Coastal Habitats of Southeast Alaska

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Habitats arrayed along the land-sea interface are important far out of proportion to their areal extent. Because of its narrowness, the beach comprises relatively few acres, but its linear extent is impressive. Southeast has more than 18,000 miles (30,000 km) of marine shoreline, and the archipelago is so intricately dissected that nearly all resident vertebrates can make use of the coastal fringe at some point in their life cycles. Extremely high productivity makes this fringe a critical foraging zone for both herbivores and predators. And all but the steepest beaches provide well-used travel corridors.

Within the coastal fringe habitat division, the linear beach habitats are separated from those of estuaries. Although estuaries comprise less than 2% of the total land area of Southeast, their ecological importance merits further subdivision into several tidal and barely supratidal zones.

INTERTIDAL BEACHES

Beaches in this discussion are subdivided according to substrate composition: (1) exposed bedrock; (2) unconsolidated beaches with coarse material such as boulders, cobbles, or gravel; and (3) sand beaches. Note that estuaries are discussed separately.

FIG 1. The Marble Islands of Glacier Bay host a rapidly growing haulout colony of Stellar sea lions (*Eumetopias jubatus*). Exposed, steep bedrock, indented with resting shelves, is good habitat for marine mammals and nesting seabirds like gulls and alcids.

FIG 2. Andesitic cliffs with columnar jointing on Saint Lazaria Island near Sitka. Fracture patterns of this bedrock type form ideal nest perches for murres and cormorants.

FIG 3. Shoals Point, Kruzof Island. Shelving basalt formations create unusual, gently sloping bedrock beaches. When molten, the basalt was highly mobile and created long, thin flows. Photo by Mandy Lindeburg, NMFS.

Bedrock Beaches

Outcroppings of bare bedrock are found on many Southeast beaches (Fig 1). They sometimes form sheer cliffs, as in the granite walls of Ford's Terror. Elsewhere, as on the gently sloping basalt flows of southern Kruzof Island (Fig 3), bedrock beaches can be as broad and flat as the surf-pounded sands of Yakutat. Obviously, beach gradient determines suitability to the coastal fauna. A beach too steep for wolf, bear, or river otter (*Lontra canadensis*) to use for travel may, for that very reason, serve as a secure nesting habitat for pigeon guillemots (*Cepphus columba*).

Because of its complex geologic history of successively accreted terrains, Southeast has an enormous diversity of bedrock types. Rock texture, friability, and chemistry affect plant and animal community composition in all coastal and inland habitats of Southeast, but nowhere are these influences more starkly apparent than on exposed bedrock beaches.

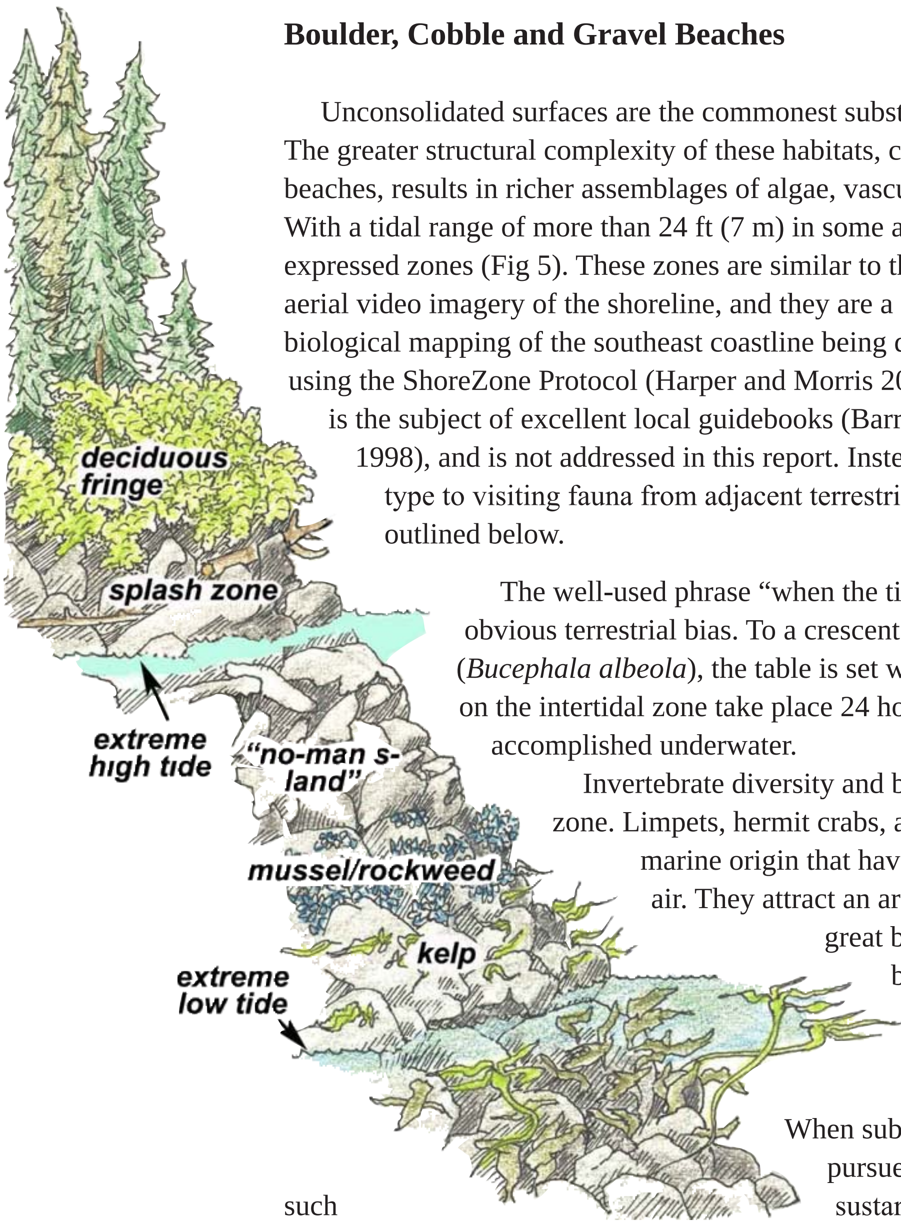
For example, on the volcanic sea cliffs of the Saint Lazaria Islands (Fig 2), right-angle fractures create an abundance of perches for sea birds, resulting in some of the highest nesting densities of common murres (*Uria aalge*) and pelagic cormorants (*Phalacrocorax pelagicus*) in Southeast. These abundant birds in turn attract rare nesters like peregrine falcons (*Falco peregrinus*) that have been placed on Audubon Alaska's Alaska Watchlist (Stenhouse and Senner 2005).

