays, especially Kukak Bay whereas surfgrass occurs on more exposed locations of the coast, notably in the south portion of the Park where hard substrate shorelines are more common.

Figure 44. Fringing eelgrass in lower intertidal and shallow subtidal of Kukak Bay. Note the bear tracks (lower left corner) for scale. Upper beach is coarse cobble-boulder-pebble and the lower intertidal is muddy sand. The milk-green color of the water is typical of glacial runoff.

Figure 45. Narrow fringing eelgrass bed on a small islet in Kaflia Bay. Eelgrass bed is less than 10m in width.

Figure 46. Eelgrass (*Zostera marina*) on lower intertidal, fine sediment beach. This station is in *protected* wave exposure in Kukak Bay. The eelgrass is mixed with foliose green algae.

Figure 47. The green coloration in the lower intertidal zone is a dense surfgrass bed on a bedrock platform within Dakavak Bay (just east of Katmai Bay). This photo also shows an example of combination rock-sediment beach where some of the stable rock platform is colonized by epibiota, and the upper intertidal zone sediments (boulder-cobble) are unstable and do not support epibiota.

Figure 48. Detail of surfgrass from rock platform in Katmai Bay. The physical appearance of surfgrass is very similar to eelgrass but surfgrass occurs in higher exposure areas and is always attached to hard substrate.

## Kelp Beds

Two species of canopy kelps occur in Katmai: bull kelp (*Nereocystis luetkeana*) and dragon kelp (*Alaria fistulosa*). Bull kelp is widely distributed in the park (Figure 49) while the dragon kelp is less common, and is found mostly at the southwest portion of the park. A large area of bull kelp was observed on the offshore Douglas Reef, south of Cape Douglas (Figure 49 and 50).

