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State of Washington
Department of Ecology

COASTAL ZONE ATLAS OF WASHINGTON

LAND COVER / LAND USE NARRATIVES

Volume II: Wetlands, Exposed and Other Lands, Appendices, Glossary, Index (Pages 449-887)

Rick Albright, Ron Hirschi, Ron Vanbianchi, Claire Vita

June 1980

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Coastal Zone Atlas of Washington

Land Cover/Land Use Narratives

Volume II

Rick Albright, Ron Hirschi, Ron Vanbianchi, Claire Vita

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Artists

Karen Helmerson, Jaime Orogo

1980

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WETLANDS (No. 6)

The wetlands classification designates those lands which are either covered by water or strongly influenced by adjacent waters. Wetlands are extremely productive areas and are important to many wildlife species.

Includes:

Forested Wetlands (No.61)
Nonforested Vegetated Wetlands (No.62)
Beach Substrate (No.63)

FORESTED WETLAND (No. 61)

Includes:

Freshwater Swamp (No. 611)
Brackish Swamp (No.612)

NONFORESTED, VEGETATED WETLAND (No.62)

Nonforested, densely vegetated wetlands consist of some of the most highly productive habitats in the world.

Inland Freshwater Marsh (No. 621)
Coastal Freshwater Marsh (No. 622)
Salt Marsh (No. 623)
Bog (No. 624)
Salt Meadow (No. 625)
Brackish Marsh (No. 626)
Seagrass (No. 627)
Kelp Community (No. 628)
Other Algal Communities (No. 629)

FRESHWATER SWAMP, BRACKISH SWAMP, BOG (Nos. 611, 612, 624)

I. INTRODUCTION

Included in this narrative are three habitat types that are structurally similar and provide similar animal habitat, but with dissimilar plant species composition. Similarities shared by all three include the presence of standing water or saturated substrate, and domination by woody vegetation. Plant species, drainage, substrate, and several other factors differ between the three types.

Brackish swamp is the most uncommon of the three types, mapped at scattered locations in Pacific, Snohomish, Kitsap, Island, and Mason counties. All sites are occasionally inundated by tidal waters.

Freshwater swamps are far more common, occurring in valley bottoms, along river drainages, and in other low-lying sites throughout the coastal zone. Two major types of freshwater swamps occur, tree-dominated and shrub dominated, and intermediate stages are not uncommon. Shrub-dominated sites are generally wetter than those with well-developed tree cover.

Continuous woody cover is typical of most swamps, however, sites with uneven terrain frequently have open water. Marshes with scattered, regularly occurring trees or shrubs were mapped as "swamp" to indicate the presence of woody vegetation.

Bogs are fascinating natural communities, displaying a combination of physical, chemical, and biological features unduplicated in any other habitat type. They are relatively common throughout the glaciated portion of the Puget Trough, but were mapped at only one site on the Long Beach Peninsula, and were lacking along the Strait of Juan de Fuca.

Swamps and bogs represent terminal stages of succession of wetlands, eventually improving drainage in the immediate areas, and producing conditions favorable for the establishment of climax forest.

Swamps have been altered by filling and draining in the past, and these activities continue to reduce the number and total acreage of coastal swamps. Bogs have also been subjected to these disturbances and additionally have been impacted by the extraction of sphagnum peat and conversion to huckleberry and blueberry farms. Presently, coastal bogs and swamps are being altered or destroyed primarily as a result of residential construction.

II. SIGNIFICANT BIOLOGICAL FEATURES

A. Plant Communities

Brackish swamps: The following three sites illustrate the variety of habitats included in this class.

The Point Bolin, Kitsap County, site was formerly a coastal pond, now filled in and dominated by a dense shrub thicket of sweet gale. Around the margin, common cattail and hardstem bulrush occur, and occasionally scattered within the sweet gale thicket are red alder and Nootka rose. The frequency of tidal indunation is unknown, but it is probable that with all higher high tides, salt water seeps through the berm separating the swamp from the beach. After a 13.2-foot tide in December, 1977, the standing water in the swamp was decidedly brackish.

The Hancock Lake (Island County) site is a zone within a large wetland association unique in the coastal zone (see Figure 611-1). Bordered by a bog to the south, and a salt marsh to the north, the swamp receives fresh water from the upland and tidal water from Hancock Lake (a misnomer, it is open to Admiralty Inlet by a marine slough and mapped as an open lagoon). Like the preceding site, the vegetation here is a dense thicket of sweet gale. Although lacking on our maps due to mapping constraints, between the bog and brackish swamp is a narrow strip of freshwater swamp.

A third site, at the Hamma Hamma River delta in Mason County, differs from the previous two by the dominance of large Sitka spruce over the entire area. Scattered in the canopy layer are western red cedar and several snags, especially around the perimeter. The understory at this site is hummocky and supports a diverse assemblage of herbs and shrubs. Highest areas support typical coniferous forest understory species including sword fern, false lily-of-the-valley, evergreen huckleberry, and trailing blackberry. Lower areas that are flooded by tidally influenced waters support fat-hen, creeping bentgrass, Douglas' aster, and western dock, all species occuring typically in coastal marshes.

Freshwater swamp: Freshwater swamps are much more common than brackish swamps and support a broader range of plant communities. They were mapped in many of the coastal counties and are especially frequent on the Long Beach Peninsula in Pacific County.

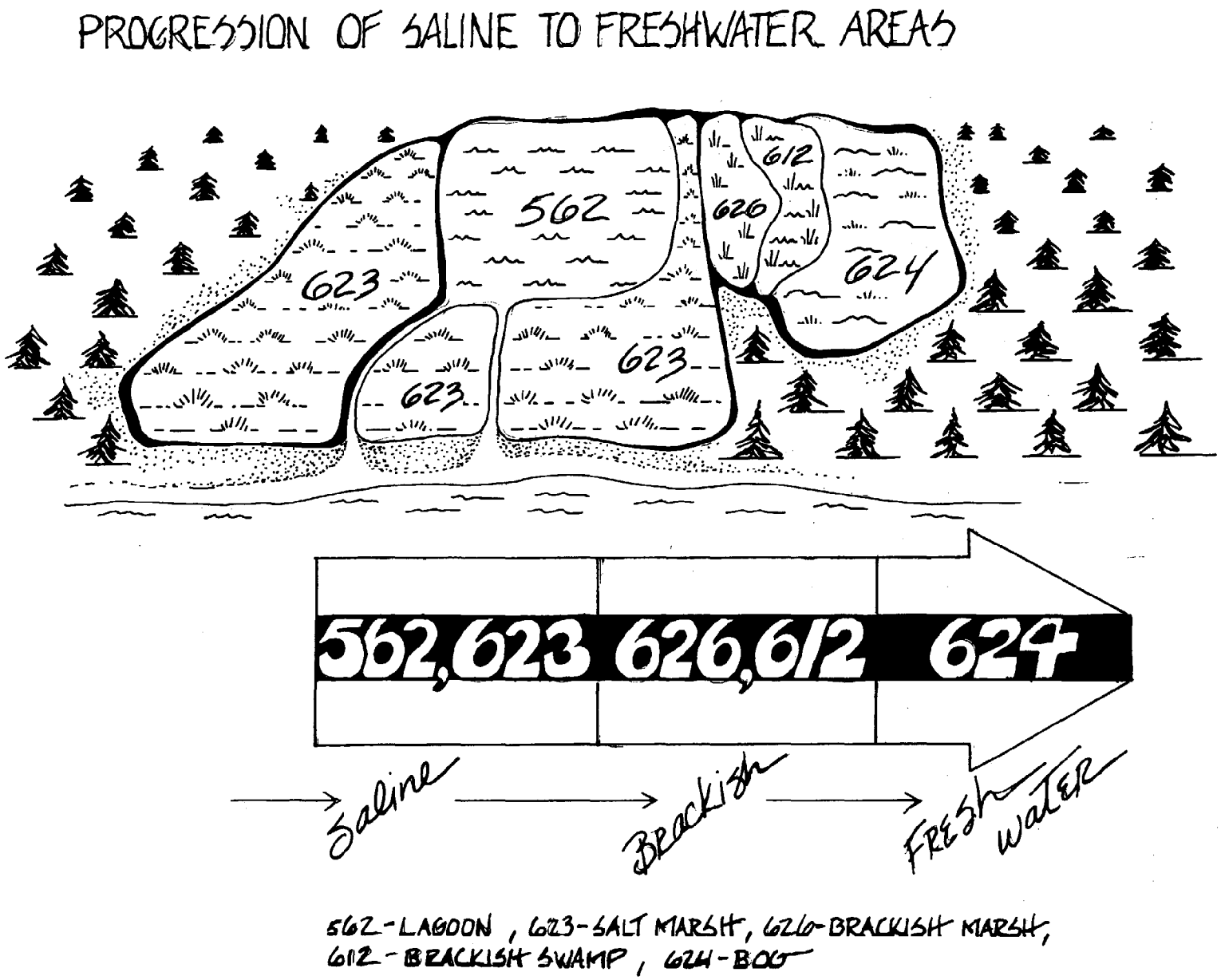


FIGURE 611-1

Hancock Lake Wetlands (Whidbey Island)

Three shrub-dominated freshwater swamps were visited in Kitsap and Mason counties during the course of this study. In each instance, the plant community was dominated by hardhack. Two of the sites were impenetrable hardhack monocultures with approximately 25 cm. (10 inches) of standing water during the rainy season. The third site, in Pierce County, was much more open, with a large area of standing water containing typical pond vegetation and scattered hardhack thickets.

Swamps with continuous tree cover are most common, and any one of several species may be dominant, or mixed stands may occur. Species include quaking aspen, red alder, black cottonwood, willows, western red cedar, and Sitka spruce. The freshwater swamp at the head of Oakland Bay, Mason County, is representative of the structure and species composition of coastal freshwater swamps. Sitka spruce and western red cedar dominate the open canopy at this site, with cascara and red alder occurring sporadically throughout. The understory is a dense stand of common cattail, black twinberry, skunk cabbage, water parsley, kneeling angelica, and occasionally crabapple, and yew. Scattered throughout the understory are raised spots with typical forest understory species, further diversifying this habitat.

In Pacific County, freshwater swamps dominated by red alder or willows are extensive. The understory is often a nearly solid stand of slough sedge.

Additionally, broadleaf-dominated swamps throughout the coastal zone may contain bitter chokecherry in the canopy, and several herbs and shrubs including red osier dogwood, Douglas' water-hemlock, salmonberry, small-fruited bulrush, and marsh skull-cap in the understory. Quaking aspen swamps were infrequent in the coastal zone, located only on Henry Island (San Juan County) and Stretch Island (Pierce County).

Swamp sandwort, currently included on the state working list of rare or endangered plant species, has been reported from coastal swamps in southwestern Washington and near Tacoma.

Bogs: Bogs are characterized by poor drainage, highly acidic water and substrate, low nutrient levels, and a well-defined plant community. The terms "bog," "swamp," and "marsh" are often used indiscriminately, but the habitats they describe are very different. The characteristics of these three types are compared in Table 611-1.

Table 611-1

A COMPARISON OF BOG, MARSH, & SWAMP CHARACTERISTICS
(After Fitzgerald, 1977)

		BOG	MARSH	SWAMP
Drainage		blocked - allows accumulation of organic material; further congested by bog development	does not allow accumulation of organic material	
Depth		deep or shallow	shallow	
Filling-in		floating mat invades open water-fills in from top and bottom	open water invaded by submergent, emergent, or floating vegetation--fills in from the bottom upwards	
Water Quality		brown, low nutrients, strongly acidic, low oxygen level	green, high nutrients, acid or alkaline, high oxygen level	
Bottom		false bottom often formed by the accumulation of colloids	No false bottom	
Micro-organisms		few	abundant	
Vegetation:	mosses	abundant, especially *Sphagnum* sp.	relatively scarce	
	herbs	sundew, orchids, bog St. John's wort, sedges, cotton-grass, beakrush	sedges, rushes, grasses	sedges, rushes, skunk cabbage
	shrubs	bog laurel, Labrador tea, bog cranberry	absent	red-osier dogwood, salmonberry, hardhack
	trees	lodgepole pine, western hemlock, white pine	absent	quaking aspen, willows, red alder, Sitka spruce, western red cedar
Fauna		black bear, deer, meadow mice, ground and shrub foraging birds, habitat of Beller's Ground Beetle (proposed R & E species), frogs, salamanders	waterfowl, mink, blackbirds, bittern, rails, frogs, salamanders	Wood Duck, woodpeckers, swallows, River otter, often includes many marsh spp. also

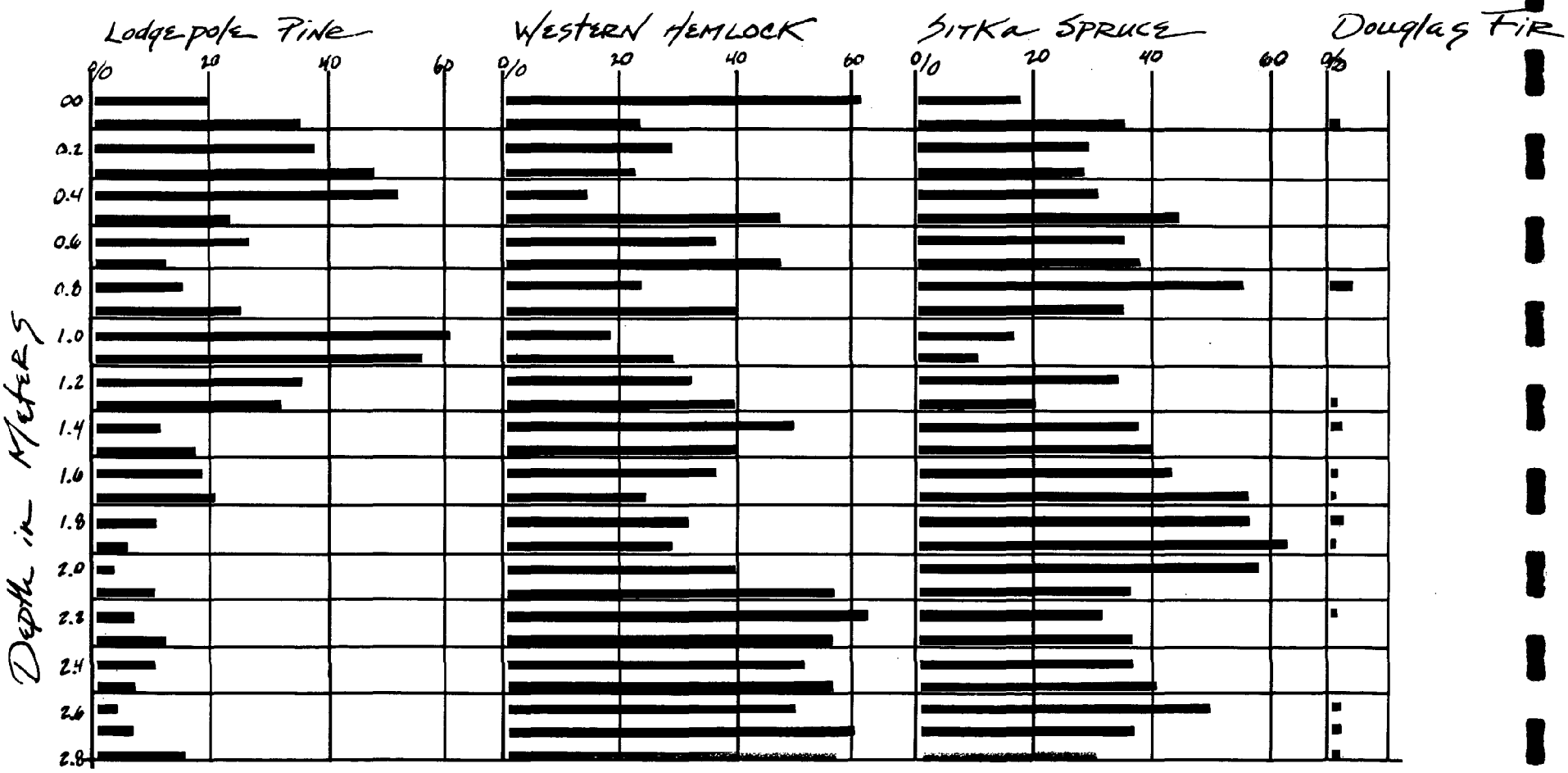


FIGURE 611-2. Pollen profile from Ilwaco, Washington, showing relative abundance of pollen of Lodgepole pine, western hemlock, Sitka spruce, and Douglas fir.

Bog development begins with the establishment of Sphagnum and other typical bog species around the edge of a lake, or in a marsh or swamp. As the mat of bog vegetation spreads out into open water or around existing vegetation, chemical and physical conditions become more favorable for the development of a bog, i.e., drainage is retarded by the mat, and the water and substrate becomes more acid from the expanding growth of Sphagnum. Because bacterial decay is retarded by the poorly aerated, acid water, plant and animal matter sinking to the bottom decomposes very slowly. This partially decomposed organic matter, called "peat," contains identifiable plant and animal remains for long periods of time. Con equently, bogs are invaluable "storehouses" of the past biological history of the immediate area. Much of the botanical history of the Northwest has been elucidated by studying pollen profiles taken from various bogs (see Figure 611-2). Likewise, a bog near Sequim (Clallam County) was recently discovered to contain the well-preserved remains of a Mastadon and several other prehistoric animals, believed to have been buried for approximately 15,000 years.

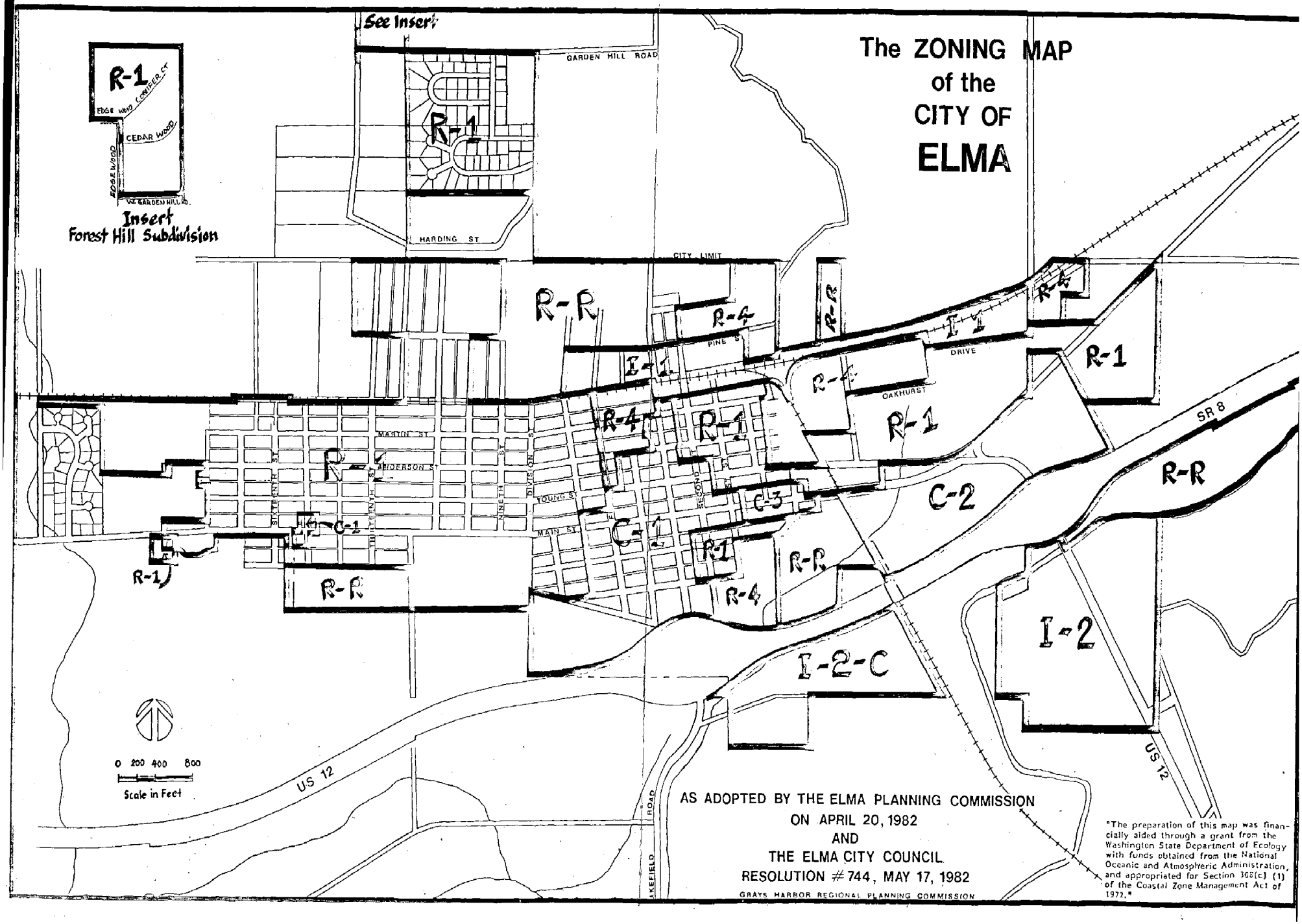
Bog Zonation

Several vegetation zones are often obvious in bogs, including the pioneer zone, herb zone, and shrub-tree zone (see Figure 611-3). When bog vegetation is invading open water, the leading edge or pioneer zone usually contains woody shoots of Labrador tea and bog laural, as well as buckbean and purple cinquefoil. These woody stems help support the advancing Sphagnum mat, the leading edge of which initiates the herb zone. Typical species in this zone include cotton grass, beak rush, several sedges, sundew, bog St. John's wort, and bog cranberry growing in a solid Sphagnum mat. The shrub-tree zone generally has a fewer number of plant species than the pioneer and herb zones, but greater structural diversity. The Sphagnum mat is generally uneven, with low spots containing standing water. Shrubs include bog laural, labrador tea, and sweet gale, often forming dense stands. Trees most tolerant of the bog environment are western hemlock, lodgepole pine, and western white pine, although western red cedar, Sitka spruce, and cascara may be present. The effects of the bog environment on tree growth are illustrated by a study in western Washington reporting 30-70 year old western hemlocks standing only 5-6 feet tall. The herb zone and the shrub-tree zone usually occupy the largest area of a bog, and are the most conspicuous zones. Between the bog and the adjacent upland, there often occurs a marginal ditch, especially at very mature sites. Conditions in the marginal ditch are similar to those found in swamps, i.e., well oxygenated, nutrient-rich water. The vegetation reflects these conditions, and typical swamp flora often develops. Common species include hardhack, salmonberry, red-osier dogwood, black twinberry, and skunk cabbage. Sphagnum is limited to patches at the base of stems, or is often completely lacking.

This generalized view of a bog is subject to much variation, and the following should be kept in mind:

1) Most of the bogs mapped in the coastal zone were in a mature state of development, with little or no open water and dominated by the herb and shrub-tree zones.
2) Bogs on the outer coast contain different species of gale and bog laurel.
3) Several other plants, relatively uncommon in lowland bogs may be present. These include crowberry, bog birch, and Menzie's burnet, a species under consideration for rare or endangered status.
4) Paper birch has been reported as a successful invader of sphagnum bogs in Whatcom County.

Productivity - Studies measuring the productivity of Washington's coastal swamps are lacking, but in general, swamps are noted as having complex spatial patterning, high plant and animal species diversity, and high productivity.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ON APRIL 20, 1982
AND
THE ELMA CITY COUNCIL
RESOLUTION #744, MAY 17, 1982
GRAYS HARBOR REGIONAL PLANNING COMMISSION
"The preparation of this map was financially aided through a grant from the Washington State Department of Ecology with funds obtained from the National Oceanic and Atmospheric Administration, and appropriated for Section 308(c) (1) of the Coastal Zone Management Act of 1972."

Animal Communities

Freshwater and Brackish Swamp

Many of the species associated with freshwater marshes also occur in swamps. Several ducks, blackbirds, herons, and amphibians are among the animals inhabiting both wetland habitats. Standing water and low, herbaceous vegetation within the swamp provides suitable habitat for these species while the presence of shrubs and trees increases structural diversity and the number of available niches. Woodland species often forage or nest in swamps, and typical marsh inhabitants which nest in trees benefit from their interspersion within the marshy understory. Snags are often present and are especially beneficial for cavity nesters.

In general, the diversity and abundance of animals within a swamp are greatest where trees are scattered within a matrix of open water and marsh. Diversity may also be high in those areas in which trees are dense, however, fauna will be more characteristic of the dominant forest canopy type than a wetland. This is evident along the outer coast where extensive forested swamps occur. Sufficient high ground is scattered throughout these swamps to allow terrestrial species to penetrate. The continuous coniferous coverage results in a terrestrial bird population in the canopy layer which is much like that of surrounding forests. Ground dwellers also include many terrestrial species, and bear, deer, and elk are common inhabitants. Densely forested swamps may also support a significant percentage of nesting populations of Great Blue Herons in the Coastal Zone. For example, one of the largest known rookeries in the state, on Samish Island in Skagit County, is within a black cottonwood swamp.

Swamps in which trees, marshes and open water areas are interspersed provide habitat for terrestrial species, and are also noted for the diverse assemblage of wetland birds, mammals, and amphibians. Characteristic species include some of our more intriguing wildlife such as the Wood Duck. These ducks were once near extinction due to overhunting and habitat destruction. The brightly colored male with his splashes of green, blue, red, and purple is one of our most beautiful birds. Wood ducks nest in natural cavities in trees, 5-40 feet above the water. The abandoned nest of a Pileated Woodpecker is often used as a nest site and they will also use suitable nest boxes.

The Wood Duck is an example of those species which benefit from the presence of trees in a marshy or open water wetland. Other swamp inhabitants which nest in trees include Hooded Mergansers and Great Blue Herons. Several cavity nesters which are not restricted to wetlands also frequently occur. Some, like the Pileated Woodpecker, excavate holes which are later used by cavity nesters such as the Wood Duck which is unable to create its own nest cavity. Other hole nesters include Violet-green Swallows, Tree Swallows, Chickadees, Common Flickers, and Downy Woodpeckers.

Marsh inhabitants discussed in the Freshwater Marsh Narrative (No. 621) are often abundant in swamps. Their presence and the added diversity of tree dwellers supports predators which reside in the swamp and in adjacent habitats. Hawks and owls, coyotes, bobcats, and river otters are examples of predatory birds and mammals which may be present. The occurence of larger carnivores is especially dependent on the size of the swamp and presence of suitable adjacent habitats. Some predators such as Bald Eagles and river otters occur in swamps prim-

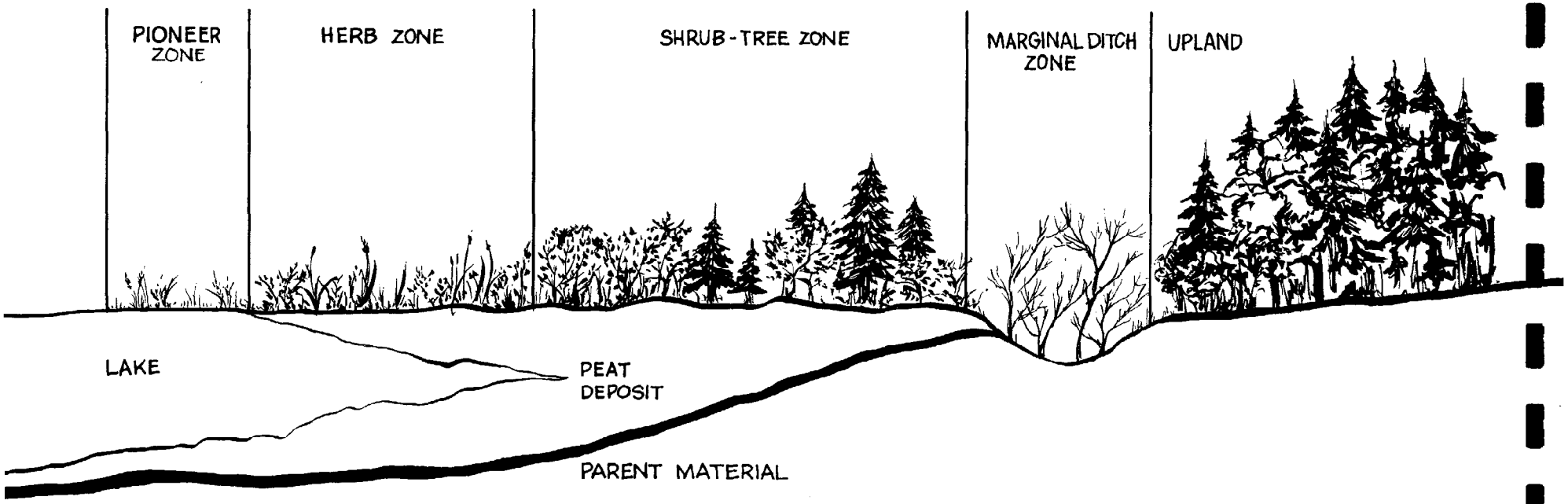


FIGURE 611-3: BOG ZONATION

PIONEER ZONE	HERB ZONE		SHRUB-TREE ZONE		MARGINAL DITCH ZONE	UPLAND
green algae blue-green algae Chara spp. Sphagnum spp. sedges buckbean Labrador tea bog laurel purple cinquefoil	rushes sedges cotton grass sphagnum	sphagnum beakrush wild cranberry sundew bog St.John's wort	bog laurel Labrador tea bog rosemary western hemlock lichen sphagnum	Labrador tea western red cedar huckleberry bracken fern salal lodgepole pine	hardhack red osier dogwood salmonberry alder cascara willows skunk cabage	conifer forest broadleaf forest swamp

arily because of their proximity to the coast. Brackish swamps such as at the mouth of the Hamma Hamma River are especially valuable for these coastal predators since they move freely between the swamp and adjacent salt water habitats. Eagles roost in the swamp and feed in the adjacent salt marsh, sloughs, and in the estuarine zone of the river. Bald Eagles are also frequently observed in the Hancock Lake swamp.

Shrub-dominated freshwater swamps such as those composed of hardhack thickets lack a great deal of floristic diversity. Faunal diversity and abundance is also quite low, characteristic species include Song Sparrow, Swainson's Thrush, Wilson's Warbler, and Red-winged Blackbirds.

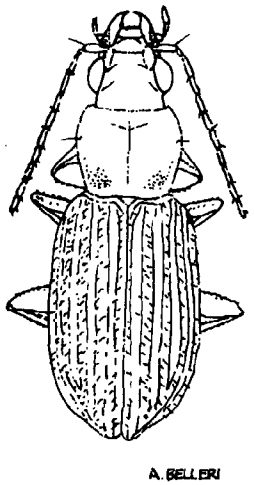
Bogs

The fauna of bogs is not as highly restricted to these unusual wetlands as are the many unique plant species. No vertebrates are known to be found exclusively in our coastal bogs, however, the proposed rare and endangered Beller's ground beetle, illustrated in Figure 611-4, is restricted to sphagnum bogs of the northwest. Beller's ground beetle has been reported from bogs in King, Snohomish, and Island counties.

One of the most characteristic bog vertebrates is the Townsend's vole. These voles, also known as meadow mice, are frequently encountered in coastal bogs. Their presence is noted by a maze of open runways and tunnels lacing through the Sphagnum mosses. They feed on a variety of herbaceous plants and may in turn become prey of coyotes, Red-tailed Hawks, or Marsh Hawks. Other herbivores which frequent bogs include varying hares and deer.

When sufficient open water is present, beaver, river otters, and waterfowl may frequent the bog. Beavers will feed on woody and herbaceous plants at the bog edge and have been observed to fall conifers within the shrub-tree zone. River otters frequent the

Figure 611-4



Beller's ground beetle
(Agonum belleri)

pioneer zone of the bog where they come ashore on the floating mats of vegetation. Holes in these mats are common and are known to be used by otters as convenient routes between shore and open water, much like a seal uses holes in floating sheets of ice. Waterfowl will frequent the edge adjacent to open water and some nesting is likely to occur in this pioneer zone.

The upland edge of bogs is used by a wide variety of wildlife, as with other wetlands. Several woodland birds have been observed nesting in this area and many also occur on the bog proper when shrubs and trees are present. Snags are occasionally present, however, trees grow slowly on the bog and large trees and snags are usually limited to the upland edge. These larger trees and snags are required by wildlife as roost or nest sites and are an example of the importance of maintaining an upland buffer zone around the bog. Birds of prey including owls and hawks will use the large trees surrounding the bog and fly over the open Sphagnum mat where meadow mice provide an abundance of prey.

Characteristic Vertebrates

The following species have been observed in coastal bogs during our studies:

SPECIES	Pioneer & Herb Zone (Relatively open, low growing herbs, shrubs)	Shrub-Tree Zone (stunted trees, shrubs)	Marginal Ditch & Upland Edge (shrubs & trees)
BIRDS			
Mallard		X	
Common Goldeneye		X	
Hooded Merganser		X	
Red-tailed Hawk		X	
Screech Owl			X
Saw-whet Owl			X
Belted Kingfisher			X
Pileated Woodpecker			X
Western Flycatcher			X
Common Crow			X
Chestnut-backed Chickadee			X
Bushtit			X
Red-breasted Nuthatch			X
Brown Creeper			X
Winter Wren			X
Beswick's Wren			X
American Robin			X
Swainson's Thrush			X
Golden-crowned Kinglet			X
Ruby-crowned Kinglet			X
Cedar Waxwing			X
Starling			X
Warbling Vireo			X
Orange-crowned Warbler			X
Red-winged Blackbird			X
American Goldfinch			X

SPECIES	Pioneer & Herb Zone (Relatively open, low growing herbs, shrubs)	Shrub-Tree Zone (stunted trees, shrubs)	Marginal Ditch & Upland Edge (shrubs & trees)
Rufous-sided Towhee	X	X	X
Dark-eyed Junco		X	X
Song Sparrow		X	X
MAMMALS			
Townsend's vole (*Microtus townsendii*)	X	X	X
Varying hare (*Lepus americanus*)		X	X
Black-tailed deer (*Odocoileus hemionus*)		X	X
Beaver (*Castor canadensis*)		X	X
River Otter (*Lutra canadensis*)		X	X
AMPHIBIANS			
Red-legged frog (*Rana aurora*)		X	X
Rough-skinned newt (*Taricha granulosa*)		X	X

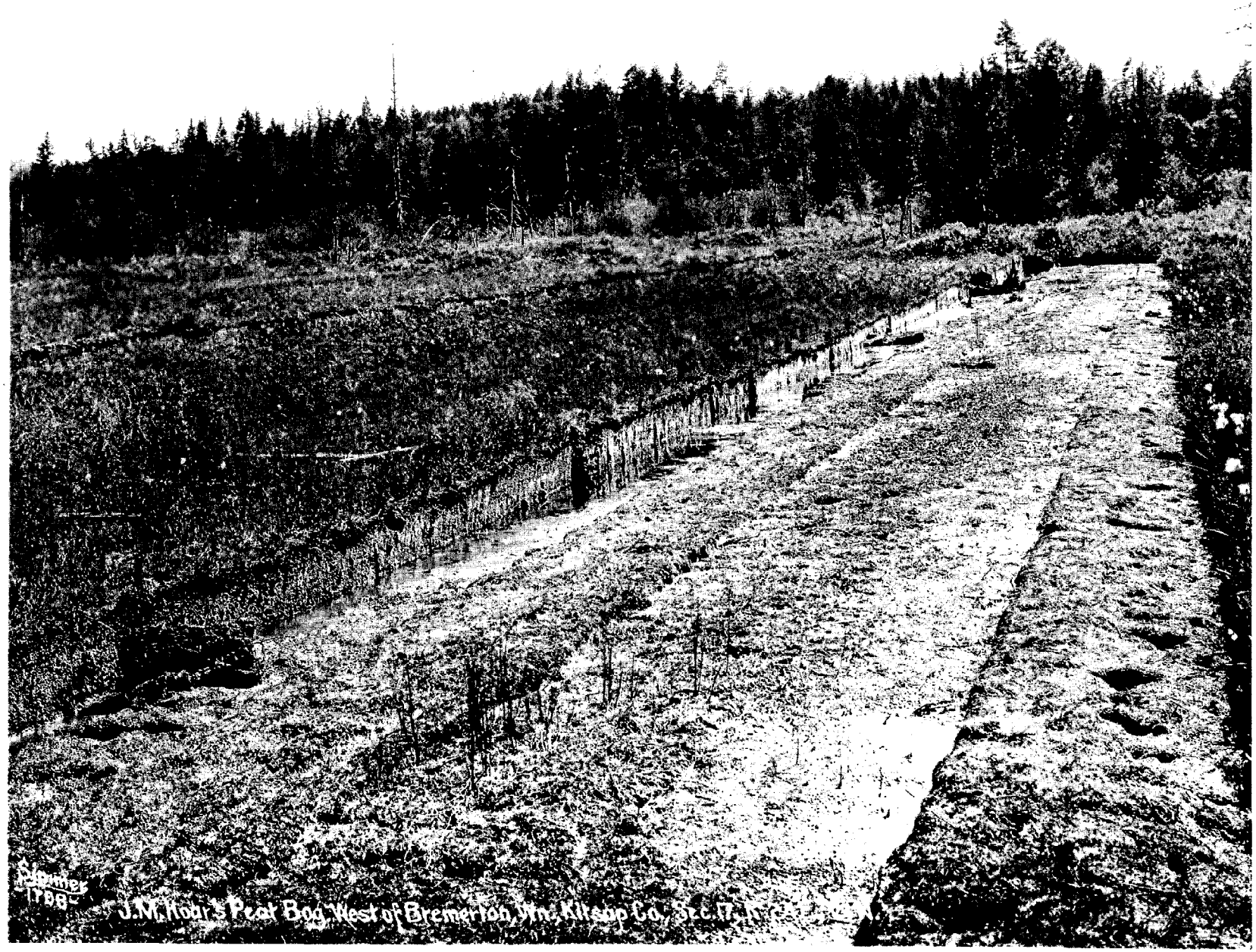


Figure 611-5. Peat excavation at Tahuya Lake, Kitsap County, during the 1940's.

IMPACTS

The plant and animal communities of both swamps and bogs are dependent on a relatively stable water level. The most widespread disturbance to these habitats has been the alteration of the level, often by filling or draining. The impact of this type of disturbance is to hasten succession, by artificially creating drier conditions, and the destruction of habitat for animals dependent on these wetlands. Swamps are particularly susceptible to blocked drainage and a resultant rise in water level. Such disturbance may push succession back to the pond stage by raising the water to an intolerable level, resulting in the death of swamp vegetation. If propagules of bog vegetation are available, blocked drainage may also set the stage for the development of a bog.

In past years, peat removal has been a major disturbance in Washington's sphagnum bogs. From 1951 to 1954, Washington's peat production was greater than that of any other state. The 1955 crop was 37,640 tons, and valued at $113,254. Sphagnum peat has been used for packing vegetables and live plants for shipment, building insulation, as a soil amendment, for surgical dressings during World War I, and as chicken litter. The impact of commercial peat removal is devastating to the biological community of a bog. (See Figure 611-5).

The most frequent disturbance observed during this study was filling for residential construction, and encroachment by residential and commercial development. The inherent problem with building on unstable substrate is discussed in Peat Resources of Washington, by George Rigg:

> "A few small sphagum bogs in Seattle passed directly from their natural condition to sites for small homes. The construction of houses was begun without adequate investigation of the material on which they were to rest, and difficulties were encountered. Some concrete foundations sank into the bog before the houses were finished. Some occupied houses sank irregularly two feet or more. Some concrete sidewalks sank a few feet, and some of them on the margin moved sideways as much as four feet. One bulldozer plunged into the soft peat and was recovered only with difficulty."

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FRESHWATER MARSH

Includes: Inland Freshwater Marsh (No. 621)
Coastal Freshwater Marsh (No. 622)

I. INTRODUCTION

Marshes are a major feature of freshwater wetlands in Washington, occurring throughout the state from just above sea level to high mountainous areas. Within the area covered by the Coastal Zone Atlas, coastal freshwater marshes are distinguished from those further inland, for the following reasons:

A) Coastal freshwater marshes often receive salt water from seepage or spray.

B) As a result of the saline influence, coastal freshwater marshes often contain plant species tolerant of brackish conditions.

C) Coastal freshwater marshes, because of their close proximity to the marine environment, are used by several animals which may be absent from marshes further inland.

All freshwater marshes form in blocked drainages and have standing water for all or part of the year. Marshes are dominated by herbaceous plants, distinguishing these wetlands from swamps in which shrubs and trees are dominant. Presence of standing water for much of the year distinguishes fresh from salt and brackish marshes. Brackish marshes and coastal freshwater marshes have several features in common including many plant species. For example, cattails and bulrushes are common in both these coastal wetlands.

Freshwater marshes are often small and widely scattered in the coastal zone. Like other wetlands, they have been filled, dredged, or otherwise manipulated by human activities. They are also becoming increasingly recognized as valuable habitat for waterfowl, aquatic mammals, and amphibians. They diversify dry upland habitats and their presence within the coastal zone should be guarded with the same care given all our diminishing wetlands.

II. SIGNIFICANT BIOLOGICAL FEATURES

Characteristic Plant Species

Several species are characteristic of freshwater or brackish marshes in Washington, but perhaps none more so than common cattails. Many people equate marshes with cattails and rightfully so. They are a major feature of most freshwater marshes and have been put to many uses by humans, and support many familiar wildlife species. Examples of human uses include:

- Native Americans used cattails as food. The roots and inner stalks were baked. Roots were also eaten raw.
- Cattails were also woven to make mats which were used as screens, covers, shelters, mattresses, pads, raincoats, capes, packsacks, and baskets.
- Cattails are also eaten today and often appear in dried flower arrangements and other decorations.
- Cattails support recreationally and commercially valuable waterfowl and other marsh wildlife.

Additional species include hardstem or softstem bulrush, often dominant or co-dominant with common cattail. Reed canarygrass, an introduced species, is very common throughout the Pacific Northwest, and often forms dense, solid stands in freshwater marshes. Additional species which tend to develop dense stands include creeping buttercup, yellow flag, california false hellebore, water parsley, and small-fruited bulrush. Species common in

freshwater marshes, but seldom or never forming dense stands, are skunk cabbage, marsh yellowcress, felonwort, small and common spike-rush, common forget-me-not, and speedwell.

Numerous sedges, rushes, and closely related species are common in freshwater marshes, especially those underlain with peat. A partial list follows:

common rush (*Juncus effusus*)
Baltic rush (*J. balticus*)
dagger-leaf rush (*J. ensifolius*)
tapered rush (*J. acuminatus*)
spreading rush (*J. supiniformis*)
beaked sedge (*Carex rostrata*)
green sedge (*C. oederi*)
slough sedge (*C. obnupta*)
Sitka sedge (*C. sitchensis*)
sawbeak sedge (*C. stipitata*)
dulichium (*Dulichium arundinaceum*)
beakrush (*Rhynchospora alba*)

Coastal freshwater marshes receiving salt water seepage or salt spray may support species tolerant of brackish conditions. These include Pacific silverweed, lilaeopsis, low clubrush, seaside and blister buttercup, and seacoast bulrush. Common cattail and hard and softstem bulrush are tolerant of brackish conditions, and frequently dominate these sites.

Areas mapped as freshwater marsh may include small ponds which were impossible to delineate separately. At these sites, plants and animals discussed in the Lakes and Ponds Narrative (No. 52) may be present.

Wildlife

Freshwater marshes provide many of the same features which support wildlife discussed for salt and brackish marshes, except on a more confined scale. Vegetative structure and wildlife use is very similar, and in coastal freshwater marshes there is signficiant exchange or "spillover" between the marine environment and the marsh. They are highly productive systems and although nutrients produced within the marsh are not flushed to distant areas by the tides, birds and mammals do "flow" freely from the marsh to adjacent

salt water habitats. The marshes contribute to other systems through this exchange of organisms, just as the salt marsh contributes through tidal flushing action.