Carbonate rocks such as limestone and marble have equally distinctive shapes and erosional patterns within the intertidal zone. Soluble rocks are eaten into "Swiss cheese" by contact with sea water. Resulting pockmarks, fissures, and tunnels are expressed at many scales, from cubbyholes for marine invertebrates to giant karst caves bearing ancient human pictographs and artifacts.

The effect of rock chemistry on plant and animal communities is less obvious, but equally important, and was previously treated at greater length in discussion of inland terrestrial habitats. In the coastal fringe, the clearest examples of plant affiliations with specific bedrock types are found on carbonate outcrops. Some species like harebells (*Campanula rotundifolia)* (Fig 4) are fairly widespread in the splash zone on a variety of rock types, but reach greatest abundance on steep limestone beaches. Others, such as yellow mountain avens (*Dryas drummondii*) and green spleenwort (*Asplenium viride*), are calcicoles.

FIG 4. Harebells and cinquefoil (*Potentilla villosa*) on limestone sea cliff, Lemesurier Island, Cross Sound. Carbonate rocks support a unique flora in the splash zone, as well as a distinctive invertebrate community in tidal elevations.

FIG 5. Zonation on an un-consolidated beach. Daily fluctuations g ive foraging access to anything from terrestrial song sparrows (*Melospiza melodia*) to marine rockfish.



Boulder, Cobble and Gravel Beaches

Unconsolidated surfaces are the commonest substrate on the beaches of Southeast. The greater structural complexity of these habitats, compared to raw bedrock or sand beaches, results in richer assemblages of algae, vascular plants, and macroinvertebrates. With a tidal range of more than 24 ft (7 m) in some areas, Southeast beaches have well-expressed zones (Fig 5). These zones are similar to the “biobands” that are observed from aerial video imagery of the shoreline, and they are a key component of the physical and biological mapping of the southeast coastline being done by The Nature Conservancy using the ShoreZone Protocol (Harper and Morris 2004). The resident invertebrate fauna is the subject of excellent local guidebooks (Barr and Barr 1983, O’Clair and O’Clair 1998), and is not addressed in this report. Instead, the value of this intertidal beach type to visiting fauna from adjacent terrestrial and marine habitats is briefly outlined below.

The well-used phrase “when the tide is out, the table is set” has an obvious terrestrial bias. To a crescent gunnel (*Pholis laeta*) or bufflehead (*Bucephala albeola*), the table is set when the tide is *in*. Foraging raids on the intertidal zone take place 24 hours a day, but half of them are accomplished underwater.

Invertebrate diversity and biomass peaks in the lowest intertidal zone. Limpets, hermit crabs, and diverse mollusks are animals of marine origin that have adapted to part-time exposure to air. They attract an array of terrestrial predators such as great blue herons (*Ardea herodias*), black oystercatchers (*Haematopus bachmani*, an Audubon Watchlist species (Stenhouse and Senner 2005), and mink (*Mustela vison*). When submerged, the same invertebrates are pursued by larger marine predators such sustarfish, flounders, and harlequin ducks

FIG 6. Unconsolidated beach at Mill Creek, on the mainland east of Wrangell. A = brush; B = grasses; C = halophytes; D = bare boulders, cobbles and gravel (Young spruces are recolonizing the old mill site.)

FIG 8. Black turnstone (*Arenaria melanocephala*) foraging in dulse-covered low intertidal rocks.

FIG 7. The sea stars *Dermesteria imbricata* and *Pisaster ochraceous*, outer Chichagof Island. These species are intolerant of conditions in the Inside Passage waters.

(*Histrionicus histrionicus*).

Richness of marine algae is also greatest at the low intertidal levels. Oddly, almost no terrestrial or marine vertebrates make direct use of these nutritious seaweeds, except perhaps for a few starving black-tailed deer (*Odocoileus hemionus*) in winter. Instead, the algae feed invertebrates like sea urchins, which in turn become prey for predators such as sea otters (*Enhydra lutris*).

Above the zone of kelps, barnacles, and mussels, but below the highest reaches of the intertidal zone is a relatively barren zone that some ecologists refer to as “no man’s land”. This level is exposed too frequently for the comfort of most bottom-dwelling marine invertebrates, but submerged too often for most resident plants and animals of terrestrial ancestry. Because of the mix of exposure and submersion, this zone is the least productive foraging zone for visiting land or sea creatures.

“Halophytes,” vascular land plants that have evolved tolerance of periodic submersion in salt water, extend down to about the upper limit of neap tides. These species (Fig 10) are typically succulent and have few chemical defenses against herbivory. Therefore, they are extremely attractive to grazers like deer, bear, geese, and even humans. Goosetongue (*Plantago maritima*), beach spinach (*Atriplex patual*), and glasswort (*Salicornia virginica*) are the most sought-after species. Few of these plants can live on coarse substrates like wave-washed cobbles or large gravel. But on more protected beaches where these larger particles mix with sand or mud, well-developed belts of halophytes are found.

Just as terrestrial foragers reach down to the lowest portions of the intertidal zone, marine foragers come up into the highest reaches when the tide is in. Marine algae trapped in the stems and leaves of

FIG 9. Black bear (*Ursus americanus*) foraging for shore crabs on Tuxekan Island. This small crab is absent where large glacial rivers alter seawater conditions. (Black bears also feed on intertidal barnacles at low tide by sideways chewing or by wiping their paw across the rocks and licking up the residue.)

FIG 10. Sea milkwort (*Glaux maritima*) and Lyngbye sedge (*Carex lyngbyei*) in the upper levels of a rocky intertidal

halophytes form the food base for invertebrates that in turn feed rearing fish such as juvenile coho salmon (*Oncorhynchus kisutch*), herring (*Clupea pallasi*), and threespine sticklebacks (*Gasterosteus aculeatus*)

Rocky intertidal invertebrate communities are much richer on the outer coast of Southeast (Fig 7). Creatures that live in a fully marine environment have adapted to ocean salinity of about 30 parts per thousand, and many are inhibited where input from freshwater rivers dilutes the salt content. River influence on the inside waters also lowers temperatures and increases turbidity, reducing light penetration and photosynthesis (Fig 9).