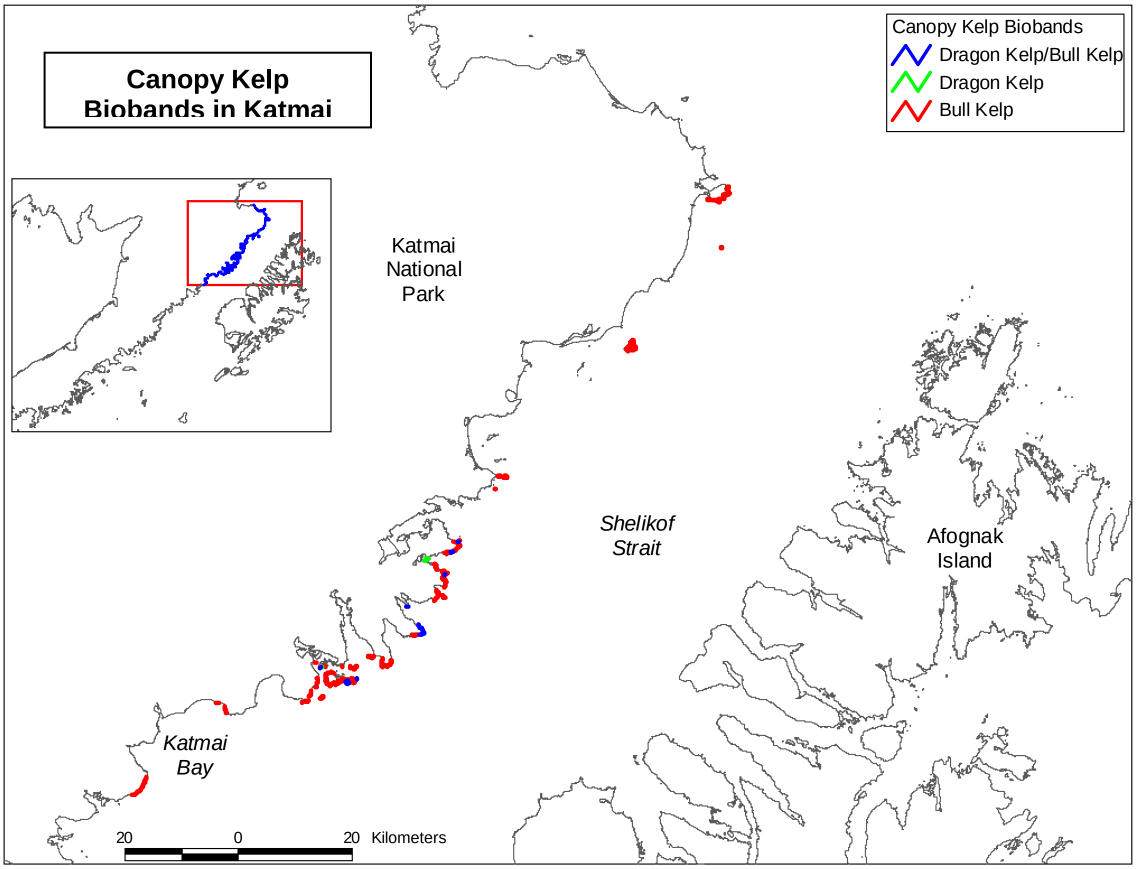



Figure 49. Distribution of Bull Kelp and Dragon Kelp in Katmai.

Canopy kelps are highly valued fish habitat. The difference in the distribution of these two canopy kelps is likely due to a combination of the oceanographic conditions, the affects of freshwater runoff, and the overall substrate types on the shoreline. Note that the distribution of the dragon kelp with bull kelp in the southwestern park generally mirrors the distribution of surfgrass (in Figure 43).

## Soft Sediment Beaches and Flats

Figure 50. Nearshore bull kelp (*Nereocystis luetkeana*) bed, around Douglas Reef, south of Cape Douglas.

Much of the Katmai coast is mobile, sediment-dominated shorelines and of those beaches, many are the lower exposure and finer material necessary for a rich benthic infauna. During a 2003 ground survey some beaches were sampled for infauna and a total of 16 different infaunal bivalve species were observed (Table 4). Blue mussels (*Mytilus trossulus*) were by far the most common bivalve, and were seen at 39 of the 41 stations visited during the survey.

Most of these bivalves were observed at the two soft-sediment stations (Fig. 51 - 56) and it is likely that these species assemblages are typical for other soft-sediment sites in Katmai. Observations from the head of Kaflia Bay are typical of the coarse sediment beaches (Fig. 51-53) that occur in sheltered bays, while the beach on Ninagiak Island in Hallo Bay is typical of the wider, finer sediment beaches in Katmai (Fig. 54-56)..

Soft-sediment beaches, in particular the lower wave exposure bays associated with wetland vegetation, are highly valued habitats and are sensitive to oil spills. Bears and other wildlife make extensive use of the sediment flats for feeding areas, by digging and foraging for shellfish.

**Table 4. List of Infaunal Bivalve Species Observed during the 2003 Katmai Ground Survey**

| Species Name | Common Name | Count of Occurrences |
|---|---|---|
| *Clinocardium californiense* | Aleutian cockle | 2 |
| *Clinocardium nuttallii* | Nuttall’s cockle | 1 |
| *Macoma balthica* | Baltic macoma | 1 |
| *Macoma golikoui* | macoma | 3 |
| *Macoma inquinata* | pointed macoma | 4 |
| *Mactromeris polynyura* | Arctic surf clam | 2 |
| *Modiolus modiolus* | northern horse-mussel | 2 |
| *Mya arenaria* | softshell clam | 1 |
| *Mya pseudoarenaria* | softshell clam | 1 |
| *Mya truncata* | blunt softshell clam | 1 |
| *Mytilus trossulus* | blue mussel | 39 |
| *Protothaca staminea* | Pacific littleneck clam | 2 |
| *Saxidomus giganteus* | butter clam | 2 |
| *Tellina hacculoides* | tellin clam | 1 |
| *Tellina lutea* | tellin clam | 1 |
| *Tresus capax* | horse clam | 1 |

Figure 51. Aerial view of low wave exposure beach near in upper Kaflia Bay . Mixed sediment sizes similar to this station are typical of the coarse beaches noted in lower wave exposure, sediment-dominated shorelines.

Figure 52. A low-energy, coarse-sediment beach at the head of Kaflia Bay. Note the blue mussel (black color) and rockweed (green color) on the stable boulder of the upper beach (left) and the mixture of sediment sizes across the lower beach (right). Sediment includes: boulder, cobble, pebble and shell over sand.