Many of the species which use coastal freshwater marshes do so because they are adjacent to saltwater. They may be more abundant here than in inland marshes or occur more regularly. Characteristic species are very similar to those found in higher intertidal areas of brackish marshes dominated by cattails and hard or softstem bulrushes.Representative species include the following:

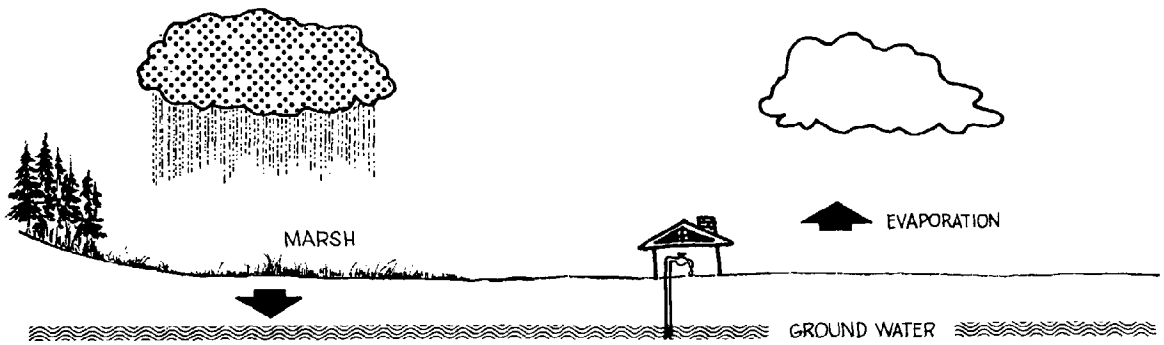
BIRDS	MAMMALS	REPTILES & AMPHIBIANS
Great Blue Heron	Pacific Water Shrew	Rough-skinned newt
Green Heron	Yuma myotis	Northwestern Salamander
American Bittern	Townsend's vole	Western Toad
Canada Goose	Racoon	Pacific Treefrog
Mallard	Mink	Red-legged Frog
Wood Duck	Striped Skunk	Bullfrog
Green-winged Teal	River Otter	Common Garter Snake
Merlin		
Virginia Rail		
Sora		
American Coot		
Common Snipe		
Belted Kingfisher		
Barn Swallow		
Long-billed Marsh Wren		
Red-winged Blackbird		
Song Sparrow		

Several of these species are illustrated in Figure 621-1 which depicts their preferred habitat in the marsh.

Fish occur in marshes with permanent standing water but are very restricted; the three-spine stickleback is often the sole representative. Permanent water surfaces within the marsh also add greatly to the marsh's overall wildlife value. Predators such as Kingfishers feed on sticklebacks and other aquatic organisms inhabiting these wet marshes. Increased water depths provide additional habitat for wildlife and their prey.

Marshes are enhanced by a coastal location as exhibited by the frequent occurrence of wildlife such as river otters, which would otherwise be restricted to the larger inland marshes or those near lakes and streams. They are also enhanced by the presence of buffer vegetation and adjacent natural habitats. Wooded margins surrounding the marsh will act as a noise and visual buffer for wetland wildlife and provide nest or roost sites for several species. Birds which nest in tree cavities such as Wood

Figure 621-2



Ducks will occur if snags or nest boxes are available and platform nesters such as Great Blue Herons will nest near marshes with large trees to support their bulky nests.

Hydrology

Freshwater marshes perform an important function in the hydrologic cycle (see Figure 621-2). Runoff accumulating in the marsh slowly seeps into the groundwater layer, replenishing subterranean reservoirs. The elimination of marshes in areas where groundwater supply is critical may aggravate the problem.

All wetland habitat types are natural flood control zones, able to accommodate large amounts of water without suffering damage. Marshes are no exception, and it has been estimated that a ten-acre wetland capable of accommodating several inches of water, will store over one million gallons.

Recreational/Commercial and Other Social Values

Freshwater marshes are major nesting sites for waterfowl and other aquatic birds. Many of these species are highly regarded by hunters and all are enjoyed by birdwatchers and other nonconsumptive recreationists. Mallards, perhaps the best known of the waterfowl which nest in freshwater marshes in western Washington, are popular among duck hunters who particularly value the drake or "greenhead." Local populations of mallards depend on marshes and other wetlands for breeding habitat.

Mallards and other water birds contribute significantly to the State's economy through sales of guns, shells, binoculars, recreational vehicles and other expenditures by hunters and outdoor enthusiasts. They also contribute significantly to the quality of life, providing all of us with the enjoyment of watching wetland wildife.

Marshes often serve as natural laboratories because they are microcosms of larger aquatic systems. They are stimulating systems which have led many children to understanding the life stages of frogs and

have led many other persons to develop explanations for several basic principles of ecology. Studies of blackbirds and Marsh Wrens alone have yielded major contributions to our understanding of vertebrate territorial systems, competition for food resources, mating strategies, and aggressive behavior. An overriding principle inherent to many of these studies is the fact that marshes are limited habitats. Although not abundant, freshwater marshes do support recreationist, children at play, aquatic wildlife, educational and research endeavors, commercial activities, and provide esthetic benefits for all to enjoy.

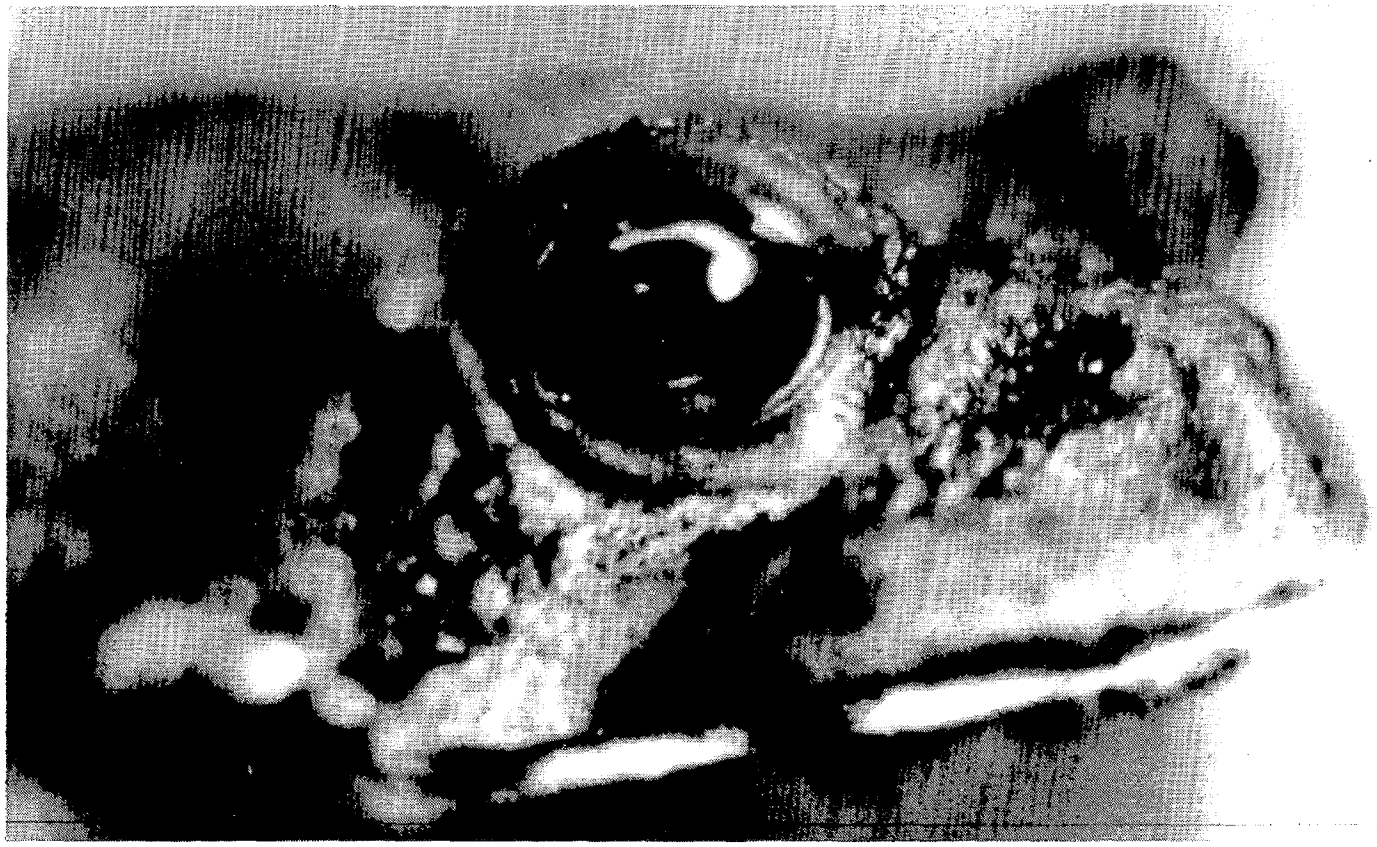
III. IMPACTS

Freshwater marshes are among the most susceptible of all wetlands to adverse impacts. They are easily drained or filled because they are often small and water levels are low. Wildlife use of the marsh and water level or quality can also be altered if surrounding vegetation is disturbed. In general, freshwater marshes and associated wildlife should not be encroached upon. Buffer strips of native vegetation should be maintained and will vary in width according to several factors such as:

- Shape of drainage basin: All lands sloping into the marsh act as watersheds, controlling runoff and silt. When vegetation is removed, increased flows, siltation, contamination with various toxins, and loss of other buffer effects may result.

- Presence of sensitive species: Inventories should be conducted in freshwater marshes within areas slated for development or other uses which might affect the wetland. Species sensitive to predicted disturbances should be identified and corrective actions taken. Marsh wildlife will be least affected by activities which do not disturb the wetland and maintain upland buffer strips. However, some species which nest nearby in more extensive uplands and feed in the marsh will require special attention. These species include Bald Eagles, Wood Ducks, and Great Blue Herons.

- Presence of sensitive habitats: Marshes are often associated with other wetland habitats. The marsh and/or marsh wildlife may be related to these adjacent wetlands in such a way that activites in one will affect the other. Interrelationships with these other habitats must be viewed on a case-by-case basis. Common associations include marshy margins of lakes and ponds.



Coastal freshwater marshes have also been created by the activities of humans. Dikes and tidegates are often constructed to impound freshwater and restrict tidewater on former saltmarshes. Examples include some of the most extensive freshwater marshes in the coastal zone such as Gray's Marsh in Clallam County and portions of the Nisqually and Willapa National Wildlife Refuges. These marshes were created to benefit selected waterfowl such as Canadian Geese and Mallards, and hunters who pursue them. Freshwater marsh creation does benefit these species and other marsh wildlife. However, dikes and tidegates restrict the exchange of marsh and nearshore nutrients and organisms. The result may be a net loss of benefits to waterfowl, oysters, juvenile salmonids, flounders, shorebirds, and other species dependent on estuarine marsh productivity.

References:

Good, Ralph E., Dennis F. Whigham, and Robert L. Simpson (Editors). 1978. Freshwater wetlands. Academic Press. 378 pp.

SALT MARSH (No. 623)

SALT MEADOW (No. 625)

BRACKISH MARSH (No. 626)

INTRODUCTION

Salt marshes, salt meadows, and brackish marshes occur along protected shorelines, in bays, estuaries, and lagoons throughout the coastal zone. Highly productive terrestrial systems subject to tidal inundation, they occupy a unique position in the coastal ecosystem, contributing large amounts of organic matter to estuarine and nearshore waters, and form the base of a complex, widespread food web.

Several studies have been performed in northwest coastal marshes (in this narrative defined to include salt marsh, salt meadow, and brackish marsh) in recent years, most intending to determine plant community composition, zonation in relation to tide level, the wetland/upland transition, and bird, mammal, and fish use. One of the first detailed studies was performed in Oregon by Dr. Carol Jefferson in 1975. Based on substrate and elevation, Dr. Jefferson proposed a classification system that has been used in several subsequent studies, occasionally in modified form. Other workers have devised original classification schemes. The classificaton system used in the Coastal Zone Atlas is relatively simple, based on elevation and salinity, and has the advantage of being easily used and understood by persons only marginally familiar with coastal marshes. Figure 623-1 present a graphic comparison between the Atlas classification scheme and several others likely to be encountered in the literature on Washington's coastal marshes.

A partial list of Washington areas with published descriptions of coastal marsh communities includes: (numbers refer to literature listed at the end of this narrative)

Grays Harbor County[11]

Grays Harbor

Jefferson County[8]

Becket Point
Black Point
Broad Spit
Bywater Bay
Chevy Chase North
Chevy Chase South
Fisherman's Point
Gardner
Hadlock
Kala Point
Oak Bay
Quatsap Point
Quilcene
Right Smart Cove
Scow Bay
South Indian Island
South Ludlow Bay
South Point
Suquamish Harbor
Thorndyke Bay

Kitsap County[2]

Chico Bay

Mason County[2]

Coulter Creek

Pacific County[7]

Willapa Bay

Pierce County[2]

Burley Lagoon

San Juan County[2]

Griffin Bay
Wescott Bay

Thurston County[5,12]

Nisqually River Delta

Whatcom County[1]

Bellingham Bay

Several other areas have been mentioned by various authors. W. C. Muenscher, in The Flora of Whatcom County states:

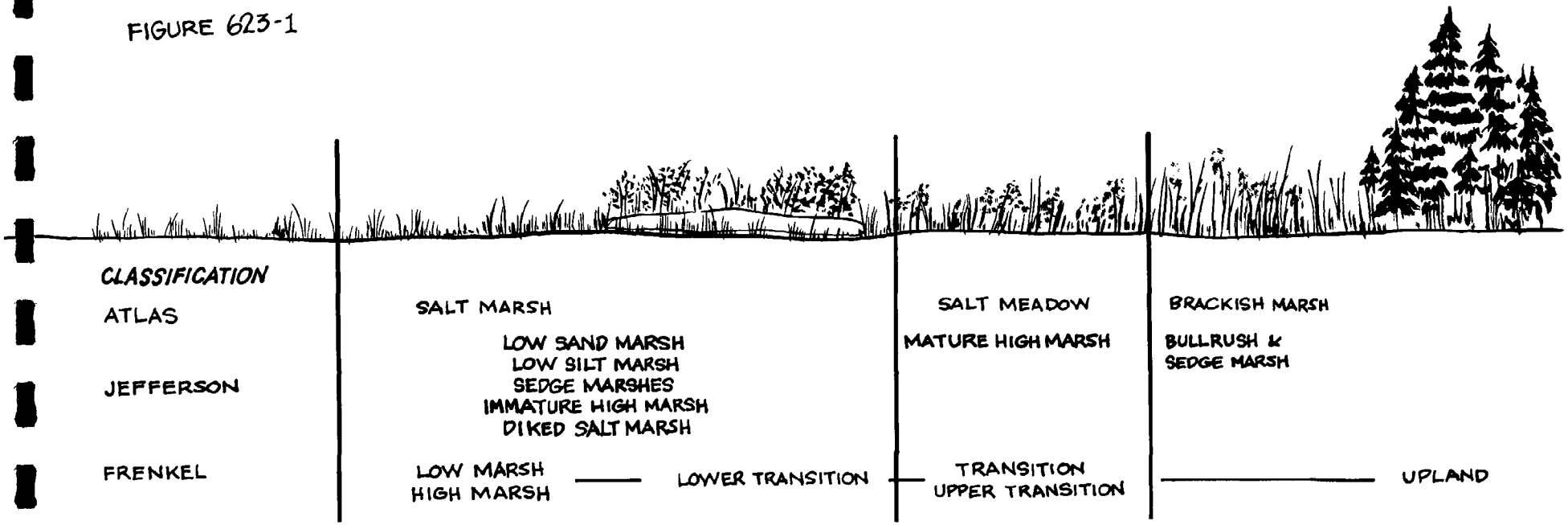
> "Salt Marshes - Several salt marshes ranging from a few to twenty acres occur along the shores of Puget Sound, forming the western boundary of Whatcom county. These are covered with a rather uniform vegetation frequently forming a dense meadow. Most of these meadows occur behind gravelly or sandy beaches or along the tidal or lower courses of small streams. The best examples of salt marshes occur at:

Point Roberts	Gooseberry Point
Semiahmoo Spit	Lummi River
California Creek	Marietta
Dakota Creek	South Bellingham
Birch Bay	Chuckanut Bay
Terrell Creek	Lummi Island
Sandy Point	Eliza Island

In A Botanical Survey of the Olympic Peninsula, George Neville Jones briefly mentions the marshes at the mouths of the Dosewallips and Duckabush Rivers in Jefferson County.

Salt Marsh. Areas mapped as salt marsh in the Coastal Zone Atlas occur in every county, beginning with the lowest vegetation on the tideflat (excluding eelgrass and algae, mapped separately) and extending to approximately mean higher high water. Salt marsh formation begins when a sparse plant cover, tolerant of long periods of daily tidal inundation, colonizes the tideflat. With time, sediments are deposited and become stabilized by the vegetation, and as elevation slowly increases, plant cover becomes dense. Tidal inundation over the entire marsh varies depending on elevation, from twice daily to only occasionally with spring tides, but is often enough that the plant community consists almost entirely of halophytes (species tolerant of saline environments). Typically, a highly branched pattern of drainage channels spreads throughout the marsh, and salt pans, pools of highly saline water, are a characteristic feature.

FIGURE 623-1



Salt Meadow

Between the upper margin of salt marsh and strictly upland vegetation, salt meadow occurs. Inundated only by extreme high tides and storm tides, strongly salt-tolerant species co-dominate with semi-tolerant species, and at highest elevation, species more characteristic of upland habitats are often present. Areas just beyond tidal influence were occasionally mapped as salt meadow, to indicate the presence of halophytes and origin of the formation. Drainage channels and salt pans are characteristically deeper than in salt marshes, and freshwater seepage is frequently apparent at the salt meadow/upland ecotone. Salt meadows were mapped in every county except King, and are particularly extensive around Willapa Bay (Pacific County).

Brackish Marsh

Brackish marshes were mapped in areas where saline waters are sufficiently diluted by freshwater to permit the development of a weakly salt-tolerant marsh community. Characteristically occuring in estuaries, brackish marsh is mapped in Skagit, Island, Snohomish, Kitsap, Thurston, Mason, Jefferson, and Clallam Counties. The largest tracts of brackish marsh occur in Skagit and Snohomish counties, on the Skagit and Stilliguamish River deltas.

Historically, Washington's coastal marshes were much more extensive than they are today. Encroachment and alteration to other land uses have reduced the total number of marshes, and acreage of those remaining, to a fraction of what was present when the early settlers arrived. Reported losses since the 1800's or 1700's include approximately 30 percent of the coastal marsh habitat in Grays Harbor (Grays Harbor County), and greater than 80 percent on the Skagit River Delta (Skagit County). Similar figures are probable throughout the coastal zone, and as extreme examples, virtually all of the coastal marsh habitat has been destroyed in the Duwamish and Puyallup River deltas (King and Pierce counties). See Figure 623-2.

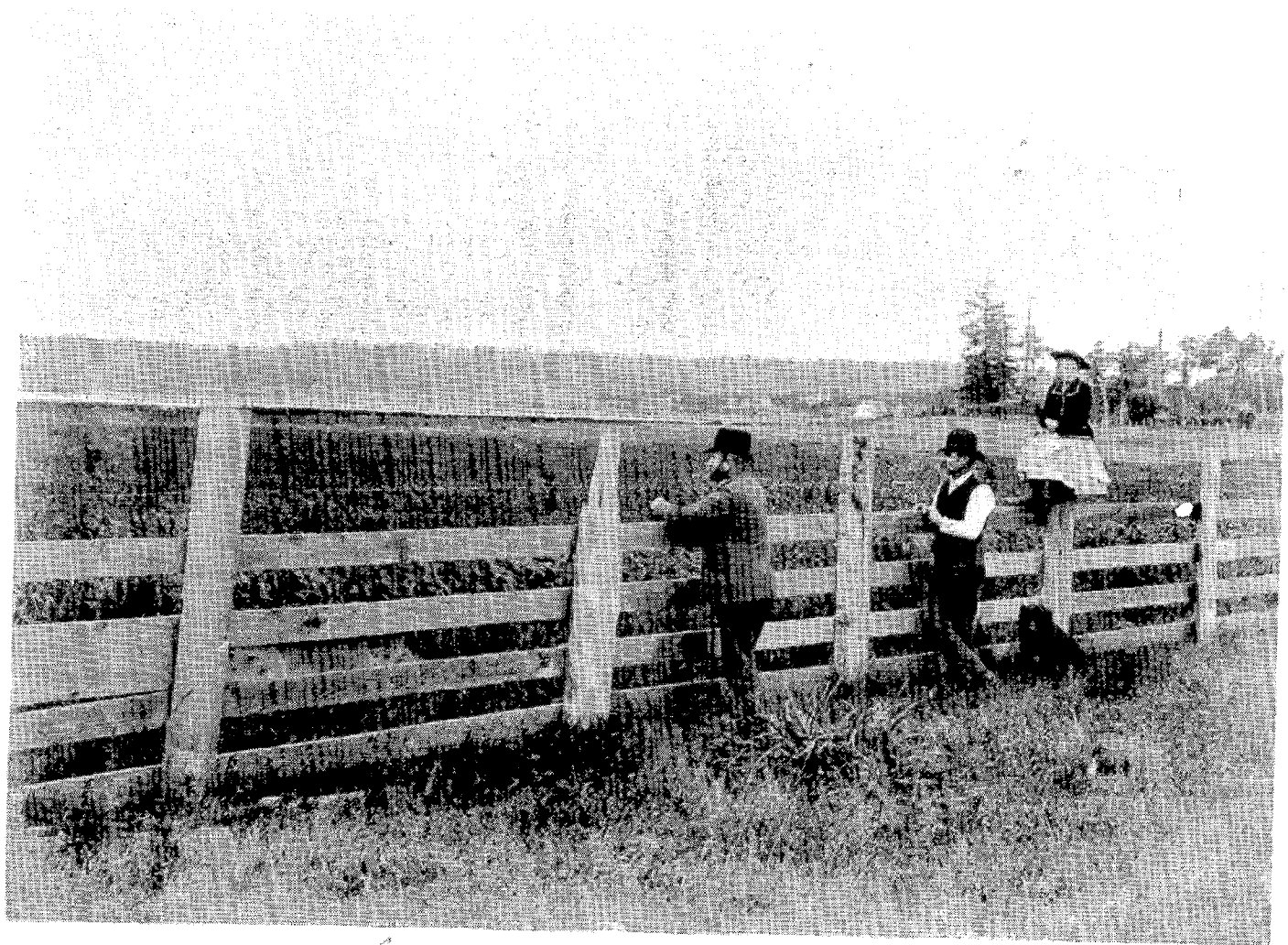
Primary causes of the loss of coastal marsh habitat are diking, filling, and dredging for agricultural, commercial, or residential use. These activities were perpetrated in ignorance of the value of tidal marshes, and in an effort to mitigate previous losses, there is currently much interest in reestablishing marsh vegetation on dredge spoils. In Oregon, studies are underway to determine the feasibility of reestablishing coastal marshes by removing dikes, thus allowing the return of tidal influence.

SIGNIFICANT BIOLOGICAL FEATURES

Salt Marsh Plant Community

Two major zones of vegetation are usually apparent in salt marshes. The lowest vegetated zone, the low marsh, occurs on the tideflat, and is composed of very salt-tolerant species, able to withstand long periods of daily submergence. Plant cover in the low marsh is generally sparse, and limited to relatively few species. In highly saline areas, pickleweed and arrowgrass are characteristic mudflat colonizers. In areas where the salinity is lowered by freshwater runoff, three square bulrush, seacoast bulrush, and Lyngby's sedge occur. The presence of vegetation stabilizes the tideflat and reduces the velocity of tidal flow, allowing suspended sediments to settle out and slowly increase the elevation of the tideflat. Other low marsh species include saltgrass, Canada sandspurry, brass buttons, sea lettuce, rockweed, a green alga (*Enteromorpha intestinalis*) and microscopic benthic algae (mostly diatoms). Smooth cordgrass, the dominant low marsh species in eastern seaboard salt marshes, has been introduced at a number of sites throughout the state. At all Washington locations, this species is apparently unsuccessful in reproducing by seed, and is restricted to isolated clumps, expanding slowly by vegetative reproduction. European eelgrass occasionally is found in the low marsh.

The second zone, the high marsh, is here defined as the area of continuous vegetative cover occurring between the low marsh and salt meadow or upland vegetation. Several plant associations have been identified in the literature as belonging to this zone, and species richness is intermediate between low marsh and salt meadow. Generally, a pickleweed-dominated community occurs nearest the low marsh,



No. 7 Dyked Salt Marsh in Catsmoot Inlet, Oak Bay Farms

Photography Collection
University of Washington Library
Photographer Unknown

often with an abrupt rise of several inches above the low marsh. When instead this elevational change is gradual, and especially if there is freshwater influence, Lyngby's sedge may occur in the transition zone between low and high marsh. Salt grass is a frequent co-dominant with pickleweed in the high marsh, and many other species are characteristic, including arrowgrass, jaumea, seaside plantain, saltwort, fat hen, gumweed, seablite, and dodder, a common parasite on pickleweed and fat hen. Spreading starwort, an uncommon species with limited distribution, was observed at a few sites along the Strait of Juan de Fuca and at Willapa Bay. This species is under consideration for proposal as a rare, endangered or threatened species in Washington.

In the uppermost reaches of the high marsh, several new species may appear. Baltic rush, mud rush, and tufted hairgrass often occur, and become more abundant as elevation increases. Species characteristic of salt meadows, including Pacific silverweed and creeping bentgrass may be scattered throughout the upper margin of the high marsh.

Salt Meadow Plant Community

Beyond the reach of regular tidal inundation, the limiting effects of high salinity are moderated by precipitation and freshwater runoff. Soils are well developed with a substantial humus layer, and these conditions are reflected by the rich plant community. Tufted hairgrass, creeping bentgrass, and Pacific silverweed are common dominants in salt meadows. Remnants of the preceeding salt marsh community may be present, but rapidly decline in importance. Towards the upland edge of salt meadows, Douglas' aster is often present, as are several species also found in upland habitats, including yarrow, foxtail and meadow barley, and western and seaside dock. Stranded drift logs may be scattered throughout salt meadows, and often accumulate at the upland edge. Upland species frequently become established on the drift logs. At the mouth of the Pysht River in Clallam County, several large (approximately four feet in diameter) drift logs are stranded on the marsh and support a surprisingly complete upland community composed of stunted western hemlock and Sitka spruce, salal, sheep sorrel, and several mosses and lichens.

Freshwater influence at the upland margin is often apparent with the occurrence of species characteristic of brackish or freshwater wetlands. These include hardstem bulrush, common cattail, water parsley, and slough sedge.

Brackish Marsh Plant Community

Common cattail and hardstem or softstem bulrush dominate this coastal marsh type. Lilaeopsis, seaside buttercup, and low clubrush are also good indicators of brackish conditions, but are easily overlooked due to their small size. Areas of slightly higher elevation or better drainage may support characteristic species of salt meadows, including Pacific silverweed, Lyngby's sedge, creeping bentgrass, Douglas' aster, baltic rush, water parsley, and slough sedge.

Table 623-1 summarizes several characteristics of Washington's coastal marshes.

TABLE 623-1 SELECTED CHARACTERISTICS OF COASTAL MARSHES OF WASHINGTON

		Characteristic Plants	Substrate	Tidal Inundation
Salt marsh	low	arrowgrass pickleweed	saturated mud, sand, gravel, silt	twice daily
	high	pickleweed saltgrass saltwort	some organic material	twice daily - frequent
Salt Meadow		hairgrass Pacific silverweed creeping bentgrass Baltic rush	well-developed soil, highly organic	infrequent - only with extreme high & storm tides
Brackish marsh		cattail hardstem bulrush	saturated silt, mud, sand w/organic matter or peat	daily - infrequently

Function and Value of Coastal Marshes

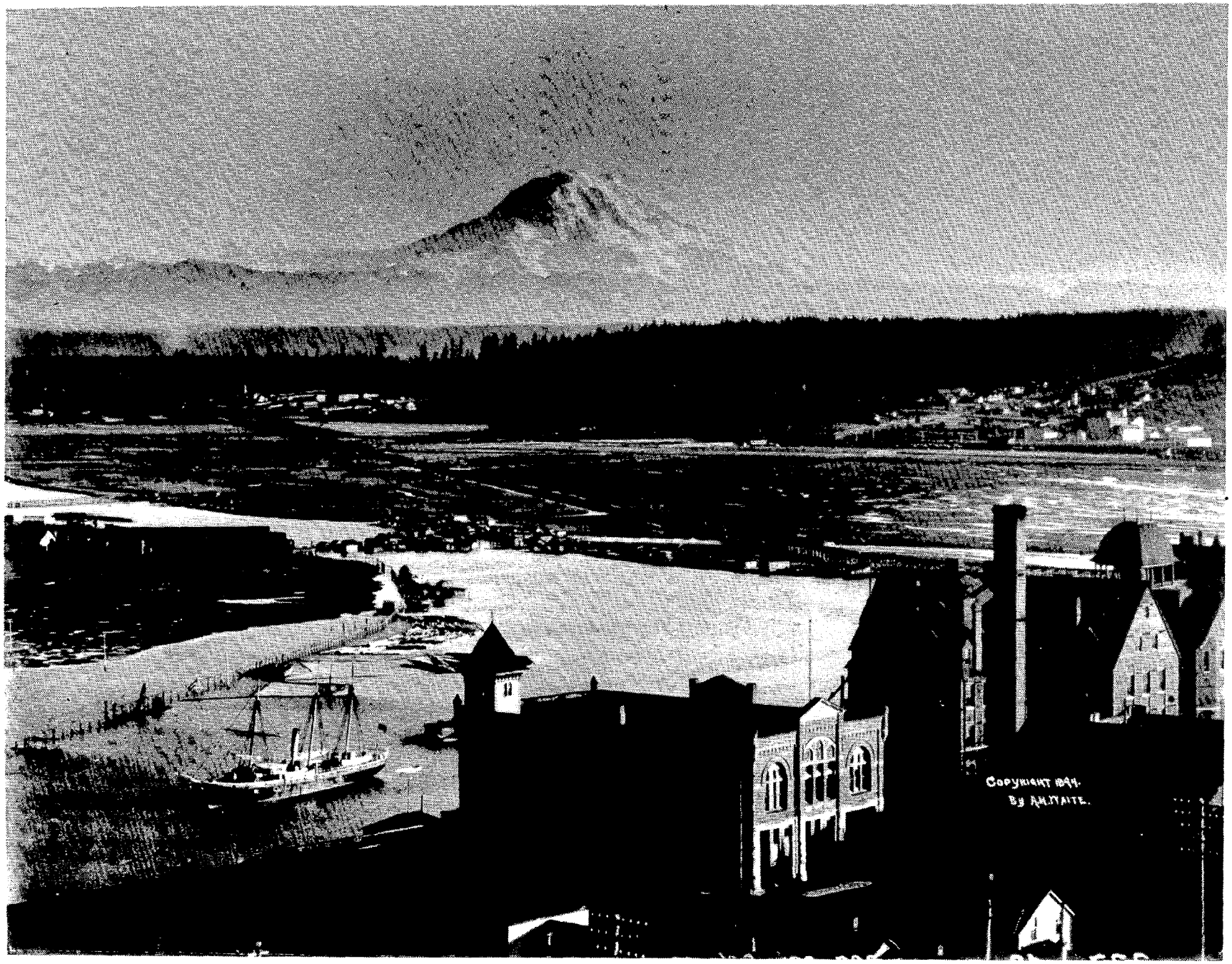
Coastal marshes are among the most productive ecosystems known to man. The productivity of the dense vegetation, supplied with nutrients transported by the incoming tides and nearby rivers and streams, has often been favorably compared to intensively cultivated agricultural crops (see Table 623-2).

TABLE 623-2

COASTAL MARSH NET PRODUCTION

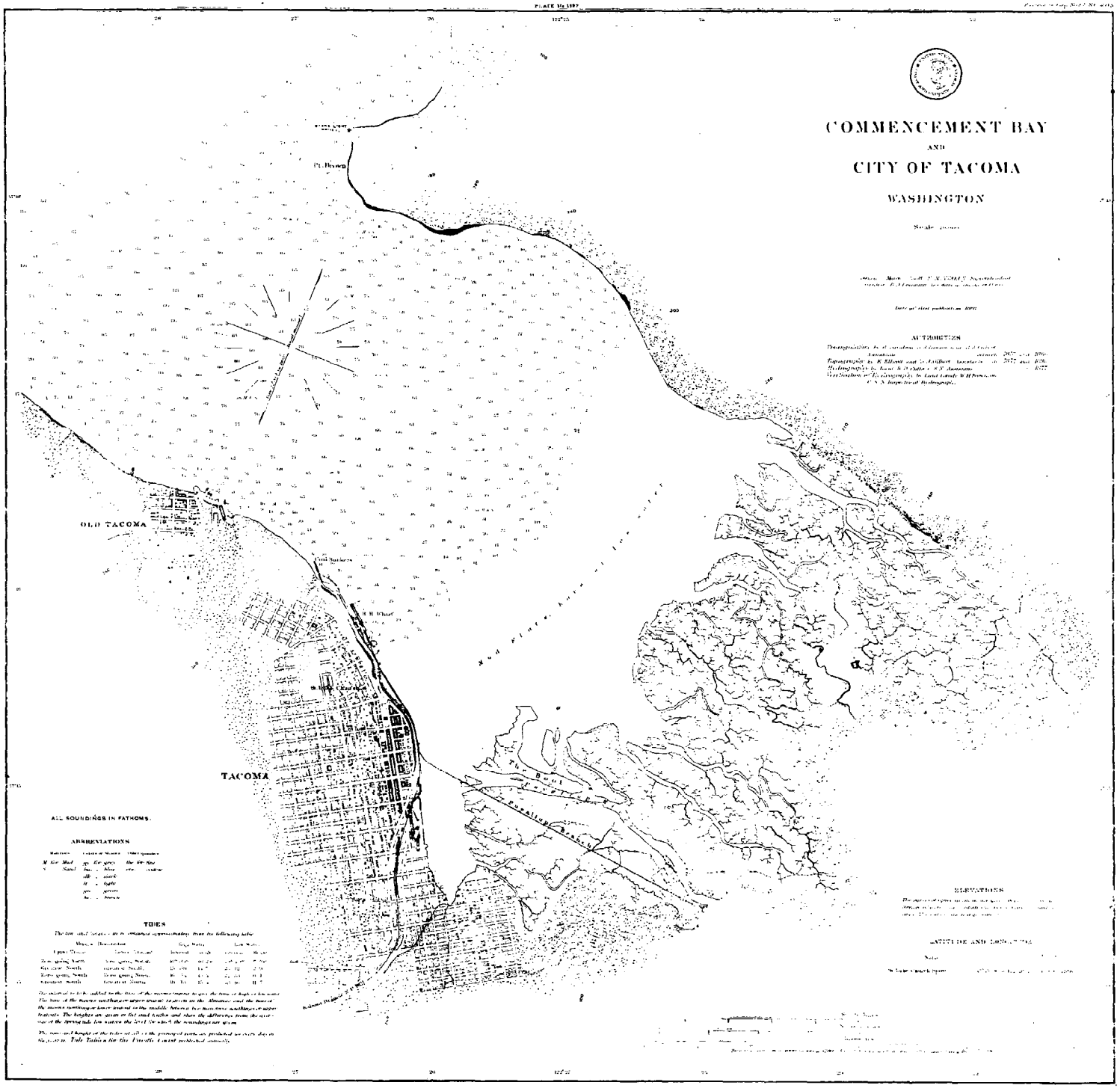
	Grams/square meter/year
Wheat field (world average)	288
Rice field (world average)	511
Sugar cane (Hawaii)	2,711
Low Sandy Marsh (Jefferson Co., Wa.)	738
Immature High Marsh (Jefferson Co., Wa.)	1,041
Mature High Marsh (Jefferson Co., Wa.)	283
Sedge (*Carex* sp.) Marsh (Jefferson Co., Wa.)	2,000
Sedge (*Carex lyngbyei*) Marsh (Nehalem Bay, Or.)	1,746
Bulrush (*Scirpus maritimus*) Marsh (Nehalem Bay, Or.)	609
Rush/Bentgrass (*Juncus*/*Agrostis*) Marsh (Nehalem Bay, Or.)	1,479

The fate of this productivity has been the subject of much study, and the results have established coastal marshes as basic to the functioning of a healthy coastal ecosystem. The energy produced is consumed within either of two feeding pathways; the direct grazing pathway or the detrital pathway. Figure 623-3 is a schematic representation of both pathways.



Photography Collection
University of Washington Library
Photographer: A.H. Waite

Figure 623-2. Tacoma and the Puyallup River Estuary in 1894.


COMMENCEMENT BAY
AND
CITY OF TACOMA
WASHINGTON
AUTHORITIES
Pt. Brown
OLD TACOMA
TACOMA
ALL SOUNDINGS IN FATHOMS.
ABBREVIATIONS
TIDES
ELEVATIONS
LATITUDE AND LONGITUDE

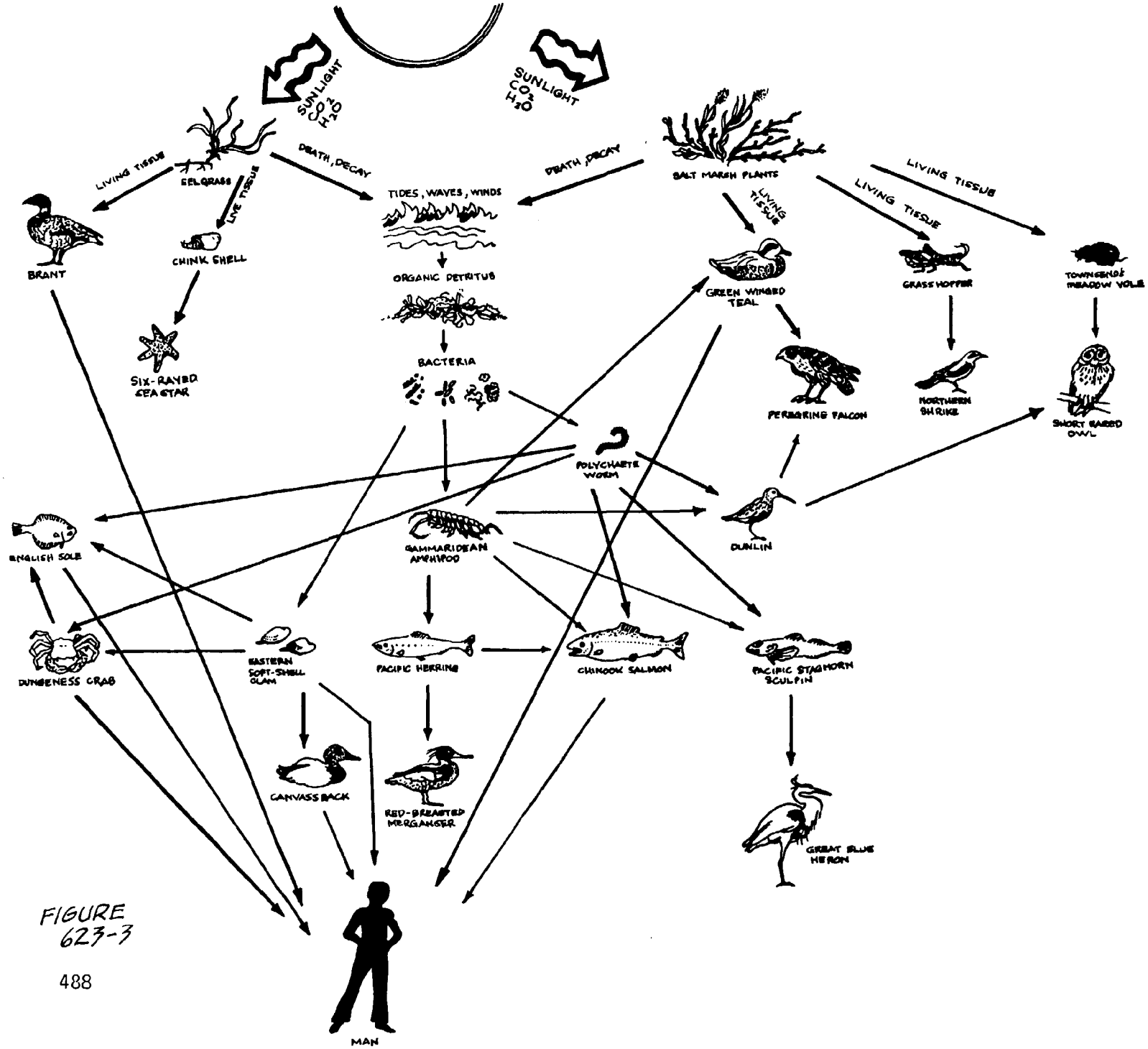

SUNLIGHT
O_2
H_2O
SUNLIGHT
CO_2
H_2O
EELGRASS
LIVING TISSUE
LIVE TISSUE
DEATH, DECAY
TIDES, WAVES, WINDS
DEATH, DECAY
SALT MARSH PLANTS
LIVING TISSUE
LIVING TISSUE
LIVING TISSUE
BRANT
CHINK SHELL
SIX-RAYED SEA STAR
ORGANIC DETRITUS
BACTERIA
GREEN WINGED TEAL
GRASSHOPPER
TOWNSEND'S MEADOW VOLE
PEREGRINE FALCON
NORTHERN SHRIKE
SHORT EARED OWL
POLYCHAETE WORM
DUNLIN
ENGLISH SOLE
GAMMARIDEAN AMPHIPOD
DUNGENESS CRAB
EASTERN SOFT-SHELL CLAM
PACIFIC HERRING
CHINOOK SALMON
PACIFIC STAGHORN SCULPIN
CANVASSBACK
RED-BREASTED MERGANSER
GREAT BLUE HERON
MAN

FIGURE 623-3

Grazing Pathway

Much of the direct use of coastal marshes by wildlife is by herbivores, the primary consumers of coastal marsh vegetation. Many of these species are in turn preyed upon by secondary consumers. These first and second level consumers represent simple examples of food chains which become much more complex as other feeding pathways are considered and third and fourth levels of consumption are added. A simple food chain is exemplified by one of the most abundant and widespread salt marsh vertebrates, the Townsend's vole. These voles, also known as meadow mice, feed on salt marsh plants such as Lyngby's sedge. Marsh hawks often hunt low to the ground over salt marshes and capture these plump rodents.

Other food chains include steps involving species within several major taxomonic groups. Many invertebrates (especially insects) are consumers of plant matter produced in salt marshes, and many birds, mammals, and fish feed directly or indirectly upon them. Examples include shorebirds and juvenile salmon. Birds of prey capturing shorebirds and humans eating salmon are examples of other predators involved in food chains based on the grazing pathway.

Many species which feed on smaller grazing organisms are omnivorous, often consuming varying quantities of salt marsh plant seeds or other plant parts. Consumption by omnivores is also considered primary consumption and probably involves the greatest number of wildlife species feeding directly on salt marsh plants.

Marsh plant seeds are especially important as wildlife food and are consumed by many species. For example, Pintails, Mallards, Green-winged Teal, Ruddy Ducks, Trumpeter Swans, dowitchers, Soras, Savannah Sparrows, and Song Sparrows are known to eat seeds of sedges. Larger mammals, such as deer and elk, are primary consumers of other plant parts. Elk are especially abundant on salt meadows along Willapa Bay in Pacific County, and also occur in Jefferson and Grays Harbor County marshes.