For terrestrial predators that forage on intertidal beaches, one of the most important consequences of this gradient in seawater conditions is the presence or absence of the quarter-sized herbivorous shore crab (*Hemigrapsus nudus*). Away from glacial rivers, these crabs of the low- to mid-intertidal zone are sometimes found by the dozens under large rocks. On islands like Kuiu and Prince of Wales (Fig 9), bears observed foraging on beaches below the zone of vascular halophytes are usually walking from boulder to boulder, rolling them over, and licking up this succulent seafood. Middens of otter and mink are often dominated by shell fragments of the shore crab.

Fortunately for bears, where shore crabs are absent, this food source is often replaced by lush salt-marsh communities and uplift meadows. The cause of this “either-or” situation is found in recent Little Ice Age history. The glaciers of northern Southeast are much more vigorous than those of the south. Not only do they continue to dump far more cold, turbid freshwater into inland passages than do rivers of the southern mainland and outer islands, but they also expanded much more dramatically 2 centuries ago. The greater weight of ice in the north pressed down the crust of the earth in this area. Subsequent melting of these glaciers has resulted in glacial rebound, which is quite pronounced at Glacier Bay and Juneau, but essentially nil southward from Petersburg. On gently shelving beaches, glacial rebound results in food-rich herbaceous habitats that are described below in the section on estuaries.

Sand Beaches

Apart from estuaries, where sand and silt deposition is common, examples of extensive pure-sand beaches are rather few and far between in Southeast. The largest by far is an almost continuous sand beach extending from Icy Point 130 miles (208 km) northwest to Yakutat Bay. Even here, great rivers such as the Alsek and Dangerous are the ultimate sources of the sand, but these sediments have been carried far from the parent river mouths by ocean waves striking at angles to the beach, creating barrier spits, and “smearing” the sands northwestward at rates of about 160 ft (50 m) per year. The Situk River mouth

FIG 11. From top to bottom, tracks of wolf, red fox (Vulpes vulpes) and brown bear. Sandy beach southeast of Yakutat.

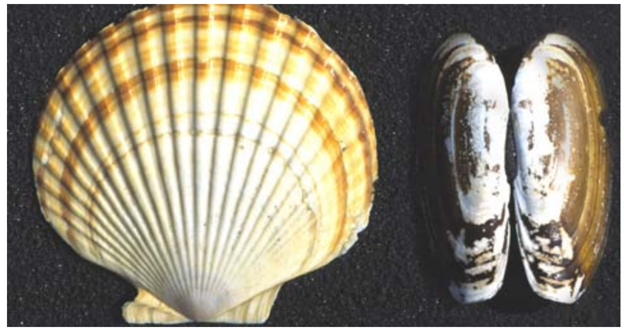


FIG 12. Weathervane scallop (*Pectin caurinus*) and razor clam (*Siliqua patula*), black sand beach on outer coast.

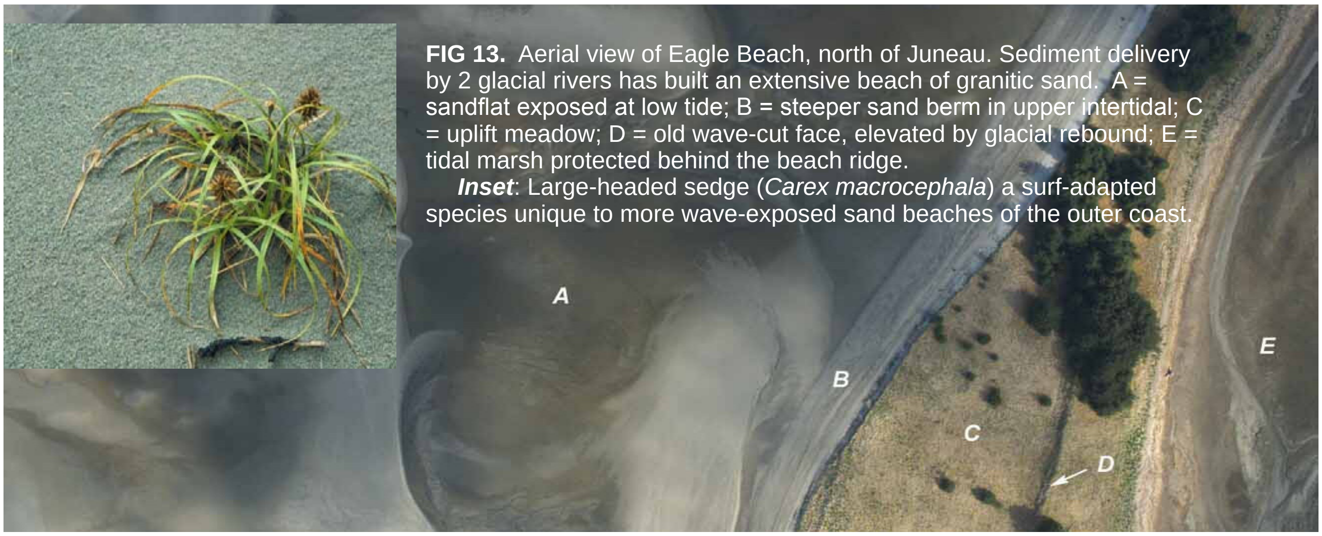


FIG 13. Aerial view of Eagle Beach, north of Juneau. Sediment delivery by 2 glacial rivers has built an extensive beach of granitic sand. A = sandflat exposed at low tide; B = steeper sand berm in upper intertidal; C = uplift meadow; D = old wave-cut face, elevated by glacial rebound; E = tidal marsh protected behind the beach ridge.

Inset: Large-headed sedge (*Carex macrocephala*) a surf-adapted species unique to more wave-exposed sand beaches of the outer coast.

migrated 1.5 miles (3.6 km) northwest between 1948 and 1989, based on measurements from aerial photography (Shepard and Brock 2002).