Figure 53. Detail of the course, angular sediment on the lower beach at the head of Kaflia Bay (same location as Fig. 53). Bivalves recorded at this site included: Aleutian cockle; two species of *Macoma;* two species of soft-shelled clam (*Mya*); Pacific littleneck clam; and butter clam.

Figure 54. Aerial view of the sand beach/offshore reef complex on the northwest side of Ninagiak Island in Hallo Bay. The spit growth shows that longshore sediment transport is from right to left.


Figure 55. View of sand beach terrace on the northwest side of Ninagiak Island, in Hallo Bay. Bivalves recorded at this site included: Aleutian cockle; Nuttall's cockle, pointed Macoma; Arctic surf clam; softshell clam (*M. arenaria*); Pacific littleneck clam; butter clam; tellin clam (Fig. 54); and horse clam.

Figure 56. Detail of tellin clam (*Tellina hacculoides*) on lower intertidal sand beach, Ninagiak Island.

## Higher-Energy, Bedrock Habitats

Higher wave exposure shorelines are included in the discussion of special habitats because of the complex and diverse species assemblages found at these sites. These types of shorelines represent habitats with the highest intertidal species diversity of flora and fauna. For example, at a stable bedrock shore station in a protected wave exposure in Geographic Harbor twenty-eight species of macrobiota were recorded, while at the higher exposure bedrock station on Kiukpalik Island (10km east of the Swikshak River mouth), eighty-two species were observed.

The lower intertidal of these high-diversity sites in Katmai is especially interesting, because the species assemblages observed there are somewhat different than at high exposure bedrock sites elsewhere in south-central Alaska. That is, in Katmai, the *dark brown kelps bioband* in the lower intertidal is not dominated by the stalked ribbon kelp (*Lessoniopsis littoralis*) as it is in similar shorelines in Kenai Fjords National Park, but instead is dominated by combinations of ribbon kelp (*Alaria spp.*), three-ribbed kelp (*Cymathere*), and Bongard's laminarin (*L. bongardiana*) (Fig. 57, 58). This difference in geographic distribution of the large brown algae may reflect the difference in oceanographic conditions between Shelikof Strait and elsewhere in the northern Gulf of Alaska.

Figure 57. Aerial view of Kiukpalik Island (10km east of the Swikshak R. mouth), showing the lush lower intertidal bioband of *dark brown kelps*.

Figure 58. The lower *intertidal dark brown kelp bioband* at Kiukpalik Island. Over 80 species of macrobiota were observed at this site, including 28 species of red algae, and 16 species of brown algae.

Another unusual higher exposure stable habitat was observed on the offshore reefs in Kamishak Bay, off the mouth of the Douglas River. These sandstone flats are slightly above mid-tide and are completely inundated at high tides. On these reefs, a lush assemblage of mixed red algae is the dominant epibiota, with the most of the cover due to several species of the small foliose red algae, *Palmeria* (Figure 59). Because of the large intertidal area of these reefs (Figure 60), the unusual geomorphology and the dominant biota, these are odd coastal features and worthy of special mention.

Figure 59. Bleached red algae *Palmeria* on offshore reefs north of the Douglas River in Kamishak Bay. The lush red algae are by far the dominant macrobiota on these platforms and cover a large

Figure 60. View across the wide intertidal platforms in Kamishak Bay. In addition to these reefs that are contiguous from the mainland shore, several other large offshore reefs are part of the complex.