TABLE 623-3

SALT MARSH WILDLIFE

SPECIES	MARSH / SLOUGHS	ADJACENT TIDEFLATS (Exposed at low tide)	ADJACENT NEARSHORE (Submerged tideflats)
BIRDS			
Common Loon			X
Red-throated Loon	X		X
Red-necked Grebe			X
Horned Grebe			X
Eared Grebe			X
Western Grebe			X
Pied-billed Grebe			X
Double-crested Cormorant	X		X
Great Blue Heron	X	X	X
Green Heron	X		
Great Egret	X	X	X
Whistling Swan	X	X	X
Trumpeter Swan	X	X	X
Canada Goose	X		
Brant		X	X
Snow Goose	X	X	X
Mallard	X	X	X
Gadwall	X		
Pintail	X	X	X
Green-winged Teal	X	X	X
Cinnamon Teal	X		
European Wigeon	X	X	X

SPECIES	MARSH /SLOUGHS	ADJACENT TIDEFLATS (Exposed at low tide)	ADJACENT NEARSHORE (Submerged tideflats)
American Wigeon	X	X	X
Northern Shoveler	X		
Canvasback	X		X
Greater Scaup	X		X
Lesser Scaup	X		X
Common Goldeneye	X		X
Barrow's Goldeneye			X
Bufflehead	X		X
White-winged Scoter			X
Surf Scoter			X
Black Scoter			X
Ruddy Duck	X		X
Hooded Merganser	X		X
Common Merganser	X		X
Red-breasted Merganser			X
Turkey Vulture	X	X	
Red-tailed Hawk	X		
Rough-legged Hawk	X		
Bald Eagle	X	X	X
Marsh Hawk	X		
Osprey	X		X
Merlin	X	X	
American Kestrel	X		
Virginia Rail	X		

TABLE 623-3

SALT MARSH WILDLIFE

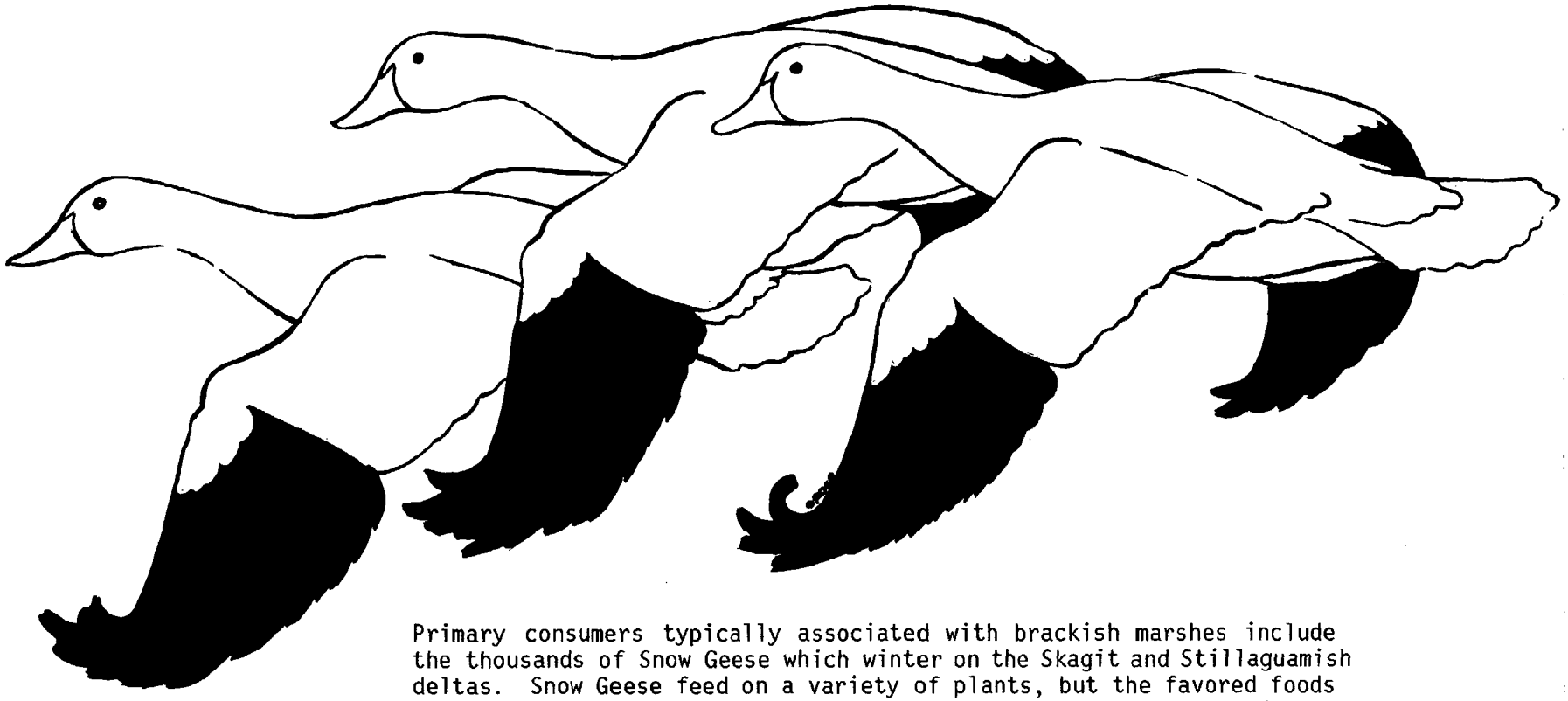
	MARSH / SLOUGHS	ADJACENT TIDEFLATS (Exposed at low tide)	ADJACENT NEARSHORE (Submerged tideflats)
Sora	X		
American Coot	X	X	X
Semi-palmated Plover	X	X	
Killdeer	X	X	
Black-bellied Plover	X	X	
Common Snipe	X		
Whimbrel	X	X	
Spotted Sandpiper	X		
Greater Yellowlegs	X	X	
Lesser Yellowlegs	X	X	
Willet	X	X	
Sanderling	X	X	
Western Sandpiper	X	X	
Least Sandpiper	X	X	
Pectoral Sandpiper	X		
Dunlin	X	X	
Dowitcher sp.	X	X	
Glaucous-winged Gull	X	X	X
Western Gull	X	X	X
Herring Gull	X	X	X

TABLE 623-3

SALT MARSH WILDLIFE

SPECIES	MARSH / SLOUGHS	ADJACENT TIDEFLATS (Exposed at low tide)	ADJACENT NEARSHORE (Submerged tideflats)
California Gull	X	X	X
Ring-billed Gull	X	X	X
Mew Gull	X	X	X
Bonaparte's Gull	X	X	X
Heermann's Gull	X		X
Common Tern	X		X
Mourning Dove	X		
Barn Owl	X		
Short-eared Owl	X		
Belted Kingfisher	X		X
Common Flicker	X		
Violet-green Swallow	X	X	X
Tree Swallow	X	X	X
Rough-winged Swallow	X	X	X
Barn Swallow	X	X	X
Cliff Swallow	X	X	X
Purple Martin	X	X	X
Common Raven	X	X	
Common Crow	X	X	
Dipper	X		
House Wren	X		
American Robin	X		
Western Bluebird	X		

SPECIES	MARSH /SLOUGHS	ADJACENT TIDEFLATS (Exposed at low tide)	ADJACENT NEARSHORE (Submerged tideflats)
Water Pipit	X	X	
Northern Shrike	X		
Loggerhead Shrike	X		
Starling	X		
Western Meadowlark	X		
Red-winged Blackbird	X		
Brewer's Blackbird	X		
American Goldfinch	X		
Savannah Sparrow	X		
Vesper Sparrow	X		
White-crowned Sparrow	X		
Song Sparrow	X	X	
MAMMALS			
Harbor Seal (*Phoca vitulina*)	X	X	X
River Otter (*Lutra canadensis*)	X	X	X
Coyote (*Canis latrans*)	X	X	
Blacktail Deer (*Odocoileus hemionus*)	X	X	
Elk (*Cervus elaphus*)	X		
Raccoon (*Procyon lotor*)	X	X	
Townsend's vole (*Microtus townsendii*)	X		
Deer Mouse (*Peromyscus maniculatus*)	X		
Shrews (*Sorex* spp.)	X		
Muskrat (*Ondatra zibethica*)	X		
European rabbit (*Oryctolagus cuniculus*)	X		
REPTILES & AMPHIBIANS			
Red-legged frog (*Rana aurora*)	X		
Garter snake (*Thamnophis* spp.)	X		
Rough-skinned newt (*Taricha granulosa*)	X		



Primary consumers typically associated with brackish marshes include the thousands of Snow Geese which winter on the Skagit and Stillaguamish deltas. Snow Geese feed on a variety of plants, but the favored foods are the rhizomes and sprouts of three-square bulrush. The head and neck of these white birds is often blackened with mud after rooting about in the low intertidal for this favored plant.

Algae occurring in the lower portions of salt marshes are also grazed directly, primarily by small snails. The most common of these snails are Phytia myosotis and Assiminea californica. More rarely found are Cecina manchurica and several littorine snails. Newcomb's littorine (Littorina newcombiana), is known to occur in only four estuaries worldwide, two of which are in Washington (Grays Harbor and Willapa Bay). This snail has been proposed as a threatened species by the U.S. Fish and Wildlife Service.

These snails provide food for shorebirds and some fish which forage in salt marshes at high tides. Hairy shore crabs, often abundant in burrows along the edges of tidal sloughs, also wander among the marsh vegetation at high tide looking for young snails, insects, or decaying animal matter.

Detrital Pathway

As marsh plants die, bacteria begin the process of decomposition. The decaying organic matter (called detritus) and associated bacteria forms the base of the second major food web originating in coastal marshes. Much detritus stays in the marsh, but most is carried away by the tides to adjacent marine waters.

Recent research indicates that the amount of marsh plant material going through detrital pathways exceeds the amount going through direct grazing pathways. The detritus produced in any particular marsh is spread over a large and unconfined area, making it difficult to quantify the value of a single marsh to animals in the detrital pathway. Some areas, especially deeper subtidal locations, are totally dependent on imported organic matter to function biologically, but may receive only a small part of their imported energy from marshes. However, on tideflats adjacent to marshes, a large portion of the imported detritus may come from the marsh.

A large number of invertebrates in both intertidal and subtidal areas, particularly small crustaceans, clams, and worms, feed exclusively or largely on bacteria-rich detritus. These species in turn provide the primary food sources for other invertebrates, fish, birds, and mammals, many of which are commercially or recreationally important species. Dungeness and red rock crabs and shrimp are economically important invertebrate carnivores.

Many of the fish which eat invertebrates were discussed in the Muddy Sand and Mud Narratives (Nos. 637 and 638) and include juvenile salmon, English sole, and starry flounder. Some of these fish move in with the tide to feed over and within the marsh proper. Salt marshes forming at the mouths of spawning rivers and streams are especially important to juvenile salmonids. The marsh and estuary serve as a major feeding area and zone of transition for salmon migrating to sea from these freshwater sources. Prey of juvenile salmonids within the marsh includes insects emerging from the marsh and other invertebrates. Adult salmon and other fish occurring in offshore marine waters feed on invertebrates and smaller fish which use salt marshes as nursery areas.

Most of the birds and mammals noted in Table 623-3 feed within marshes, sloughs, and adjacent flats, or otherwise benefit from the high productivity of marshes. These animals are dependent on marsh productivity and sensitive to activities on the marsh proper. All species listed were observed within marshes or in associated adjacent habitats during the coastal inventory. Many of the species noted as occurring in adjacent tideflats and near-shore areas are discussed in the Muddy Sand and Mud Narratives (Nos. 637 and 638). They are included here to emphasize their relationship to the marsh.

Shorebirds feed on a variety of invertebrates on the marsh and adjacent mudflats. Two shorebirds which restrict most of their feeding acitity to the marsh proper are Common Snipes and Pectoral Sandpipers. Common Snipes were often observed in brackish marshes during our studies and were also seen in low pickleweed marshes. Dowitchers are examples of species which feed on mudflats and on the marsh as was often observed in our studies. One observation is worth noting to demonstrate the relationship between shorebirds and invertebrate detritivores. Eighty-five to ninety of these plump, long-billed shorebirds were observed feeding in a closely packed flock among pickleweed on Gibson Spit marsh in Clallam County. A few Dunlin and a Black-bellied Plover were feeding with the dowitchers as we approached to an unusually close distance. Beneath the dense mat of pickleweed was a loose layer of detritus alive with beach hoppers (*Orchestia traskiana*). These amphipods were feeding on decayed plant material which was being quickly transferred to a form useable by the shorebirds. Several hundred other shorebirds were also in the vicinity, most of which are known to feed on beach hoppers and other amphipods.

Several ducks and other water birds feed within the marsh at high tide, or in sloughs or other wet spots within the marsh throughout the day. They feed on a variety of invertebrates or fish, and include Hooded Mergansers, Bufflehead, and Kingfishers. Hooded Mergansers are uncommon, small diving ducks and the crested male is one of our most striking water birds. They occur in freshwater, where nests are placed in tree cavities, and in coastal areas they frequent quiet waters such as sloughs or lagoons within salt marshes. Their prey includes a high percentage of invertebrates. Water birds often associated with brackish marshes include Red-winged Blackbirds, Soras, and Virginia Rails. These marsh birds are also characteristic of freshwater marshes, a reflection of the similarities between brackish marsh and inland wetlands.

Birds of prey associated with aquatic areas, such as Bald Eagles and Osprey, occur on salt marshes, but more often feed over associated bodies of water. The Osprey hunts only over water, and is uncommon along our coast. Bald Eagles are much more common on marshes where they feed on fish and waterfowl over the marsh proper or in adjacent aquatic habitats. Eagles are most common in winter when spawned-out salmon are washed onto the marsh by flooded stream waters and high tides. The marsh also is used as a day roost at this time.

Aquatic carnivorous mammals (secondary consumers) of our coastal marshes are represented almost exclusively by river otters and harbor seals. River otters forage in sloughs, nearshore, and in streams which flow through the marsh, while harbor seals feed mostly offshore. Both species use marshes as rest sites and harbor seals in particular are intolerant of human activity on the marsh. Other secondary consumers include coyotes, raccoons, and the tiny vagrant shrew which occurs at the upper marsh edge. These secondary consumers prey on organisms which graze on marsh plants or feed on detritus produced within the marsh.

Cover - Nest and Escape

A few vertebrates complete their entire life cycle within the salt marsh. These include one of the most frequently encountered small mammals of Washington marshes, the Townsend vole and one of our most common small birds, the Song Sparrow. Townsend voles, or meadow mice, are active both day and night and their above-ground runways are concealed by dense marsh and salt meadow vegetation. They feed on a variety of marsh plants and may affect plant community composition and structure through grazing and tunneling activities. They certainly contribute significantly to marsh energy flow for wildlife species which consume them, including Short-eared Owls, Marsh Hawks, coyotes, Barn Owls, and Red-tailed Hawks. Remains of meadow mice have consistently appeared in feces and pellets of these predators collected on salt marshes during our studies. Other small mammals which occur in salt marshes include deer mice, shrews, muskrats, and in the San Juan Islands, European rabbits.

Song Sparrows are but one example of birds which nest in coastal marshes. Song Sparrows are year-round residents of Washington and nest or feed within salt marsh, salt meadow, and brackish marshes. The Song Sparrow requires marsh vegetation for nest sites, hiding places, song perches, and for concealment while feeding. It is also dependent on marsh plants directly and indirectly for food which includes seeds of gumweed and bulrushes. They also forage along meadow mouse trails and among pickleweed in the low marsh. In these low areas, food includes nereid worms, snails, insects, and other small invertebrates. Foraging is primarily on the ground in salt marshes, but Song Sparrows seldom are far from escape cover and are often seen singing from atop gumweed perches.

Ground level nesting birds typically occur in high marsh or salt meadows, however, waterfowl occasionally nest in low marshes along quiet sloughs. Ground nesters frequently observed include Savannah Sparrows which conceal their spotted eggs in a

grass-lined nest. Vesper Sparrows and Killdeer are also known to nest within the low, but concealing cover of salt marsh vegetation, although Vesper Sparrows are uncommon.

Other ground nesters which were probably more common prior to large-scale human disturbance of marshes include the Short-eared Owl. Thus, E. A. Kitchin wrote in 1919, "Our Tacoma tideflats cover several square miles of territory." He went on to tell of the two Short-eared Owl nests he discovered along the edge of a slough within the marsh which has been largely eliminated since that time by the city of Tacoma (see Figure 623-2).

Meadow mice are known to be the major prey of Short-eared Owls in salt marshes and there is evidence that these and other birds of prey often feed when high tides restrict the hiding places of salt marsh rodents. Meadow mice almost always have tall vegetation on their home range which they will swim to if high water floods their runways. They are then more visible to predators and more concentrated, particularly along slough margins where taller plants often grow.

Another small marsh mammal is the vagrant shrew which has been found to restrict its activities to higher areas on the marsh above tidal influence. These nocturnal shrews are among the prey of Barn Owls at the Pysht River marsh in Clallam County. Barn Owls were observed roosting here in the Spruce wooded margin of the marsh and are examples of predators which seek cover in adjacent habitats during the day and hunt the marsh at night. Other nocturnal predators include Great Horned Owls, coyotes, and raccoons. These hunters of the night benefit from the cover of darkness and the increased activity of small mammals after sunset.

Brackish marsh vegetation and taller plants growing along slough or stream margins in coastal marshes often increase the diversity of nesting birds. Increased plant height provides singing perches for birds, adds to concealment, and offers a nest substrate for birds such as Red-winged Blackbirds and Long-billed Marsh Wrens. Both of these species also occur in freshwater marshes having similar vegetation. Cattails and hardstem or softstem bulrush are used as cover, nest attachment, nest material, singing perches, and as feeding sites. Other birds benefiting from the cover and food within tall brackish marsh vegetation include Soras, Common Snipes, Song Sparrows, and waterfowl.

Rest Sites

Salt marshes are major rest sites for wildlife, particularly shorebirds which feed at low tide within marsh sloughs or along adjacent mudflats. Shorebirds often continue to feed in the marsh and are known to switch from invertebrates to seeds of marsh plants when high tides force them off lower intertidal feeding areas. However, invertebrates (including insects and their larvae) may still be consumed when shorebirds move up onto higher ground.

Waterfowl also use marshes for rest sites and often intermingle periods of rest and feeding. They most often occur at the marsh edge, and where sloughs dissect the marsh, a greater shoreline area is available for ducks to feed, rest, and potentially nest.

Mammals also use the marsh as a rest site and frequently occur at the land-marsh or water-marsh interface. Upland edges provide escape cover for terrestrial mammals that may bed down on marshes. These species include coyotes, deer, and elk.

The aquatic edge is also used as a rest site, primarily by river otters and harbor seals. Both these species require water for feeding and as an escape route, but harbor seals are more selective in their choice of marsh rest or haul out sites. Harbor seals are much more adapted to an aquatic life and select haul out sites adjacent to deep water at river mouths or along sloughs. Marsh haul out sites include those at the mouth of the Skokomish, Duckabush, and Dosewallips Rivers, all of which enter Hood Canal.

River otters move about easily on land, but select rest or landing sites which are near water. Thirty-six percent of all otter landings located during our coastal inventory were on salt marshes and were adjacent to a variety of aquatic areas including streams, lagoons, open water, and large rivers. Otters and harbor seals both come ashore to rest, but the marsh landings of otters serve several other purposes. These small marsh-edge sites are often trampled and vegetation is sometimes removed as a result of their rolling, scratching, and playing behavior.

Other wildlife which frequently rest on salt marshes include gulls, terns, and Great Blue Herons. Herons are especially common and are sometimes seen in large numbers. At Quilcene Bay marsh, 27 herons were seen resting on the marsh edge at high tide on a recent July day.

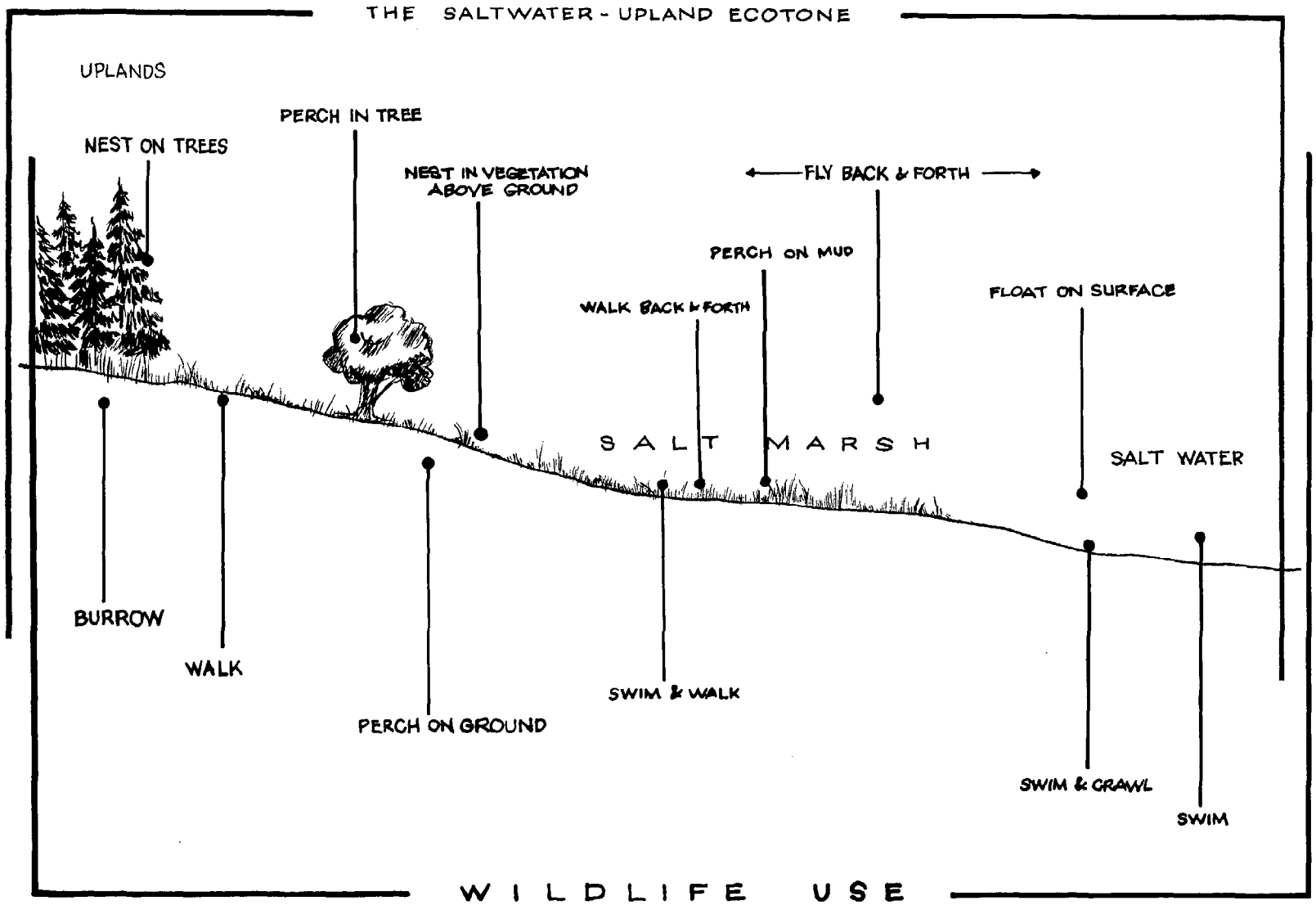
Edge Effect

Because salt marshes are one of the most productive of coastal ecotones, they support large numbers of species which are primarily terrestrial or aquatic as well as those requiring both systems.

Terrestrial wildlife either move into the marsh from adjacent uplands or occur primarily within the marsh. This varies considerably and is generally related to the diversity of adjacent uplands, extent of undeveloped upland edge, and size of the marsh. Larger marshes generally support a more diverse wildlife community, but small marshes have relatively more edge per unit of area. This marsh edge length may be a significant contribution to marsh energy transfer, and wildlife populations will benefit from this effect (see discussion of relationship of size to function and value of coastal marshes on page 504.

Undisturbed and continuous wooded edge habitats provide corridors, cover, roost and nest sites for several species which forage in marshes. Streams and associated riparian vegetation are corridors allowing the movement of elk, bobcat, deer, coyotes and other wildlife between marsh and upland. Inland agricultural fields are also valuable uplands used by marsh waterfowl and other wildlife. Many of these farmlands were created by diking marshes. This process has benefited certain species such as Canadian Geese and Mallards which feed in stubble fields and diked marshes. However, diking has also removed many acres of productive salt marsh from the coastal ecosystem which supports a far more diverse, wider ranging, and more economically valuable group of organisms.

Feeding by terrestrial species occurs to the water's edge and above ground by aerial foragers such as Barn and Cliff Swallows. Both swallows capture insects emerging from the marsh, sloughs, and high intertidal mudflats adjacent to the marsh, and often fly out over nearshore areas to feed or collect mud at the marsh edge. The moist mud is scooped with the swallow's bill and used to construct their familiar open and gourd-shaped nests. Western Bluebirds and Northern Shrikes are other


THE SALTWATER - UPLAND ECOTONE
UPLANDS
NEST ON TREES
PERCH IN TREE
NEST IN VEGETATION ABOVE GROUND
FLY BACK & FORTH
PERCH ON MUD
WALK BACK & FORTH
FLOAT ON SURFACE
SALT MARSH
SALT WATER
BURROW
WALK
PERCH ON GROUND
SWIM & WALK
SWIM & CRAWL
SWIM
WILDLIFE USE

examples of insectivorous birds which may occur on marshes. Shrikes feed on insects, but also prey on other small birds or mammals. Loggerhead Shrikes are much less common, but have been observed on coastal marshes. Both shrike species are members of the large order of small landbirds, Passeriformes (the Passerines). The Water Pipit is another passerine which occurs on marshes. While the shrikes behave much like small hawks, the pipit is often associated with and behaves much like a shorebird. They are sparrow-sized and feed in low marsh or muddy areas on insects and other invertebrates.

Larger terrestrial species frequenting salt marshes include several predators which generally require adjacent upland cover. Some large marshes with well-developed high marsh or salt meadow may provide all the habitat requirements for some of these species. For example, scattered spruces often occur in salt meadows along Willapa Bay. The trees and associated understory vegetation provide cover for raccoons and coyotes which forage on the marsh and tideflats, and also serve as roost and nest sites for birds of prey such as Red-tailed Hawks.

In general, as body size of the predator increases, home range or territory size also increases. Thus, large carnivorous marsh birds and mammals generally require marsh and a variety of adjacent terrestrial areas to satisfy their habitat requirements. This is especially true in the marshes of our inland waters which are typically smaller than those occurring in Willapa Bay.

Nutrient Cycling

Coastal marshes serve as nutrient traps in the coastal ecosystem. Nutrient-rich sediments from upland, riverine, and marine sources are deposited on the marsh surface by incoming tides and are converted and stored as plant material during the growing season. These nutrients then re-enter the cycle through either the grazing or detritus food webs discussed earlier. An understanding of this cycle enables one to draw the following conclusions:

1. Areas mapped as salt marsh contribute to the maintenance of coastal ecosystems on a daily basis. Salt meadows and brackish marshes are important on a seasonal basis, contributing large amounts of detritus at infrequent intervals;
2. Both the grazing and detritus-based food webs are ultimately dependant on nutrients from marshes, as well as a wide variety of other habitats;
3. The productivity of coastal wildlife is directly related to the total amount of coastal marsh available (including that beyond the political boundaries of Washington State);
4. Disturbances affecting nutrient supply from both upland and marine sources will impact coastal marshes and dependent wildlife.

Water and Air Quality

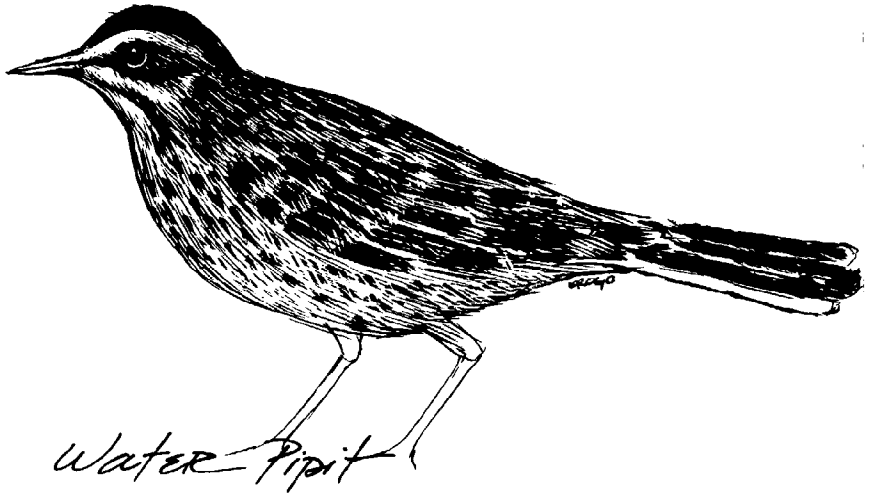
Coastal marshes have been shown to have significant beneficial effects on water and air quality in several ways. Marshes reduce turbidity of coastal waters by functioning as settling areas for sediments carried in longshore currents or in runoff from the surrounding watershed. Turbid water has been shown to inhibit algal growth, and in the absence of suitable settling out areas, deposited sediment may bury and smother bottom-dwelling organisms.

Because marsh plants remove nutrients from coastal waters for metabolic use, they increase the capacity of the water to assimilate additional nutrient-loaded discharge. A study conducted in a 512-acre marsh on the East Coast found that phosphorous was being absorbed at the rate of 4.9 tons per day, ammonia (NH_3) at 4.3 tons per day, and oxygen, a by-product of photosynthesis, was being produced at a rate of 20 tons per day. Additionally, microbes present in the sediment are capable of breaking down sulphur pollutants.

> "The most important contribution marshes and estuaries can make in waste treatment is tertiary treatment to remove and recycle inorganic nutrients."
>
> The Value of the Tidal Marsh
> J. G. Gosselink, et al.

Erosion and Flood Control

Coastal marshes naturally diminish the erosive effects of tidal action by reducing wave force and stabilizing sediment deposits. Marshes are particularly valuable in this respect when situated at the base of steep bluffs which would otherwise be exposed to wave action.



Flood control is possible because the marsh is a system that is not only able to tolerate, but is dependent upon, regular inundation. Coastal marshes are essentially reservoirs which can accommodate flood waters and storm tides, and suffer little or no adverse effects.

Temperature Control

Marshes and associated tideflats absorb and hold the sun's heat and have a moderating effect on local water temperature and microclimate. This moderating effect has been shown to have a stong positive influence on the growth and reproduction rate of estuarine organisms.

Recreational Use

Coastal marshes are a valuable recreational resource for both consumptive and nonconsumptive uses. Waterfowl hunters for quite some time have understood the vital role played by coastal marshes as habitat for many game birds, and as a result, revenue from the purchase of duck stamps is appropriated for marsh conservation and management. Several marshes throughout the coast are managed or preserved primarily for the production of waterfowl, including Gibson Spit (Clallam County), Thorndyke Bay (Jefferson County), Nisqually Delta (Thurston County), and portions of the Skagit River Delta (Skagit County).

Nonconsumptive recreational use of coastal marshes is difficult to quantify, but a recent Washington Department of Game report shows that the dollar amount spent on nonconsumptive use of wildlife on the department's lands was greater than the amount spend for all hunting and fishing activities on the same land.

Educational and esthetic values of coastal marshes can be considerable. Students at The Evergreen State College have performed numerous studies on the Nisqually River Delta, making significant contributions to our knowledge of Wahington's coastal marsh flora and fauna.

Relationship of Size to Function and Value of Coastal Marshes

Because many of Washington's coastal marshes are relatively small, consideration must be given to their total contribution to the coastal ecosystem. Studies have shown that upland and water edges may have relatively greater value than other areas of the marsh, due to the edge effect which occurs at the ecotone between adjacent habitats. Although the capability is lacking to compute what percent of the total edge is represented in smaller Washington marshes, figures from other states suggest it may be substantial, e.g., in Maryland, 68 percent of the total upland edge, and 73 percent of the total seaward edge is accounted for by marshes of less than five acres.

Due to mapping restrictions, marshes of less than approximately one acre are not indicated in the Atlas volumes, but this does not mean their value should be disregarded. Workers in other areas have drawn the following conclusions concerning small marsh strips or remnants:

1. "Any marsh which is at least two feet or more in average width . . . has significant value as an erosion deterrent and is capable of filtering sediment." Coastal Wetlands of Virginia, G. Silverhorn, et al.

2. "Any marshes greater than 0.1 acre in size may have, depending on type and viability, significant value in terms of productivity, detritus availability, and habitat." Ibid.

3. Tidal flushing, nutrient and detritus transfer, and buffer effects appear to be greater if the ratio of edge length to marsh area is larger.

Thus the exchange of nutrients which occurs along borders of small marshes and their overall value makes them an important part of the coastal ecosystem. Larger marshes may often support more recognizably valuable wildlife species, but small marshes and those surrounded by urban areas also contribute significantly to the productivity of coastal waters.

IMPACTS

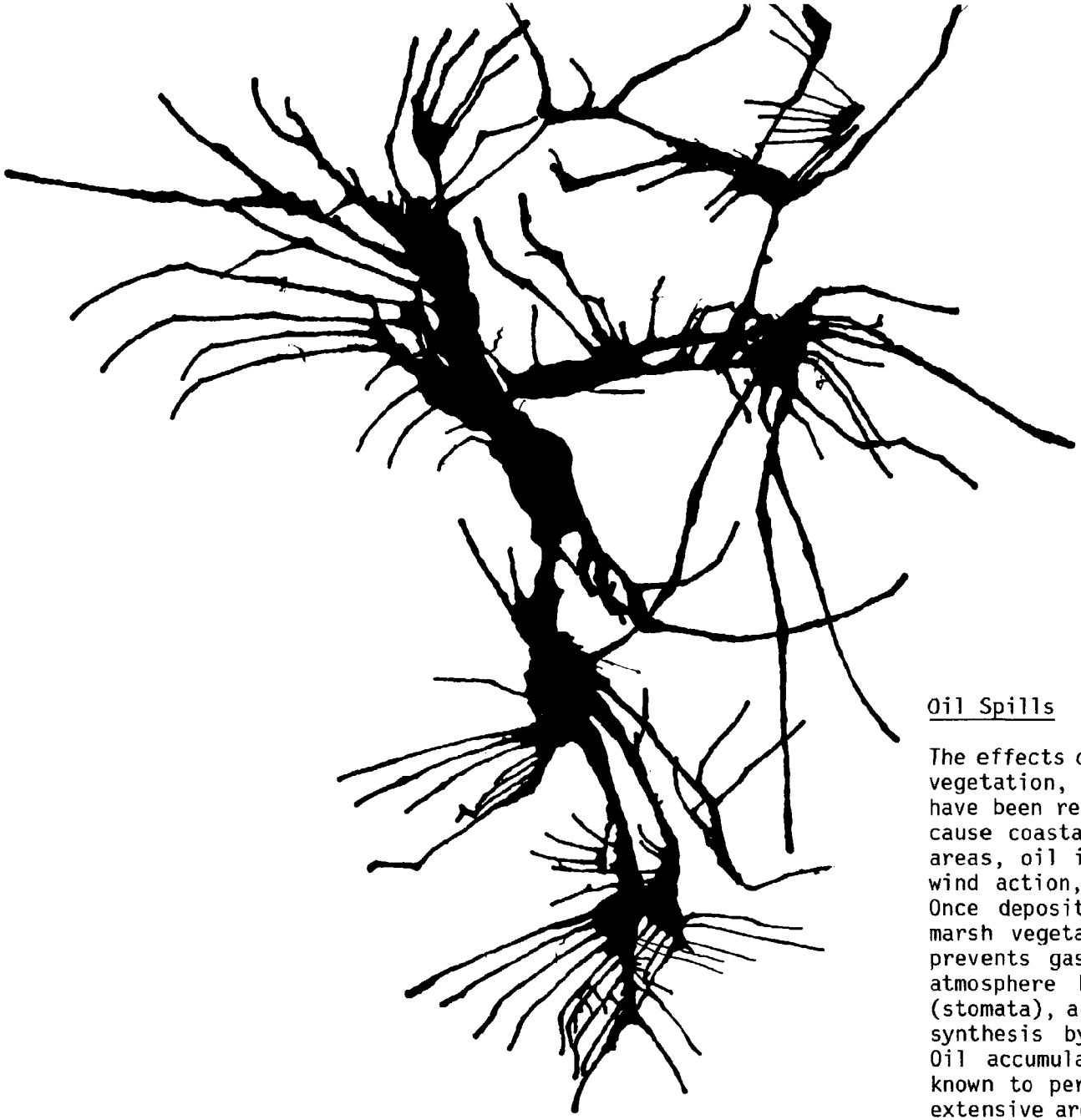
As summarized in the introductory section to this narrative, a signficantly large amount of Washington's coastal marsh habitat has been destroyed since settlers first arrived. Presently, losses are continuing, and during the course of this study, the disturbances most commonly observed included:

1. Filling for residential and commerical construction, or use as dredge spoil disposal sites. These activities generally result in the complete destruction of the marsh in the affected area;

2. Alteration of the salinity regime, i.e., length and frequency of tidal inundation, by the construction of dikes and tide gates. Unbroken dikes are generally constructed in salt meadows to prevent the influx of tidal waters. This is equivalent to an increase in elevation and succession is accelerated as precipitation and runoff leach salts from the soil, allowing colonization and gradual replacement of salt meadow vegetation by upland species. Furthermore, by removing the diked area from tidal influence, the seasonal contribution of detritus from the area to adjacent marine waters is lost. Diked salt meadows are often used for pasturing farm animals, further accelerating the rate of change in the plant community by the removal of palatable species, and the introduction of "weedy" species;

3. Alteration of adjacent previously undisturbed upland habitat. This disturbance will reduce the diversity of wildlife inhabiting the marsh in two ways: by altering or destroying the corridors or upland habitat required by terrestrial species that use coastal marshes, and, especially if residential development alters the adjacent uplands, the presence of domestic animals which disturb or destroy marsh wildlife;

4. Although not a common disturbance, the introduction of nonnative plant species has proved to be a serious problem in Port Susan (Snohomish and Island Counties). Port Susan is part of the area that annually supports the west coast winter population of Snow Geese, numbering in the hundreds of thousands. The major food resource of the Snow Geese are the underground stems (rhizomes) of three-square bulrush, growing in the lowest part of the salt marshes in the area. In 1961, Townsend's cordgrass was introduced to Port Susan, and has since spread throughout the area, out-competing the native bulrush. The rhizomes of Townsend's cordgrass are unpalatable to the Snow Geese, and concern has been expressed for their winter habitat if the cordgrass continues to spread. Herbicide applications have been tried on experimental plots, with no success, and it presently appears there is no satisfactory way to control Townsend's cordgrass in Port Susan.



Oil Spills

The effects of oil spills on coastal marsh vegetation, unobserved in Washington, have been reported from other areas. Because coastal marshes occur in protected areas, oil is not dispersed by wave and wind action, but accumulates on marshes. Once deposited, oil readily adheres to marsh vegetation, creating a film that prevents gas exchange between plant and atmosphere by obstructing leaf pores (stomata), and decreases the rate of photosynthesis by reducing available light. Oil accumulated within marshes has been known to persist for several years, and extensive areas of coastal marsh have been denuded as a result of spilled oil.

Salt Marsh References

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SEAGRASS (No. 627)

INTRODUCTION

Seagrasses are vascular plants (i.e., related to terrestrial plants rather than algae) which grow in the marine environment. There are two groups of seagrasses in Washington; eelgrass (Zostera) and surfgrass (Phyllospadix). They occur in intertidal and shallow subtidal areas throughout much of the state.

Seagrasses are highly productive plants, and are important in the trophic functioning and nutrient cycling of the entire coastal zone. They provide unique habitats which support distinct communities of algae and animals, many of which are of great value to humans.

The ecology of seagrasses is just now in the process of being widely studied. Previous research on Washington State seagrasses dealt almost exclusively with eelgrass (Zostera marina). Several studies from the East Coast and Europe have also dealt with this same plant, and are the base for much of the knowledge on seagrasses. While quantitative values from these studies cannot be applied to the Washington Coastal Zone, the general principals established by these studies can be relevant to our shoreline ecosystems.

SIGNIFICANT BIOLOGICAL FEATURES

Productivity

Seagrasses generally have high rates of productivity. Studies on eelgrass in Puget Sound indicate that production (500 to 600 grams of dry weight per square meter per year or .10 to .12 pounds per square foot per year) compares vary favorably to figures for seagrasses in other areas of the world, even though root production was not included.

The production of eelgrass is greater per unit area than the world averages for cultivated corn or rice, the U.S. averages for hayfields or tall-grass prairies, or phytoplankton production off Peru in nutrient-rich upwelling areas. A study in an east coast estuary indicated that eelgrass, despite covering only 17 percent of the total estuarine area, was responsible for 64 percent of the primary production (including salt marsh production). The productivity of surfgrass has not been measured in Washington, but should also be relatively high.

Production of seagrasses is further enhanced by algae living within the seagrass bed. These algae, which include benthic micro- and macro-algae, epiphytic algae (algae attached to the seagrasses themselves), and phytoplankton, may contribute as much to overall production as the seagrasses. Surfgrass, which grows on rocky beaches, occurs adjacent to seaweed beds whose productivity is probably significantly higher than that of surfgrass.

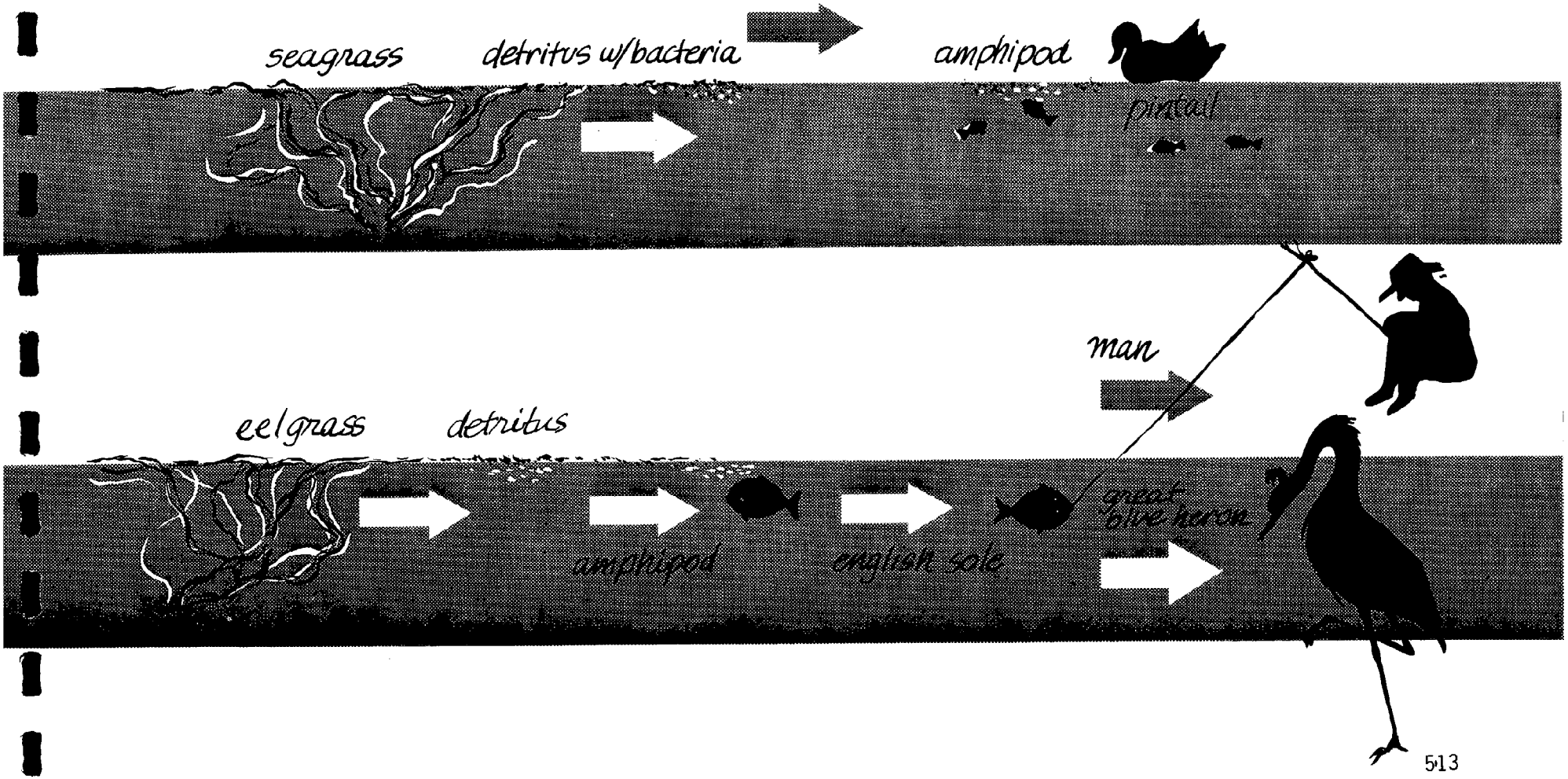
Trophic Relationships

Seagrass beds provide food for animals through either of two pathways; the direct grazing pathway or the detritus pathway. Food chains in the direct grazing pathway are usually short and relatively simple, while food chains in the detritus pathway are often longer and more complex, involving a much greater diversity of animals.