Ten miles (16 km) of sandy beach form the southern edge of the apron of Little Ice Age glacial outwash at Gustavus. Much smaller sand beaches occur on the outer coast of Kruzof Island in places like Shelikof Bay and Sea Lion Cove. On the archipelago, most outer-coast sand beaches occur in association with granitic bedrock. The granite of the outer coast is relatively youthful (Tertiary age) and more friable than the older granite of mainland terranes, perhaps more prone than older rocks to rapid weathering in quantities sufficient to nourish beach formation.

The surf-swept sand beaches are unique habitats. The ocean even smells different here. Species such as razor clams (*Siliqua patula*) (Fig 12) and the halophytic large-headed sedge (*Carex macrocephala*) (Fig 13) are restricted to this habitat.

One special feature of the outer-coast sand beaches is dune formation. Only here is fine sand available in enough quantity for wind to move substantial amounts of sediment into dune formations aligned parallel to the beach. At Sea Lion Cove on Kruzof Island, dunes to 20 ft (6 m) high are composed of fine sand and silt, covered with a rich meadow community of Nootka lupine (*Lupinus nootkatensis*), fireweed (*Epilobium angustifolium*), grasses, and bog orchids (*Platanthera dilatata*). Behind these meadows, very large spruce trees grow in the fine wind-blown sediments that have better water-holding qualities than the excessively drained coarser sands of “uplift beaches” near Juneau and Glacier Bay.

The broad sandy beaches stretching southeast from Yakutat host a unique predator assemblage (Fig 11). Wolf, brown bear, and red fox (*Vulpes fulva*) are a trio more characteristic of the northern boreal forest than of Southeast beaches. Tracks of mink and river otter—the typical Southeast beach predators—are relatively scarce on the northern outer coast. Pershaps these slow-moving mustelids are too exposed to wolf predation on the wide sand beaches, and their scavenger niche is instead filled by the more nimble red fox.

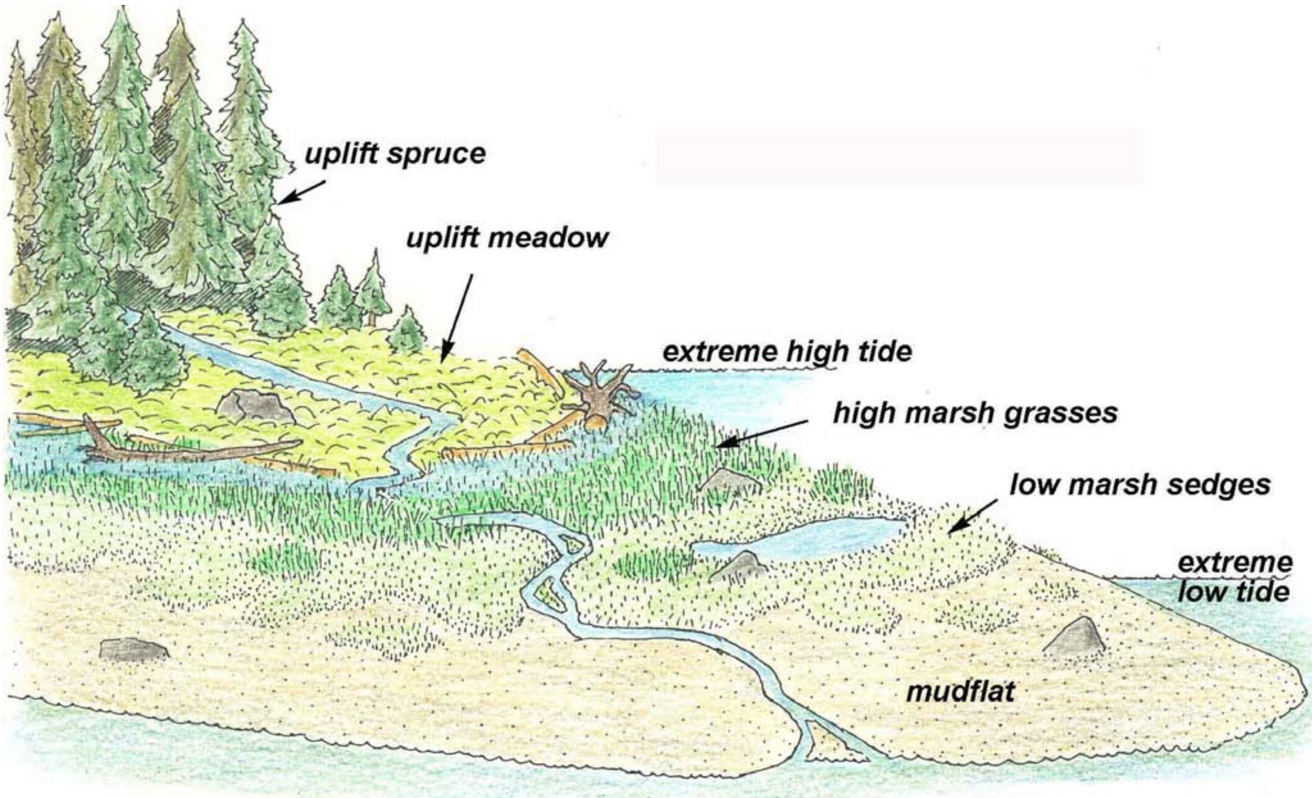


FIG 14 Estuarine community zonation. The high and low marsh zones collectively comprise the salt marsh.

ESTUARIES

By the most encompassing definition, the entire complex of protected inside waters in Southeast is considered an estuary. For the purpose of this report, estuaries can be considered as the depositional surfaces where freshwater streams and rivers meet the sea. The discussion covers not only the intertidal portions of these habitats, but also the adjoining supratidal meadows, shrub thickets, and young spruce forests that are especially common in the north where glacial rebound is occurring.

The National Wetlands Inventory maps about 350,000 acres (141,640 ha) of tidal estuaries on the Tongass, about 2% of its land area. Only 42,000 acres (17,000 ha) of this are covered with "emergent" vegetation, or salt marsh. But each estuary is the ecological nexus of its watershed, important far out of proportion to the area covered. Only in the estuary do the 3 great realms of terrestrial, freshwater, and marine ecosystems intersect. Energy flux between these ecosystems—for example the return of marine nutrients to the land in the form of salmon and the downstream flush of deciduous leaves in autumn—is most concentrated in the estuary. The list of terrestrial and marine species that make seasonal use of estuaries, or at least benefit indirectly from energy exchange taking place there, is basically the complete flora and fauna of the Southeast bioregion. And because estuaries are such highly productive habitats that support a diversity of fish and wildlife, watersheds associated with significant estuaries have higher overall ecological values than do similar watersheds that lack substantial estuarine habitat.