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## Appendix A

Description of ShoreZone Biobands
Mapped in Katmai National Park and Preserve

**Table A - 1. Bioband Definitions: Shelikof Strait including the Katmai/Aniakchak coast**

| Zone | Bio-band Name | Colour | Indicator Species | Description | Exposure | Associated Species |
|---|---|---|---|---|---|---|
| Supratidal | **Splash Zone** | Black or bare rock | *Verrucaria sp*.<br>Encrusting lichens | Visible as a dark band on bare rock, marking the upper limit of the intertidal zone. Occurs on bedrock or boulder/cobble shorelines, at all wave exposures.<br>**Note:** This band is recorded by width<br>• Narrow (N) = less than 1m<br>• Medium (M) = 1m to 5m<br>• Wide (W) = more than 5m | Width varies with exposure<br><br>N=VP-SP<br>M=SP-SE<br>W=SE-VE | *Enteromorpha sp.*<br>*Hildenbrandia sp.*<br>*Littorina sitkana*<br>*Lottia sp.*<br>*Neomolgus littoralis*<br>*Tectura persona* |
| | **Dune Grass** | Pale blue-green | *Elymus mollis* | Located in the upper intertidal zone, on dunes or beach berms. Dune grass is often the only band present on high-energy beaches. | VP-SE | *Honkenya peploides* |
| | **Sedge** | Bright green, yellow-green to red-brown. Often appears as a mosaic of greens. | *Carex ramenskii*<br>*Carex lynbyei*<br>*Carex sp.*<br>*Eleocharis sp.*<br>*Eriophorum sp.* | Appears in wetlands around lagoons and estuaries; always associated with freshwater. Tends to occur as a wide flat stand, often forming a circular pattern, and commonly bordered by a PUC band. | P-SE | * species referenced for this band from Cook Inlet ground survey reports: Bennett, 1996 and Tande, 1996. |
| | **Marsh grasses, herbs and sedges** | Light, bright or dark green; red or brown | *Puccinellia sp.*<br>*Plantago maritima*<br>*Triglochin sp.*<br>*Carex sp.*<br>*Honkenya peploides* | Occurs in wetlands around lagoons, marshes, and estuaries. Also appears on dunes, and can be distinguished from dune grass band by its colour. | VP-SE | other grasses and sedges |
| Intertidal | **Barnacle** | Grey-white to pale yellow | *Balanus sp.*<br>*Semibalanus sp.*<br>*Chthamalus dalli* | Visible on bedrock or large boulders, this band can appear as a continuous frosting of barnacles, especially where overstory algae is absent. Generally occurs in upper intertidal, but at higher wave exposures, there is often a band of *Semibalanus* just above the waterline. | VP-E | *Endocladia muricata*<br>*Pterosiphonia bipinnata*<br>*Porphyra sp.*<br>*Fucus sp.*<br>*Neorhodomela sp.*<br>*Mytilus trossulus*<br>*Lottia sp.*<br>*Littorina sitkana.* |
| | **Rockweed** | Golden-brown to red-brown | *Fucus sp.* | Appears on bedrock, boulder, cobble or gravel. Commonly occurs at the same elevation as the barnacle band. | VP-E | *Pterosiphonia bipinnata*<br>*Balanus sp.*<br>*Semibalanus sp.*<br>*Chthamalus dalli*<br>*Mytilus trossulus*<br>*Littorina sitkana* |