Waterfowl are the most important direct grazers of seagrasses in Washington. Eelgrass is predominant in their diet and constitutes 80 percent or more of the food of Brant during winter. The significance of eelgrass consumption was noted in a bay in Alaska in which 17 percent of the eelgrass crop was consumed by Brant and Canada Geese during fall and summer. Other waterfowl feeding heavily on eelgrass in Washington include Pintails, American Wigeons, and Greater Scaup. These birds feed either on plants attached to the substrate or on free-floating leaves which have broken off from the remainder of the plant. Algae and invertebrates attached to eelgrass contribute to the food value of the plants consumed by these waterfowl.

The eelgrass beds in Washington help make our shoreline an important stop-over and wintering ground along the Pacific Flyway, one of four major migratory bird routes in North America. Willapa and Padilla Bays are examples of major sites in Washington along the flyway and are especially significant for their productive eelgrass beds. Both bays support substantial concentrations of birds and other wildlife, and within Willapa Bay are 10,000 acres of National Wildlife Refuge managed primarily for Brant and Canada Geese as an integral part of the U.S. Fish and Wildlife Service Pacific Flyway migratory bird program. Many other species are present in addition to geese and include wigeon, scaup, Pintail, teal, loons, grebes, and shorebirds. Several hundreds of thousands of birds feed within Willapa Bay each year with peak populations of 100,000 birds.

The detritus pathway is the dominant trophic pathway involving seagrasses. Detritus is organic matter (seagrasses in this case) which is in the process of being decomposed by bacteria. Plants begin to break off as a result of wave action or death from exposure to sun during low tides and enter various food chains. A generalized food chain in the detritus pathway is as follows:



The majority of animals found in eelgrass beds (or 'meadows', as they are often called) are dependent upon detritus as a food source (this may not be true for surfgrass beds). Invertebrates which feed directly on detritus suspended in the water column or which has settled onto the substrate include isopods, amphipods, polychaete worms, brittle stars, and some clams. These invertebrates make eelgrass beds rich feeding areas for fishes and marine birds, which in turn provide food for other birds, fishes, and marine mammals. Observations in Hood Canal showed that diving bird use of eelgrass beds was three times greater than use of non-vegetated nearshore areas.

Studies on the East Coast have indicated that two-thirds to three-quarters of the eelgrass produced in beds is used as detritus rather than being grazed directely. Another study estimated that up to 45 percent of the detritus is consumed in areas outside of the eelgrass bed. An even greater percentage of surfgrass would probably be exported to other areas, as the high energy of splashing waves where it occurs would more readily sweep plant material away. Thus, seagrass beds contribute food to animals throughout nearshore areas, as well as in offshore areas. Decaying seagrass leaves have been collected in trenches as deep as 29,000 feet.

Nutrient Cycle

While little is known of the nutrient cycling properties of surfgrass, eelgrass is known to be important in the cycling of several key nutrients. Detritus from eelgrass, and probably surfgrass to a certain extent, which settles into mud or muddy sand substrates initiates sulfate reduction and helps maintain an active sulfur cycle. Eelgrass also absorbs both nitrogen and phosphorus through its roots. Some of this nitrogen and phosphorus is released into the water column, making it available for use by other plants. Eelgrass plants can absorb nitrogen as they contain nitrogen-fixing bacteria in their rhizomes (or roots). Eelgrass, and perhaps surfgrass, excretes dissolved organic carbon into the water column, and thus is also an important part of the carbon cycle. Algae which grow on seagrasses may also derive some of their nutrients directly from seagrasses; if this does occur, these algae are actually a type of parasite.

EELGRASS DETRITUS, PADILLA BAY

Protection and Stability

Seagrass leaves reduce current flow and wave action both within and on the shoreward side of seagrass beds, creating a protected environment. This protection increases the sediment of detritus and mud particles in the case of eelgrass beds, and detritus and sand in the case of surfgrass beds, and thus can alter the substrate composition by allowing finer particles to become a part of the substrate. This change in substrate type allows organisms to be present which would not normally occur.

During low tides, seagrasses help provide protection to small plants and animals from extreme temperatures and the danger of dessication. Seagrasses give this protection largely by forming an insulating mat, under which temperatures are greatly moderated. On nearly level tideflats where dense eelgrass beds often occur, eelgrass leaves restrict receding water flow during outgoing tides. As a result, a shallow water layer is maintained over the tide flats which affords additional protection for small organisms, as well as the eelgrass itself.

Eelgrass roots bind sediments, and along with the protection afforded by the leaves, reduces surface sediment erosion. This protects the highly productive bacteria in the sediments and at the sediment-water interface. These bacteria are an important source of nutrition for many small invertebrates. The resulting increased stability of sediments caused by the presence of eelgrass, and surfgrass to a lesser extent, is correlated with an increase in both invertebrate density and diversity.

Finally, seagrasses supply a refuge from predators for a variety of invertebrates and fishes. Many animals use seagrass beds, especially eelgrass beds, only for nursery areas, while others spend their entire existence swimming or walking on or among the leaves, or burrowing in the sediment among the roots.

Characteristic Plants and Animals

Plants

Two species of eelgrass and three species of surfgrass occur in Washington.

eelgrass

Broad-bladed eelgrass (*Zostera marina*) is usually referred to as eelgrass, and is the most widespread seagrass in the state. Roughly 125,000 acres (50,600 hectares) of eelgrass are present in Puget Sound alone. Extensive beds also occur in both Grays Harbor and Willapa Bay.

Eelgrass grows in protected areas in sediments ranging from fairly coarse sand to mud, and occasionally on mixed fine and mixed coarse beaches. The optimal substrate type is a combination of mud and sand in which there is a black, anaerobic environment just below the lighter-colored, oxygenated surface sediments.

Eelgrass normally grows between -25 feet (-6.6 meters) and +3 feet (+1 meter) relative to mean lower low water. Eelgrass may occasionally be found at higher elevations in pools or depressions which remain moist during low tides. The lower limit is determined by light penetration, and in turbid waters may be only -3 to -6 feet (-1 to -2 meters) deep.

Eelgrass distribution is limited in southern Puget Sound. Becoming less common south of the Tacoma Narrows, eelgrass is extremely rare west of a line between Nisqually Head and the tip of the Longbranch Peninsula.

Narrow-bladed or European eelgrass was reported introduced into Washington around 1920. The scientific name is *Zostera noltii*, but this same plant was formerly called *Z. nana* and *Z. americana*, and these names are sometimes still seen in various reports concerning eelgrass.

The distribution of European eelgrass is more limited in Washington than the distribution of broad-bladed eelgrass. It occurs in sand and silty sand in Willapa Bay, Grays Harbor, the San Juan Islands, upper Hood Canal, and Whatcom and Skagit counties (most notably in Padilla Bay), and probably in Island and Snohomish counties as well. It is scarce or absent in the lower half of Hood Canal and in Puget Sound south of Snohomish County. However, since European eelgrass is apparently an introduced species, it is possible that its distribution is still increasing in Washington.

European eelgrass occurs at slightly higher intertidal elevations than broad-bladed eelgrass, although their ranges do overlap. Its upper limit appears to be +6 to +7 feet above MLLW.

surfgrass

Three species of surfgrass occur in Washington (Phyllospadix scouleri, P. torreyi, and P. serrulatus) on exposed rock or mixed coarse beaches. Their distribution is thus limited to the outer coast, the Strait of Juan de Fuca, the west side of Whidbey Island, and the southern parts of the San Juan Islands. The exposed nature of surfgrass occurrence leaves little room for overlap in distribution with eelgrass. Freshwater Bay, in Clallam County, is an exception where surfgrass and eelgrass occur in close proximity; this results only from a unique combination of beach orientation and wave direction which supplies both exposed rock and protected sand beaches.

algae

Seagrass leaves support a large number of epiphytic algae (algae which live on another plant). Over 100 species of these algae, some of which occur almost exclusively on seagrasses, are known in Washington. A few of these algae are listed in Table 627-1. Eelgrasses generally have greater amounts of epiphytes than surfgrasses as the pounding of waves along exposed beaches tends to clean off surfgrass leaves. The biomass of epiphytes in some eelgrass beds, however, may equal the biomass of the eelgrass itself. Thus these epiphytes can significantly increase the productivity of a seagrass bed; however, if epiphytes become too dense, they can lower seagrass production by preventing ample light from reaching the seagrass. It may be that excessive growth of epiphytes is the single most important factor in restricting surfgrass growth to exposed beaches.

Animals

invertebrates

A wide variety of invertebrates are characteristically associated with seagrass beds (Table 627-1). That most of these animals are dependent upon seagrasses for food, shelter, or nesting is demonstrated by how their seasonal population fluctuations reflect changes in seagrass abundance during the year. Some animals, such as those which live on seagrass blades, become more abundant during spring and summer when seagrasses are most abundant. Other animals, such as those which feed on seagrass detritus, become more numerous during fall and winter when large quantities of seagrasses are torn loose by waves.

The invertebrates associated with seagrasses can be divided into several categories depending upon where they occur. One group includes those animals living on the seagrass blades. This group contains an extremely diverse and interesting set of mostly small animals, some of which are present almost exclusively on seagrass or large seaweeds. Included are anemones, skeleton shrimp, isopods, snails, crabs, hydroids, and beautifully colored sea slugs.

Another group of animals includes those which occur either on the sediment or swimming in the water

TABLE 627-1. CHARACTERISTIC PLANTS AND ANIMALS

Common Name (Scientific Name)	Trophic[1] Type	Zone(s) of[2] Occurrence	Economic[3] Value	Comments
PLANTS				
Seagrasses (Vascular Plants)				
Eelgrass (*Zostera marina*)	PP	L,SB		See "Significant Biological Features" section.
European or narrow-bladed eelgrass (*Z. noltii*)	PP	H,M,L		See "Significant Biological Features" section.
Surfgrass (*Phyllospadix scouleri*)	PP	L		See "Significant Biological Features" section.
Surfgrass (*P. torreyi*)	PP	L		
Surfgrass (*P. serrulatis*)	PP	L		
Green algae				
Sea lettuce (*Monostroma zostericola*)	PP	L,SB		Epiphytic; food for waterfowl.
(*Ulva lactuca*)	PP	L,SW		Edible; epiphytic or on substrate between plants; food for waterfowl.
(*Enteromorpha linza*)	PP	L,SB		Edible, epiphytic or on substrate between plants.
Brown algae				
(*Ectocarpus*)	PP	L,SB		Epiphytic.
Red algae				
Nori, or laver (*Porphyra haiadium*)	PP	L,SW		Epiphytic.
Microscopic algae				
Filamentous diatoms	PP	M,L,SB		Epibenthic.

TABLE 627-1. (continued)

Common Name (Scientific Name)	Trophic[1] Type	Zone(s) of[2] Occurrence	Economic[3] Value	Comments
INVERTEBRATES				
Molluscs				
Rocking chair limpet (*Aemaea paleacea*)	HERB	L		Only on seagrass leaves.
Chink shells (*Lacuna* spp.)	HERB	L,SB		
Bubble shell (*Haminoea vesicula*)	?	L		On sediments in eelgrass beds; lay eggs on eelgrass blades.
Heart cockle (*Cinocardium nuttallii*)	FF	H,M,L,SB	R,PC	Most abundant in eelgrass beds.
Transparent sea slug (*Melibe leonina*)	CARN	L,SB		
Sea slug (*Hermissenda crassicornis*)	CARN	L,SB		
(*Aeolidia papillosa*)	CARN			
(*Phyllaplysia taylori*)	CARN?	L,SB		Only on eelgrass.
Arthropods				
Gammarid amphipods (many species)	HERB, CARN, DETR	H,M,L,SB		
Skeleton shrimp (Caprellid amphipods)	CARN	L,SB		
Pillbugs or isopods (*Idotae* spp.)	HERB	L,SB		
Shrimp (*Pandalus*)	CARN	L,SB	C,R	
(*Crangon*)		L,SB	PC	
(*Heptacarpus*)		L,SB		
(*Hippolyte*)		L,SB		

TABLE 627-1. (continued)

Common Name (Scientific Name)	Trophic[1] Type	Zone(s) of[2] Occurrence	Economic[3] Value	Comments
Kelp crab (*Pugettia gracilis*)	HERB	L,SB		
Northern kelp crab (*P. producta*)	HERB	L,SB		
Helmet crab (*Telmessus cheiragonus*)	CARN	L,SB		
Red rock crab (*Cancer productus*)	CARN	L,SB	R,PC	Popular recreationally.
Dungeness crab (*C. magister*)	CARN	L,SB	C,R	Economically very important.
Segmented worms (Annelids)				
Nereidae (*Nereis* sp.)	HERB	L,SB		
Ribbon worms (Nemerteans)	CARN	L,SB		
Coelenterates				
Brooding anemone (*Epiactic prolifera*)	CARN	L,SB		
Hydroid (*Obelia longissima*)	CARN	L,SB		
Jellyfish (*Gonionemus vertens*)	CARN	L,SB		
Sessile jellyfish (*Haliclystis auricula*)	CARN	L,SB		
Echinoderms				
Six-rayed starfish (*Leptasterias hexactis*)	CARN	L,SB		

LEGEND:

[1]Trophic Type

HERB = Herbivore
FF = Filter Feeder
CARN = Carnivore
DETR = Detritivore

[3]Economic Value

C = Commercial
R = Recreational
PC = Potential Commercial

[2]Zones of Occurrence

H = High Intertidal
M = Mid-Intertidal
L = Low Intertidal
SB = Shallow Subtidal

column amongst the seagrass plants. Animals in this group use seagrass beds for feeding, nesting, or to seek refuge from predators. Examples of invertebrates in this group are numerous shrimp and two types of crabs, the Dungeness and red rock crabs.

Yet another group of animals live in the sediments. Polychaete worms are perhaps the major invertebrates in this group. The organisms in this group are primarily detritus feeders, using the organic matter produced or trapped by seagrass plants for food. The presence of seagrass rhizomes (or 'roots') apparently make it more difficult for predators to capture animals living in the sediments.

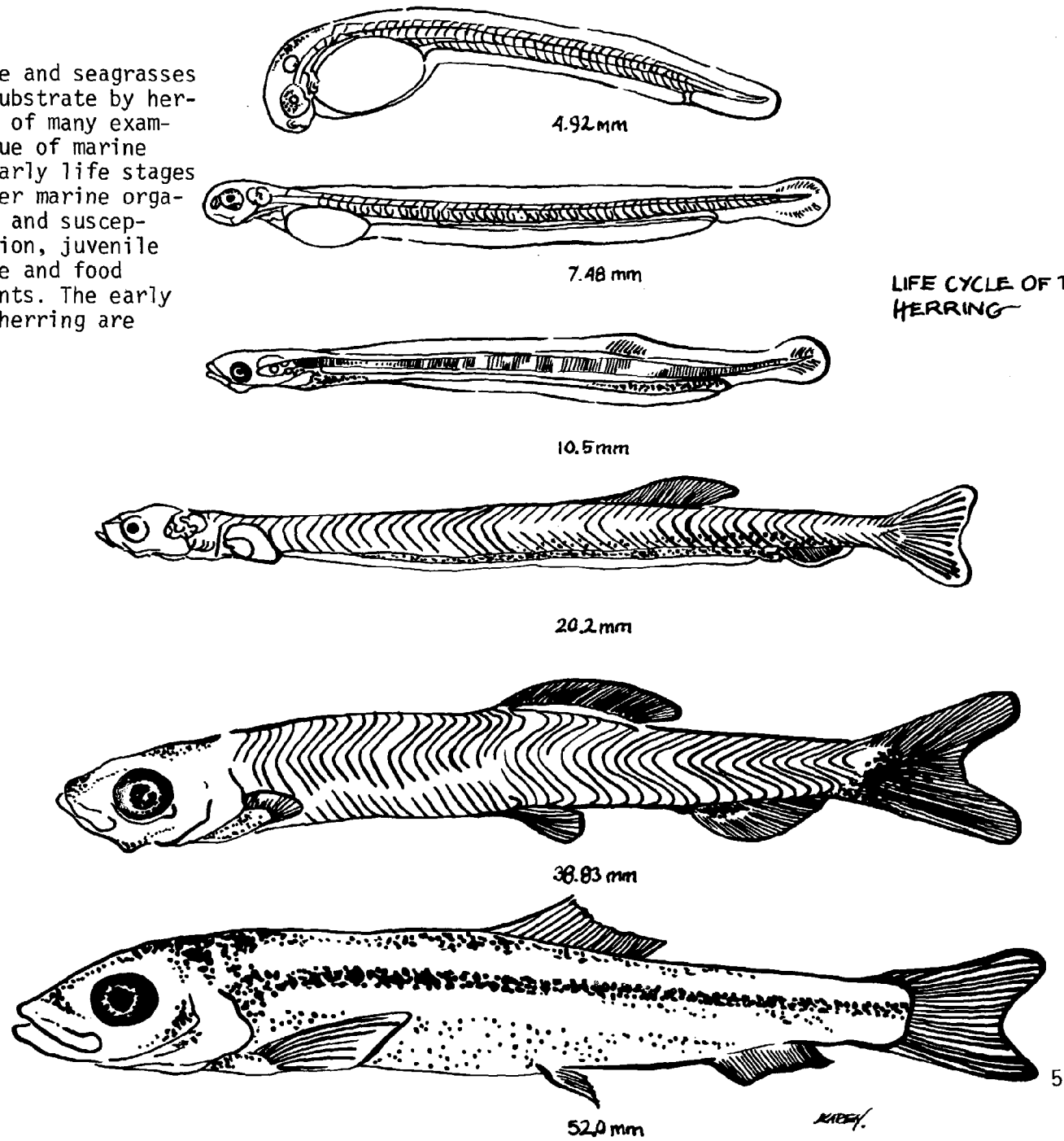
fish

Seagrasses, particularly extensive beds of eelgrass, provide key habitat for fish. Eelgrass plants offer a refuge from predators for small fish such as juvenile flounders and a fich feeding ground for larger fish. The plants are also a site for attachment of egg masses for fish such as herring which spawn in large numbers each spring in eelgrass beds. Egg masses of herring can be used as a food source for humans and are consumed by many birds, fish, and crabs.

Large and diverse flocks of diving ducks congregate when herring are spawning and as they feed over submerged eelgrass beds, plants are detached and float to the surface where non-diving birds such as gulls feed on the egg covered plants. Feeding flocks are signals to fishermen that bait and herring predators (such as salmon) are present. These flocks are also an intriguing spectacle for those who enjoy watching wildlife. One such feeding assemblage observed at Port Gamble in northern Hood Canal (March 1978) included: 300 Common Goldeneyes, 8 Barrow's Goldeneyes, 40 Bufflehead, 350 Oldsquaws, 1000 Greater Scaup, 350 White-winged Scoters, 1 Canvasback, 2 Brant, 2 Double-crested Cormorant, 2 Red-necked Grebes, 1 Red-throated Loon, 7 Black Scoters, 175 Mew Gulls, 100 Glaucous-winged Gulls, and 20 Unidentified Gulls.

Adult herring support a commercial fishery and provide the major source of bait for sport salmon fishing. They are a natural prey of salmon as well as several other fish, seabirds, seals and other marine mammals, include the Minke whale. It is important to remember that eelgrass beds serve a vital role in the maintenance of herring populations and the organisms supported by these fish.

The use of algae and seagrasses as a spawning substrate by herring is but one of many examples of the value of marine plants to the early life stages of fish and other marine organisms. Delicate and susceptible to predation, juvenile fish seek refuge and food amongst the plants. The early life stages of herring are illustrated .



LIFE CYCLE OF THE HERRING

Eelgrass is important in the life history of herring, and it also serves as a nursery area for many other fish. Juvenile English sole, sand sole, sturgeon poachers, chum salmon, and tomcod were among the large numbers of fish recorded in eelgrass beds during recent northern Puget Sound baseline studies. Other fish noted in eelgrass beds during these studies included staghorn sculpins, surf smelt, starry flounder, snake pricklebacks, and shiner perch.

Note: Many of the fish referred to in the beach substrate narratives (Mud, Muddy Sand, Sand, and Mixed Fine) also occur in, or are dependent upon, eelgrass beds along those beaches.

birds and mammals

A diverse assemblage of birds and mammals feed in eelgrass beds or on other species (especially fish and invertebrates) produced within the beds. The wide range of feeding techniques employed by these birds and mammals is a reflection of the variety of prey available in the rich feeding grounds offered by seagrasses. Some birds feed on eelgrass plants at low tide, while others dive amongst the plants at high tide. Still others dive from high in the air to capture prey just below the water's surface. Additional foraging occurs farther offshore where waterfowl feed on detached plants floating on the surface and many seabirds feed on fish reared nearshore in the eelgrass beds. The following are among the many species which occur [note that species listed and discussed for several beach substrates (e.g., muddy sand, mixed fine) are often dependent upon or occur at higher densities along those beaches when seagrasses are present]:

Brant o

The eelgrass bird. Brant feed extensively on eelgrass, which is consumed directly and comprises as much as 80 percent or more of the total food of these small geese. The importance of eelgrass to Brant was demonstrated on the east coast of the U.S. in the 1930's when Brant were reported to have suffered population declines as a result of an eelgrass die-off.

Along the Washington coast, Brant occur in large flocks in areas such as Padilla and Willapa Bays, where extensive eelgrass beds provide their favored food. Popular as game birds, Brant are also a familiar and valued sight as they fly low to the water throughout Puget Sound.

American Wigeon o

Wigeon also feed extensively on eelgrass, including both broad- and narrow-bladed species. During recent studies in Grays Harbor, they were the most abundant duck observed and were especially dependent on areas where eelgrass was present. Wigeon were also frequently observed over eelgrass beds during the course of our studies, and are probably the most numerous and common surface feeding duck in the coastal zone. The value of Wigeons and other ducks which feed in eelgrass beds is substantial. Duck hunters, bird watchers, and numerous other coastal residents enjoy the presence of these nearshore wildlife. Wigeon and Brant are especially watchable because they feed on the surface, or even come ashore to feed.

Several other birds also feed on or in eelgrass beds, but much of their feeding is done below the water's surface and out of sight of human eyes. These species are probably not as familiar because of their diving habits, which put them out of our vision for long periods of time. However, they often feed nearshore because of the presence of rich eelgrass beds in which they feed either directly or indirectly on eelgrass plants. The following species are among those present:

Greater Scaup o

Greater scaup are one of several diving ducks common and often abundant in eelgrass beds. Scaups feed directly on eelgrass plants and also on invertebrates and herring eggs attached to the blades. Surface feeding ducks often associate with diving scaups (and other divers such as coots and Ruddy Ducks) which detach plants as they forage. The eelgrass then floats to the surface where it is consumed by Wigeon, Brant and, when covered with herring eggs, several species of gulls. These detached plants may be consumed at considerable distance offshore by flocks of birds which would normally have to forage closer to shore. In portions of Hood Canal, this may be the primary foraging strategy of Wigeon and Brant, especially where development affects feeding near the shoreline.

Common Loon o

A large, resident water bird often seen feeding in eelgrass beds. This bird feeds singly or in pairs, taking sculpins, crabs, and small flounders.

Horned Grebe o

One of the smallest diving birds seen in eelgrass beds and perhaps the most dependent of the grebes on eelgrass, they feed on small fish and invertebrates, including Crangonid shrimp. They also occur over beds of surfgrass.

Bufflehead o

These small active ducks have been observed to restrict their feeding activity to eelgrass beds in Hood Canal. They dive for small invertebrates and also consume small amounts of eelgrass directly. Bufflehead are also known to consume surfgrass.

Surf Scoter o

Surf Scoters have also been observed to restrict much of their feeding to eelgrass beds. These divers also feed along exposed shorelines where surfgrass shelters potential prey for the scoter and other marine birds.

Marbled Murrelet o

Murrelets feed over eelgrass beds where small fish, including herring, are taken. Often seen in pairs, large but loose flocks have also been observed nearshore along eelgrass beds in Cowlitz Bay (Waldron Island, San Juan County) and in Hood Canal.

Rhinoceros Auklet o

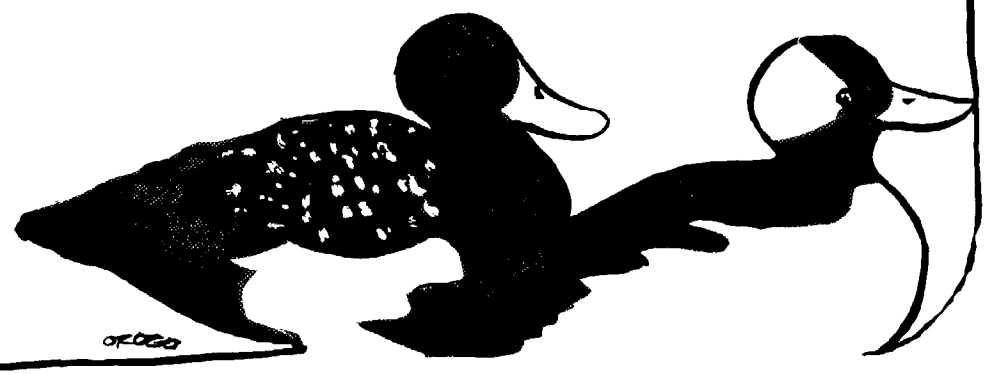
Although feeding is usually offshore, prey includes schooling fish such as herring which are dependent on eelgrass beds for part of their life cycle.

Raccoon o

Raccoons forage at night among plants when low tides expose crabs and other invertebrates.

Great Blue Heron o

One of the most common year-round occupants of eelgrass beds, Great Blue Herons also forage in surfgrass tide pools. They stalk prey hiding among the plants and may occur in large concentrations of 60 to 100 birds on extensive eelgrass flats. Great Blue Herons are colonial nesters and may have well defined feeding territories near heronries. These feeding sites very often include eelgrass beds and are essential to maintain local heron populations.



Glaucous-winged gulls o

These large, resident gulls are well-known scavengers along Washington's beaches and are often observed feeding in eelgrass beds.

Black-bellied plover o

Shorebirds do not often feed directly within eelgrass beds. However, many of the invertebrate prey species feed on seagrass detritus washed over tidal flats shoreward of seagrass beds. Black-bellied Plovers and several other shorebirds commonly feed on these tidal flats, often in flocks of several hundreds or thousands.

Bonaparte's Gull o

These small gulls often feed by picking small prey items from the surface in shallow submerged eelgrass beds as well as far offshore.

Killer Whale o

Killer whales may occur in submerged eelgrass beds, but more often farther offshore where prey includes several organisms dependent on seagrass for part of their life cycle. Killer whales are at the top of the marine food chain, therefore, interrelations with all nearshore communities are complex. They are known to consume herring which provide a direct link to eelgrass beds. In Hood Canal, they have been observed hunting harbor seals which also feed on several organisms dependent on eelgrass.

River Otter o

River otters spend varying amounts of time in marine waters. In all areas where eelgrass occurs, river otters probably forage more often (or at least as often) in salt water than freshwater. Where seagrass occurs, some river otter populations may be restricted to the marine environment and often forage among the plants for fish and invertebrates. River otters have been observed several times to restrict their feeding dives to narrow strips of eelgrass as they swam nearshore. Prey include starry flounder, sculpins and rockfish.

Bald Eagle o

Eagles feed in a variety of ways and consume a wide range of food organisms. They feed on carrion on exposed flats; dive, then snatch waterbirds from the water over submerged beds; or dive and snatch fish swimming near the surface. Prey captured in other habitats may also include organisms which depend on seagrass for a part of their life cycle.

Peregrine Falcon o

Peregrines feed primarily on birds. They are known to take both waterfowl and shorebirds which depend on eelgrass habitat.

Common Tern o

Like several seabirds, terns more often feed on schooling fish which are sometimes brought to the surface by diving birds or large fish. Terns then quickly dive into the water to capture their prey. Occasionally, Parasitic Jaegers then chase the tern attempting to force a dropped fish which the Jaeger then picks up. Large flocks of Common Terns have been observed feeding over submerged eelgrass beds in Birch Bay, the San Juan Islands, and in Hood Canal.

Belted Kingfisher o

The Kingfisher is a wide-spread chattering aerial predator which hovers then dives for small fish in shallow submerged eelgrass and surfgrass beds.

Humans o

Eelgrass beds are a significant source of commercial and recreational seafood. Dungeness crab, geoducks, and many fish are harvested in or adjacent to eelgrass.

Use by Man

Seagrasses are not used directly by man in the Pacific Northwest except by a few people collecting dead leaves washed upon the shore as a fertilizer. However, seagrasses have been or are currently used for several other purposes in North America. Dried eelgrass is extremely resistent to decay and has been used as packing and upholstering material, as well as insulation for homes. Other uses include fuel, fodder, or (despite the low fiber content) for making a high quality paper. Seagrasses have also been used for basket-weaving by Native Americans.

One of the more interesting uses of eelgrass is by a group of Indians in Mexico as a staple food. Eelgrass seeds are collected and ground up into a bland-tasting, flour-like powder. The seeds are apparently as nutritious as most terrestrially harvested grains.

The major importance of seagrasses to man is through their use as a food source for economically important animals. Waterfowl which feed on seagrasses (especially eelgrass) are important economically in Washington for the hunting and bird watching they provide. Since most of these birds are migratory, they are economically valuable in other states and countries as well.

Much of the seagrass matter going through the detrital pathway is also eventually consumed by animals of value to man.

Some species of fish, for example English sole and starry flounder, use eelgrass beds extensively as nursery areas. In 1976, total sales by commercial fishermen in Washington grossed $522,762.00 and $64,126.00 respectively for these bottom fishes. The sale of herring eggs (called "roe") and adult herring support commercial fisheries also, and as previously mentioned, herring are important food fish for many birds, fishes (including salmon), man and occasionally crabs.

Striped seaperch and fingerling silver salmon commonly feed and seek refuge from predators in eelgrass beds, along with several species of shrimp (Pandalus and Crangon), Dungeness crabs, and red rock crabs. Pandalid shrimp and Dungeness crabs support both commercial and recreational harvesting in nearshore areas, while red rock crabs are only collected recreationally. The association of crabs with seagrasses, especially eelgrass, is so frequent that many people refer to eelgrass as "crabgrass". Crangonid shrimp, which once supported a commercial fishery in Puget Sound, are no longer harvested.

IMPACTS

Little is known regarding seagrass ecosystem functioning, and as a result subtle changes caused by human pollution usually cannot be detected; only gross changes have been documented with confidence. Even with gross changes, causal relationships cannot always be established. Several natural phenomena, such as storms, unusually high numbers of grazing species, extended hot weather, and disease, can have drastic impacts upon seagrasses. Impacts caused by natural phenomena, however, are usually reversible, while some forms of human impacts are chronic.

Once again, most of the seagrass research on impacts relates to eelgrass or other seagrasses not present in Washington. There is little information relevant specifically to surfgrass.

The discussion in the Significant Biological Features section indicates that the total destruction of seagrass beds, even for relatively short periods of time, will have a profound impact on a wide variety of marine organisms. Such an impact would also strongly affect human use of many commercially and recreationally important species. This conclusion was substantiated when eelgrass along the Atlantic Coast of Europe and North America underwent a massive die-off in the 1930's, presumably caused by disease. Those animals dependent upon eelgrass for food or shelter disappeared or were reduced drastically in numbers. For example, Brant all but disappeared (numbers of birds along the coast were reduced by 90 percent). Fish and invertebrate resources (e.g., flounders, scallops, clams,

and crabs) were also greatly reduced. In areas intensively studied following the die-off, these animals increased in numbers as eelgrass became re-established. However, the eelgrass took approximately 20 years to re-establish itself to its prior extent.

Activities which remove or destroy eelgrass beds include dredging and disposal. Surfgrass is not likely to be impacted by these activities because of its occurrence on moderately to highly exposed rocky and mixed coarse beaches. However, studies related to dredging and disposal activities in eelgrass beds have documented losses of waterfowl, fishes and invertebrates. Dredging may or may not permanently remove eelgrass, depending on how deep an area is dredged in relation to the depth light can penetrate through the water, whether dredging must be done on a regular basis, or whether propwash will constantly disturb bottom sediments. Disposal of sediments in eelgrass beds will permanently remove eelgrass if substrate elevation is raised above the level at which the plants can survive. Small amounts of disposal can destroy or reduce abundance of eelgrass temporarily. European, or narrow-bladed, eelgrass can only tolerate changes of ±2 3/4" during the course of an entire year or just over one inch during a week before succumbing. Recovery by eelgrass in either dredging or disposal areas, if it can occur, is greatly slowed compared to areas where eelgrass is hand-cleared. Dredging and disposal activities cause additional impacts which can extend their effects beyond the immediate area of activity. These impacts include increased turbidities, which can lower productivity; increased sedimentation, which can smother plants; reduced circulation, which can also decrease productivity; and the potential release of toxins present in the disturbed sediments.

Toxic materials, such as pesticides, chlorinated hydrocarbons, heavy metals, and petroleum derivatives apparently affect the animals associated with seagrasses much more than the seagrasses themselves. Impacts on these animals could in turn affect seagrass productivity. For example, losses of animals which graze epiphytic algae growing on seagrasses could lead to exceptionally heavy epiphyte growth, which could reduce the amount of light reaching the seagrasses and result in decreased plant growth.

There is some evidence that long-term exposure to oil products may cause a decline in eelgrass populations. This raises the possibility that subtle sub-lethal effects of toxins may reduce seagrass vigor or reproductive capacity. This could lead to a gradual decline in seagrass abundance or production, thus impacting those animals dependent upon seagrasses. Perhaps a more serious threat, however, is evidence that seagrasses may take up toxins from their environment

and pass them on to animals dependent on seagrass production for food (indirectly including humans). Eelgrass is known to remove copper from seawater, and a seagrass in Texas is known to accumulate certain radioactive isotopes.

Thermal wastes, as with toxins, appear to affect the animals associated with seagrasses more than the seagrasses themselves. However, some sub-lethal effects on seagrasses apparently occur as a result of increased temperatures. For example, an increase of 15°F. (8°C.) in water temperature can reduce the growth rate of surfgrass by 25 percent. In addition, Dr. Ron Phillips of Seattle Pacific University, an acknowledged seagrass expert, feels that increased water temperatures could distrupt the reproductive cycle of eelgrass, which is in part a temperature dependent activity. The transplantation of warm-water strains of eelgrass and surfgrass may help alleviate impacts resulting from thermal pollution.

Sludge deposits should be expected to destroy seagrasses in the same manner that disposal of sediments would destroy them. Long-term exposure to sewage effluents appears to damage eelgrass beds, although eelgrass does show some tolerance. Short-term effects of sewage effluents on eelgrass are apparently minimized as eelgrass can respirate anaerobically for short periods of time.

Sustained increases in water turbidity can reduce the lower limit of eelgrass depth to as shallow as -3 to -6 feet (-1 to -2 meters) by decreaseing light penetration in the water. Excessive increases in turbidities can greatly increase sedimentation rate, resulting in the possible smothering of plants. Organic waste disposal is an example of an activity causing chronically increased water turbidity. However, elevated turbidity levels in nearshore areas are often the result of disturbances along streams flowing into marine waters. Logging practices, agricultural activities, and stream bank alterations are types of disturbances which can increase the sediment load of rivers and streams, eventually causing turbidity problems in nearshore marine areas. However, these activities can also increase the amount of nutrients flowing into coastal areas.

The mechanical harvest of shellfish in eelgrass beds can reduce the abundance of eelgrass plants by tearing leaves and roots. Soft-shell clams and oysters are the primary shellfish likely to be dredged where eelgrass occurs. Soft-shell clams are not currently being dredged in Washington, but in the past been harvested from Skagit and Port susan Bays. Oysters,however, are harvested by mechanical means throughout much of the state. Many oyster growers, on the other hand, consider eelgrass to be a pest to culture and harvest operations. Large amounts of eelgrass can mechanically interfere with dredging for oysters, or may promote sedimentation harmful of even fatal to oysters.

Recreational activities can impact seagrasses to varying extents. The use of power boats will impact seagrass through the physical tearing of plants and oil pollution. Cuts made by boat propellers through shallow water seagrass meadows have remained noticeable for as long as 15 years. Boating, and other noise producing human activities adjacent to seagrass beds, will also scare away much of the bird life present in seagrass beds. Activities such as fishing, bird watching, waterfowl hunting, crabbing, and photography will have relatively minor impacts on seagrasses.

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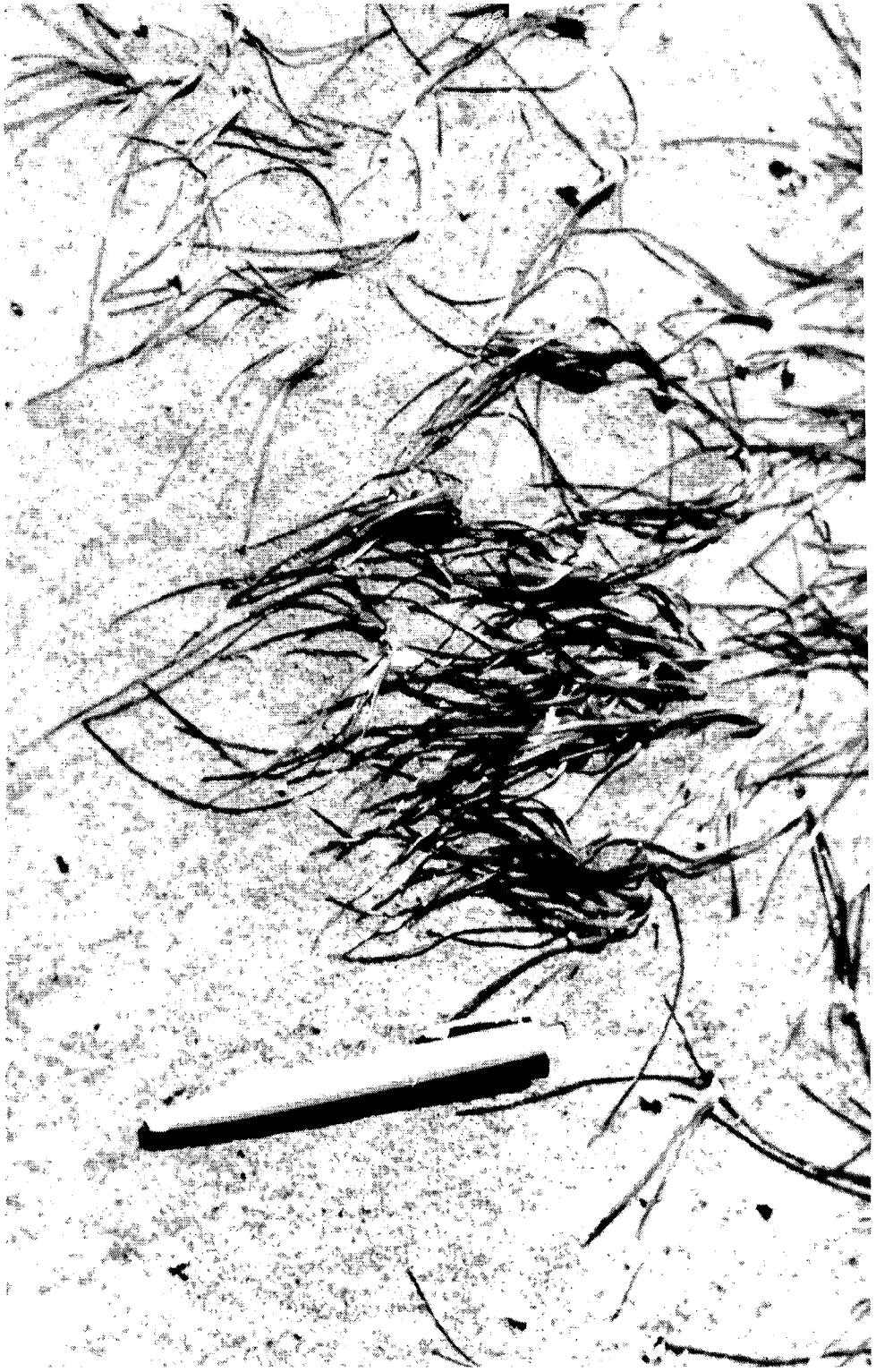


The number of living creatures
of all orders, whose existence
intimately depends on the kelp
(Macrocystis pyrifera). . .
is wonderful. . .
Innumerable crustaceans frequent
every part of the plant.

Charles Darwin, from
The Voyage of the Beagle

KELP (No. 628)

INTRODUCTION

The biomass of seaweeds in the Pacific Northwest is rivaled by few areas of the world, largely because of the abundance of kelps. Kelps are highly productive, and supply food resources and habitat for large numbers of marine organisms.

The term 'kelp' originally referred to the burnt ash of seaweeds. In America, however, this term has come to mean any of the large brown seaweeds in the order Laminariales, which includes all the species commonly called kelps. They grow in the lower intertidal and shallow subtidal zones, and their zone of abundance is often identified as the laminarian zone.

Most kelps possess a holdfast (a root-like structure) which attaches firmly to the substrate, a stipe, and a blade; several also have a float (a gas-filled bulb aiding flotation). Their distributions are determined by water movement (i.e., tidal currents and wave exposure), depth of water, character of the substrate, and sometimes by invertebrates which eat them. The preferred substrates of kelps are rock (including boulders) and mixed coarse substrates, but they will also occasionally grow on sediments containing nothing larger than gravel. Gravel, and even cobble, can be a risky site for attachement, however, as tides and waves can carry the plants to areas unsuitable for survival.

Most of the discussion of kelps will revolve around bull kelp and giant kelp, as they are the only northwest kelps which have received much study.

Many algae other than kelps are also present in the 'kelp' community, living either attached to the kelp plants or on the substrate between them.