Sections below describe estuarine zones from low to high: bare tideflat, salt marsh (subdivided into low marsh and high marsh), and uplift habitats (meadow and young spruce forest) resulting from glacial rebound.

Bare Tideflat

Below the outermost vascular plant communities of the salt marsh are broad expanses of mud, sand, and gravel. Although the expanses are visually barren looking, they in fact are extremely food-rich places for mobile predators like shorebirds, gulls, and waterfowl. The benthic macroinvertebrate communities of bare tideflats in Southeast have received little study. A survey on the Mendenhall Wetlands (Willson and Baldwin 2003) examined invertebrate populations in bare mudflats, mussel/cobble beds, and rockweed clusters. Total invertebrate densities were greatest in the sediments. Amphipods and isopods were most common in the mussel/cobble beds, tiny clams (*Macoma,* an important food for shorebirds) in the sediments, and snails in the rockweed. Corophiid amphipods (small crustaceans) were found in great numbers in tube colonies on the bottom of low-salinity sloughs. Submerged, these crustaceans feed salmon smolts. Exposed, they help to fuel the thousands of shorebirds that biannually trace the dotted line of estuaries north and south across hemispheres. Studies in the Bay of Fundy (Peer et al. 1986) found that *Corophium* constituted 86% of prey by volume for semipalmated plovers (*Charadrius semipalmatus*), short-billed dowitchers (*Limnodromus griseus*), and least sandpipers (*Calidris minutilla*).

The NWI database delineates 3 community types in estuaries: vegetated salt marsh, bare tidal flats, and the "algal bed" of rockweed, barnacles, and mussels. Figure 20 lists the 10 largest estuaries of Southeast, based on the total of all 3 intertidal habitats. Relative proportions of the 3 types differs considerably. The Mendenhall Wetlands have the third largest acreage of salt marsh in Southeast, but rank only ninth in total estuary size. In contrast, the Chilkat River mouth has only 95 acres (38 ha) of salt marsh, but thousands of acres of bare tidal flat. Algal bed communities are abundant in some estuaries like upper Duncan Canal, but essentially absent at many river mouths. Algae, barnacles, and mussels need to anchor on coarse material like cobbles or at least large gravel mixed in with the low tidal muds. Algal bed communities are especially common in the small estuaries of southern Southeast islands like Prince of Wales.

FIG 15 Surfbirds (*Aphriza virgata*) and dunlin (*Calidris alpina*, foreground) hunt through a clump of barnacles, mussels and rockweed in the mudflats of Mendenhall River estuary near Juneau.

FIG 16 Amphipods are often found in great swarms by gulls, shorebirds and even bears turning over clumps of rockweed on the mudflats.

Salt Marsh

The vascular plant community growing on estuarine deposits in the upper intertidal is called salt marsh. On the Pacific coast, many ecologists subdivide this zone into grass-dominated high marsh and sedge-dominated low marsh. The low marsh community of tidal sedges, goosetongue, and arrowgrass is the salad bowl of Southeast. In contrast, the high marsh is dominated by grasses like beach rye (*Elymus mollis*)—more fibrous and less palatable than sedges—and this belt has generally lower wildlife value.

NWI maps do not delineate high and low marsh. This key ecological break needs more cartographic attention throughout Southeast Alaska. Only for the Mendenhall Wetlands near Juneau have the marsh differences been well-mapped (Carstensen et al. 2004). Studies there show that the high marsh-low marsh break has changed dramatically during the past century. Human construction and river sedimentation are partially responsible, but the primary driver of salt-marsh community changes is glacial rebound. As glaciers and icefields melt, northern Southeast is responding by rising from the sea. The phenomenon, known as glacial or isostatic rebound, is more pronounced here than anywhere else in the world. Rebound rates in Glacier Bay and surroundings (Fig

FIG 17 Black bear trails in low marsh sedges, Traitor's Cove, Revillagigedo Island.

25) are as high as 1.23 inches (32 mm) per year (Larsen et al. 2005).

In spite of its confinement to a narrow intertidal belt, Lyngbye sedge (*Carex lyngbyei*) may be the most important Southeast plant for many wide-ranging grazing birds and mammals. Its importance is especially significant in spring, before plants of the forest become available to herbivores. Sedges feed grazing black and brown bears, deer, moose (*Alces alces*), and several goose species.

Lyngbye sedge also produces copious seeds that form a large part of the fall diet of resident Vancouver Canada geese (*Branta canadensis fulva*) (J. King, retired Biologist, U.S. Fish and Wildlife Service, Juneau, AK, personal communication 2002) as well as mallards (*Anas platyrhynchos*), green-winged teal (*Anas crecca*), and northern pintail (*Anas acuta*). Crop examinations on the Stikine River showed this plant was by far the most important food for the latter ducks in autumn migration (Hughes and Young 1979).

Near extreme high water, several species of grasses dominate the high marsh. The most common are beach rye and tufted hair grass (*Deschampsia caespitosum*). Foxtail barley (*Hordeum jubatum*) is also moderately salt tolerant, but is less widespread in Southeast salt marshes and is thought by some to be invasive. High marsh grasses are used by migrating flocks of seed eaters like American pipits (*Anthus rubescens*) and lapland longspurs (*Calcarius lapponicus*). Northwestern crows (*Corvus caurinus*) often forage in high marsh, and grassy swards serve as resting habitat for birds like geese and mallards that require large open spaces where approaching predators can be detected. The grasses also support voles that attract hunters like northern harrier (*Circus cyaneus*), American kestrel (*Falco sparverius*), and short-eared owl (*Asio flammeus*). Several times per month, high tides reach up into these grasses, forcing brief evacuation by voles, and destroying eggs of ground-nesting birds that have placed their nests a little too far below the uplift meadow. In early spring, freshly sprouting grasses attract migrant grazers like snow and white-fronted geese (*Chen caerulescens* and *Anser albifrons*). But in general, the grassy high marsh is a less important habitat than the sedge low marsh.