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| **Intertidal** | **Green Algae** | Green | *Enteromorpha sp.* (usually in upper intertidal)<br>*Ulva sp.* (usually in mid to low intertidal). | Found on a variety of substrates and includes filamentous and/or foliose species. Filamentous species often form a low turf of dark green in lower wave exposures. Foliose species often occur with red algae in a species-rich assemblage at higher exposures. | VP-SE | *Fucus sp.*<br>*Pilayella sp.*<br>*Alaria sp.*<br>*Scytosiphon lomentaria*<br>Diatom chains<br>Filamentous and foliose red algae<br>*Lottia sp.* |
| | **Blue Mussel** | Black or blue-black | *Mytilus trossulus* | Visible on bedrock and on boulder, cobble or gravel beaches. Occurs in dense clusters that form distinct black patches or bands above or below the barnacle band. Predation by *Pisaster sp* or *Nucella sp* causes this band to occur at higher elevations. | P-E | *Fucus sp.*<br>*Pterosiphonia bipinnata*<br>*Neorhodomela sp.*<br>*Balanus sp.*<br>*Chthamalus dalli*<br>*Semibalanus cariosus*<br>*Lottia sp.*<br>*Littorina sitkana*<br>*Nucella lima* |
| | **Bleached Red Algae** | Olive, golden or yellow-brown | Bleached foliose red algae including:<br>*Palmaria sp.*<br>*Halosaccion glandiforme* | Occurs on most substrates except fine sediments. Distinguished from the RED11 band by colour. Bleaching may be caused by a nutrient deficiency. | SP-SE | *Cryptosiphonia woodii*<br>*Pterosiphonia bipinnata*<br>*Neorhodomela sp*<br>*Ulva sp.* |
| | **Red Algae** | **Coralline*:*** pink or white<br>**Foliose or filamentous***:*<br>Dark red, bright red or red-brown. | *Lithothamnion sp.*<br>*Cryptosiphonia woodii*<br>*Pterosiphonia bipinnata*<br>*Odonthalia floccosa*<br>*Palmaria sp.*<br>*Porphyra sp.* | Occurs on most substrates except fine sediments. Lush coralline algae indicate high exposures; foliose red algae indicate moderate exposures, and filamentous species, often mixed with green algae, indicate moderate to low wave exposures. | SP-E | *Alaria sp.*<br>*Fucus sp.*<br>*Semibalanus cariosus*<br>*Katharina tunicata*<br>*Littorina sitkana* |
| **Lower Intertidal & Shallow Substidal** | **Alaria** | Dark brown or olive-brown | *Alaria marginata* morph | Occurs on bedrock cliffs and platforms, and boulder/cobble beaches. This often single-species band has a distinct ribbon-like texture, and may appear iridescent in some imagery. | SP-E | *Laminaria sp.*<br>*Lithothamnion sp*<br>Foliose red and green algae<br>*Katharina tunicata.*<br>*Nucella sp.*<br>*Semibalanus cariosus*<br>*Urticina crassicornis* |
| | **Surfgrass** | Bright green | *Phyllospadix sp.* | Occurs in tidepools on rock platforms, often forming extensive beds. This species has a clearly defined upper exposure limit of semi-exposed. Easily confused with ZOS, which occasionally occurs in similar conditions where there is fine sediment on platforms. | SP-SE | *Laminaria bongardiana*<br>*Alaria sp.*<br>Foliose and coralline red algae<br>Bleached red algae |

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| **Lower Intertidal & Shallow Subtidal** | **Eelgrass** | Bright to dark green | *Zostera marina* | Occurs in estuaries, lagoons and channels, in low intertidal and subtidal zones. Eelgrass is usually found in areas with fine sediments, and grows in sparse patches or extensive dense meadows. | VP-SP | Filamentous and foliose green algae<br>*Pilayella sp.*<br>*Macoma sp.* |
| | **Soft brown Kelp** | Olive-brown or brown | *Laminaria saccharina*<br>*Laminaria bongardiana*<br>*Cystoseira sp.* | This band includes large brown algae characteristic of lower wave energy shores. Blades often have epiphytic diatoms and bryozoans, giving them a 'dusty' appearance. | P-SE | *Alaria sp.*<br>*Cymathere sp.*<br>*Costaria costata*<br>*Zostera marina*<br>Coralline red algae<br>*Tonicella sp.* |
| | **Stalked Dark Brown Kelp** | Dark chocolate brown | *Cymathere triplicata*<br>*Laminaria bongardiana*<br>*Alaria marginata* morph | Kelps in this band occur in the lower intertidal and upper subtidal zones in higher wave exposures. Blades are leathery and shiny. Limited distribution of this bioband in Katmai, as the primary indicator species for this band do not occur in this region. RED band more common than CHB at high exposures in Shelikof Strait. | SE-E | *Costaria costata*<br>*Odonthalia floccosa*<br>*Palmaria sp.*<br>Coralline algae<br>*Semibalanus sp.* |
| **Subtidal** | **Dragon Kelp** | Golden-brown | *Alaria fistulosa* | Canopy-forming alga with a long blade and hollow floating midrib. Occurs in nearshore habitats, and when found in association with NER, it occurs inshore of that band. | SP-SE | *Nereocystis luetkeana* |
| | **Bull Kelp** | Dark brown | *Nereocystis luetkeana* | A distinctive canopy-forming nearshore kelp, with many long strap-like blades growing from a bulb atop a long stipe. This band usually occurs further offshore than *Alaria fistulosa*, and usually indicates high current areas when observed at lower wave exposures. | SP-E | *Alaria fistulosa*<br>*Costaria costata*<br>*Cymathere triplicate*<br>*Laminaria sp.*<br>Diverse assemblage of filamentous, foliose and coralline red algae |