SIGNIFICANT BIOLOGICAL FEATURES

Productivity

In the past, the productivity of kelp has been greatly underestimated. Estimates were based on total biomass, not taking into consideration that biomass may turn over several times per year. Annual kelps such as bull kelp not only produce a large standing stock each year, they also produce plant matter which is lost to grazing, disease, waves, and excessive heat. Studies on perennial kelps have shown that they may also grow quickly, even though there is little visible change in their standing stock. These perennial kelps have been likened to conveyor belts, continually producing new plant tissue while the excess growth is grazed by animals or worn away by wave action to produce detritus. Recent studies of kelps have shown some of them to be among the more productive plants known to man.

Habitat

Kelps provide 'living space' for plants and animals in many ways. Some organisms are totally dependent upon the presence of kelp for their survival, but most obtain increased surface area or refuge from predators which allow them to occur in greater abundance in the presence of kelp. Perennial kelps may have a complex community associated with them, while annual kelps support a simpler community. This is because long-living species cannot be totally dependent on an annual plant as a habitat. Examples of how plants and animals depend upon kelp follow:

1) Kelps provide a surface upon which other plants and animals grow. These plants and animals, called "epiphytes" and "epifauna" respectively, are generally much more abundant in calmer waters than in exposed areas. They provide food for a host of animals, and increase the diversity of the kelp bed community. Some animals use the surfaces of kelp plants for attachment of their eggs (e.g., herring and chink shells), while certain amphipods build nests on kelps.

2) Kelps provide an "overstory" or "canopy", much like trees in a forest. Certain algae only grow in the understory, where they are protected by kelps against wave action, currents, or temperature extremes at low tide. Many invertebrates are also largely dependent upon this protection from harsh physical conditions.

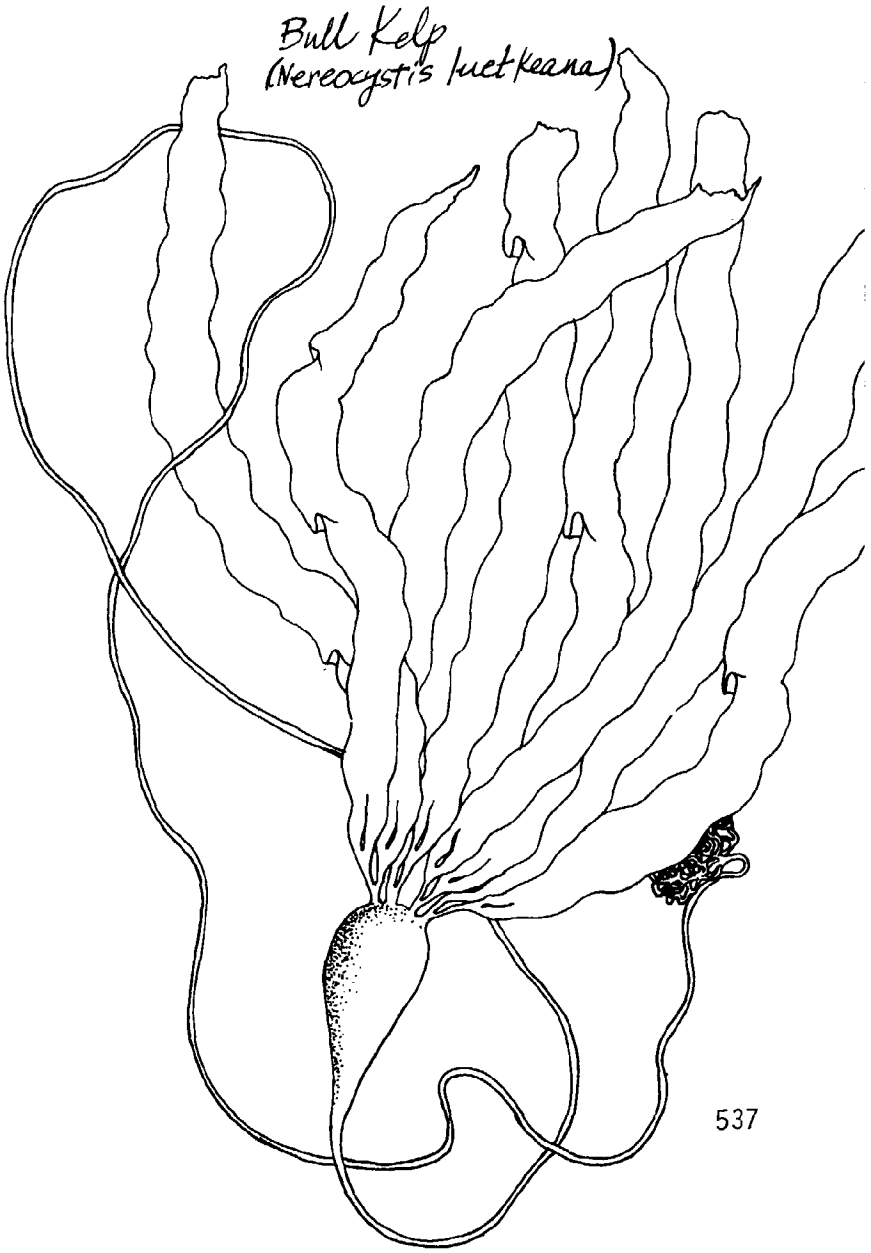
3) Kelp beds supply a refuge from predators for such animals as blennies, cottids, shrimps, and crabs. The holdfast of kelps are very important to many juvenile invertebrates in this respect, and have tremendous numbers of individuals per square meter of holdfast. Animals found in holdfasts include snails, crabs, shrimps, isopods, polychaete (or bristle) worms, chitons, amphipods, brittle stars, bivalves, anemones, starfish, urchins, sea cucumbers, and sea squirts.

4) Windrows of kelps supply an ephemeral habitat for a variety of detritivores, which in turn support many vertebrate predators.

5) Kelp beds provide a resting area for some birds and mammals. Included are gulls, herons, waterfowl, shorebirds, cormorants, and otters. Floating mats of detached kelp also serve as resting sites for birds in open water.

6) Kelps provide a food source for many animals, as well as a rich feeding area through the large number of food organisms associated with kelp beds.

7) Wave action and currents shoreward of kelp beds are reduced, creating a less exposed environment for intertidal plants and animals, and reducing inshore erosion on sand and gravel beaches. This protection is especially noticeable along the Strait of Juan de Fuca where extensive kelp beds form bay-like areas along their shoreward side. Along these exposed shorelines, the bay-like waters serve as feeding areas for several diving birds such as scoters, loons, grebes, goldeneyes, and Buffleheads.



8) The reduced current and wave conditions created by kelp beds cause increased settling of sediments and organic debris. This creates habitat for organisms which would not normally be present in the vicinity of kelp beds.

Trophic Relationships

As with all plants, kelps may be grazed directly or consumed as detritus. In constrast to seagrasses, there are large numbers of animals which graze kelps, most of which are crustaceans, gastropods, and echinoderms. Red, green, and purple sea urchins are major kelp grazers in Washington, and can have a profound impact on the community structure of a kelp bed. Areas with large populations of urchins may be devoid of any visible algae at all, while in some areas the dominant kelp can be drastically altered by grazing. As an example, the sea colander is maintained as the dominant kelp in some areas by urchin grazing. Urchins preferentially feed on kelps other than the sea colander, such as bull kelp, allowing the sea colander to become more abundant. Without the grazing, first bull kelp, then eventually kelps such as Laminaria, would establish themselves as dominants in place of the sea colander.

Grazers can cause considerable damage to kelp plants. Urchins commonly feed at the base of kelps, which, while only supplying the urchin with a small amount of food, can kill the entire plant. Animals which prey on sea urchins such as sea otters, sun stars, and Black Scoters, help maintain kelp abundance. Examples of kelp grazers include northern abalone, snails, chitons, amphipods, urchins, limpets, and keyhole limpets.

These herbivores provide food for a variety of birds, fishes, and invertebrates. Adult kelp greenling, for example, feed in kelp beds, taking worms, crustaceans, and small fish. (Young kelp greenling move offshore where they are commonly found in stomachs of steelhead and salmon.) Rock cod also feed on invertebrates and other fish in kelp beds. Black Scoters and Harlequins are known to occasionally feed on urchins, and Harlequins feed heavily on snails, limpets, and chitons. Carnivorous crabs, shrimps, and worms also feed upon kelp herbivores.

Many invertebrates associated with kelps feed solely upon algae which grow on the surfaces of the kelp plants. Examples include chink shells, rocking chair limpets, and littorine snails (or periwinkles, as they are sometimes called). Fish and birds, such as kelp greenling, Harlequins, Oldsquaws, and Black Scoters are known to feed heavily on these small invertebrates.

Kelp plants also produce large numbers of gametes (or zoospores). For example, one bull kelp plant produces about four trillion zoospores. These zoospores form a significant part of the plankton community during reproductive periods, and are an important food source for zooplankton and bottom-dwelling filter feeders such as clams and oysters.

Refer to the Characteristic Plants and Animals Section for additional examples of trophic relationships.

The percentage of kelp biomass which ends up in the detrital pathway is probably much greater than the precentage which is grazed directly by animals. Annual kelps such as bull kelp die off in the fall and winter, forming great windrows of decaying kelp on beaches. Perennial kelps provide a more even supply of detritus throughout the year than annuals. However, perennial kelps which lose all or some of their fronds during winter storms also add to these windrows.

As the kelp decomposes, the detritus not consumed on the beach is washed back into the sea by storm waves and high tides where it is consumed by detritivores such as sea cucumbers, polychaete worms, amphipods, anemones, clams, brittle stars, and many other animals. These detritivores comprise the food source for a variety of animals of commercial and recreational importance in the nearshore zone. Examples include sole, flounder, crabs, salmon, shrimp, rock cod, and ,many marine birds and mammals. Species which do not feed directly on detritivores often consume the predators of detritivores. Much of this detritus is carried to areas far from the kelp bed where it was produced, including subtidal areas where little or no primary production occurs.

Some of the detritus consumed on beaches also contributes to terrestrial systems. Raccoons, fairly common visitors to beaches at night, often make a complete meal out of the detritus-eating beach hoppers they collect.

Many of the fishes, birds, and marine mammals wich feed in kelp beds spend only a portion of their life cycles in the beds. Examples include loons, grebes, herons, scoters, Buffleheads, Alcids (a group of birds spending most of their lives on open water), otters, and harbor seals. In addition, killer whales have been observed hunting along the outer kelp bed margins.

Characteristic Plants and Animals

Plants

The characteristic plants associated with kelp beds are listed in Table 628-1.

bull kelp

Bull kelp is the most consipicuous and familiar kelp in Washington's waters. Habitat requirements for this kelp are: 1) a suitable substrate for attachment, 2) strong tidal currents, 3) proper depth of water, and, to a lesser extent, 4) proper salinity. A suitable substrate for attachment is rock or boulder; however in more protected areas small cobble or even gravel may be adequate. Bull kelp is an annual, and thus beds disappear during late fall and early winter. Dense beds occur in shallow subtidal waters to a depth of 35 feet (10 meters). Individual plants are up to 80 feet (24 meters) long, although specimens 130 feet (40 meters) have been reported, and can grow four inches (10 cm) per day during the growing season. Reportedly, the largest bed in Washington waters occurs on the west side of Smith Island (Island County). Bull kelp is also abundant along the Strait of Juan de Fuca and in the San Juan Islands. The density of individual beds can vary greatly from year to year. Beds may even disappear for a period of years, then gradually reestablish themselves.

giant kelp

Giant kelp occurs on rock or boulder substrates in areas of heavy wave surge along the outer coast and the western portion of the Strait of Juan de Fuca, although a few plants have been reported as far east as the west side of Whidbey Island. Salinity and temperature are apparently the major facotrs limiting distribution. Giant kelp is a perenial plant which grows to 20 feet (6 meters) in length.

pompon kelp

This kelp can be found on exposed rock and mixed coarse shores along the Strait of Juan de Fuca west of Dungeness Spit, the outer coast, and the west side of Whidbey Island. It can also be found in shallow subtidal areas which have strong currents, such as Agate, Balch, and Rich Passes. The fronds of pompon kelp are annual, and thus drop off each winter, leaving only a perennial stipe and holdfast which may live up to 25 years. The stipe has a woody consistency, something highly unusual for a marine plant. Pompon kelp is found down to a depth of 33 feet (10 meters), and may grow to a length of 6.6 feet (2 meters).

honey ware or wing kelp

Honey ware kelp is often abundant in the lower intertidal zone of moderate to exposed rocky beaches. Individual plants may grow to a length of 7 to 10 feet (2 to 3 meters).

sugar wrack

Sugar wrack grows in low intertidal and shallow subtidal areas. It may grow attached to rocks, cobbles, gravel, old shells, or wood. This perennial kelp prefers protected waters, where it is usually the most common kelp present. Sugar wrack may be up to six feet (two meters) in length.

other kelps

Other common kelps include feather boa, searsucker, sea colander (which may form extensive underwater meadows in parts of Puget Sound and Hood Canal), sea cabbage, triple rib, and split whip wrack.

Invertebrates

Characteristic invertebrates associate with kelp beds are listed in Table 628-1. Many of these animals have already been mentioned.

Fish

Rocky nearshore areas heavily vegetated with kelp beds are important habitat for fish, especially juveniles of many valuable commercial and sport species. Kelp plants serve as refuges for fish, and nearshore vegetation has been shown to produce or otherwise support the majority of food items of kelp bed fish. Many fish are year-round residents, often moving in and out of nearshore areas with the tide. Others occur periodically, including migratory salmon, herring, and sand lance.

Studies in northern Puget Sound have identified many of the species associated with kelp beds and their relative abundance. Some of the more common solitary fish are the kelp greenling, copper rockfish, largefin sculpin, quillback rockfish, and lingcod. Schooling fish which were abundant include yellowtail rockfish and black rockfish. Kelp beds are used as feeding, spawning, and nursery areas by the dominant species and it has been found that spawning times are staggered so that spawning takes place the year-round. The number of species present is greatest in summer, however, the staggering of spawning times is an important factor in considering effects of impacts.

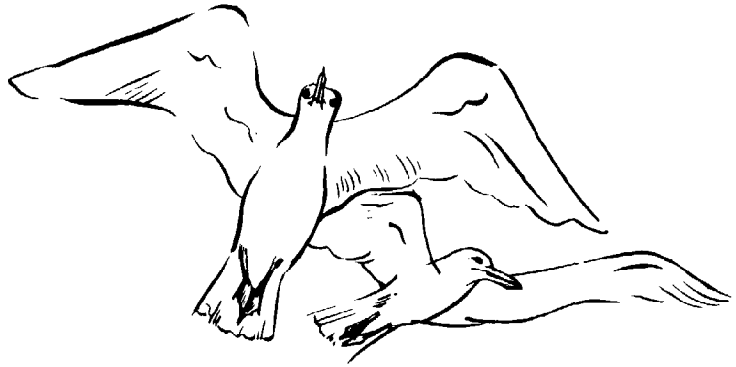
Many of the species associated with kelp beds are also discussed in the Rocky Beaches Narrative (No. 631). Table 628-1 provides examples of some of the fish inhabiting kelp, indicating their occurrence as juveniles and adults in the kelp "forest". Since larger kelps extend from the bottom to the surface in water as deep as 35 feet and more, the plants provide feeding and hiding places analagous to terrestrial forests. Thus, some fish hide among holdfasts (roots), along the stipe (trunk), or the canopy (tree top/canopy).

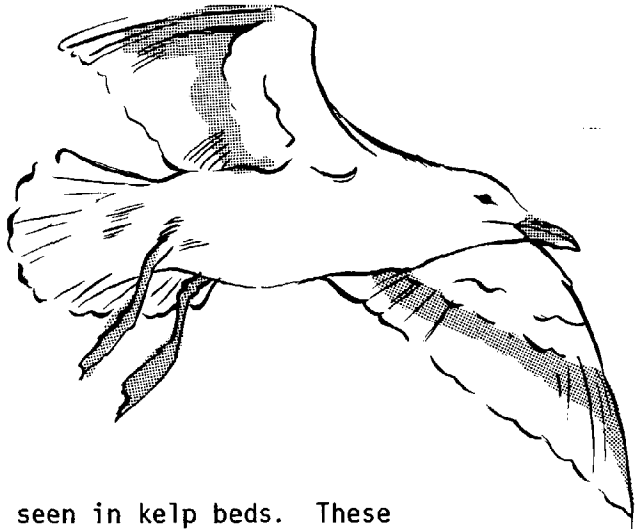
Birds

Harlequin Duck

Perhaps the most characteristic bird of kelp beds and rocky shores is the Harlequin Duck. During this study, of 53 observations in kelp beds Harlequins were seen 22 times (42 percent) - they were the most frequently observed duck/duck-like bird. Only Glaucous-winged and Bonaparte's Gulls were seen more regularly with 23 sightings apiece. Harlequins breed along fast flowing mountain streams and spend the rest of the year along the coast where they are often seen resting on kelp beds or feeding among the plants. As with most ducks, the male is more brightly colored except during a short period in late summer. At this time large numbers of drab-colored males gather at relative undisturbed sites such as Smith Island in Island County and undergo a series of molts. They are flightless for much of this period of "refeathering" and, therefore, highly vulnerable to human disturbances such as oil pollution. The winter and breeding plummage of male Harlequins is a stricking pattern of slate blue with streaks and patches of chestnut and white outline in black. The female is blackish brown with three white patches on the head. Crustaceans are the major food items, including shorecrabs, hermit crabs, and Porcelain crabs. (Fragments from as many as 97 individual porcelain crabs were found in the stomach of a Harlequin Duck collected in California.) Other prey include barnacles, chitons, chink shells, limpets, mussels, starfish, and sea urchins. Most of these organisms are dependent upon kelp and other algae. Some, such as the sea urchin, are direct consumers of kelp plants, demonstrating the close association and dependence of birds such as Harlequins on kelp beds.

Several other ducks and diving birds, such as loons, cormorants, and grebes, are commonly seen feeding in kelp beds. One unexpected member of the duck family occasionally observed is the American Wigeon. These common ducks are more typical in protected bays where flocks of several hundred are often seed feeding on eelgrass and green algae. In kelp beds, wigeon have been observed feeding on epiphytic green algae (probably *Ulva* and *Enteromorpha*) growing on bull kelp plants. They pick algae from the larger kelp plants much as they would from beach substrates elsewhere, reaching underwater, often submerging their upper body so that only their "bottoms are up".





Horned Grebes

Horned Grebes are also often seen in protected bays, but are commonly seen in kelp beds. These small divers are duck-like, but are members of a distinct group (Podicepiformes) more adapted to swimming and diving than flying. Their lobed toes, short wings, and legs set far back on the body aid in underwater pursuit of invertebrates and small fish. Food items include sculpins, stickleback, shrimp, amphipods, and littorine snails.

Pigeon Guillemot

Another duck-like inhabitant of kelp beds is the Pigeon Guillemot. They are members of the family Alcidae, a group of seabirds, which are the northern hemisphere's equivalent to Antarctica's penguins.

A study in Washington has shown that these seabirds most often nest adjacent to kelp beds which provide a rich source of food for the adults and young. During this time the adults are entirely black except for a white wing patch and bright red-orange feet. In winter, their plummage changes to a mottled white which confuses many who are only familiar with summer birds. Since they are year-round residents, the two color phases can been seen along our coast. However, as year-round residents Guillemots are vulnerable to habitat alterations or other impacts in kelp beds at all times. They are particularly vulnerable to impacts during the breeding season.

Prey of Pigeon Guillemots include sculpins, small flounders, and blennies. All these prey species commonly seek refuge in kelp beds and at least one, the rock prickleback or blenny feeds on algae within kelp beds.

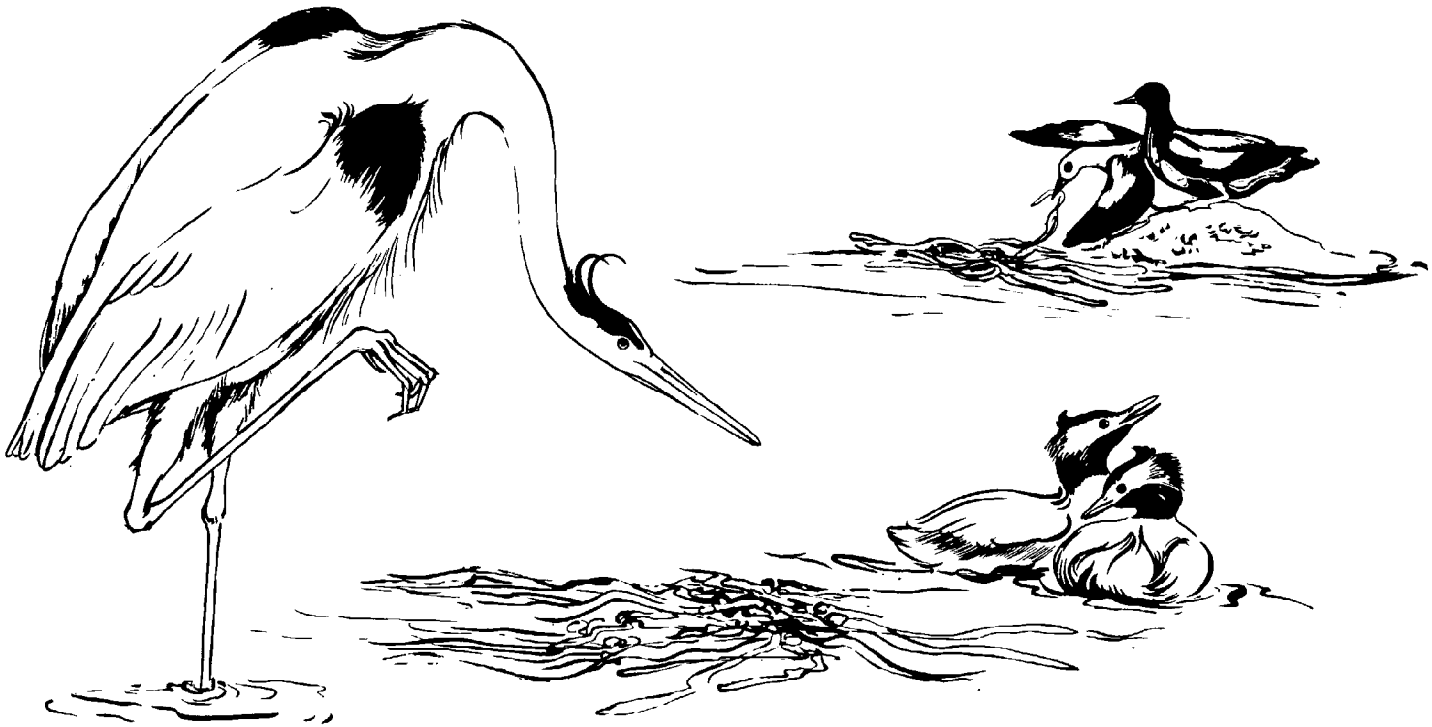
Great Blue Herons

Great Blue Herons often perch on kelp, using plants as hunting platforms. Kelp beds serve well in the Great Blue's feeding strategy of staring motionless into quiet waters between the plants until a fish is spotted and quickly snatched in a thrust of the heron's long neck and bill. Other birds which hunt their prey from above the surface of kelp beds include Belted Kingfishers, Common Terns, and several gulls.

Gulls and Shorebirds

The ubiquitous Glacous-winged Gull is a common forager in kelp beds. Two less familiar gulls frequently seen resting or feeding here are Bonaparte's Gulls and Heermann's Gulls. The tern-like Bonaparte's Gull will be seen resting on kelp in flocks of 100 or more, picking at invertebrates on the plants, taking schooling fish above diving birds, or bathing and preening on and among the plants. Heermann's Gulls are more often seen resting on kelp or nearby rocks. These unusual birds are our only "reverse" migrants, flying north to our coast after nesting on islands off California and Mexico. Their distinctive, bright, red-orange bills and black wing tips identify these striking birds among other less recognizable "seagulls".

Gulls will be seen in both submerged and exposed kelp beds which is a reflection of their broad adaptability to both aquatic and terrestrial environments. Most of the shorebirds, however, will only be seen foraging among kelp plants which have been exposed by falling tides. Black Turnstones are one of the more common shorebirds observed in kelp beds and are often seen in mixed flocks which might include Surfbirds and Rock Sandpipers. Turnstones were named for their habit of turning stones in search of prey with their bills. They are also often seen turning over algae and feeding on invertebrates seeking a moist refuge during low tide.



Mammals

Many marine mammals feed on organisms which inhabit kelp beds during a part of their life cycle or receive nutrients indirectly from kelp plants. Harbor seals feed on fish such as greenling within kelp beds, gray whales feed on invertebrates, and killer whales may take fish along the margins of kelp beds as well as an occasional seal.

The mammal most often historically associated with Pacific Coast kelp beds, however, is the sea otter. Once abundant (see Figure 628-1), the sea otter was driven to extinction off the coast of Washington because of the demand for its highly prized fur. These large and gregarious members of the weasel family have been reintroduced to the outer coast (they apparently never occurred east of Cape Flattery), and, although numbering fewer than 40 individuals, have been observed with pups. Successful reproduction and possibly more transplants from healthy populations in Alaska are keys to their future survival in Washington.

The interrelationships between sea otters and kelp beds have been well studied. Sea otters use floating plants as sanctuaries while resting, feeding, and avoiding the presence of killer whales. They also have significant impacts on the plants due to their preference for feeding on sea urchins, which are voracious grazers of kelps. Studies in Alaksa have shown that where sea otters occur, urchins are reduced, and kelp is abundant. Where sea otters don't occur, urchins are larger and more abundant, and kelp is absent. Other organisms associated with kelp beds were noted as scarce or absent where sea otters did not occur in Alaskan study areas. These species included greenling, harbor seals, and Bald Eagles.

Thus, there are key associations between sea otter, urchins, and kelp beds. Several other organisms are also affected by these interactions. We have no historical record of changes in kelp distribution following the sea otter extermination along our coast. However, it is possible there were major changes which had impacts on organisms other than otters. Any future impacts which reduce this valuable habitat will also have significant effects on wildlife populations. Now that sea otters have been reintroduced to our coastline, it would be interesting to observe changes in kelp distribution as the population increases.

FORMER DISTRIBUTION
Sea otters were driven to extinction by fur trade. Last native Washington sea otter reportedly was killed in 1911 in Willapa Bay. Distribution based on: Scheffer, V.B. 1940. The Sea Otter on the Washington Coast. Pacific NW Quarterly Vol 3:370-388.

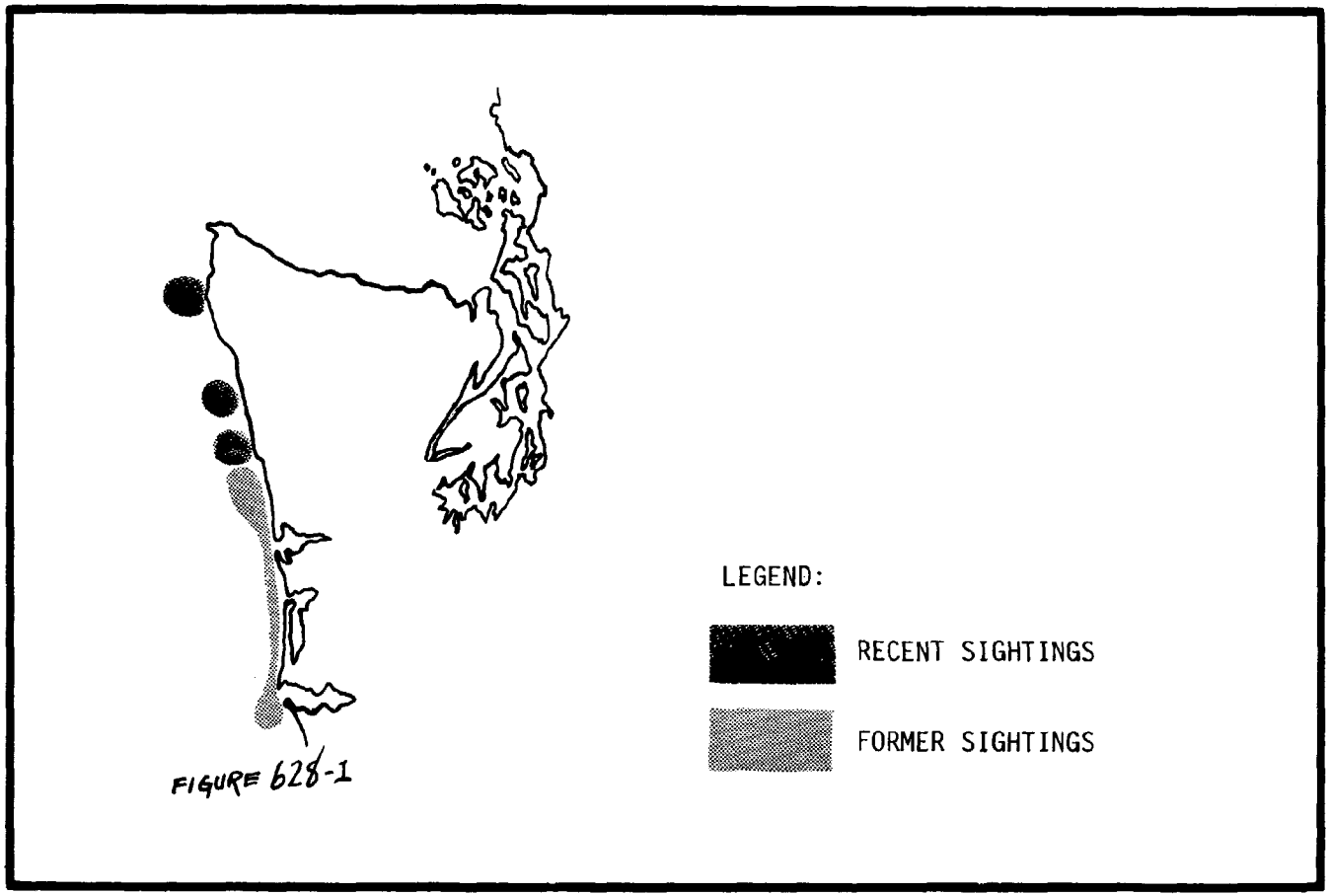


FIGURE 628-1

PRESENT DISTRIBUTION
Small numbers of otters have been reintroduced from Alaska.
Distribution based on recent sightings.

A close relative of the sea otter, the river otter, also frequents kelp beds, but is much more widely distributed throughout the state. River otters are often mistaken for the larger, but shorter tailed, sea otter. They are found throughout western Washington in freshwater and marine areas and are the only otter found in kelp beds east of Cape Flattery. River otters are not as adapted to a marine existence as sea otters and will come ashore rather than rest in kelp beds. They do forage among kelp plants, however, taking sculpins, small crabs, blennies, and rockfish. Both types of otters, therefore, will be affected by any alterations affecting prey species inhabiting kelp beds. Because of their wide distribution, river otters will be affected wherever kelp beds are impacted. The sea otter, due to its small population size, could easily be exterminated once again as a result of disturbance in outer coast kelp beds. They are especially vulnerable to oil spills since they rely on their dense fur to preserve body heat. Therefore, even a small spill on the outer coast could eliminate or seriously reduce sea otter populations of Washington.

Use by Man

Historically, the Northwest Coast Indians employed many uses for bull kelp. The stipe was often specially treated and used as a fishing line. The float and the hollow portion of the stipe were used as a container for storing fish oil. The bulb was also used for steaming wood to make bentwood fish hooks. Drying kelp in the sun produced salts which could be scarped off and used in preparing foods. Kelp was even used to cure ear aches. This was accomplished by heating water in the bulb, producing steam which, when the small end of the stipe was placed next to the ear, could help relieve pain. In a slightly different vein, Indian fishermen devised a clever method of altering kelp beds to facilitate the harvest of salmon. Cutting a path through kelp beds during salmon migrations created routes through which the fish would travel, thus concentrating and funnelling the salmon to the fishermen.

The earliest commercial uses of kelps were apparently as cattle feed and fertilizers (kelps contain both potassium and nitrogen). Current uses include as a fertilizer and for chemical extraction. Substances which can be obtained from kelps are algin, iodine, sodium chloride, potassium, potash (a compound high in potassium used chiefly in fertilizers), and acetone. While all these substances have been extracted from kelps at one time or another, only algin is currently extrcted on a large scale. The west coast algin industry is centered in California, however, and does not exist in Washington. Algin is a complex polysacchride which absorbs large amounts of water and is valuable for keeping substances in suspension. There are over 100 uses for algin in food and commerical products.

Most of Washington's kelps are edible, although few people actually engage in eating them. Bull kelp is quite tasty when pickled. Sugar wrack is eaten in the Oriental community, where it is called "kombu". The presence of the sugar mannitol make 'sugar' wrack extremely sweet tasting. The potential exists to use several other kelps as food, such as honey ware kelp which is eaten in Ireland and Scotland. Certainly many of the common names of kelps sound appealing (e.g., sugar wrack, sea cabbage, honey ware kelp). The health food industry also engages in the use of kelps, selling both dried kelp tablets and seasonings containing kelp. Dried kelp has been hailed as a mineral supplement by some.

There is presently no commercial harvest of kelps in Washington, however, except for perhaps one or two extremely small-scaled operations collecting kelps washed up on beaches for fertilizer. Bull kelp has in the past been regarded as the most likely candidate for harvest in Washington. However, harvest is considered economically unfeasible at present, largely because stock are remote and the plant, being an annual could only be harvested once per year. Harvest might also drastically reduce successful reproduction, thus damaging the crop in subsequent years. However, the plausibility of harvesting bull kelp and the more promising giant kelp are being studied by the government of British Columbia.

If kelps are to be commercially havested on a large scale in Washington, it will most likely be from culturing the plants on rafts. Most of the kelps in Washington would probably respond adequately to this type of culture, as kelps grow well on artificial substrates such as rock jetties. Species which merit further study for possible commercial use include honey ware kelp, feather boa, sugar wrack, sea cabbage, and a kelp introduced from Japan without a common name, Sargassum muticum.

The major commercial value of kelp in Washington is derived indirectly from animals which feed upon kelps or the detritus produced from them, or which use kelp beds as spawning, refuge, feeding, or resting areas. Included are abalone, sea urchins (harvested in Washington for use of their gonads as food), herring, crabs, shrimp, kelp greenling, salmon, and several rockfish species. In California (where a different species of giant kelp is present than occurs in Washington), the commercial, recreational, and ecological value of kelp beds has been estimated at one million dollars per square mile. Part of this figure, however, results from the large commercial harvest industry.

IMPACTS

Kelps usually undergo natural fluctuations in abundance as a result of storms, unusually hot weather, and changes in the populations of grazers. While these disturbances may kill kelp plants, recolonization usually occurs with a return to normal conditions. Many human impacts, however, alter the environment on a permanent or long-term basis. In this case, little or no recolonization occurs once the kelp plants have been destroyed.

Human activities which cause slight reductions in water clarity, even as small as 1 percent, can kill plants at the lower limits of their distribution. The productivity of plants that survive would also be lowered. Young plants would be affected more than mature plants, as mature plants have fronds closer to the water surface. Reductions in water quality can be caused by domestic sewage and industrial effluents, or by increased sedimentation of coastal waters resulting from logging, river channelization, or agricultural practices.

The harvest of natural populations of kelps would remove the food energy and nutrients supplied to those animals dependent either directly or indirectly upon the kelp. Tom Mumford of the Washington State Department of Natural Resources already feels that the use of bull kelp as a food seems to be affecting some beds where collection is common. The impact of harvesting kelp is currently being studied in detail in British Columbia. An important part of this research is to determine the quantity of harvest which can take place before over-harvest occurs. Over-

harvesting of giant kelp in California, in combination with other factors, led to a serious depletion of kelp beds. A kelp restoration project has since helped reestablish many of the beds previously lost.

Studies on the impact of oil on kelps have proven somewhat inconclusive thus far. It does appear long-term exposure may reduce kelp abundance. However, the animals associated with kelp beds appear to be much more sensitive to oil than the kelp plants themselves.

The dumping of domestic sewage can have more serious repercussions for kelp plants than just reducing water clarity. Sea urchins, the most voracious grazers of kelp, can also survive by feeding on the detritus contained in sewage. Thus, after urchins may decimate a kelp bed by over-grazing, they can survive on the sewage, thus preventing the reestablishment of kelps by grazing young plants before they can mature. Without the sewage effluents, urchins would normally have the choice of leaving the area or starving, thereby allowing recolonization by kelp plants to begin. This relationship has been studied for giant kelp beds in California. The cost of controlling urchin grazing mechanically or chemically is very expensive.

Most sewage effluents also contain elements shown to be toxic to certain kelps. Toxins include tolulene, copper, chromium, chlorine, and chlorinated phenols, and primarily affect spore settlement or development. Sewage effluents also affect oxygen content of sea water by increasing the biological oxygen demand.

TABLE 628-1

CHARACTERISTIC PLANTS AND ANIMALS

(See also Narratives Nos. 631, 632, and 633 for additional species which may be present; Refer to Table 63-2 for birds and mammals (those associated with Rock and Mixed Coarse substrates will also be associated with kelp)

Common Name (Scientific Name)	Zone(s) of Occurrence	[redacted]	Economic Value	[redacted]
PLANTS				
KELPS				
Bull kelp (*Nereocystis leutkeana*)			PC	
Giant kelp (*Macrocystis integrifolia*)			PC	
Pompon kelp (*Pterygophora californica*)				
Honey ware kelp (*Alaria marginata*)				
Feather boa (*Egregia menzesii*)				
Sugar wrack (*Laminaria saccharina*)				
Split whip wrack (*L. setchellii*)				
EPIPHYPES ON KELPS				
Sea lettuce (*Ulva* sp.)				
Green algae (*Enteromorpha linza*)				
Red algae (*Antithamnion* spp.)				
(*Porphyra nereocystis*)				
(*Callithamnion biseriatum*)				
Diatoms (*Navicula grevillei*)				
Brown algae (*Ectocarpus* sp.)				
Polysiphonia urceolata				
Nitophyllum latissimum				
Callophyllis flabellulata				
Desmarestia ligulata				
INVERTEBRATES				
Coelenterates				
Sessile jellyfish (*Haliclystis auricula*)				
Hydroid (*Obelia longissima*)				
Bryozoans				
Encrusting bryozoan (*Membranipora*)				

Common Name (Scientific Name)	Zone(s) of Occurrence	[redacted]	Economic Value	[redacted]
Nemertean worms				
Ribbon worm (*Amphiporus bimaculatus*)	C		CARN	
Ectoproct				
(*Hippothea hyalina*)				
Molluscs				
Sitka periwinkle or littorine (*Littorina sitkana*)				
Chink shell (*Lacuna variegata*)				
Margarite snail (*Margarites pupillus*)				
Rocking chair limpet (*Collisella instabilis*)				
Shield limpet (*Collisella pelta*)				
(*Notoacmea insessa*)				
Northern abalone (*Haliotis kamschatkana*)			R,C	
Rock scallop (*Hinnites giganteus*)			R,PC	
Sea slug (*Melibe leonina*)				
(*Doridella steinbergae*)				
(*Corambe pacifica*)				
Crustaceans				
Caprellid amphipods				
Gammarid amphipods (e.g., *Ampithoe humeralis* and *Ayale frequens*)				
Porcellain crab (*Petrolisthes eriomerus*)				
Hermit crab (*Pagurus* spp.)				
Red rock crab (*Cancer productus*)			R	
(*Cancer oregonensis*)				
Shrimp (several species)				
Kelp crab (*Pugettia producta*)				
" (*Pugettia gracilis*)				
Polychaete Worms				
Clam worm (*Nereis virens*)				
(*Nereis agassizi*)				
Scale worm (*Harmothoe imbricata*)				
(*Spirorbis spirillum*)				

Common Name (Scientific Name)	Zone(s) of Occurrence	[redacted]	Economic Value	[redacted]
Enhinoderms				
Red sea urchin (Strongylocentrotus franciscanus) Green sea urchin (S. droebachiensis) Purple sea urchin (S. purpuratus) Brittle star (Ophiopholis aculeata)			C	

FISH

A = Adult
J = Juveniles

Common Name (Scientific Name)	Bottom	[redacted]	Remarks
Pacific herring (Clupea harengus)			Occasionally in large schools.
King salmon (Oncorhynchus tshawytscha)			Some of most popular salmon fishing areas in Washington are off kelp beds, e.g., Pillar Pt., Sekiu.
Steelhead (Salmo gairdneri)			Occasionally in canopy.
Northern clingfish (Gobiesox maendricus)			Attaches to blades.
Copper rockfish (Sebastes caurinus)	A & J		Common rockfish - also called "rockcod" - valuable sports fish.
Yellowtail rockfish (S. flavidus)	J		Schooling rockfish - abundant.
Black rockfish (S. melanops)	A & J		Common - scattered and sometimes in schools.
China rockfish (S. nebulosus)	A		Occasional - on bottom in deep nearshore areas.
Boccacio (S. paucispinnis)	J		Inshore 1-1½ years, adults migrate to deeper waters.
Canary rockfish (S. pinniger)	J		Adults migrate to deeper water.
Kelp greenling (Hexagrammos decagrammus)	A & J		Common, solitary residents.
Lingcod (Ophiodon elongatus)	A		Valuable commercial and sport fish. Common, solitary residents - male guards nest in nearshore.
Painted greenling (Oxylebius pictus)	A & J		Common in shallows, solitary.
Sailfin sculpin (Nautichthys oculofasciatus)	A		

A = Adult
J = Juveniles

Common Name (Scientific Name)	Bottom	Remarks
Saddleback sculpin (*Oligocottus rimensis*)		Scattered in canopy.
Cabezon (*Scorpaenichthys marmoratus*)	A & J	Common resident - adults usually on bottom, juveniles from tidepools into canopy and on bottom.
Manacled sculpin (*Synchirus gilli*)		Scattered throughout canopy and along stipes to near bottom.
Ribbon prickleback (*Phytichthys chirus*)	A & J	In and around holdfasts.
Black prickleback (*Xiphister atropupureus*)	A & J	In and around holdfasts and in shallower rocky areas.
Penpoint gunnel (*Apodichthys flavidus*)	A	Scattered - most in kelp.
Rockweed gunnel (*Xererpes fucorum*)	A	Scattered from canopy into intertidal.
Blackeye goby (*Corphopterus nicholsii*)	A & J	Usually in sandy areas on bottom between rocks.
Speckled sanddab (*Citharichthys stignaeus*)	A & J	On bottom in sand between rocks.
Shiner perch (*Cymatogaster aggregata*)	A & J	Scattered schools.
Pile perch (*Racochilus vacca*)	A & J	Occasionally numerous in dense schools.
Striped seaperch (*Embiotoca lateralis*)	A & J	Common, beautifully marked fish taken by sport and commercial fisheries.
Wolfeel (*Anarrchichthys ocellatus*)	A	Occasional - wandering through bottom area.

from Victor Scheffer's
THE YEAR OF THE WHALE

"Only twenty-seven years after the discovery of Alaska the last sea cow was clubbed to death by a hunter in the shallows of the Bering Sea. It weighed perhaps four to five tons and it was the only mammal outside of the tropics that lived on seaweed. We shall never know the secrets of its life: how it survived the freezing winters, how it dealt with the hazards of salty food, what defenses it raised against its enemies, and all the other factors of its body structure and habits. Men will never get insight into the processes of their own lives through study of those of the sea cow.

All species, and in particular the specialized ones-the queer ones-are treasure houses from which man will increasingly draw understanding. In the very complexity of the animals lies its great value. No team of engineers, no matter how great the research budget, will ever duplicate a single whisker of a sea cow."

OTHER ALGAL COMMUNITIES (No. 629)

INTRODUCTION

The Pacific Northwest has a high diversity of algae (singlar= alga), due largely to a wide variety of environmental conditions existing here. Conditions range from the exposed shores of the outer coast to the protected inland waters of Puget Sound. In addition, a mild climate ensures that no ice flows will mar the beaches and algae will be spared from excessive temperatures during summer.