In northern Southeast, these salt-marsh zones have shifted dramatically during recent decades. On the Mendenhall Wetlands, for example, mudflats rising at about half an inch (1.3 cm) per year are eventually colonized by low-marsh sedges that in turn are colonized by high-marsh grasses. As the high marsh is finally raised above extreme high water, these salt-tolerant grasses are replaced by uplift meadow. These globally unique meadows of lupine, fireweed, and nagoonberry (*Rubus arcticus*) are ephemeral stages on the way to spruce forest.

Depending on species, wildlife may either gain or lose from the rebound-driven replacement of habitats. Rapid loss of the low marsh is a substantial

FIG 18 High marsh zone, Eagle River, north of Juneau. Rye grass in foreground. Hair grass and foxtail barley in mid distance.

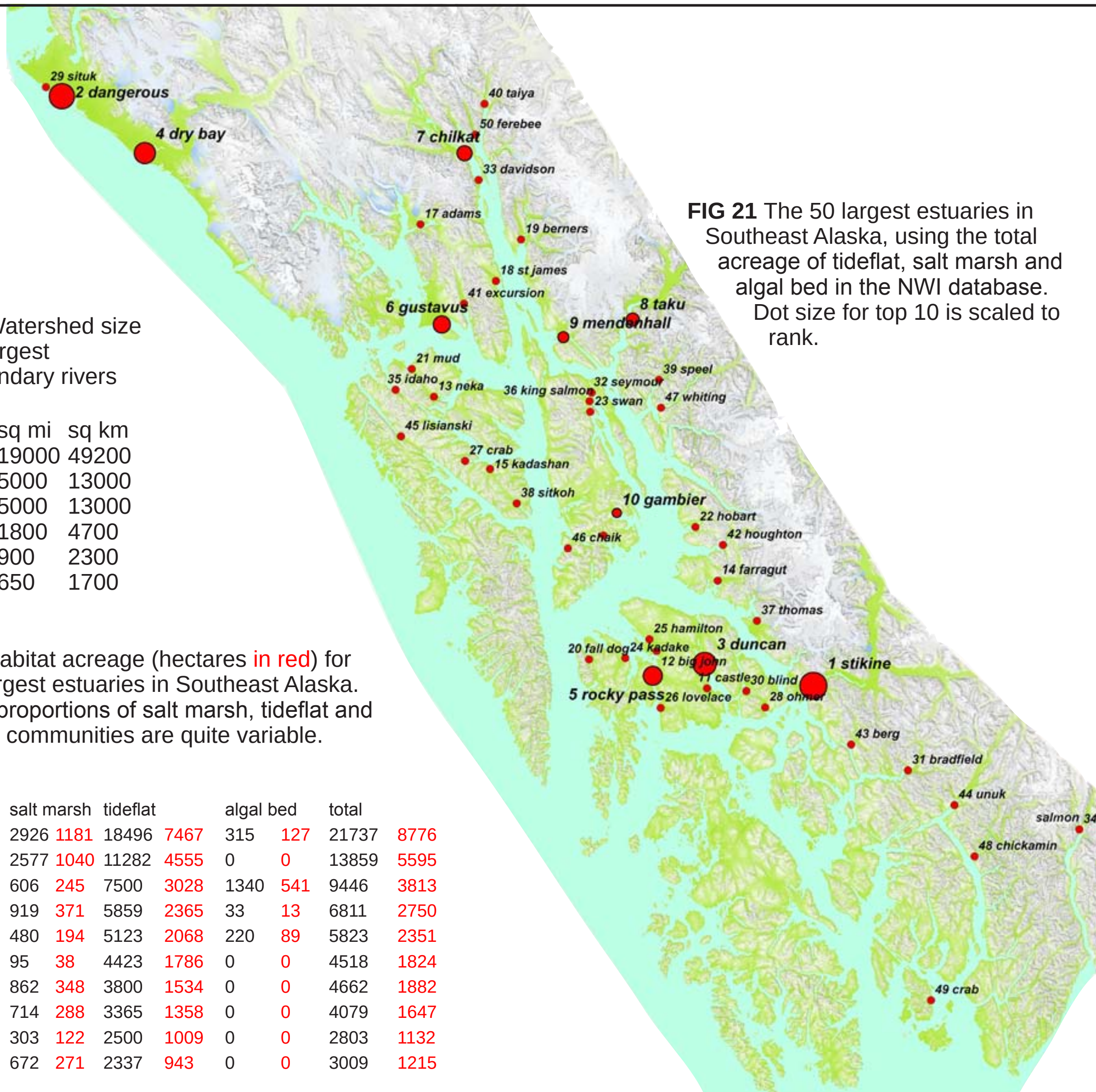


FIG 21 The 50 largest estuaries in Southeast Alaska, using the total acreage of tideflat, salt marsh and algal bed in the NWI database. Dot size for top 10 is scaled to rank.

FIG 19 Watershed size for our largest transboundary rivers

	sq mi	sq km
stikine	19000	49200
alsek/tat	5000	13000
taku	5000	13000
chilkat	1800	4700
unuk	900	2300
whiting	650	1700

FIG 20 Habitat acreage (hectares in red) for the 10 largest estuaries in Southeast Alaska. Relative proportions of salt marsh, tideflat and algal bed communities are quite variable.

	salt marsh		tideflat		algal bed		total	
stikine	2926	1181	18496	7467	315	127	21737	8776
dangerous	2577	1040	11282	4555	0	0	13859	5595
duncan	606	245	7500	3028	1340	541	9446	3813
dry bay	919	371	5859	2365	33	13	6811	2750
rocky	480	194	5123	2068	220	89	5823	2351
chilkat	95	38	4423	1786	0	0	4518	1824
gustavus	862	348	3800	1534	0	0	4662	1882
taku	714	288	3365	1358	0	0	4079	1647
castle	303	122	2500	1009	0	0	2803	1132
gambier	672	271	2337	943	0	0	3009	1215

impact to geese, dabbling ducks, and salt-marsh-rearing fishes. On the other hand, conversion of grassy high marsh to uplift meadow is beneficial for meadow lovers like savannah sparrows (*Passerculus sandwichensis*) and mammalian herbivores.