The algae dealt with here are macroscopic (visible to the naked eye). Macroalgae (as they are often called) include the familiar 'seaweeds', but not plankton. These seaweeds are benthic (attached to the substrate), and not free-floating. The largest seaweeds, the kelps, are discussed separately in the Kelp Narrative (No. 628).

There are three groups of seaweeds, each distinguished by their color: green (in the phylum Chlorophyta), brown (phylum Phaeophyta), and red algae (phylum Rhodophyta). Color differences are due to the type of pigment involved in photosynthesis.

The lower limit of seaweed occurrence in Washington varies according to the clarity of the water. The range of the lower limit is approximately 40 to almost 200 feet (12 to 60 meters) below the mean lower low water mark.

While it would be convenient to use common names for all seaweeds referred to in this narrative, it is not possible for all species. When discussing those seaweeds with accepted common names, the common name will be used. When discussing species without accepted common names, scientific names will be used. (Scientific names are easily identified as they are always underlined or italicized.)

Although seaweeds occur on the majority of Washington's beaches, seaweed zones were in many cases too narrow or too sparsely vegetated to be included in the land cover/land use maps in the Coastal Zone Atlas. Therefore, it must not be assumed that algae are absent and unimportant where not mapped. Even where seaweeds do not occur intertidally, they may be abundant in shallow subtidal areas. Seaweeds occur at many beaches only seasonally, thus winter visits may not reveal the intense algal growth which occurs in spring or summer.

SIGNIFICANT BIOLOGICAL FEATURES

Zonation

A particularly noticeable feature of seaweeds along the shoreline, especially on rock beaches, is the presence of distinct bands, or zones, of vegetation. Zonation of seaweeds is discussed in the various beach substrate narratives. However, it must be remembered that seaweeds present at a specific locale may vary radically from those which are "typical". For example, the higher zones may become very sparsely vegetated or nonexistent in the protected environments of southern Puget Sound and Hood Canal, where low salinity, lack of waves, and excessive heat make seaweed survival difficult. On highly exposed shorelines, wave splash may extend seaweed zones so they cover relatively large vertical distances, with a prominent splash zone occurring many feet above the high water mark. Other important factors affecting zonation are shading from direct sunlight and predation.

Productivity

Only recently have researchers begun to study the productivity of seaweeds other than kelps. Some seaweeds studied have been shown to have extremely high production, such as *Iridaea*, *Gigartina*, laver, sea lettuce, *Monostroma*, and *Enteromorpha*. These highly productive seaweeds (along with the kelps) contribute a major share of the food resources supporting animals in nearshore areas. Slow-growing algae, such as the beautiful red coralline species, contribute only a small amount to coastal primary production.

Seaweeds are known to release carbohydrates and nitrogen compounds into the water as soluable materials. There is some evidence that animals, bacteria, and perhaps even other plants can absorb these materials and use them as a source of food and/or nutrients. The amount of organic matter released into the water and the importance of this matter to animals or bacteria is not known at present.

Another aspect of production is reproduction. Most seaweeds use a large amount of energy during reproduction, as they tend to produce phenomenal numbers of zoospores. Ultimately, only a small percentage of these zoospores survive to become mature plants.

Trophic Importance

In contrast to tropical areas where fish are the major grazers of seaweeds, invertebrates and perhaps birds are the most important grazers of seaweeds in the Northwest. Invertebrate grazers are varied, and include periwinkles and other snails, limpets, chitons, polychaete (or bristle) worms, urchins, amphipods, isopods, and crabs (e.g., kelp crabs).

Vertebrates (especially waterfowl) graze other seaweeds far more frequently than they do kelps. For example, sea lettuce is an important food source for Greater Scaup, Harlequin Ducks, Black Scoters, and American Wigeons. A study on wigeons in Rhode Island indicated that besides feeding on sea lettuce (which they appeared to prefer), they also ate species of Enteromorpha and Monostroma. Wigeon in Hood Canal have been observed feeding on sea lettuce growing at the water's edge or free-floating in nearshore waters. Mallards in British Columbia salt marshes have also been found to include seaweeds in their diet.

The few fish in Washington which feed on seaweeds include the high cockscomb (for which algae is an important food) and buffalo and great sculpins. Other fish, such as the C-O sole, consume small amounts of algae which is perhaps unintentionally seized while capturing animals.

The large numbers of zoospores produced by seaweeds which do not survive are mostly consumed by animals. The zoospores, which are part of the plankton community, are fed on by planktonic grazers, which ultimately help support fish such as smelt, anchovies, and herring, along with their predators (e.g., salmon, sea birds, marine mammals, and man). They also provide a food source for filter feeding benthic invertebrates, such as oysters, clams, mussels, brittle stars, polychate worms, and sea cucumbers.

The detritus pathway is essentially identical to that described in the Kelp Narrative (No. 628). As with the kelps, the detritus pathway may perhaps be the pathway of greatest significance.

Both the herbivores and detritivores provide food for a large number of carnivores. Included among these carnivores are many species of commercial or recreational importance.

Habitat

Seaweeds provide habitat for many animals, as well as other species of seaweed. The surface area of plants supports many of the same algae and invertebrates that kelps do. Seaweed beds also provide a refuge for smaller animals such as amphipods, small crabs, juvenile fish, or snails, protecting them from predation, waves, or extreme temperatures at low tide. As with kelps, other algae also provide a substrate for attachment for fish and invertebrate eggs. Table 629-1 lists the types of marine vegetation upon which herring deposit their eggs.

One species of kelp crab has evolved a slightly different method of using seaweeds to provide protection. The crab transplants live seaweeds into small tubercles on the back of its shell. These seaweeds thus serve to comouflage the crabs, which blend in well with their densely vegetated surroundings. In similar fashion, the white-cap limpet, which grazes red coralline algae, usually supports a heavy growth of red coralline algae on the outside of it's shell. Thus when feeding, the limpet blends in well with its surroundings.

If visitors to the seashore look closely at the blades of seaweeds, they are bound to find small animals (particularly crustaceans) whose coloration closely resembles that of the seaweed. Most of these animals derive their coloration from pigments produced by the seaweeds they feed on. The pigments make these small animals extremely difficult for their predators to pick out, and thus help ensure their survival.

TABLE 629-1. Type of marine vegetation used as a herring spawning substrate, 1976-77.

Marine Vegetation	South Puget Sound	Central Puget Sound	South Hood Canal	North Hood Canal	Strait of Juan de Fuca	San Juan Islands	Strait of Georgia
CHLOROPHYTA							
Enteromorpha	X			X	X		
Ulva	X				X	X	X
RHODOPHYTA							
Agardhiella	X		X	X	X	X	
Botryoglossum							X
Cryptopleura							X
Gracilaria	X				X	X	X
Microcladia							X
Odonthalia							X
Polyneura							X
Polysiphonia							X
Prionitis	X						X
Rhodomela							X
Rhodymenia							X
PHAEOPHYTA							
Costaria							X
Desmarestia				X			X
Fucus						X	X
Laminaria	X		X	X		X	X
Nereocystis					X	X	X
Sargassum				X	X		X
Scytosiphon							X
ZOSTERACEAE							
Zostera	X	X	X	X	X	X	X

From: Meyer, John H. and Robert A. Adair. 1978. Puget Sound Herring Surveys. United States

Characteristic Plants and Animals

Plants, Invertebrates, and Fish

The characteristic algae, invertebrates, and fish associated with other algal communities are discussed in detail in the appropriate beach substrate narratives. See also the Characteristic Plants and Animals Section of the Kelp Narrative (No. 628).

Birds and Mammals

Wildlife associated with algal communities are discussed in beach substrate and kelp narratives. The following are examples of species which depend on the diverse algal communities of our coastal zone:

American Wigeon o

Algae, especially sea lettuce and Enteromorpha, comprise a large percentage of the food for these abundant ducks. Algae is consumed in sheltered bays throughout the coastal zone, where wigeon pick plants attached to beach substrates as well as detached pieces of algae floating freely at the water's surface. Wigeon have also been observed feeding along rather exposed beaches where they occasionally feed on epiphytic algae (possibly sea lettuce) attached to kelp plants.

Brant o

Although these geese are primarily dependent on eelgrass, they are known to feed on sea lettuce and Enteromorpha. Consumption of algae may be especially important along shorelines with a restricted eelgrass zone. Also, during fall and winter, eelgrass beds are submerged for long periods while higher intertidal zones (where sea lettuce is abundant) are more accessible to Brant and other waterfowl.

Greater Scaup o

Scaups are diving ducks which feed on both plant and animal matter and are known to feed on sea lettuce. As in eelgrass beds, scaups frequently dislodge plants while feeding on algae. The plants then float to the surface where they become available to surface feeding ducks such as wigeon.

The previously mentioned species all consume algae directly. The greatest contribution of algae to wildlife, however, is through food pathways which involve other primary consumers (mainly invertebrates and fish) of the plants.

Examples of the many species which benefit from these algal based food paths include:

Pintails o

Pintails, like American Wigeon, are abundant in western Washington and are important to waterfowl hunters and wildlife watchers. Pintails feed more heavily on marine invertebrates than wigeons, although they often feed in salt marshes where seeds of marsh plants are a preferred food item. Since much of their feeding activity is confined to tidal flats and the marsh edge, invertebrates consumed probably feed on detritus washed both from the marsh and algal beds adjacent to the marsh. Invertebrate prey include shorecrabs and littorine snails (more than 50 littorines were reported in a single Pintail collected on Nanaimo Flats).

Canvasback o

Canvasbacks occur in protected bays where small amounts of algae are consumed directly. In freshwater they feed more extensively on plants, a fact which was noted in their scientific name Aythya valisineria (valisineria = wild celery). However, invertebrates appear to be the major food of the canvasback in coastal locations.

Common Goldeneye o

Goldeneyes occur throughout the coastal zone in both protected and exposed areas. They most often feed very near the water's edge and have been observed many times inside the margin of kelp and eelgrass zones where other algae conceal and support prey items such as shorecrabs and littorine snails.

Belted Kingfisher o

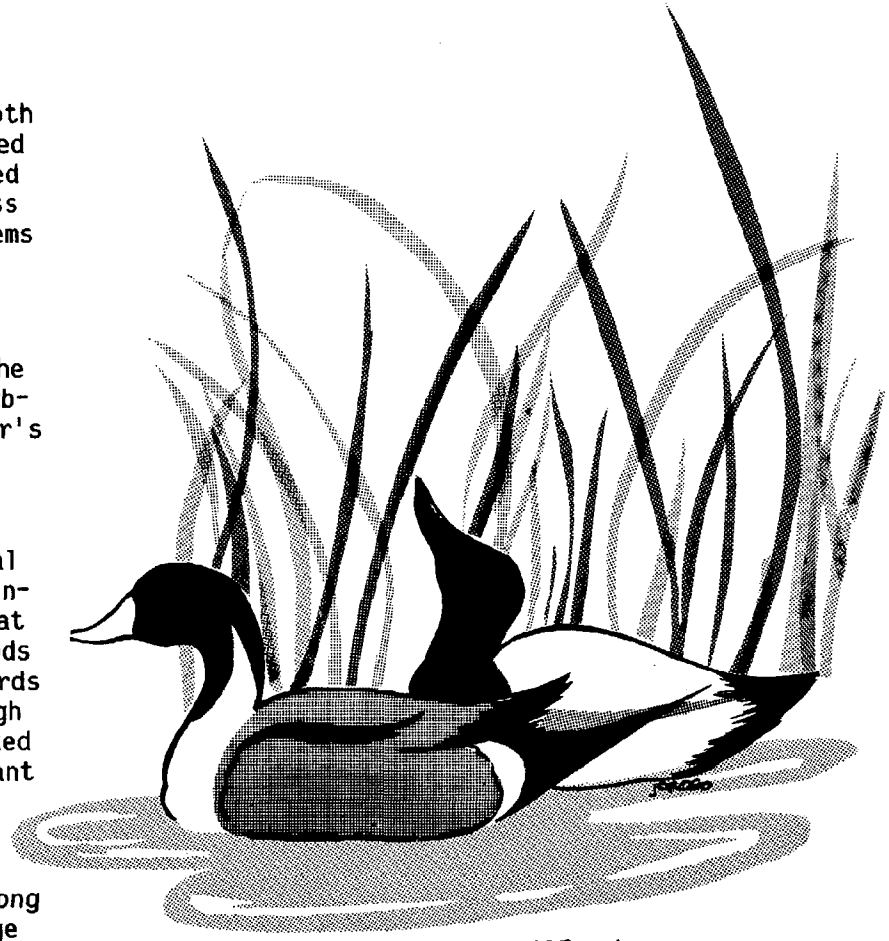
The kingfisher is a familiar sight throughout the coastal zone and is often observed diving into submerged algal beds where prey is taken near the water's surface.

Bald Eagle o

Eagles prey on fish and marine birds within algal beds. Predation also occurs in deeper water and includes prey which feed in or inhabit algal beds at some stage in their life cycle or at varying periods of the day or season. For example, many marine birds feed nearshore in the morning hours or during high tide. When they move offshore to rest, large mixed flocks often form which provide eagles an important food source.

Raccoons o

Raccoons feed extensively along beaches, hunting among plants for prey which have used algae as a refuge during low tide. Raccoons also feed extensively on beach hoppers in drift piles of algae at the high water line.



sea lettuce
buffalo sculpin

Use by Man

Limited use of seaweeds as a human food occurs in Washington, and most of this use occurs among the Oriental community. The most frequently eaten seaweeds (along with the two kelps sugar wrack and bull kelp) are nori (species of Porphyra; also called laver in Europe where it is also eaten) and ogo (species of *Neoagardhiella*). In addition, there are many other seaweeds occurring in Washington which have been used as food in other parts of the world, including:

Monostroma	*Laurencia*
Dulse (*Palmaria*)	Rockweed (*Fucus*)
Sea lettuce (*Ulva*)	*Iridaea*
Enteromorpha	*Gigartina*
Analipus	*Codium*
Gelidium	*Sargassum*
Gracilaria	*Griffithsia*
Gracilariopsis	Some blue-green algae

Few, if any, of these seaweeds are abundant enough in Washington to support commercial harvesting. However, many are potential candidates for mariculture operations. In Japan, the culture, distribution, and sale of nori provides a $600 million a year industry which employs 30,000 people.

Although many seaweeds have a fairly high percentage of carbohydrates, most of them are unsuable to humans as they are indigestible. However, many have distinctive flavors, are rich in vitamins, and provide roughage. Nori is quite nutritious, being high in vitamin C, iodine, and protein. Some seaweeds have vitamin C concentrations comparable to lemons, while some have vitamin B1 (thiamine) levels comparabel to fruits and vegetables. Other vitamins occurring in seaweeds are riboflavin, niacine, pyridoxine, pantothenic acid, cholin, biotin, and vitamins B12 and A. Seaweeds are also rich in several minerals.

Domestic animals are much more efficient than humans in digesting algal carbohydrates. As a result, seaweeds have been used to supplement the diet of cattle, horses, sheep, and pigs. Although livestock can persist on seaweed diets for reasonably long periods, they do best when seaweeds comprise 3 to 10 percent of their diet.

Seaweeds, as mentioned in the Kelp Narrative, have also been used as fertilizers. While low in phosphate compounds, seaweeds provide minerals and hormone-like substances. They also act as a soil conditioner, and contain chelating agents which make many metals more useable to plants.

Seaweeds also contain chemicals which are widely used in industrial processes, especially in the food industry. Brown algae contain algin, which was discussed in the Kelp Narrative (No. 628). Red algae contain agar, carrageenan, or other related products. There are literally hundreds of uses for these chemical products (refer to the Mariculture Narrative, No. 23).

Throughout history, seaweeds have been put to a wide variety of other uses. Examples include use as a source of iodine, medicines (e.g., vermifuges, antibiotics), and insulation. In Japan, one seaweed has even been used to make glue.

IMPACTS

Pollution Indicators

Benthic seaweeds and animals can be valuable indicators of pollution. Seaweeds, and many of the animals, are stationary and therefore cannot flee if the area they inhabit becomes polluted. Even sublethal levels of pollution may manifest themselves among benthic organisms by harming juveniles or discouraging their settlement in a particular area. Changes in species presence, dominant plants or animals, growth rate, or reproductive rate are factors which may change in response to pollution. Other factors, such as decreased resistance to disease and increased susceptibility may also result, but are usually very difficult to monitor.

Certain types of plants and animals, even though they may exist in unpolluted areas, seem to thrive in areas of pollution. Such organisms are termed "pollution indicator species" The seaweed Enteromorpha, which is very tolerant to freshwater, is often located near sewage outfalls, storm drain runoff, and industrial effluents. Thus it is throught by some researchers that Enteromorpha is an indicator species for these types of pollution. Sea lettuce, Monostroma, and nori have also been cited as being abundant in the presence of certain types of pollution.

Oil Impacts

Spilled oil can be a hazard to seaweed survival if a thick enough coating results to suffocate the plants. Smaller quantities do not appear to severely impact most seaweeds; however, some species, such as nori, Enteromorpha, and red coralline algae seem to be sensitive and can be killed. Seaweeds which secrete mucus are least sensitive to oil pollution. The detergents used to clean up oil spills in the past have proven more toxic to seaweeds than the oil itself.

Oil impacts are more severe on animals than on seaweeds. This is true not only for invertebrates, but for birds and mammals as well. Spills occurring during fall or spring bird migrations could potentially result in severe losses. Impacts to animals could lead to an indirect impact on seaweeds by changing seaweed abundance or community structure. As an example, a reduction in the number of animals grazing on seaweeds may result in an increase in seaweed abundance. However, if the predators of animals grazing on seaweeds are reduced in number while the grazers are not, uncontrolled grazing could lead to a reduction in the quantity of seaweeds present or a drastic change in the dominant species.

While phytoplankton naturally produce large quantities of hydrocarbons as a metabolic by-product, man has significantly increased the hydrocarbon level through oil spills, use of recreational and commercial boats, street runoff, and industrial discharges. Eventually the level may become so high that natural mechanisms for reducing oil levels (e.g., anaerobic breakdown by bacteria) may not be able to keep up. At the point when marine systems can no longer cope, plants (and animals) may exhibit lethal or sublethal effects. Thus many small oil spills could in the long run be just as harmful as fewer large spills. This problem may be compounded in the protected waters of Puget Sound, where water circulation is restricted.

Other Impacts

Sewage effluents can also affect plant growth by contributing excessive quantities of phosphorous and nitrogen to the water. The increased nutrient levels result in accelerated growth by seaweeds. An overabundance of vegetation occurs which will reduce the oxygen content of the water during decomposition, especially in areas where water circulation is restricted. Low oxygen levels are highly stressful for animals and seaweeds, and eventually result in an impoverished flora and fauna.

The total impact of sewage effluents depends upon the level of treatment. Primary treatment, and secondary treatment to a lesser degree, fail to remove various toxins, such as heavy metals, from the effluents. Certain heavy metals, such as zinc, cadmium, and arsenic, are known to concentrate in various seaweeds.

Little information is available on the impact of heavy metals on seaweeds themselves. Of greatest concern is the impact upon animals grazing seaweeds and their predators (which include man). Besides those metals listed above, seaweeds are known to concentrate other heavy metals. For example, rockweed can concentrate radioactive strontium as much as 40 times over the concentration occurring in sea water. Pollution of heavy metals which are concentrated by marine plants and animals may greatly interfere with the future use of marine organisms for food resources.

The operation of pulp mills produce a variety of toxins, whose effects on seaweeds are poorly understood. Lignins and fibers are both known to be detrimental to plant growth; lignins block out light in the water and fibers reduce gas exchange during photosynthesis and respiration. Organic debris lowers oxygen content of the water and creates oxygen-deficient conditions on the sediment surface. This oxygen-deficiency promotes the production of hydrogen sulfide and methane gases. Hydrogen sulfide is highly toxic to marine plants and animals.

Although no large-scale harvest of seaweeds is likely in Washington, limited harvesting for commercial purposes may soon become a reality. Harvest will remove food sources for both grazers of seaweeds and detritus feeding animals. Habitat for animals (and some plants) will be destroyed and vital nutrients will be removed from the marine environment. The culture of seaweeds by man, which is far more feasible in Washington than the harvest of existing seaweed beds, will alleviate some of these concerns. However, the use of nutrients by the cultured seaweeds and subsequent harvest will still remove large quantities of nutrients from the marine ecosystem. This may adversely affect adjacent areas, as limited nutrients will reduce productivity.

Suggested References

Carefoot, Thomas. 1977. Pacific Seashores. A Guide to Intertidal Ecology. University of Washington Press. Seattle. 208 p.

Waaland, J. Robert. 1977. Common Seaweeds. Pacific Search Press. Seattle. 120 p.

BEACH SUBSTRATE (No. 63)

INTRODUCTION

Beach substrates form the ecotone between terrestrial and marine environments and as such are highly diverse and productive areas. Beaches and nearshore areas provide man with a multitude of resources, including food, transportation, recreation and, unfortunately, a convenient source of depositing wastes. These resources have attracted the majority of people in the world, and certainly the majority of people in Washington, to reside in the coastal zone.

The disproportionate production of beaches in relation to their size results from the presence of large seaweeds, seagrasses, and marsh plants. This vegetation, phytoplankton and organic matter such as leaf litter from terrestrial sources, forms the base of food webs supporting animals along beaches and in nearshore regions. Most of the nearshore marine resources harvested in Washington are dependent to varying degrees on beach substrates for at least part of their life; others may feed, nest, or find refuge from predators on beaches, or use them as nursery areas; still others directly or indirectly rely heavily on plant or animal matter produced on beaches to be exported to offshore areas. The importance of algae (including kelp), seagrasses, and marshes led to these plant groups being mapped separately where discernable on aerial photographs. While their value is referred to repeatedly in discussions of the appropriate beach substrates in which they occur, more detailed information on their value can be found in their respective narratives:

Seagrasses (see Narrative No. 627)
Kelp (No. 628)
Other Algal Communities (No. 629)
Salt Marshes (No. 623)

Beach Substrates are only mapped on the Land Cover/Land Use maps as 63. Information on the specific type of beach substrate present in a particular area must be obtained from the Drift Sector Maps. Beach types mapped in the Drift Sector Maps correspond with the substrate narratives as follows:

Beach Type	Drift Symbol Sector	Land Use/Land Cover Beach Substrate Narrative No.
Rock	R	631
Cobble	Cob	632
Mixed Coarse	MC	633
Mixed Medium	MM	634
Mixed Fine	MF	635
Sand	S	636
Sandy Mud	S-Mud	637
Mud	Mud	638

The subclasses grouped under Beach Substrates are differentiated on the basis of the sediment size composition. Four of the categories, mixed coarse, mixed medium, mixed fine, and muddy sand, are comprised of various combinations of particle sizes

which are frequently encountered in Washington. Table 63-1 indicates the size of particles used in defining the various beach types. These size categories are fairly well standardized in scientific literature.

TABLE 63-1 SIZE COMPOSITION OF SEDIMENT PARTICLES USED TO DEFINE SUBSTRATE TYPES

Classification	Particle Size	
	Inches	Millimeters
Rock/Boulder	10"	256 mm
Cobble	2.5-10	64-256
Coarse Gravel	0.3-2.5	8-64
Fine Gravel	0.08-0.3	2-8
Sand		0.15-2
Silty Sand (or muddy sand)		0.15
Mud		0.062

The substrate type present on any particular beach is largely related to the exposure of the beach to wind, waves, and currents. Mud particles settling on highly or moderatly exposed beaches are quickly swept away by waves and currents. Only by settling in the most protected situations will mud particles remain permanently. Thus regardless of the original composition of the substrate in highly protected areas, mud begins to cover any boulders, cobble, gravel, or sand which may be present. Exposed beaches, on the other hand, consist predominantly of larger substrate particles, such as rock, boulder, cobble or gravel, which are usually too large to be moved by wind, waves, or currents.

Beaches at the base of eroding bluffs are affected strongly by the type of sediment composing the bluff. Many of the mixed coarse beaches along Washington's coast are at the base of such bluffs. Boulders, cobble, and gravel falling onto the beach from the bluff may not be subject to movement by physical forces, and thus determine the substrate type. Mud and usually most of the sand, however, may be continually swept away by waves, wind, and currents. In some highly exposed areas, even gravel or cobble sized particles may be subject to constant movement.

Within a particular beach type, the substrate size will often change between the upper part of the beach and the lower part. Such changes will affect the type of plants and animals present in different parts of the beach. Often, these changes

are predictable, and are discussed in several of the beach substrate classes. In Hood Canal, for example, mixed coarse beaches often grade into sand or muddy sand beaches in the lower intertidal region. Unfortunately, beach zones are often so narrow that not all beach types present could be delineated on the Drift Sector Substrate Maps.

Some beach types undergo substantial seasonal changes as a result of altered weather conditions. On some cobble beaches, for example, sand is pushed up into the high intertidal by wave action during the summer. This sand tends to level off the slope of the upper beach, and change the substrate type by covering the cobble. In winter, however, the increased force of the waves works to disperse the sand seaward to shallow subtidal areas, where a bar is formed. The effect in the high intertidal area is to leave behind a cobble substrate with a steeper beach slope. These dynamic processes are difficult to portray in the atlas, and persons making decisions regarding management of the coastal zone must be aware of them.

SIGNIFICANT BIOLOGICAL FEATURES

Zonation

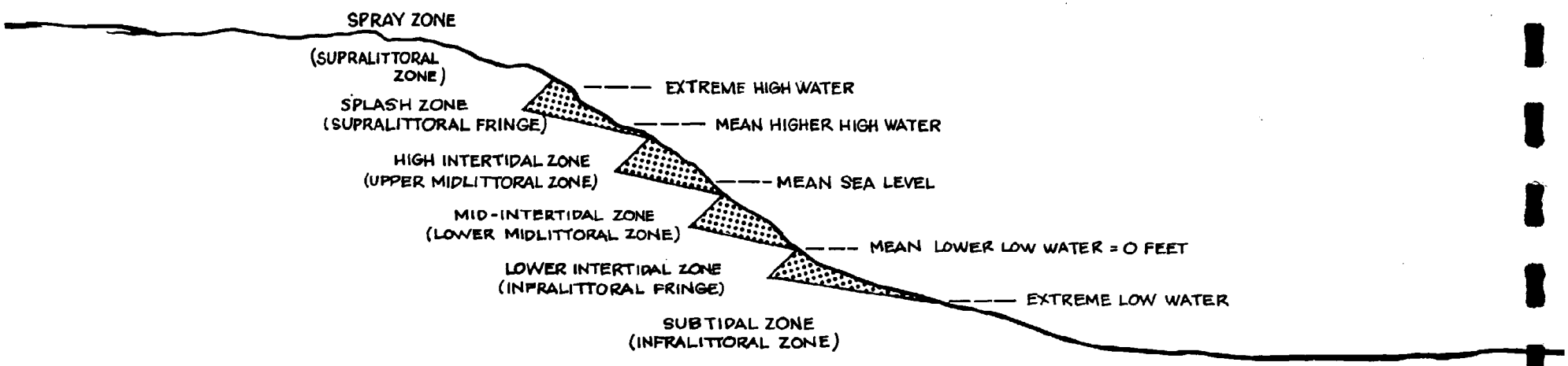
Zonation refers to the occurrence of distinct bands (or zones) of plants and animals along the shoreline. These zones occur parallel to the shoreline, and are related to changes in elevation. Characteristic plants or animals which dominate these zones, such as mussels, sometimes give them a quite distinctive appearance.

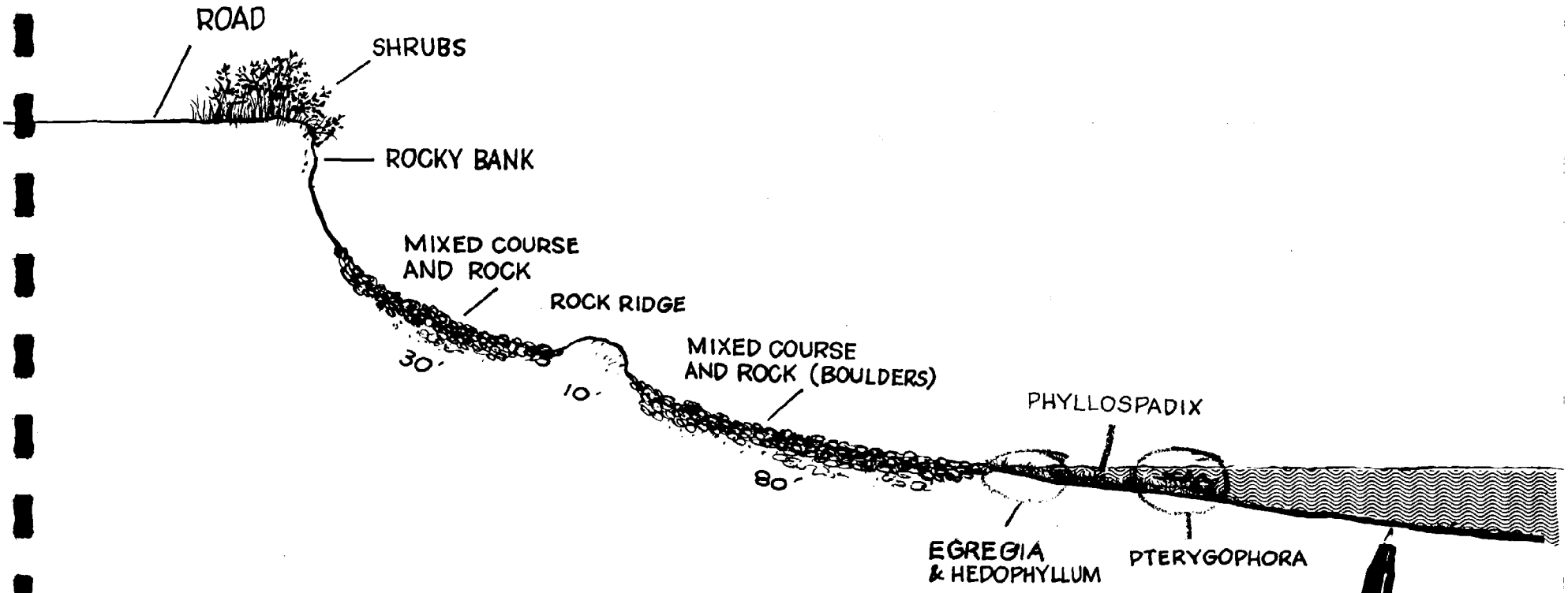
Zonation results from the distribution of dominant organisms being limited to a narrow vertical band. Generally, the upper limits of distribution are set by the tolerance of the plant or animal to physical factors such as dessication (drying out) or temperature extremes. Lower limits, however, are set by biological interactions such as predation or competition for space. As an example, the lower limit of mussels primarily results from predation by ochre stars. Experimental removal of ochre stars has shown mussels perfectly capable of surviving at lower elevations. The ochre stars, on the other hand, can only prey on the mussels at the lower part of the mussels' range, as moving higher will cause a fatal exposure to heat and sun at low tide.

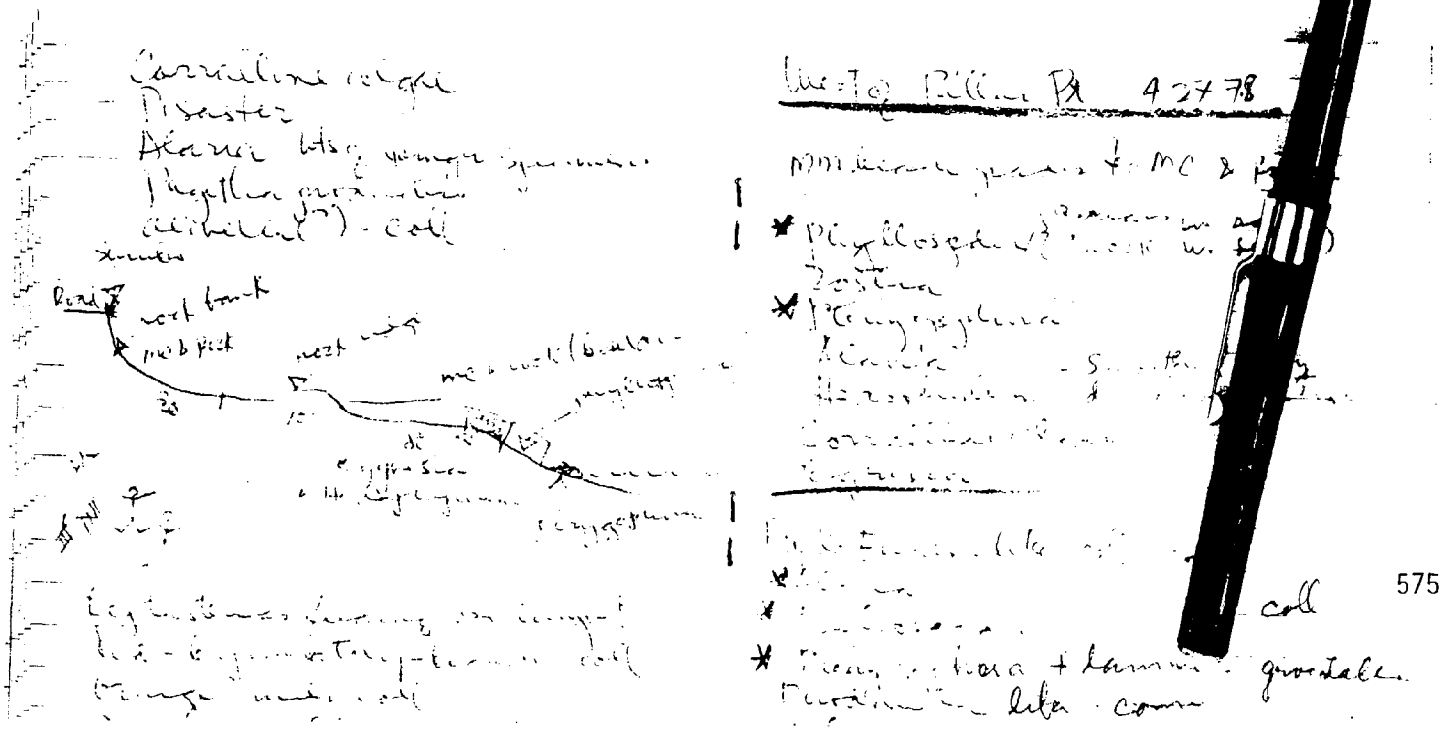
Each intertidal zone represents a community of plants and animals, not discrete sets of organisms which only exist in zones. Organisms have continuously overlapping ranges, throughout intertidal elevations. However, most organisms have their greatest abundance in only one zone. The more conspicuous of the organisms can often be used as indicators of a particular zone.

A variety of systems have been used to define the intertidal zones present on beaches. Unfortunately, most of these systems use different names to describe the major zones. (For example, the highest zone is referred to by the following names by various authors: splash zone; uppermost horizon; supralittoral fringe; zone 1; or the Littorina-glandula fasciation of the Balanus-M. Californianas association of the Balanus-Littorina biome.) Despite the maze of names, the number of zones defined and their approximate ranges correspond surprisingly well. The zones used here are listed in Figure 63-1, along with the relative positions of these zones with respect to intertidal elevation, and their approximate ranges. These names were chosen because of their intrinsically descriptive nature. The names in parentheses were derived by T.A. and Anne Stephenson after 30 years of research, and represent names commonly used in scientific literature. In general, species abundance and diversity increase with decreasing intertidal elevation.

FIGURE 63-1 terms used to define intertidal zonation




ROAD
SHRUBS
ROCKY BANK
MIXED COURSE
AND ROCK
ROCK RIDGE
30'
10'
MIXED COURSE
AND ROCK (BOULDERS)
80'
PHYLLOSPADIX
EGREGIA
& HEDOPHYLLUM
PTERYGOPHORA



Spray zone (Supralittoral zone) = The zone above the extreme high water mark and above the effects of wave splash. This zone is influenced by salt spray and might include rock outcroppings, a beach grass zone, sand dunes, or a steep feeder bluff.

Splash zone (Supralittoral fringe) = This zone is affected more by wave splash than by direct inundation by the tides. The upper part of this zone is never inundated, except during extreme weather conditions, and the remainder of the zone is only rarely covered by seawater.

High intertidal zone (upper midlittoral zone) = The high intertidal zone is exposed at low tides more than it is covered by them, especially in the upper portions of the zone.

Mid-intertidal zone (lower midlittoral zone) = This zone is covered by water more than it is exposed to air. The lower limit of this zone is mean lower low water (MLLW).

Lower intertidal zone (infralittoral fringe) = The area between MLLW and extreme low water. This zone is rarely exposed by low tides.

Subtidal zone (infralittoral zone) = This zone is never exposed by tides. The zone is divided into the shallow subtidal zone (which is the area where enough light penetrates to allow algal growth on the sea floor) and the deep subtidal (where insufficient light to allow photosenthesis reaches the sea floor).

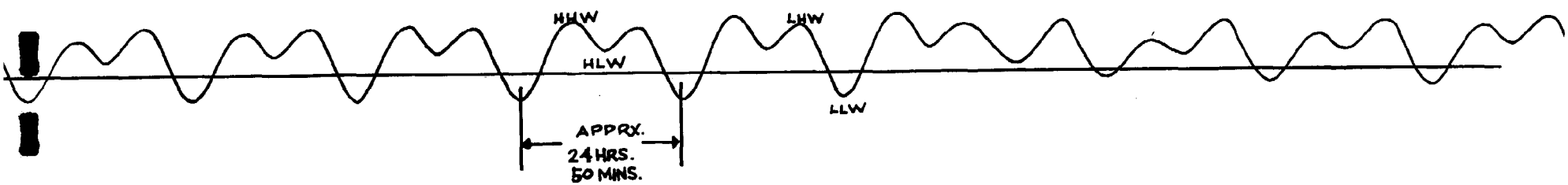
The tidal levels referred to in Figure 63-1 are illustrated in Figure 63-2. Extreme high water and extreme low water represent the highest and lowest elevations the tide will reach during a typical year, excluding abnormal weather conditions. Mean lower low water is the yearly average of all lower low tides throughout the year. The mean lower low water (MLLW) mark is designated as the 0.0 level in tide tables and most elevations are discussed in terms of feet above or below MLLW. These mean tidal levels are preferable in reference to discussions of zonation to using actual foot levels (relative to MLLW), as mean tidal elevations differ from site to site in terms of feet above or below MLLW throughout the coastal zone. For example, tidal extremes are much greater in southern Puget Sound than in Northern Puget Sound, thus the extreme high water level is above plus 16 feet at Olympia and only about plus 11 feet at Anacortes. However, the level of extreme high water (EHW) bears an important relationship to the zonation of animals in both areas, while the plus 16-foot level is only relevant to zonation in southern Puget Sound.

While zonation is defined by, and used in reference to, the occurrence of algae and invertebrates in intertidal areas, many vertebrates also exhibit zonation in intertidal or nearshore areas. Their presence may correspond to the zonation of plants or invertebrates. For example, Black Oystercatchers often feed primarily in the mussel zone, while Wandering Tattlers, turnstones, and Surfbirds have been observed feeding mainly in the rockweed (Fucus) zone of rocky beaches. However, zonation of vertebrates is often discussed in a slightly different context such as the depth of water regardless of tide height. For example, among shorebirds, Greater Yellowlegs may feed in shallow water, Dunlins near the water's edge and Least Sandpipers higher on the beach. Nearshore diving ducks may include goldeneye in one to six feet (.3-2m) of water, Buffleheads in slightly deeper waters and Surf Scoters in low intertidal and shallow subtidal areas. However, little information is available regarding fine divisions of birds or other vertebrates within specific intertidal zones as their great mobility allows a much wider range of area covered than most invertebrates.

Almost every zonation scheme currently in use has been primarily developed from studies on rocky beaches. The visibility of organisms makes rocky shoreline communities highly conducive to study. As smaller sediment particles, especially sand and mud, become more prevalent, it is increasingly difficult to visually observe patterns of zonation. Because of this, discussions on the characteristic plants and animals of some substrates will not address zonation of organisms in detail. However, it must be remembered that even though not visually apparent, zonation still occurs even in the most homogeneous appearing of tideflats.

Characteristic Plants and Animals

Organisms using the various beach types are extremely diversified. Some plants and animals are so specialized as to only occur on a particular algae, which in turn may only occur in the lowest part of highly exposed rock beaches. Others are more adaptable and might be present on several beach types. Most plants and invertebrates are restricted to a particular beach substrate, while fishes, birds, and mammals, and a few plants (such as sea lettuce) and invertebrates (such as crabs and shrimp) are of the more adaptable group and occur on several beach substrates. The characteristic plants, invertebrates, and fishes are listed in the respective beach substrate narratives. However, the great mobility of birds and marine mammals would make such lists extremely repetitive for these groups, which are presented in Table 63-2.



REFER TO TEXT FOR EXPLANATION OF TIDAL CYCLE.