Figure 21 shows the 50 largest estuaries in Southeast according to the NWI database. Several interesting patterns emerge from analysis of this data layer:

1. Estuary size is not closely correlated with watershed size. The fifth and sixth largest watersheds of the Southeast/British Columbia borderlands—the Unuk and Whiting rivers—barely rank in the top 50 for estuary size. And 3 of the 5 largest estuaries—Dangerous River, Duncan Canal, and Rocky Pass—have watersheds that are orders of magnitude smaller than those of the great transboundary rivers.

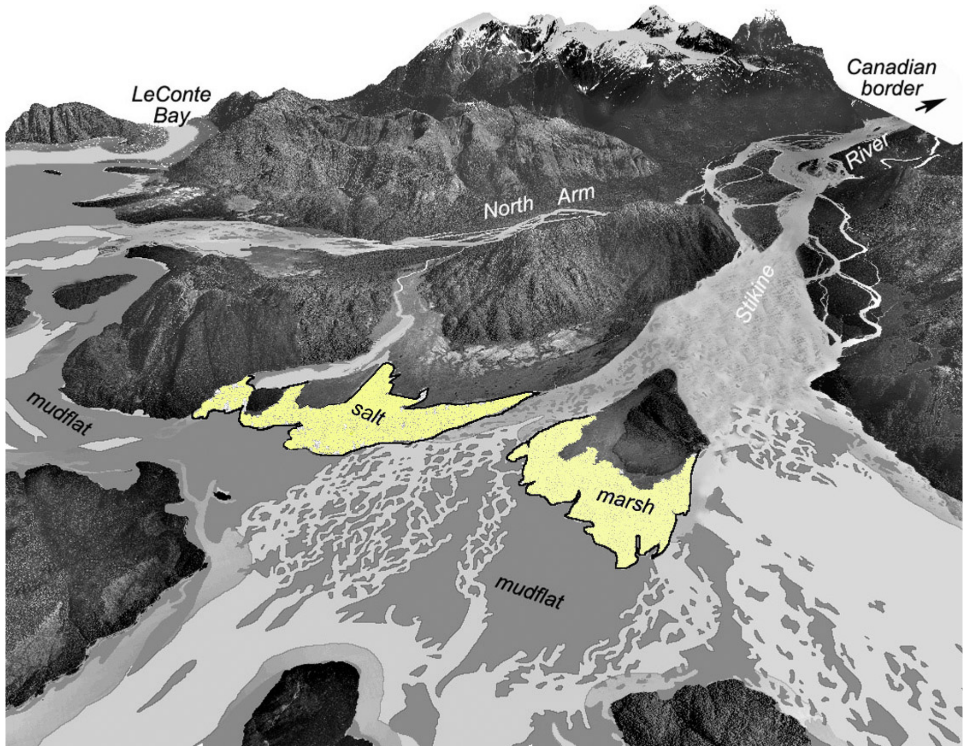
2. Southern Southeast has few large estuaries.

3. Six of the 10 largest estuaries are fed by glacial streams, but a surprising number of very large glacial systems, although heavily laden with sediment, have neglible estuaries.

4. Topographical complexities such as island clusters, convoluted shorelines, and undulating bathymetry lead to increased sediment deposition. In such locations, even small streams can have large estuaries.

5. Of all Southeast communities, Kake, on northwestern Kupreanof Island, is richest in large estuaries. Five of the largest are within a short skiff

FIG 22 Southeast Alaska's largest estuary at mouth of the Stikine River. Cover of salt marsh and mudflat from the NWI database. The Stikine Delta is an important stopover for thousands of shorebirds and waterfowl during their spring and fall migrations.



ride. This concentration of estuaries is intriguing because Kake is in a relative rainshadow, and its nearby watersheds lack tall mountains that spawn stout, snow-fed streams. Perhaps the low relief, which also extends underwater, is partly responsible. In contrast, the steeper mountainsides of Baranof Island continue their plunge into submarine realms leaving few places for stream deposits to collect.

In late February 1996, the U.S. Fish and Wildlife Service flew over nearly 200 Southeast estuaries counting overwintering Canada geese and mallards (Conant 1996). The number of geese supported seems closely related to estuary size (Fig 24). Again, the country around Kake stands out as remarkably productive. For wintering waterfowl, freezing of salt marshes during cold snaps can be a serious problem. Large creeks may spread extensive, freeze-prone freshwater lenses over their estuaries. Perhaps a small creek with a large estuary such as Big John Bay, on Kupreanof Island, is a safer combination for geese and mallards. Clearly, productive estuaries provide additional ecological value to the adjacent upland habitats.

Uplift Meadows and Parkland

Even as far south as Kake and Petersburg, glacial rebound leaves clear evidence in the immediate supratidal zone, especially on very gently shelving beaches. On such sites throughout northern Southeast, lush herbaceous meadows of variable width on recently elevated tideland (Fig 23) begin just above extreme high water and stretch gently upward to the forest. The meadow surfaces are generally well-drained and eventually succeed to forest. But as long as uplift continues at a more rapid pace than world sea-level rise, new uplift meadow will be created from tidal marsh as fast as it is lost to advancing forest.

Few shorelines worldwide are rising rapidly enough to create uplift meadows. Fewer still occur in well-watered climates that nourish chest-high meadows of fast-growing herbs. The meadows are key foraging habitats for bears and year-round home to small herbivores like long-tailed voles (*Microtus longicaudis*) that feed resident short-tailed weasels (*Mustela erminea*) and passing harriers. Nagoonberries are largely restricted to uplift meadow habitats.

Sediment composition of raised former tideland depends on the currents and waves that originally delivered these materials. Where current was slow or backwatered, fine sediments now underlie wet incipient fens that may never succeed to forest. But more typically the sediment is coarse enough

FIG 23 Diverse uplift meadow on Gustavus Forelands. Canada goldenrod (*Solidago canadensis*), Douglas' aster (*Aster subspicatus*), baneberry (*Actaea rubra*), cow parsnip (*Heracleum lanatum*), yarrow (*Achillea borealis*) and horsetail (*Equisetum arvense*)

to provide good drainage, supporting plants like fireweed, bluejoint, buttercup (*Ranunculus occidentalis)*, lupine, angelica (*Angelica* spp.), chocolate lily (*Fritillaria camschatcensis*) and hemlock parsley (*Conioselinum chinense*).

The species composition of uplift meadows is an unpredictable mosaic that seems to depend largely on whatever seeds were first able to sprout on the newly supratidal ground. Beneath these herbs, the most common meadow mosses, like *Rhytidiadelphus squarrosus* and *Ptilium crista-castrensis*, form a blanket over the mineral soil that for a time prevents establishment of the light, winged seeds of conifer trees and alders. Foresters refer to this process as "capture," a delay in the succession to forest. From the perspective of bears and voles, that delay is beneficial; the uplift spruce communities that follow are good for cover but offer almost nothing to eat. Ironically though, it is often bears that finally speed the succession to forest, by their digging activities—for roots and voles— that expose soil where spruce seed can germinate.

In many uplift meadows, young spruces advance as scattered saplings (Fig 26), resulting in an inviting parkland; at other sites, the young spruces advance as a closed wall of densely stocked young trees. Small deciduous trees and shrubs such as alder, willow, and salmonberry also invade some uplift meadows, especially on finer sediments.

As with the break between high marsh and low marsh, uplift meadows are a unique habitat that is inadequately mapped by NWI. Because of the dynamism and extreme ecological importance of this habitat, mapping it should be a priority for future GIS work. Fortunately the boundaries of this habitat are quite apparent on recent orthophotography, and even more obvious on low-elevation USFS aerial photographs

FIG 24 Overwintering waterfowl on Southeast estuaries, Feb. 1996, sorted by goose count. Conant (1997).

	canada geese	mallard
stikine	1965	648
duncan	1322	2625
rocky	955	2280
mendenhall	500	909
big john	475	1790
hamilton	390	980
farragut	380	730
unuk	356	160
fall dog	345	930
gambier	322	1443
castle	320	1580
neka	315	812
kadashan	220	96
kadake	162	720

IMPLICATIONS FOR CONSERVATION

Along inhabited coastlines such as those around Juneau and Gustavus, uplift meadows have been the first sites chosen for residential and commercial development. These meadows are now nearly absent from the margins of the Mendenhall Wetlands State Game Refuge. Preserving uplift meadow as wildlife habitat should be a key element in long-term conservation planning. This may be particularly challenging in places like the Mendenhall where private land boundaries are defined by the mean high water mark; owners can file for accretion resulting from glacial rebound.

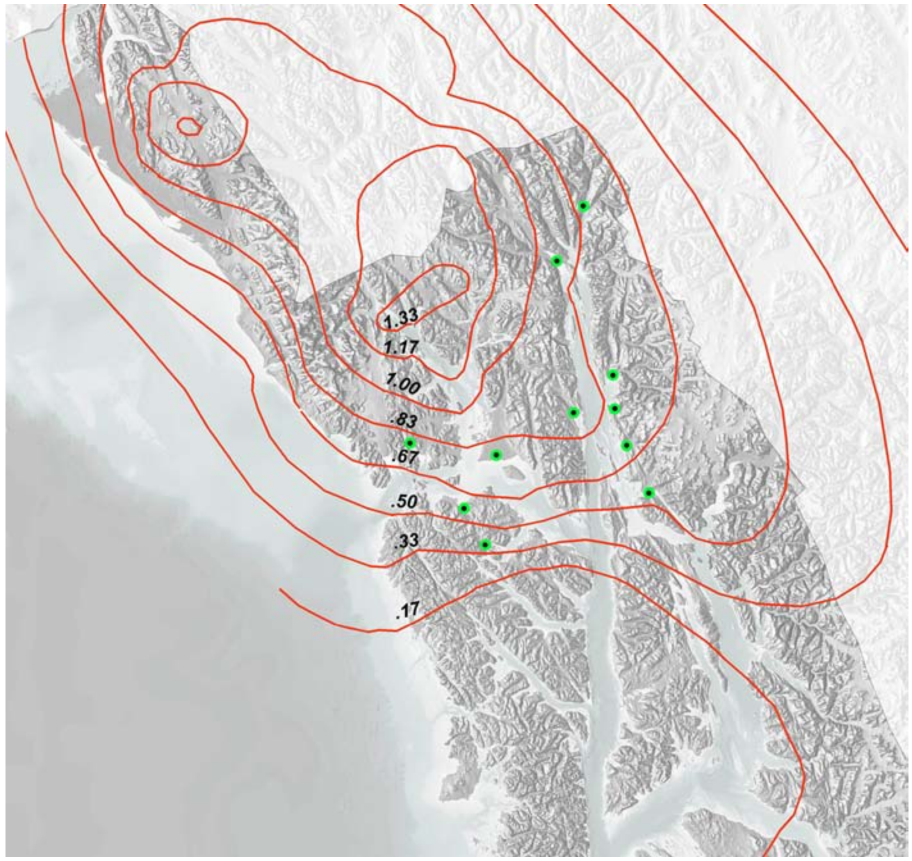


FIG 25 Rate of glacial rebound in inches. Based on Larsen et al. (2005). Green dots show locations of the most extensive uplift meadows. In Glacier Bay the largest are at Dundas River and Gustavus. From north to south down Lynn Canal: Dyea flats; Chilkat estuary; Berners Bay; Cowee meadows; St James Bay; Eagle River, and Mendenhall Wetlands. On Chichagof Island the largest uplift meadows are at Mud and Neka Bays.

As for estuaries in general, conservation issues near Southeast towns include airport development, pollution from sewage, landfills or roads, and displacement of wildlife from critical foraging habitat by recreational activities. More remote estuaries are vulnerable to oil spills, invasive plants and invertebrates, proliferation of commercial shellfish operations, swamping of native salmon runs by hatchery strays, and increasingly dispersed tourism. Logging of riparian forests between the 1950s and 1980s increased sediment delivery into estuaries, damaging habitat for many subtidal estuarine species. Effects of this deposition will influence the productivity of commercially important species like Dungeness crab (*Cancer magister*) for many decades (T. Shirley, Marine Ecologist, University of Alaska, Fairbanks, Juneau, AK, personal communication 2005). Similarly, bark deposits from log transfer facilities in estuaries continue to smother the bottoms of many estuaries, displacing benthic fauna. In addition to human-induced changes, natural changes such as loss of low marsh sedges to glacial rebound also need to be better mapped and understood.

FIG 26 At Howard Bay near Point Couverden, glacial rebound is occurring at about 0.7 inches (1.8 cm) per year. A = bare mudflat; B = tidal salt marsh; C = supratidal uplift meadows; D = invading uplift spruces.