FIG. 63-2

TABLE 63-2

BIRDS AND MAMMALS
- ROCKY TO MUDDY SHORE INHABITANTS -

SPECIES	Relative Occurrence (1)	Submerged Beach (High Tide)	Exposed Beach (Low Tide)	Trophic Relationship (2)	Rock	Cobble	Mixed Coarse	Mixed Medium	Mixed Fine	Sand	Sand-silt or Muddy Sand	Silt-clay or Mud	COMMENT(3)
BIRDS													
Common Loon	C	X		CARN	X	X	X	X	X	X	X	X	Loons are large, principally migratory diving birds.
Yellow-billed Loon	R	X		CARN	X	X	X	X	X	X			
Arctic Loon	C	X		CARN	X	X	X	X	X	X			
Red-throated Loon	C	X		CARN	X	X	X	X	X	X	X	X	
Red-necked Grebe	C	X		CARN	X	X	X	X	X	X	X	X	Grebes are also divers and among the many marine birds which make Washington waters popular for watching wildlife. They are often spectacular as when Westerns run across water in courtship displays.
Horned Grebe	C	X		CARN	X	X	X	X	X	X	X	X	
Eared Grebe	C	X		CARN					X	X	X	X	
Western Grebe	C	X		CARN	X	X	X	X	X	X	X	X	
Pied-billed Grebe	U	X		CARN					X	X	X	X	
Double-crested Cormorant	C	X		CARN	X	X	X	X	X	X	X	X	
Brandt's Cormorant	C	X		CARN	X	X	X	X	X	X			
Pelagic Cormorant	C	X		CARN	X	X	X	X	X	X			Refer to Cliff Narrative
Great Blue Heron	C		X	CARN	X	X	X	X	X	X	X	X	Nests and roosts in trees
Green Heron	U		X	CARN							X	X	
Great Egret	U		X	CARN					X	X	X	X	
Whistling Swan	U	X	X	HERB					X	X	X	X	
Trumpeter Swan	U	X	X	HERB					X	X	X	X	Potentially Threatened (a)
Canada Goose	U	X	X	HERB					X	X	X	X	Aleutian Canada Goose is an Endangered Subspecies (b)
Brant	C	X	X	HERB					X	X	X	X	Valuable game bird, depends on eelgrass.
White-fronted Goose	U	X	X	HERB						X	X	X	
Snow Goose	C	X	X	HERB							X	X	Primarily Skagit and Stillaguamish deltas.
Mallard	C	X	X	OMNI				X	X	X	X	X	Ubiquitous and highly regarded as game and nongame bird.
Gadwall	U	X	X	OMNI							X	X	
Pintail	C	X	X	OMNI				X	X	X	X	X	Pintail and teal among coastal ducks hunted by many each fall and winter.
Green-winged Teal	C	X	X	OMNI				X	X	X	X	X	
Blue-winged Teal	R	X	X	OMNI							X	X	
Cinammon Teal	R	X	X	OMNI							X	X	
European Wigeon	R	X	X	HERB					X	X	X	X	

American Wigeon	C	X	X	HERB					X	X	X	X	Abundant, valuable game bird
Northern Shoveler	C	X	X	OMNI							X	X	
Redhead	R	X		OMNI					X	X	X	X	
Canvasback	C	X		OMNI					X	X	X	X	Species of Concern (c)
Greater Scaup	C	X		OMNI	X	X	X	X	X	X	X	X	Dives for eelgrass and other ducks feed on plants it dislodges.
Lesser Scaup	C	X		OMNI					X	X	X	X	
Common Goldeneye	C	X		CARN	X	X	X	X	X	X	X	X	
Barrow's Goldeneye	C	X		CARN	X	X	X	X	X	X	X	X	
Bufflehead	C	X		OMNI	X	X	X	X	X	X	X	X	Refer to Rock Narrative
Oldsquaw	C	X		CARN	X	X	X	X	X	X			
Harlequin Duck	U	X	X	CARN	X	X	X						Refer to Kelp Narrative
White-winged Scoter	C	X		OMNI	X	X	X	X	X	X	X	X	
Surf Scoter	C	X		OMNI	X	X	X	X	X	X	X	X	Refer to Rock Narrative
Black Scoter	U	X		OMNI	X	X	X	X	X	X			
Ruddy Duck	U	X		OMNI					X	X	X	X	
Hooded Merganser	R	X		CARN					X	X	X	X	Nests locally in cavities.
Common Merganser	U	X		CARN					X	X	X	X	
Red-breasted Merganser	C	X		CARN	X	X	X	X	X	X	X	X	
Turkey Vulture	U		X	SCAV/ CARN	X	X	X	X	X				
Bald Eagle	C	X	X	SCAV/ CARN	X	X	X	X	X	X	X	X	Threatened Species (b)
Osprey	U	X		CARN	X	X	X	X	X	X	X	X	Probably Threatened along coast (a)
Peregrine Falcon	R	X	X	CARN	X	X	X	X	X	X	X	X	Endangered (b)
Merlin	U		X	CARN	X	X	X	X	X	X	X	X	Species of Concern (c)
American Kestrel	U		X	CARN						X	X	X	Most often on marsh or uplands
American Coot	C	X	X	OMNI					X	X	X	X	
Black Oystercatcher	U		X	CARN	X	X	X	X					Potentially threatened with extinction in Washington (a)
Semipalmated Plover	C		X	CARN						X	X	X	
Snowy Plover	U		X	CARN						X			Potentially threatened with extinction (a)
Killdeer	C		X	CARN			X	X	X	X	X	X	
American Golden Plover	U		X	CARN						X	X	X	Mainly outer coast
Black-bellied Plover	C		X							X	X	X	
Surfbird	C		X		X	X	X						
Ruddy Turnstone	U		X		X	X	X	X	X	X	X		
Black Turnstone	C		X		X	X	X	X	X	X			

TABLE 63-2
(Continued)

SPECIES	Relative Occurrence (1)	Submerged Beach (High Tide)	Exposed Beach (Low Tide)	Trophic Relationship (2)	Rock	Cobble	Mixed Coarse	Mixed Medium	Mixed Fine	Sand	Sand-silt or Muddy Sand	Silt-clay or Mud	COMMENT(3)
Common Snipe	C		X								X	X	Most on marsh
Whimbrel	C		X							X	X	X	
Spotted Sandpiper	C		X						X	X	X	X	Breed along streams
Wandering Tattler	C		X		X	X	X	X	X				
Willet	R		X							X	X	X	
Greater Yellowlegs	C		X							X	X	X	
Lesser Yellowlegs	U		X							X	X	X	
Red Knot	C		X							X	X	X	
Rock Sandpiper	U		X		X	X	X						
Pectoral Sandpiper	C		X								X	X	
Baird's Sandpiper	U		X							X	X	X	
Least Sandpiper	C		X							X	X	X	
Dunlin	C		X							X	X	X	Refer to Mud Narrative
Short-billed Dowitcher	C		X							X	X	X	
Long-billed Dowitcher	C		X							X	X	X	
Semipalmated Sandpiper	R		X							X	X	X	
Western Sandpiper	C		X							X	X	X	
Marbled Godwit	R		X							X	X	X	
Sanderling	C		X				X	X	X	X	X	X	Refer to Sand Narrative
Red Phalarope	R	X	X							X			Phalaropes are shorebirds which alight and feed on water's surface.
Wilson's Phalarope	U	X	X							X	X	X	
Northern Phalarope	U	X	X							X	X	X	
Glaucous Gull	R	X	X	CARN/ SCAV	X	X	X	X	X	X	X	X	
Glaucous-winged Gull	C	X	X	CARN/ SCAV	X	X	X	X	X	X	X	X	Refer to Island Narrative
Western Gull	C	X	X	CARN/ SCAV	X	X	X	X	X	X	X	X	Breed on outer coast
Herring Gull	C	X	X	CARN/ SCAV	X	X	X	X	X	X	X	X	
Thayer's Gull	C	X	X	CARN/ SCAV	X	X	X	X	X	X	X	X	
California Gull	C	X	X	CARN/ SCAV	X	X	X	X	X	X	X	X	

Ring-billed Gull	C	X	X	CARN/ SCAV	X	X	X	X	X	X	X	X	Small numbers nest in western Washington (Grays Harbor and Willapa Bays).
Mew Gull	C	X	X	CARN/ SCAV	X	X	X	X	X	X	X	X	
Bonaparte's Gull	C	X	X	CARN	X	X	X	X	X	X	X	X	Black headed and Tern-like.
Heermann's Gull	C	X	X	CARN/ SCAV	X	X	X	X	X	X	X	X	
Common Tern	C	X	X	CARN	X	X	X	X	X	X	X	X	
Arctic Tern	R	X	X	CARN	X	X	X	X	X	X	X	X	
Caspian Tern	U	X	X	CARN					X	X	X	X	Potentially threatened with extinction in Washington (a)
Common Murre	C	X		CARN	X	X	X	X	X	X			
Pigeon Guillemot	C	X		CARN	X	X	X	X	X	X	X		Refer to Kelp Narrative
Marbled Murrelet	C	X		CARN	X	X	X	X	X	X	X		May nest in trees along coast.
Ancient Murrelet	U	X		CARN	X	X	X	X	X	X			
Cassin's Auklet	C	X		CARN	X	X	X	X	X	X			
Rhinoceros Auklet	C	X		CARN	X	X	X	X	X	X			Refer to Island Narrative for Puffin and Rhinoceros Auklet
Tufted Puffin	C	X		CARN	X	X	X	X	X	X			
Band-tailed Pigeon	C		X					X	X				Picks gravel on beach for digestive tract.
Belted Kingfisher	C	X		CARN	X	X	X	X	X	X	X	X	
Violet-green Swallow	C	X	X		X	X	X	X	X	X	X	X	Swallows often feed on insects emerging from mudflats or over open water along other beaches.
Tree Swallow	C	X	X		X	X	X	X	X	X	X	X	
Rough-winged Swallow	C	X	X		X	X	X	X	X	X	X	X	
Barn Swallow	C	X	X		X	X	X	X	X	X	X	X	
Cliff Swallow	C	X	X		X	X	X	X	X	X	X	X	
Purple Martin	U	X	X		X	X	X	X	X	X	X	X	May nest in old pilings.
Common Raven	C		X	CARN/ SCAV	X	X	X	X	X	X			
Common Crow	C		X	CARN/ SCAV	X	X	X	X	X	X	X	X	
Winter Wren	C		X			Several terrestrial birds feed among detritus in upper intertidal. Water Pipits often feed on exposed mudflats like shorebirds.							
Robin	C		X										
Water Pipit	C		X										
Song Sparrow	C		X										
Fox Sparrow	C		X										
Savannah Sparrow	C		X										
Lapland Longspur	C		X										
Snow Bunting	U		X										

TABLE 63-2
(Continued)

SPECIES	Relative Occurrence (1)	Submerged Beach (High Tide)	Exposed Beach (Low Tide)	Trophic Relationship (2)	Rock	Cobble	Mixed Coarse	Mixed Medium	Mixed Fine	Sand	Sand-silt or Muddy Sand	Silt-clay or Mud	COMMENT(3)
MAMMALS													
Vagrant shrew (Sorex vagrans)	C		X	CARN				X	X	X			Shrews and other small mammals may frequent high intertidal or splash zone.
Yuma myotis (Myotis yumanensis)	*	X	X	CARN									*Little known about status of bats in western Washington. Some, such as Yuma myotis are known to feed over water.
Townsend's vole (Microtus townsendii)	C		X	HERB				X	X	X	X	X	Occasionally in intertidal, especially adjacent to salt marsh.
Muskrat (Ondatra zibethica)	C	X		OMNI							X	X	In estuarine zones.
Killer whale (Orcinus orca)	C	X		CARN	X	X	X	X	X	X			See Open Water Narrative.
Gray whale (Eschrichtius robustus)	C	X		CARN	X	X	X			X			Endangered (b), see Sand Narrative.
Coyote (Canis latrans)	C		X	OMNI				X	X	X	X	X	Occasionally forage on beaches.
Raccoon (Procyon lotor)	C		X	OMNI	X	X	X	X	X	X	X	X	Highly valued as furbearer and as a very watchable wildlife species.
Long-tailed weasel (Mustela frenata)	C		X	CARN				X	X	X	X	X	Known to forage along beaches. Prey includes shorecrabs.
Mink (M. vison)	U		X	CARN	X	X	X	X	X	X	X	X	May forage nearshore.
Striped skunk (Mephitis mephitis)	C		X	OMNI				X	X	X	X	X	Forage at night.
River otter (Lutra canadensis)	C	X	X	CARN	X	X	X	X	X	X	X	X	See Rock Narrative.
Sea otter (Enhydra lutris)	R	X	X	CARN	X		X			X			See Kelp Narrative.
Northern sea lion (Eumetopias jubata)	U	X	X	CARN	X	X	X						Sea lions haul out on rock islands - San Juan and outer coast.
California sea lion (Zalophus californianus)	U	X	X	CARN	X	X	X						
Harbor seal (Phoca vitulina)	C	X	X	CARN	X	X	X	X	X	X	X	X	See Mixed Find and Rock Island Narratives.
Black-tailed deer (Odocoileus hemionus)	C		X	HERB				X	X	X	X	X	Frequently observed on beaches-occasionally in low intertidal within eelgrass beds.

LEGEND:

1. Relative occurrence (in western Washington)

   C = Common
   U = Uncommon
   R = Rare

2. Trophic Relationship

   CARN = Carnivore
   HERB = Herbivore
   OMNI = Omnivore
   SCAV = Scavenger

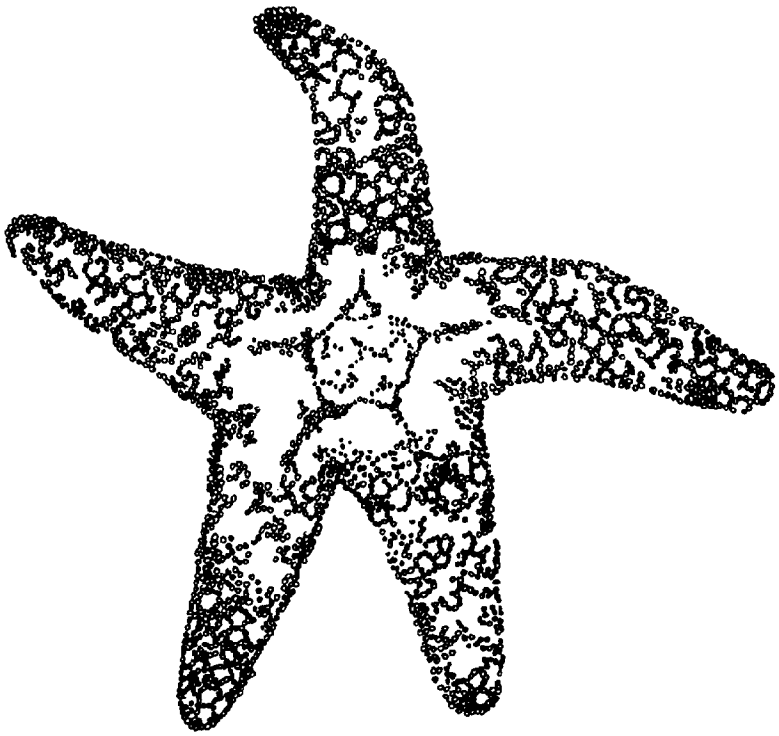
3. Comment

   a. Status as determined by Washington Departments of Game and Ecology. 1975. Marine Shoreline Fauna of Washington Status Survey (Edited by Randall Eaton)

   b. Endangered and Threatened Status, USFWS.

   c. Species of concern as determined by National Audubon Society and included on their 1978 Blue List.

Several shorebirds also consume seeds of marsh plants



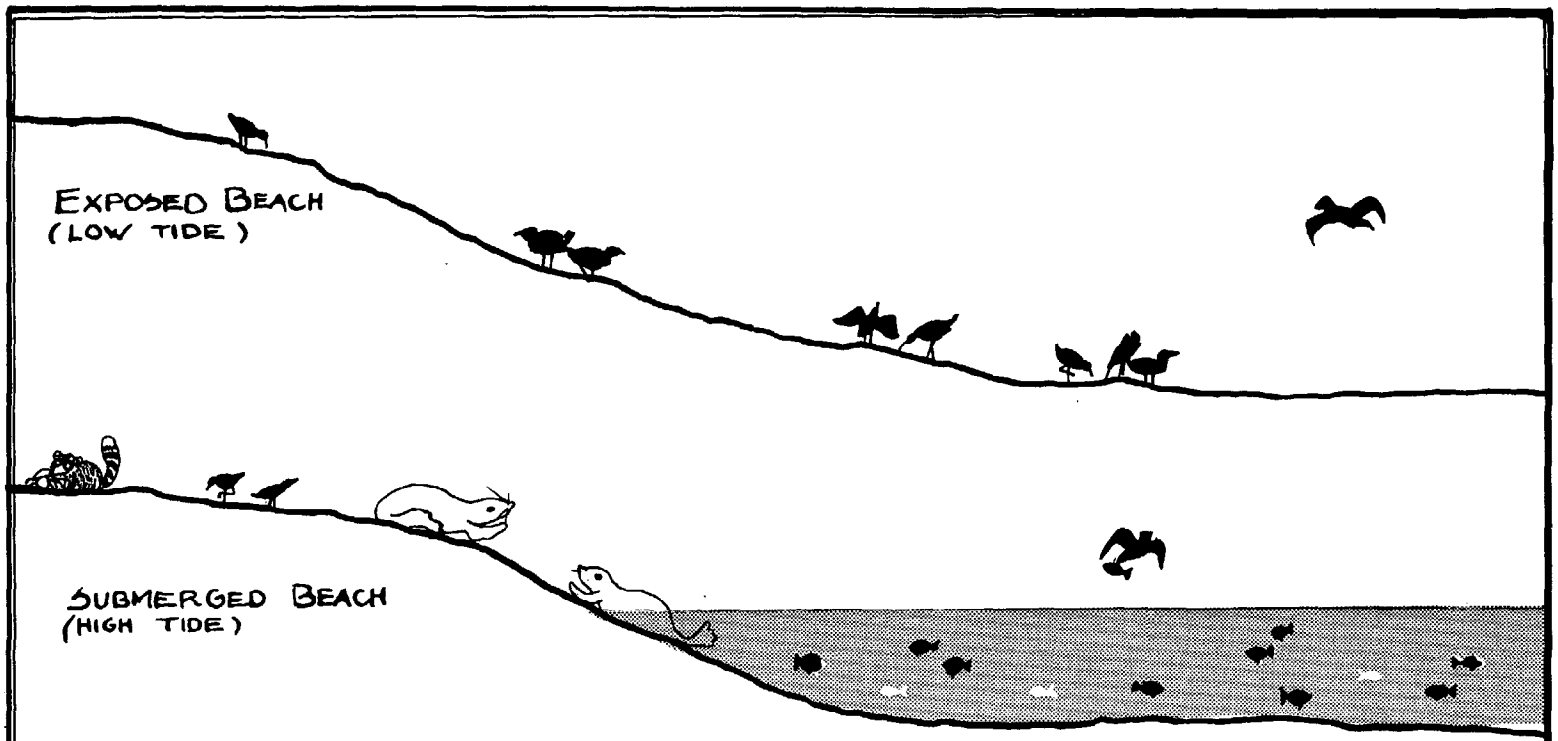
Interrelationships

The various beach substrates, like all other land cover or land use types within the coastal zone, are highly interrelated not only among themselves but also with other adjacent areas. Several interrelationships are given here to serve as examples of the broad range of interactions which exist.

Shoreline drift involves the movement of sediment particles along the shoreline as a result of winds, waves, or currents. Sediments tend to have a net movement in one direction, and are often critical in supplying substrate materials for adjacent areas such as sand beaches, sand dunes, beach grasslands, or spits. The original sources of sediments are rivers or eroding bluffs.

Rivers and streams also carry large amounts of organic matter (largely in the form of leaf litter) produced by terrestrial plants to marine beaches. Riparian vegetation produces the bulk of this organic matter that nourishes invertebrates in both intertidal and subtidal areas. Nutrients are also carried by rivers and streams, and are important in maintaining high productivity in estuaries and other nearshore areas.

Salt marshes, eelgrass and algae beds (including kelp beds), are important contributors to the primary production of coastal areas. Production from these plant communities not only provides food for animals which graze them directly, but supplies food in the form of decaying plant material to less productive beaches (such as cobble beaches) and subtidal areas which have little or no primary production.



In general, there are two basic groups of wildlife which forage along beaches: 1) Those of exposed areas above, and 2) Those of submerged areas beyond and beneath the water's edge. A great deal of overlap occurs within these groups. For example, gulls may feed on the beach or offshore, and many diving birds actually forage on the beach substrate, but when the beach is submerged. Fish often move in and out with tides and are often stranded in, or adapted to tidepools. Seals feed in the water and rest ashore. Terrestrial wildlife occasionally feed over the water's surface (e.g., swallows), but most often feed along beaches (e.g., racoon). The tremendous variety of foraging types is a reflection of the high diversity of species dependent on the beach, that zone where land and sea intermingle.

Algae, as well as many invertebrates also release large numbers of zoospores into the water column during reproduction. These zoospores consitutue an important part to the plankton community, and are carried about by tidal action. Suspension (or filter feeding) organisms such as clams, oysters, and mussels filter large numbers of zoospores as they collect planktonic food upon which to feed.

Many of the animals which feed in coastal areas are migratory. These animals provide a link to areas which are often far removed from Washington's coastal zone. Other animals are not migratory but move about among several beach types, or between upland and marine areas. The feeding, defecating, nesting, or consumption of all these animals as they move between areas facilitates the exchange of nutrients and organic matter between different areas.

IMPACTS

Intertidal existence is extremely stressful to the plants and animals inhabiting beaches. Organisms must expend a large amount of energy to cope with these stresses. Stresses of exposure during low tides include temperature extremes, salinity (especially during rainy weather, although this isn't normally a problem in the Pacific Northwest Coastal Areas), dessication, and the inability to feed or excrete wastes. These stresses tend to make plants and animals more susceptible to impacts. This sensitivity, coupled with the inability of beach vegetation and most invertebrates to move from an area which is impacted, make benthic organisms (those organisms living on or in the substrate) excellent indicators of environmental impacts.

The sensitivity of benthic organisms causes them to be the first organisms impacted by pollution problems in nearshore areas. As a result, fish, bird, and mammal predators which feed on benthic organisms are impacted more than those which feed on organisms in the water column.

Each substrate type reacts differently to a given kind of impact. For example, consider a hypothetical case where a toxic substance is spilled on both a moderately exposed rock and a protected mud beach. The toxin would be dispersed quickly from the rock beach as a result of wave and current action. If plants and animals were killed by the toxin, recolonization of the rock would begin quickly. The community could take many years to reach its pre-impact state, however, as some of the plants and animals of rock beaches apparently live for as long as 80 or more years. Mudflat organisms have shorter life spans than most rock species, and could potentially reach their pre-impact population in a shorter period. Unfortun-

ately, toxins would be incorporated into the sediments. Burrowing activity by organisms such as worms and mud shrimp could cause a gradual long-term release of the toxin, which would greatly prolong its impact.

Long-term, low level toxins tend to impact beach communities in a slightly different manner than short-term large scale impacts such as oil spills. Toxins may become more selective at low levels by killing only certain species, or sublethal impacts may occur. Sublethal impacts may mean reduced reproductive capacity, lower resistance to predation or disease, or a reduced ability to obtain food or photosynthesize. Such changes in an animal or plant are extremely difficult and expensive to detect.

Location and season of occurrence of an impact also have considerable bearing of effects on near-shore communities. For example, oil spills along a given stretch of rocky shoreline may disperse much more rapidly than in a more protected location. However, an oil spill along the rocky shores of a seabird nesting island poses a significant threat regardless of how quickly the oil disperses. Spills during the breeding season will be of special concern in this situation and affect each species differently since each generally feeds at varying distances from shore. In protected locations and other areas where large feeding assemblages occur, spills during winter or migratory periods potentially threaten thousands of marine wildlife. For example, it has been estimated that a hypothetical oil spill in Padilla Bay would eliminate 1,500 Brant.

Red Tides

Red tides in Washington coastal waters are a result of blooms of microscopic plants called dinoflagellates, and outbreaks may possibly be affected by human pollution. These dinoflagellates become so abundant that they actually give the water a reddish tinge. One of the dinoflagellates, *Gonyaulax catenella*, contains a powerful neurotoxin which is responsible for paralytic shellfish poison. Although humans do not consume *Gonyaulax* directly, clams, oysters, mussels and other filter feeding animals which humans do eat, feed directly upon *Gonyaulax*. Small amounts of the toxin are enough to make a person quite sick, and large amounts can be fatal. Approximately 600 people have been killed by paralytic shellfish poisoning on the west coast of North America. Blooms occur regularly along the western portion of the Strait of Juan de Fuca and the Pacific Coast, usually during late spring, summer, or early fall. Inside Puget Sound and Hood Canal, however, toxic red tides are an infrequent occurrence. It is not known what triggers a bloom in protected waters, but many researchers feel it is a combination of factors, among them temperature, salinity, and nutrients.

There is some evidence which suggests that the occurrence of red tides is increasing. Some researchers feel that human pollution may be the reason. Agricultural practices, logging, stream channelization, sewage disposal, or other activities which alter nutrient levels in nearshore areas may create conditions which trigger the blooms. Current research is attempting to answer the question of what triggers toxic red tides. People involved in the sale and consumption of seafoods might be truly relieved by an answer, as outbreaks of red tide (even minor ones) cause a severe decline in the consumption of sea foods by the public. Severe outbreaks of red tides may also result in mass mortalities of fish and many shellfish.

Interference with Shoreline Drift

Structures which interfere with shoreline drift include bulkheads, revetments, and jetties. Interference can jeopardize the existence of spits, sand dunes, sand beaches, or beach grasslands dependent upon shoreline drift to supply sediments. Removal of sediments from beaches may have the same effect on dependent areas as blocking shoreline drift. Dam construction on rivers supplying sediments to the shoreline, along with revetments at the base of eroding bluffs, can reduce the supply of drift sediments at their source. Ediz Hook, in Clallam County, was formed and maintained by drift sediments originating both from eroding feeder bluffs immediately to the west and from the Elwah River. Construction of a dam on the Elwha River in the 1950's and placement of revetments at the base of much of the feeder bluff cut off the supply of sediments to the spit. The spit, which is heavily developed, began to erode away, creating the need for the costly placement of riprap along the entire west side of the spit to protect this development.

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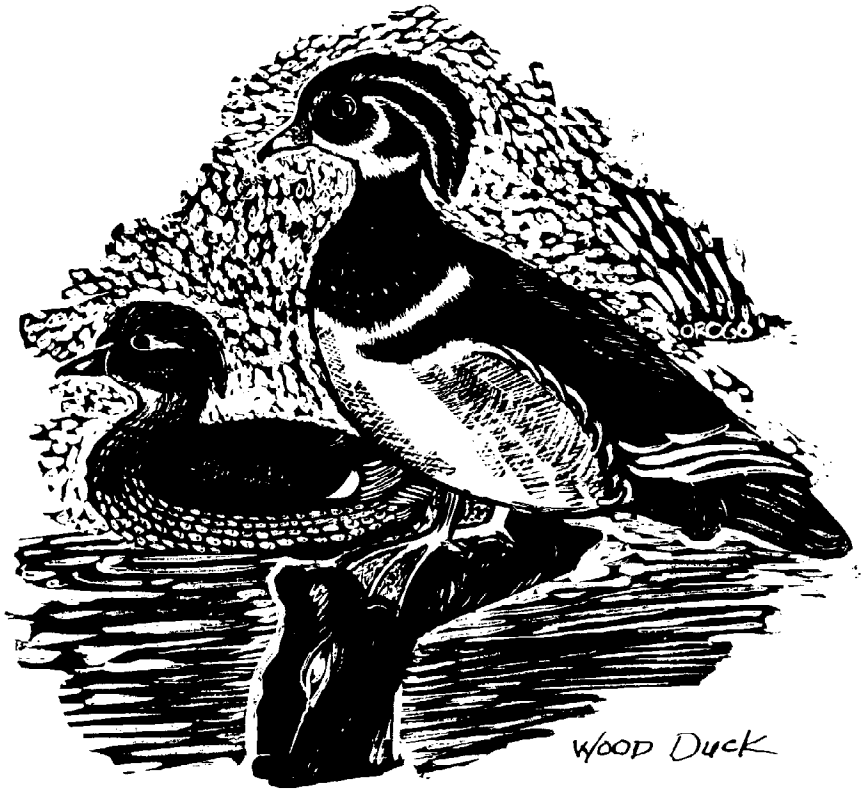

WOOD DUCK

ROCK (No. 631)

I. INTRODUCTION

Rock beaches consist of solid bedrock and boulders which are too large to be moved about by current or wave action. While not comprising a major portion of Washington's coastal zone, rock beaches certainly provide one of the most unique and fascinating types of environment in the state. This is especially true of moderately to highly exposed beaches which are characterized by lush growths of algae and large numbers of animals.

The organisms living on exposed beaches must be adapted to withstand the countinuous powerful pounding of the surf. Kelp beds and surfgrass, when present, are most often associated with moderately or highly exposed rocky shores. A wealth of bird life is present, and exposed rock beaches are the best areas in the state for observing marine mammals. A variety of fishes come in with the tide to feed or spawn on rock beaches. Others are a part of tidepool communities.

The high biomass of algae on exposed rock beaches, and the high production of algae, imply that these beaches are perhaps the most productive (per unit area) in the state. Large surpluses of primary production are exported to other areas. The value of these exposed beaches is so great that they should be viewed as critical biological areas, especially considering their limited distribution in the state and contribution to commercial and recreational fish and other wildlife.

While rock beaches are more characteristic of moderate to high wave and/or current exposure, they do occasionally occur in the protected waters of Puget Sound and Hood Canal. These beaches are not nearly as spectacular or luxuriant as more exposed beaches, but they still contain a relatively diverse biota. Protected rock beaches must necessarily be fairly steep-sloped, or sedimentation would shortly result in the beach being covered by sand and mud.

The occurrence of small rock islands along rocky shorelines is an important feature biologically. While providing the same biological features as rock beaches on the mainland or large islands, special uses such as seabird and marine mammal breeding and resting areas are associated with small islands. These special features of rock islands are discussed in a separate narrative (see No. 713).

Beaches with high or moderate exposure occur predominately along the Pacific Coast of the Olympic Peninsula from Cape Flattery to just south of the Copalis River, along the Strait of Juan de Fuca, portions of the west side of Whidbey Island and the southwest portion of Fidalgo Head, the southwest shore of San Juan Island and the southern end of Lopez Island. Many small islands occurring offshore from these areas also have exposed beaches. Protected rock beaches are most common in northern Puget Sound (such as in the San Juan Islands, Chuckanut Bay, Lummi and Cypress Islands, Deception Pass, and Fidalgo Head). Some of these beaches are, however, exposed to swift currents. Rock beaches are rare in southern and central Puget Sound and Hood Canal, occurring in only a few scattered locations, e.g., Steamboat Island, Sisters Rocks, Pulali Point, Blakely Rocks, and north of MacDonald Creek on Hood Canal.

II. SIGNIFICANT BIOLOGICAL FEATURES

Diversity and Biomass

Rock substrates have extremely high species diversity, meaning the number of species present is very high in relation to their substrate types. Thorough sampling of rock will usually reveal in excess of 200 species of invertebrates and macro-algae. This figure may be lower on protected rock shorelines, especially in southern Puget Sound and Hood Canal, where salinities are lower. Biomass is similarly high and when kelp is present, is the highest of any substrate type. One study reported biomass was as high as 17.5 kg per meter squared at an exposed rock site along the Strait of Juan de Fuca. This value does not account for the numerous birds, fish, marine mammals and mobile invertebrates which use the area, but which are capable of moving elsewhere during sampling.

Both diversity and biomass tend to increase in the lower intertidal. Biomass often peaks in the lowest intertidal or adjacent shallow subtidal areas, especially when kelps are present. Diversity and biomass are also greatly enhanced by the presence of micro-habitats such as tidepools, crevices, caves, variation in beach slope (from gentle slopes and terraces to vertical cliffs or overhanging ledges), gullies, reefs, and the presence of seagrass or large algae such as kelps. Other factors which increase diversity and biomass are high wave exposure, strong currents, and deep waters offshore which supply nutrient-rich water.

Productivity

The major contributors to the high biomass of exposed rock beaches are the algae, especially in the lower intertidal and shallow subtidal areas. Algae are extremely important primary producers, some species being among the most productive plants known to man (see Kelp and Other Algal Communities Narratives, Nos. 628 and 629, respectively). Thus, the productivity of exposed rock beaches is probably higher than for any other beach type in Washington's coastal zone. A great surplus of production means large quantities of organic matter is carried to other areas by the strong wave and current action, where it is used as detritus. Only a small amount of detritus which either settles among mussel beds, surfgrass, or dense algae or is filtered out of the water by suspension feeders, is consumed in the rocky beach itself.

Since protected rock beaches do not exhibit the quantity of algae that exposed beaches do, it is likely that their production is lower. However, their production must be fairly high, as they support substantial populations of grazing animals. Where kelp is present, the productivity is surely much higher than areas from which it is absent.

Habitat

Exposure

Exposure to waves and currents is an important factor affecting the structure of rock communities. The higher diversity and biomass of exposed beaches has already been mentioned. While it is thought that exposure controls the distribution of some plants and animals such as giant kelp, surfgrass, and California mussels, it is not the only factor affecting distributions. Protected waters often have lower salinities, greater temperature extremes, different nutrient concentrations, or more pollution, all factors which can limit plant or animal distributions. However, as changes in exposure reflect changes in the rock community, differences in communities are often discussed by scientists in terms of exposure.

Bird observations during this study compared some exposed and protected rock beaches. Species diversity and total number of birds seen was greater at more exposed sites (Fidalgo Head, Cattle Point on San Juan Island and Tongue Pt. near Port Angeles) than at a protected rock area in Hood Canal (north of MacDonald Creek in Jefferson County) for each month sampled.

The highest bird diversity and abundance was at Tongue Point. The presence of extensive kelp beds, gentle sloping rocks which provide more horizontal rock surface, a large number of microhabitats (tide pools, crevices, boulders, etc.) and the presence of a small rock islet all contributed to the consistently high diversity and abundance. (Rock islets are of such special significance to bird and mammal populations that a separate narrative, No. 713, has been written.)

Oystercatchers were seen from October through February, indicating the importance of Tongue Pt. as a wintering area for a small flock of six to 12 of these birds. Other shore birds seen at Tongue Pt. were Surfbirds, Black Turnstones, Ruddy Turnstones, Rock Sandpipers, and Sanderlings. A total of 11 birds and mammal species seen at the exposed beaches were not observed at the protected beach:

Northern sea lion	Surfbird	Sanderling
Heermann's Gull	Black Turnstone	Brandt's Cormorant
Harlequin Duck	Ruddy Turnstone	Arctic Loon
Black Oystercatcher	Rock Sandpiper	

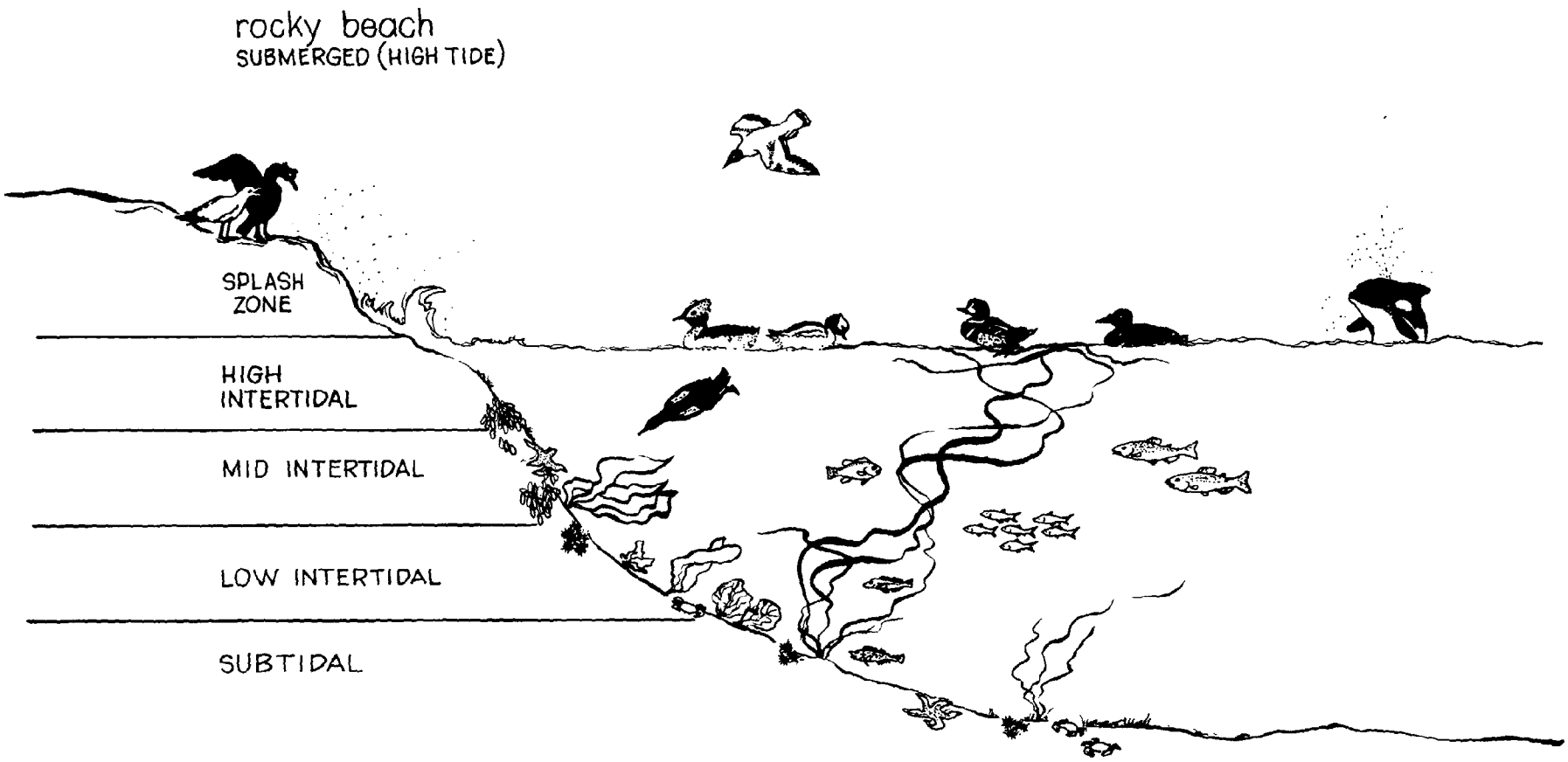
As most of these species are uncommon or absent in the protected waters of southern Puget Sound and Hood Canal, it is unlikely that they would be observed in protected rock locations in these areas.

Similar differences among plants and invertebrates at exposed and protected sites were also noted. The three species of surfgrass are totally restricted at such sites. Extensive kelp beds, a strong contributing factor to animal and plant diversity and biomass, rarely occur at protected rock sites. Conspicuous algae largely or totally restricted to more exposed conditions include:

Giant kelp (*Macrocystis integrifolia*)
Sea palm (*Postelsia palmaeformis*)
Pelvetiopsis limitata
Honey ware kelp (*Alaria* sp.)
Pompon kelp (*Pterygophora californica*) (Occurs subtidally in Puget Sound where currents are strong, such as Agate Pass.)
Feather boa (*Egregia menziesii*)
Laminaria setchelii
Lessoniopsis littoralis

Conversely, there are few algae which are "restricted" to protected rock situations, and algae common on protected beaches are often abundant on exposed beaches. Algae which are most often conspicuous on protected shores include:

Sea lettuce (*Ulva* spp.)
Monostroma spp.
Sugar wrack (*Laminaria saccharina*)
Enteromorpha spp.
Rockweed (*Fucus distichus*)
Sargassum muticum


rocky beach
SUBMERGED (HIGH TIDE)
SPLASH ZONE
HIGH INTERTIDAL
MID INTERTIDAL
LOW INTERTIDAL
SUBTIDAL

In addition, large algae which occur in a variety of conditions usually have a greater biomass of epiphytes growing on them in protected areas. Exposed conditions may be important for some marine plants which cannot tolerate heavy epiphytic growth, by scouring epiphytes from them. However, despite this, the number of species of algae occurring in southern Puget Sound and Hood Canal is reduced in comparison to northern Puget Sound and other more exposed areas. Reduced salinity is probably a major factor in this trend.

Conspicuous invertebrates characterizing exposed rock beaches include:

Purple sea urchin
California mussel
Gooseneck barnacles
Green sea anemone
Turban snails
Red turban snails

Structural Dominants

Structural dominants are organisms such as barnacles, mussels, surfgrass, or algae which provide some sort of refuge from physical factors (waves, currents, sun at low tides, etc.) and predation. Their role is analogous to that of an upland forest. Structural dominants on rock beaches often trap small amounts of sand, shell fragments, and organic debris, creating a microhabitat for organisms which would not other wise be present on a "rocky" beach. Animals dependent upon these structural dominants consist mostly of small crusteceans (amphipods, isopods, and tanaids) and insect larvae, but also may include a variety of other organisms. For example, beds of California mussel often contain polychaete worms (e.g., Nereis vexillosa), ribbon worms (e.g., Emplectoneura gracile), peanut worms, hermit crabs, and a small sea cucumber, as well as small crusteaceans and insect larvae. The fate of these dependent organisms is intimately tied to the fate of the structural dominant, and when the structural dominant is removed or dies off, the dependent organisms will quickly follow suit.

These small organisms are usually extremely abundant, and provide important sources of food for many birds and fishes. Thus, the structural dominants are important in indirectly supplying food for many organisms. Many birds and fishes, however, feed specifically on the structural dominants themselves. The role of plants in providing habitat is discussed further in the Kelp and Other Algae Narratives.

Feeding/Resting/Nesting

A variety of animals use rock beaches for nesting, feeding, and resting activity. Most of the invertebrates and some fish spend their entire life cycle on rocky shores. However, some of the more mobile animals, including some invertebrates (such as shrimp), birds, fish, and mammals spend only part of their life in intertidal or shallow subtidal areas, the rest of their time being spent in other areas.

Marine mammals such as harbor seals and river otters use rocky beaches as resting and feeding areas, and some terrestrial mammals, such as raccoons, mink, and skunks occasionally forage here. Garter snakes have also been observed feeding on a variety of organisms during low tides. Many birds, including shorebirds, gulls, crows, diving birds, Bald Eagles, and Peregrine Falcons feed along rock beaches in adjacent nearshore areas.

Some migratory fishes, such as salmon and herring, also use rock beaches for a portion of their life cycles. Juvenile salmon feed heavily on small invertebrates before leaving for the open ocean, and herring attach their eggs to intertidal and shallow subtidal vegetation. See the Characteristic Plant and Animal section for more detailed information on fish and other wildlife use.

Importance of Amount of Space Available

A study in California on shorebird ecology revealed that available space rather than the amount of available food appears to be the environmental factor most important in limiting size and density of migratory shorebird populations. Thus, rock shelves which provide extensive horizontal feeding areas have higher density and species numbers than other rocky sites which have fairly steep profiles. However, rocky intertidal areas in general have few kinds of shorebirds and do not often have large aggregations as often seen on mudflats. The steep slopes, wave action, and brief exposure at low tide (most are migrants, therefore are here in winter when the tidal variation is least) have probably been major factors limiting shorebird abundance. Those species, such as Oystercatchers and Surfbirds, which are essentially restricted to rock are not abundant; because they are not often found outside this habitat it is very important to maintain undeveloped rocky shores with adequate refuges for these species.

Characteristic Plants and Animals
Algae and Invertebrates

The zonation of algae and invertebrates is more clearly evident on rock beaches than on any substrate type. The degree of zonation and the species present depend on the type of rock (e.g., hardness of rock), topography, and exposure to wind, waves, and currents. Plants generally are more abundant in lower zones than higher zones. Distributions of many species are patchy, especially in the upper zones. Some species, barnacles for example, show large seasonal fluctuations in number and biomass. Tidepools provide special refuges during low tide for organisms which could not otherwise survive the exposure to air.

Table 631-1 lists the characteristic species of algae and invertebrates found on rock beaches.

a. splash zone

This zone is characterized by a small number of species. The exposure to dessication (drying out) is too great for all but a few hardy species. Salt water influence eliminates essentially all terrestrial organisms except a few lichens. Lichens often form a distinct band in this zone, and two common types are the black *Verrucaria* and the orange *Caloplaca*. An isopod, the rock slater, which feeds on decaying algae, is truly representative of this zone. Little algae is visable in this zone, unless the green algae *Prasiola meridionalis* is present. In areas where there is freshwater seepage onto the rocks, another green algae, *Enteromorpha*, may be abundant. Despite the apparent lack of algae, the limpet *Collisella digitalis* and littorine snails, which are herbivorous, occur in abundance. Microscopic algae (diatoms) are important primary producers, especially in winter when waves and cool weather keep rock surfaces damp, and may be the primary source of food for herbivores. Blue-green algae are also ususally present. Some of the species more characteristic of the next lower zone, especially barnacles and some of the limpets, are often abundant in the lower part of the splash zone.

TABLE 631-1. Characteristic Algae and Invertebrates on Rock Beaches

SPECIES Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
PLANTS				
Green Algae				
(Prasiola meridionalis)	PP	SPL		
(Enteromorpha spp.)	PP	SPL,H,M,T	PC	Grows where freshwater seepage occurs or water is brackish. Edible
Sea lettuce (Ulva spp.)	PP	H,M,L,T	PC	Edible
Green rope [Acrosiphonia				
(Spongomorpha) coalita]	PP	M,L		
(Monostroma spp.)	PP	M,L,T	PC	Edible
Brown Algae				
Rockweed (Fucus distichus)	PP	H,M	PC	
Tar Spot (Ralphsia pacifica)	PP	H		
Honey ware kelp (Alaria spp.)	PP	H,M,L	PC	Edible
Sea cabbage (Hedophyllum sessile)	PP	M,L		
(Leathesia difformis)	PP	M		
Split whip wrack (Laminaria setchellii)	PP	L,SB		
Sugar wrack (L. saccharina)	PP	L,SB	R,PC	Edible
Seersucker (Costaria costata)	PP	L,SB		
Feather boa (Egregia menziesii)	PP	M,L	PC	
(Desmarestia ligulata)	PP	L,SB		
(D. viridis	PP	L,SB		
Bladder leaf (Cystoseira geminata)	PP	L,SB		
Bull kelp (Nereocystis leutkeana)	PP	SB	R,PC	Edible
Pompon kelp (Pterygophora californica)	PP	SB		
Giant kelp (Macrocystis integrifolia)	PP	SB	PC	Limited distribution (highest exposure)

SPECIES Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
(Lessoniopsis littoralis)	PP	L		Limited distribution (highest exposure)
Sea Palm (Postelsia palmaeformis)	PP	M,L		Limited distribution (highest exposure)
(Sargassum muticum)	PP	L,SB		An introduced alga, most prominent in protected rock areas.
Sea colander (Agarum spp.)	PP	L,SB		
Red Algae				
(Endocladia muricata)	PP	H,M	R,PC	Edible
Red laver (Porphyra perforata)	PP	H,M,L	PC	Edible
(Bargia fuscopurpurea)	PP	H		
Tar spot (Petrocelis meddendorffii)	PP	H,M		
(Hildenbrandia sp.)	PP	H		
(Gigartina papillata)	PP	H,M,L	PC	Contains high percent of carrageenan
Tidal pool coral (Corallina vancouveriensis)	PP	M,L,SB,T		Coralline red algae
(Bossiella plumosa)	PP	M,L,SB,T		Coralline red algae
(Lithothamnion spp.)	PP	L,SB,T		Coralline red algae
(Calliarthron spp.)	PP	L,SB,T		Coralline red algae
Turkish towel (Gigartina exasperata)	PP	M,L,SB	PC	Contains high percentage of carrageenan
Iridescent seaweed (Iridaea cordata)	PP	M,L,SB	PC	Contains high percentage of carrageenan
(Ordonthalia floccosa)	PP	L,T		
Black pine (Rhodomela larix)	PP	M,L,T		
(Prionitis spp.)	PP	L,SB,T		
Vascular Plants				
Surfgrass (Phyllospadix spp.)	PP	L,T		

TABLE 631-1. Characteristic Algae and Invertebrates on Rock Beaches (con't).

SPECIES Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
INVERTEBRATES				
Molluscs				
Littorine snail or Periwinkle (Littorina scutulata)	HERB	SPL,H,M,T		
Periwinkle (L. sitkana)	HERB	SPL,H,M,T		
Dog whelk (Thais emarginata)	CARN	H,M		Edible
Dog whelk (T. canaliculata)	CARN	H,M		Edible
Dog whelk (T. lamellosa)	CARN	H,M	PC	Edible
Dire whelk (Searlesia dira)	CARN	H,M		
(Barleeia haliotiphilla)	HERB	M		
Chink shell (Lacuna variegata)	HERB	M		
Top shell (Calliostoma ligatum)	HERB	M,L,SB		
Margarite snail (Margarites pupillus)	HERB	M,L,SB		
Wrinkled snail (Amphissa columbiana)	SCAV	L		
Smooth velutina (Velutina bevigata)	CARN	L,SB		
Turban snail (Tegula funebralis)	?HERB	M,L		Edible
Northern abalone (Haliotis kamtschatkana)	HERB	L,SB	C,R	Edible
Fingered limpet (Collisella digitalis)	HERB	SPL,H,M		
Mask limpet (Notoacmea persona)	HERB	SPL,H,T		
Shield limpet (Collisella pelta)	HERB	H,M,L,T		
Strigate limpet (C. strigatella)	HERB	H,M,T		
Plate limpet (Notoacmea scutum)	HERB	H,M,L,T		Edible
White-cap limpet (Acmaea mitra)	HERB	M,L,T		
Keyhole limpet (Diodora aspera)	HERB	L,SB		
Slipper shells (Crepidula spp.)	FF	M,L		
Sea lemon (Anisodoris nobilis)	CARN	L,SB		Foot is edible.
Sea lemon (Archidoris montereyensis)	CARN	L,SB		
Jingle shell (Pododesmus macroschisma)	FF	L		
California mussell (Mytilus californianus)	FF	H,M	R,PC	Edible
Bay mussel (M. edulis)	FF	H,M	R,C	Edible; current commercial harvest involving raft culture.

SPECIES Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
Pygmy mussel (Musculus pygmaeus)	FF	H		
Purple-hinged rock scallop (Hinnites multirugosus)	FF	L,SB	R,PC	Edible
Arctic Saxicave (Hiatella arctica)	FF	L,SB		
Flat-tipped piddock (Penitella penita)	FF	M,L		Burrows in rock; can cause considerable erosion.
Pacific oyster (Crassostrea gigas)	FF	M	C,R	Uncommon; found only in protected waters
Leather chiton (Katharina tunicata)	HERB	M,L		
Lined chiton (Tonicella lineata)	HERB	M,L		
Hairy chiton (Mopalia spp.)	HERB	M,L		Eat some animal matter.
Hairy chiton (Cyanoplax dentiens)	HERB	M		
Gum boot chiton (Cryptochiton stelleri)	HERB	L,SB		World's largest chiton
Octopus (Octopus defleini)	CARN	L,SB	R,C	Edible
Arthropods				
Barnacle (Chthamalus dalli)	FF	SPL,H		
Acorn barnacle (Balanus glandula)	FF	SPL,H,M,T		
Horse barnacle (B. cariosus)	FF	H,M,T		
Giant barnacle (B. nubilus)	FF	L,SB		
Gooseneck barnacle (Pollicipes polymerus)	FF	H,M		Edible
Purple shore crab (Hemigrapsus nudus)	SCAV,CARN	H,M		
Kelp or spider crab (Pugettia gracilis)	HERB	L,SB,T		
Northern Kelp crab (P. producta)		M,L,SB		
Hairy cancer crab (Cancer oregonensis)	SCAV-CARN	M,L,SB		
Red rock crab (C. productus)	SCAV-CARN	L,SB	R,PC	Edible
Hairy hermit crab (Pagurus hirsutiusculus)	DETR-SCAV	H,M,T		
Hermit crab (P. granosimanus)	DETR-SCAV	M,L,T		
Transparent shrimp (Heptacarpus spp.)	CARN	L,SB,T	PC	Edible
Green shrimp (Hippolyte spp.)	CARN	L,SB,T	PC	Edible
Pandalid shrimp (Pandalus spp.)	CARN	SB	R,C	Edible
Short spined shrimp (Spirontocaris spp.)	CARN	L,SB	PC	Edible
Gray shrimp (Crangon spp.)	CARN	L,SB,T	PC	Edible

TABLE 631-1. Characteristic Algae and Invertebrates on Rock Beaches (con't).

SPECIES Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
Rock slater (Ligia pallasii)	DETR	SPL		
Isopod (Idotea spp.)	HERB	M,L		
Other isopods	DETR-HERB-SCAV	H,M,L,SB		Numerous
Tanaids	?	H,M,L,SB		Numerous
Gammarid amphipods	DETR-HERB-CARN	H,M,L,SB,T		Numerous
Caprellid amphipods	CARN	M,L		
Insect (Dipteran) larvae	HERB	SPL, H,M		
Echinoderms				
Ochre star (Pisaster ochraceus)	CARN	M,L,SB		Most characteristic starfish
Leather star (Dermasterias imbricata)	CARN	L,SB,T		
Sun star (Solaster stimpsoni)	CARN	L,SB		Eats other starfish
Six-rayed star (Leptasterias hexactis)	CARN	L		
Mottled star (Evasterias troschelii)	CARN	L,SB		
Blood star (Henricia levinscula)	?	L		
Purple sea urchin (Strongylocentrotus purpuratus)	HERB	L,SB,T	PC	Occurs on exposed beaches
Red sea urchin (S. franciscanus)	HERB	L,SB,T	C	
Green sea urchin (S. droebachiensis)	HERB	L,SB,T		One of the longest scientific names of all animals.
Black sea cucumber (Cucumaria pseudocurata)	DETR	M,L		
Red sea cucumber (C. miniata)	DETR	L,SB		Edible
Coelenterates				
Green anemone (Anthopleura xanthogrammica)	CARN-SCAV	L		Contains symbiotic microalgae in its tissue.

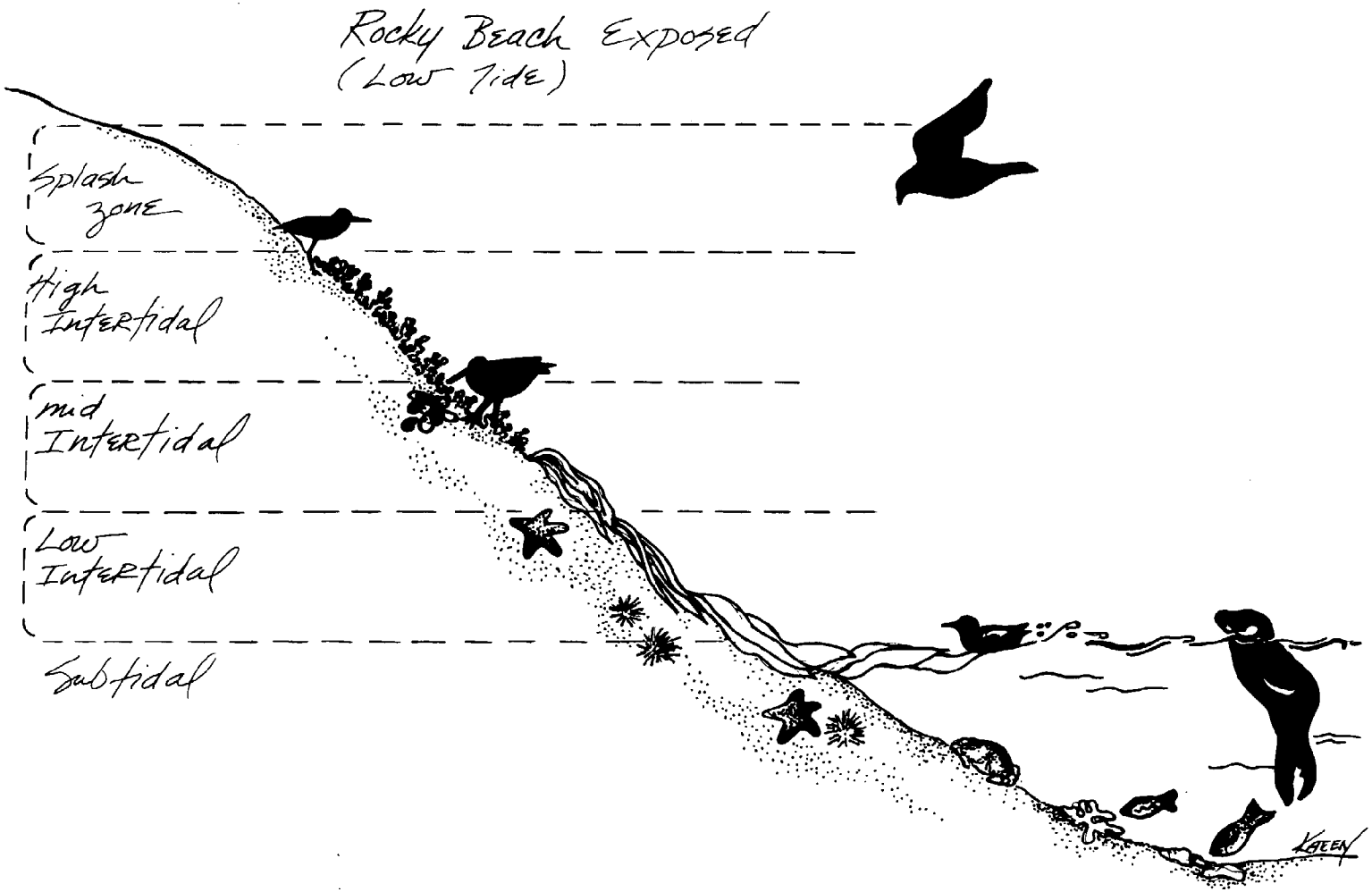
SPECIES Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
Pink-tipped green anemone	CARN-SCAV	M,L		
(A. elegantissima)	CARN	L,SB		
(Tealia spp.)	FF	L,SB		
(Metridium senile)				
Sipunculids	DETR	M,L		
Peanut worm (Phascalosoma agassizii)	DETR	L		
Peanut worm (Themiste pyroides)				In burrows of rock boring molluscs along outer coast.
Annelids	DEP	M,L		
Oligochaetes	FF	L,SB		
Calcareous tube worm (Serpula vermicularis)	FF	L,SB		
Feather duster worm (Endistylia vancouveri)	HERB	M,L	R,PC	
Pile worm (Nereis vexillosa)				Popular for use as fish bait
Nemerteans	CARN	M,L		
Ribbon worms (Emplectonema gracile)				Lives among mussels

Legend:

1. PP = Primary Producer
   FF = Filter Feeder (feeds on plankton and small particles of detritus)
   DETR = Detritivore
   CARN = Carnivore
   SCAV = Scavenger
   HERB = Herbivore

2. SPL = Splash zone
   H = High intertidal
   M = Mid=intertidal
   L = Low intertidal
   SB = Shallow Subtidal
   T = Tidepool
   Underlined zone(s) are zones of greatest abundance

3. Economic Value - R = Recreational
   C = Commercial
   PC = Potential Commerical


Rocky Beach Exposed
(Low Tide)
Splash zone
High Intertidal
mid Intertidal
Low Intertidal
Subtidal
KATEEN

b. upper intertidal zone

This zone still has relatively few species relative to the the lower zone, with a fair amount of empty space due to the patchy distribution of most of the species. Algae becomes more conspicuous than they were in the splash zone. Most common are the red algae Endocladia muricata in the upper portions of the zone, with two species of filter feeding barnacles (Chthamalus dalli and Balanus glandula) dominating. The algae and barnacles provide habitat for numerous small crustaceans (such as isopods, amphipods, tanaids, and small hermit crabs) and insect larvae. Other common animals in this zone include the littorine snails and several species of limpets. During portions of the year, flies (adult dipterans) are abundant on rocky beaches.

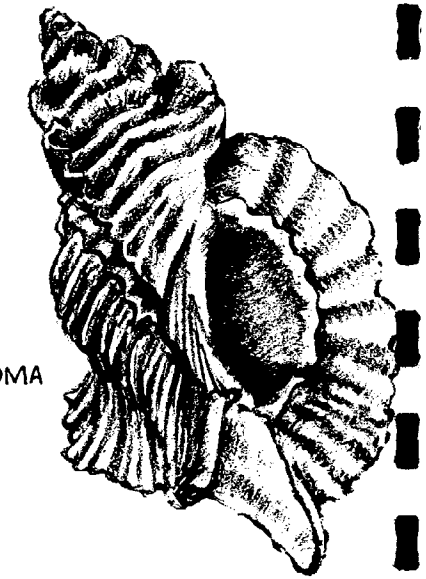
c. mid-intertidal zone

Mussels are a very characteristic feature of the mid-intertidal zone. On exposed beaches the California mussel, along with gooseneck barnacles, invariably dominate this zone. On protected beaches, expecially when the slope of the rock is rather steep, no characteristic bank of mussels occurs due to heavy predatation by starfish (chiefly the ochre star, and the mottle star, and snails Thais spp.). In such situations, algae or barnacles may occupy the space left by the absence of mussels, or there may be large patches of bare rock. In Hood Canal the Pacific oyster often dominates this zone in place of mussels.

Rockweed usually occurs in the upper and middle portions of the mid-intertidal zone, being especially abundant in protected areas. Larger brown algae such as the sea cabbage and honey ware kelp are often present in the lower part of the zone. In highly exposed waters, the lower algae are usually dominated by the kelp Lessoniopsis littoralis or the sea palm, Postelsia palmaeformis. In the middle portions of this zone, sea lettuce may form a conspicuous dark green band. Sea Lettuce, being easily torn by strong waves, does not form the obvious band on exposed shores that it does on more protected shores, where it may replace the large brown algae lower in the zone. Halosaccion glandiforme may also be a dominant alga on exposed beaches.

Both the mussels and algae provide a complex, miniature "forest," which is literally swarming with small invertebrates, expecially small crustaceans. Included among these small organisms are nematodes, polychaetes, oligochaetes, tanaids, isopods, amphipods, insect larvae, a small sea cucumber (Cucumaria pseudocurata), nemertean worms, and peanut worms (members of the phylum Sipuncula).

Other important species present in this zone include herbivorous chitons (Mopalia spp., Katherina tunicata, and Tonicella lineata), coralline algae, barnacles (especially Balanus cariosus and B. glandula), whelks (Thais spp.), and limpets. Anemones (particularly Anthopleura elegantissima) and echinoderms (starfish and urchins) begin to appear toward the lower end of the zone, but are more typical of the lower intertidal.

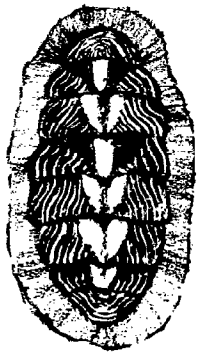


CERATOSTOMA

d. lower intertidal zone

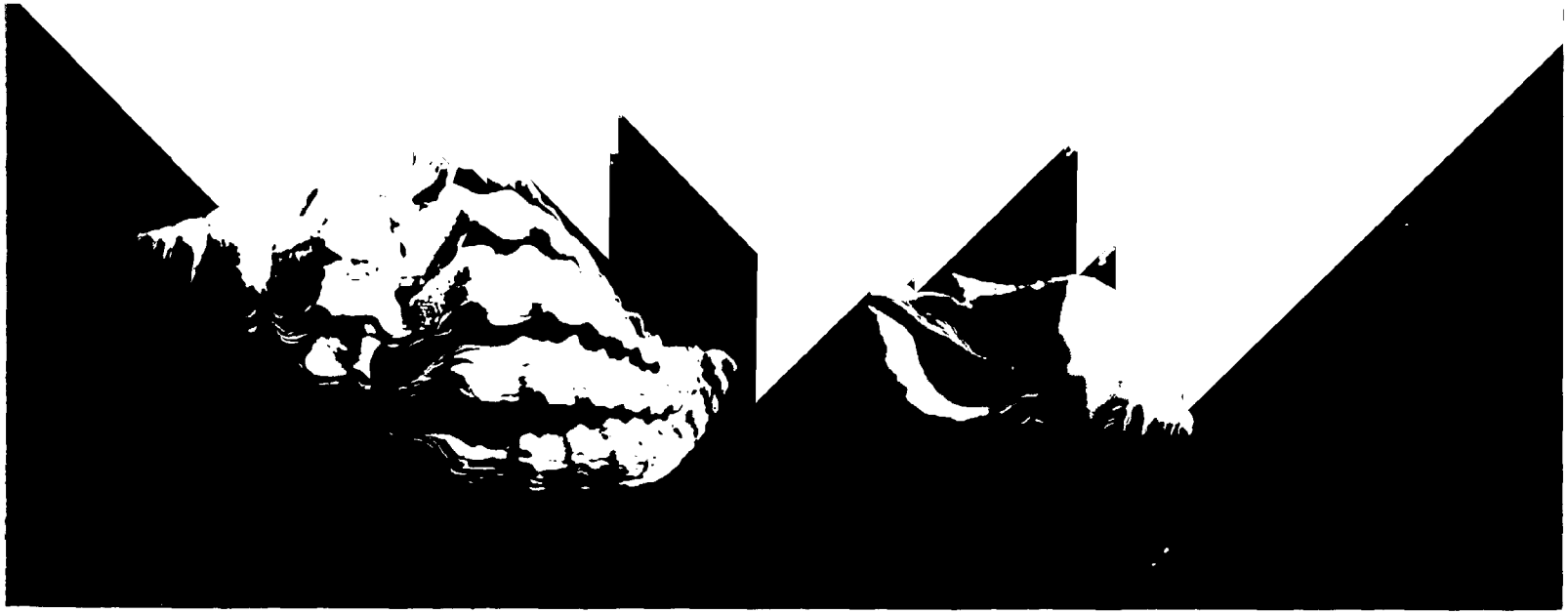
Since the lower intertidal zone is only rarely uncovered by the tides, it is a less stressful environment. As a result, it has the highest diversity in plant and animal life, and fewer fluctuations in populations. Soft bodied animals, which cannot tolerate the exposure to air found in the upper tidal zones, become conspicuous. In addition, many specialized organisms which feed or live on only one species of plant or animal occur, indicating the complexity of this community.

On moderately and highly exposed beaches, the biomass of plants is considerable, due mostly to the presence of kelps. Typical kelps include feather boa, honey ware kelp, searsucker, split whip wrack (Laminaria setchellii and L. groenlandica), and triple rib. Common red algae include Odonthalia floccosa, Rhodomela larix, Gigartina papillata, and Iridaea cordata. Surfgrass is extremely characteristic of the lower intertidal zone.



TONICELLA

In quieter waters, sea lettuce and closely related algae (Monostroma and Enteromorpha) may extend well down into the lower intertidal zone. The turkish tower is also common. In lower portions of the zone, large brown



algae characteristic of quieter waters may begin to appear, although these kelps are more abundant in subtidal areas. These include sugar wrack, seersucker, sea colander, and the sea cabbage. In Hood Canal and southern Puget Sound, the introduced brown alga Sargassum muticum is often the only large algae present in this zone.

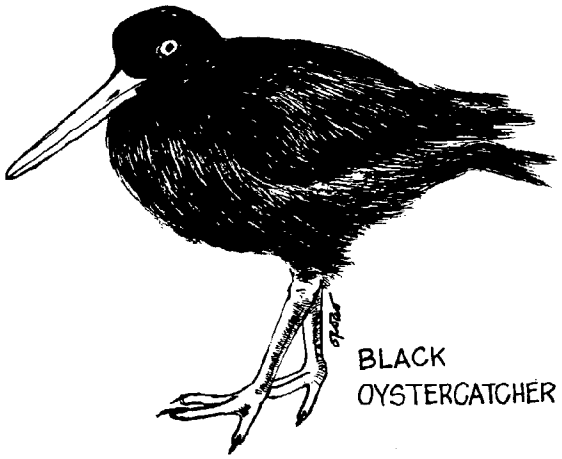
The animals of this zone are characterized by starfish, sea cucumbers, anemones, sea urchins, and certain crabs. Althrough several species of starfish may occur, the ochre star is certainly most typical on both exposed and protected shorelines. Sea cucumbers, especially the reddish-brown Cucumaria miniata, are abundant where boulders and crevices are numerous. Three species of urchins, all herbivores, occur in this zone. Purple urchins are restricted to exposed beaches, while green urchins appear to prefer moderately exposed or protected shores.

Anemones include the green (Anthopleura xanthogrammica) and pink-tipped anemones (A. elegantissima), the former restricted to highly exposed beaches and the latter occurring at either exposed or protected sites. These anemones are unique in that symbiotic microalgae live inside them. Other anemones include members of the genus Tealia, which inhabit moderately exposed and protected shores, and Metridium senile, which predominately occurs on protected beaches. Metridium is a filter feeder, while the other anemones mentioned here are carnivores and scavengers. Common crabs in this zone are the herbivorous kelp or spider crabs (Pugettia spp.) and carnivorous crab Cancer oregonensis. Several types of shrimp (Heptacarpus, Crangon, and Spirontocaris) move into intertidal regions during high tide to forage for food. These shrimp either move offshore at low tide or seek refuge in tidepools.

Other important herbivores include several species of chiton, among them the gumboot chiton reputed to be the world's largest chiton, chink shells, limpets, Margarite's snail, and the top snail. Filter feeding barnacles (Balanus spp.) are sometimes present, and occasional clams especially adapted to burrowing in rock may be present. In some areas these clams are so abundant as to riddle the rock with holes, causing large pieces of rock to be broken off during stormy weather by the battering of floating logs. This can result in greatly accelerated erosion of some beaches.

Other organisms typical of the lower intertidal zone include sea slugs (nudibranchs), sea squirts (tunicates), and sponges.

Below this zone the shallow subtidal zone begins. The most outstanding feature of this zone is the presence of the larger kelps (bull kelp, giant kelp, and pompon kelp), especially on moderately to highly exposed beaches. As this area is never uncovered by tides, it is the least stressed area, and thus has a more diverse, complex community.



Birds and Mammals

a. exposed intertidal zones

Rocky intertidal areas provide feeding substrate for a number of species, (see Table 63-2, Characteristic Species for all Beach Substrates) many of which are essentially restricted and highly adapted to feeding here. Gulls forage on exposed rock beaches in tide pools and among algae covered rocks. Great Blue Herons feed in tidepools and perch on rock or kelp, snatching sculpins and other fish from the water.

Crows are common throughout the beaches of Washington, but a relative, the Raven, has a much more restricted range. Ravens are more wary than crows, and are restricted primarily to the San Juans, Strait of Juan de Fuca, and outer coast. They are larger than crows, have thicker bills and a distinctive wedge-shaped tail. Along rocky shores, they scavenge like the crow, but are generally seen only in small numbers. Ravens require a large breeding territory which may cover more than 2,000 acres.

Rocks exposed at low tide are also used as rest sites by many species, including harbor seals and sea lions. Other aquatic and terrestrial mammals forage along exposed rocky beaches. Raccoons, mink, and skunks, are among the more typical examples. Terrestrial birds, including Winter Wrens, Fox Sparrows, Savannah Sparrows, and Song Sparrows, also forage among rocks and algae exposed by falling tides.

Shorebirds are much more dependent on exposed rock beaches than these terrestrial species and include some of our most uncommon and unusual birds such as:

Black Oystercatcher o

Black Oystercatchers feed primarily on rock substrate in the mid-intertidal zone where mussels are a preferred food item. The long, chisel-like bill of the oystercatcher is inserted between the valves of the mussel, cutting the adductor muscle to expose an otherwise difficult to remove source of food. This feeding method is not used by all oystercatchers, however, some hammer the thin shell of the edible mussel until it breaks. Other food of Black Oystercatchers includes limpets, chitons, small crabs, snails, and isopods.

Oystercatchers breed along isolated rocky beaches just above high tide line, Washington breeding populations being estimated at 250-300 birds. Breeding sites have been located only on small islands, although major winter areas and feeding habitat are more widespread. These winter locations include

several mainland sites such as at Tongue Point in Clallam County and on main San Juan islands such as along the south shore of Lopez Island.

Black Turnstone o

The Black Turnstone is another of the shorebirds associated with rocky shores. Turnstones are named for their habit of turning over stones, pieces of algae and shore debris under which they snatch invertebrates seeking a moist refuge during low tide. A study on Destruction Island indicates that much of the turnstone's feeding activity occurs among the rockweed (Fucus distichus) in the mid-intertidal zone. Other shore birds which feed primarily on rocky substrates and are often found together with turnstones are Rock Sandpipers, and Surfbirds.

b. submerged intertidal and shallow subtidal

Large numbers of birds move in with the tide to feed over the submerged rocky intertidal. They also feed in adjacent subtidal areas and are especially abundant when kelp is present [see Kelp Narrative (No. 628) for more information]. Predators, including Bald Eagles and the rare Peregrine Falcon are attracted to concentrations of marine birds along rocky shorelines where undisturbed conditions are critical for them to maintain breeding sites. Examples of other species using submerged rocky shores include:

Bufflehead o

The Bufflehead, also called "spirit-duck" or "butterball" is a common bird throughout western Washington on fresh and salt water. This exuberant member of the duck family (Anatidae) might be seen in the smallest farm pond, in a sheltered bay, or along rocky shores where it dives among kelp plants and within the protected waters shoreward of floating kelp beds. The tiny female might fit in your hand and the male is only slightly larger. He has a white patch on his dark head which on close examination reveals a glossy array of greens and purple. The head feathers are often erected as the males actively court gray and black feathered females. They seem always to be courting, swimming toward one another with chin up, then chasing, then diving together in small flocks. Diving for food which includes amphipods, shorecrabs, and mysids is most often interrupted by a continued bout of play.

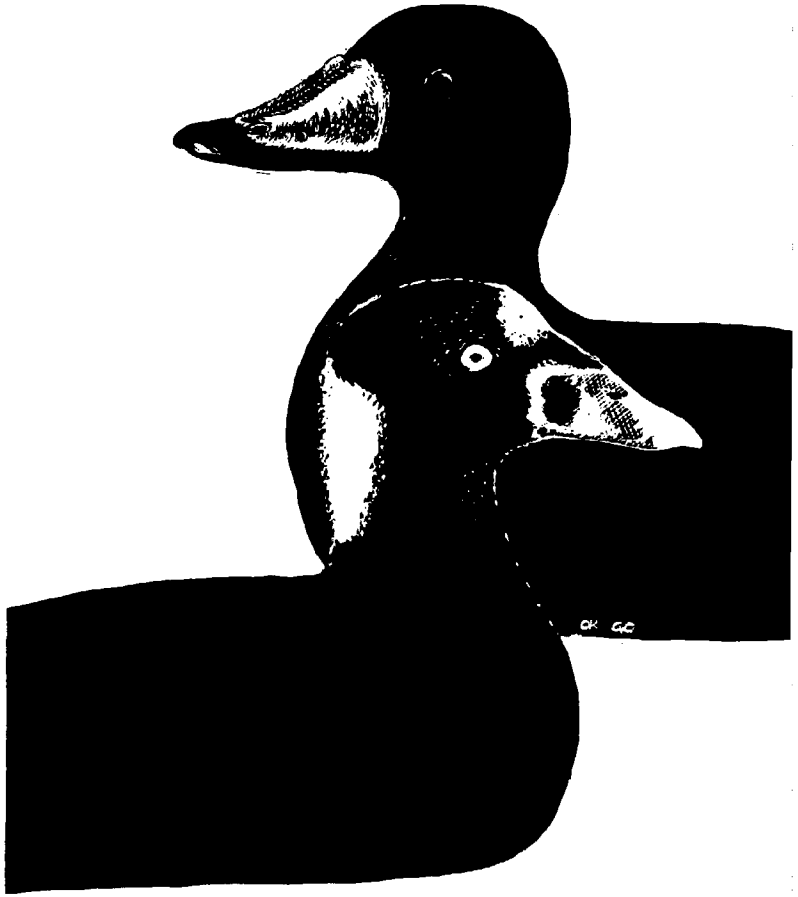
Surf Scoter o

Also known as patchhead, sea coot, surf duck, skunkhead, mussel bill, King coot, and bald-headed sea coot, the Surf Scoter is a very impressive and somewhat maligned diving duck. Although more partial to eelgrass than its relative, the White-winged Scoter,

animal food remains its most important prey. Molluscs, primarily bivalves, are the Surf Scoters primary food source. They do feed on commercial species such as little-neck clams, however, food habits studies reveal that most items taken are noncommercial species. In rocky intertidal areas their food consists almost entirely of noncommercial species including barnacles, littorine snails, chitons, and starfish.

Black Scoter o

Black Scoters are the least common of the three scoters which occur in Washington. Ironically, they were once known as the "Common" scoter. Throughout the coastal zone they might be found diving in somewhat deeper water than their two more abundant relatives. However, in rocky areas they tend to feed quite close to shore. Several other deep-water species also are often seen closer in along rocky shorelines. These same animals are only seen further out, sometimes far offshore, in more protected waters. A partial explanation for this is that rocky intertidal areas typically have steeper profiles. Thus, deep water where Black Scoters forage is nearer to shore. This is especially understandable for larger animals such as killer whales which are able to skirt the shoreline along rocks, while only being physically able to swim in deep offshore waters within shallow bays of Puget Sound.



Another reason birds and mammals feed closer to shore along rocky intertidal areas is the extremely rich and diverse fish and invertebrate community which is concentrated along a fairly narrow band nearshore. Bottom feeders such as the Black Scoter must feed within the intertidal and shallow subtidal, not being able to dive much deeper than the outer margin of kelp beds. Prey of this scoter in rocky areas reflects the diversity of prey available and includes mussels, littorines and other snails, limpets, slipper shells, chitons, barnacles, and sea urchins.

Pelagic Cormorant o

The Pelagic Cormorant is one of several marine diving birds not restricted to feeding on the bottom. Pelagics are the smallest of three cormorants of Washington waters. Sometimes called shags, these long-necked, black birds are capable of extremely deep dives. They have highly wettable contour feathers,

sleek bodies, and webbed feet which allow them to pursue fish in waters as deep as 120 feet. They often feed in shallows along rocks and kelp beds, however, and perch on rocks or pilings with wings spread to dry. They nest in the San Juans and along the outer coast on steeper cliff faces than other cormorants. Nest ledges are often so narrow that the birds cannot turn around and must land and take off facing the cliff. They also roost on ledges or rock islands, thus they are not as vulnerable to oil spills as are grebes and alcids and other birds which roost on water at night.

Although capable of deep dives, Pelagic Cormorants have been found to feed closer to shore and take shallower dives while in deep water than Brandt's Cormorants and several other diving birds. This allows each species to forage in somewhat separated zones and maximize feeding success. At other times, several species will all fly off to a concentrated area offshore where schooling fish are preyed upon in a mixed frenzy. These feeding assemblages are well advertised by screaming gulls and are signals to alert salmon fishermen that something is going on below the surface that they might be interested in. Pelagic and other cormorants, murres, auklets, grebes, and gulls might all participate as will seals and salmon. Feeding continues until the schools of fish are scattered. The birds quiet down and perhaps fly to another flock of screaming gulls. If all is quiet, the Pelagic Cormant often returns to a feeding area inside the margin of a kelp bed along a rocky shore.

River Otter o

River otters occur throughout Washington, but reach their highest densities in marine areas where they are often mistaken for sea otters. Any otter in salt or freshwater seen east of Cape Flattery is a river otter, and while both species occur along the outer coast, the river otter is far more numerous throughout the range of overlap. A smaller relative of the sea otter, river otters have longer tails, sleeker bodies, and swim with a lower profile than the sea otter. River otters move freely between freshwater and marine areas, maintaining small, but critical "landings" along lakes, streams, and marine shores. Along rocky beaches otters spend most of the year in marine areas, feeding nearshore and periodically coming ashore at their traditional landings and den sites. Landings are often located on rock outcrops, islets, or at a point where beach substrate changes abruptly such as at the mouths of small pocket bays in the San Juan Islands.

Rocky intertidal areas adjacent to shore landings provide a rich feeding area for otters in a concentrated area close to other habitat requirements. Otter densities are highest along rocky shorelines such as in the San Juans and unusually high numbers of otters are often seen together in these areas. Over most of its range in North America, the river otter occurs singly or in small family groups of two to five. In the San Juans as

many as 12 otters have been observed together, suggesting that river otter social organization may be much different in marine areas.

Unlike the sea otter, river otters prey mostly on fish, including rockfish, sculpins, herring, and blennies. Invertebrate prey in rocky areas includes small numbers of purple shore crabs, kelp crabs, mussels and possibly abalones. On sea bird nesting islands, they have also been known to prey on eggs and chicks of gulls and petrels.

Because they live at the edge of the sea, river otters, like Bald Eagles, nesting sea birds, and Peregrine Falcons, are particularly vulnerable to shoreline development. Several critical areas are mapped in the Coastal Zone Atlas, however, all rocky shorelines are potentially critical otter habitat and should be maintained as valuable natural areas. If we preserve rocky shoreline suitable for otters, we can be ensured of a healthy marine environment for other coastal predators, their prey, and ultimately for ourselves.

Fish

Above surface, there are few year-round vertebrate residents of the rocky intertidal. River otters, Pigeon Guillemots, and Glaucous-winged Gulls occur throughout the year, but most birds and some marine mammals are migratory. Thus, many birds will be extremely numerous during migration and conspicuously absent during summer months.

Below the surface, however, the fish community associated with rocky intertidal beaches is largely residential and nonmigratory. Movement between adjacent subtidal and intertidal areas occurs daily for many fish, much of the time being spent in deep waters. Onshore movement occurs at high tide when fish move in to the intertidal to feed. Fish restricted to the intertidal are small tidepool species including sculpins and blennies.

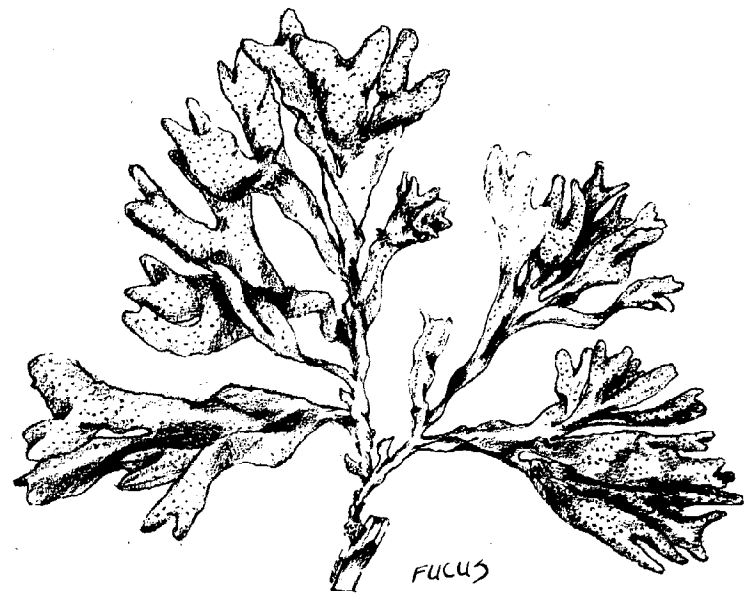
Ledges and crevices increase structural diversity in rocky areas and offer numerous hiding places and refuges for eggs, juveniles and adult fish. Since kelp beds are often present, resident fish are distributed vertically as well as horizontally along rocky shores. Thus, some species prefer the canopy layer of kelp beds while others occur primarily along the slopes or on the bottom. Other fish prefer small patches of sandy substrate between rocks. Migratory fish, such as herring, salmon, and sand lance, occur periodically, sometimes in large numbers and often during both juvenile and adult stages. This is the case for herring, which occur as larvae in early spring and later as juveniles in early summer and into the

fall. Outmigrating chinook salmon are present from late spring to early fall, while adults weighing twenty to over sixty pounds are often caught along rocky shores in late summer. Some of the most popular sports salmon fishing sites in Washington include the rocky shores at Pillar Point, near Neah Bay, Sekiu, and in the San Juan Islands. Examples of rocky shore fish include the following (see Table 613-2 for a more complete list):

Kelp Greenling

The most common large, resident fish along rocky shores is the kelp greenling. These smaller relatives of the lingcod are solitary, and as their name suggests are associated with, but not restricted to kelp beds. They are very beautifully marked fish, and have been mistakenly called rocktrout and kelptrout. Formerly known "officially" as the Chirus, they were perhaps best described by J. K. Lord in the mid-1800's as follows: "THE CHIRUS.....a handsome shapely fish, about 18 inches in length. Its sides, though somewhat rough, rival in beauty many a tropical flower; clad in scales, adorned with colours not only conspicuous for their brilliancy, but grouped and blended in a manner one sees only represented in the plummage of a bird, the wing of a butterfly, or the petals of an orchid, this 'ocean swell' is known to the ichthyologist as the Chirus- the Terpush (a file) of the Russians - the Idyajuk of the Aluetian Islanders - the Tath-le-gest of the Vancouver Islanders."

"...to give the faintest conceptions of the colourings that adorn the Chirus red, blue, orange, and green are so mingled, that the only thing I can think of as a comparison is a floating flower-bed, and even the gardener's art, in grouping is but a bungle contrasted with Nature's painting!"



Beautiful as well as tasty, the kelp greenling is seldom caught by commercial fishermen. They are, however, among the many species of rock inhabitants enjoyed by sports fishermen. Prey of the kelp greenling include amphipods, clams and clam siphons, snails, crabs and small fish. Other than man, they are preyed upon by lingcod, harbor seals, river otters, salmon and steelhead. Juveniles spend a portion of their lives in deeper offshore waters before migrating to nearshore rocky areas where, as adults, they remain throughout the year. Predation by salmon apparently occurs when juveniles (one to three inches) are in offshore waters. Sports fishing and predation by other species mentioned occurs primarily in nearshore waters.

Lingcod

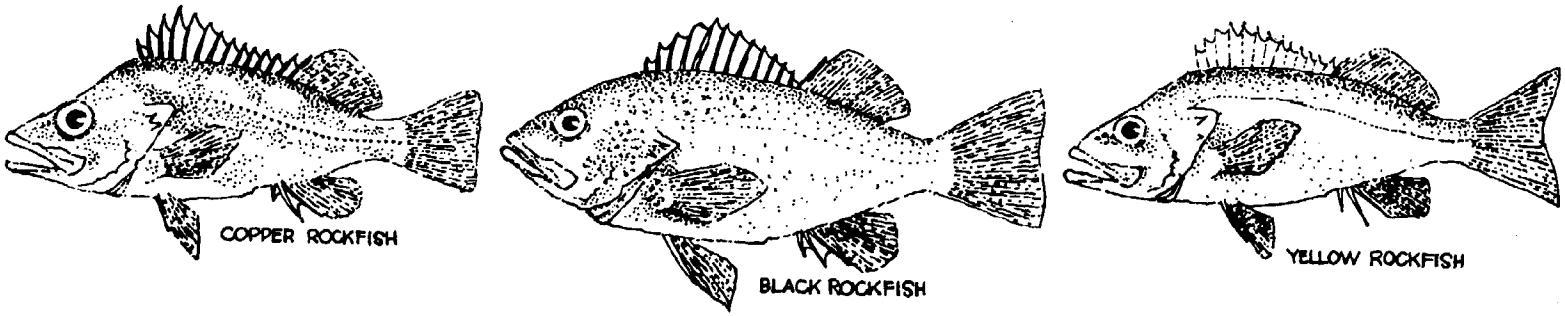
The lingcod is one of the most highly prized nonsalmonid fish. These large (length to five feet) relatives of the kelp greenling are fished commercially and by sports anglers and divers. Unfortunately, the high demand for lingcod has seriously depleted populations in Puget Sound and Hood Canal. Fishing closures are now in effect and efforts are being made to reestablish depleted areas with transplants of lingcod. They are not restricted to rocky areas, however, lingcod in nearshore rock habitat are especially vulnerable to overfishing since many adults are nonmigratory. The strong attachment to one site has been demonstrated by tagging studies in which lingcod have been recaptured in the same location 12 years later. Other fish have been tagged, moved as far as six miles and recaptured at the original point of tagging.

Adult males are particularly vulnerable since they are more often found nearshore than females. Males are also the guardian of nests which are located in rock crevices or beneath overhanging rocks extending from the intertidal to at least 62 feet below low tide. A study in Seattle found that the majority of nests were above the -25-foot level (relative to mean lower low water) and several (ten of 74) were within the intertidal. When the adult male is taken by a spearfisherman or by hook and line, the eggs are then vulnerable to predators.

Prey of the lingcod includes a wide variety of fish including herring and sand lance which occur periodically in rocky areas. Rockfishes have been identified as a primary prey and lingcod are also cannibalistic, a fact which may suppress the movement by younger lingcod into rocky areas. Other prey include squid, octopus, snails, crabs, shrimps, and flatfish. Juvenile lingcod feed extensively on copepods and other small crustaceans.

Rockfish

The term "rockfish" applies to a group of fishes within the family Scorpaenidae represented in Washington by approximately 35 species in the genus Sebastes. Also known as "rockcod," this group is quite diverse and not all are restricted to rocky areas. Some of the more common species within rocky areas are the copper rockfish, black rockfish, and the yellowtail rockfish.



Rockfish are very important to both commercial and sports fisheries. For example, catches by commercial draggers in 1977, yielded over 28,600 pounds and an estimated catch of over 90,000 fish were taken by sports fishermen in that same year. Increased fishing pressure has stimulated research into the management of this important group of fish. This research has pointed out many different habitat requirements, food habits, and behavior within the group. Thus, black rockfish are schooling fish which tend to move seasonally between deep and shallow nearshore areas along the same stretch of shoreline. Copper rockfish are solitary and have been observed to leave the nearshore environment along rocky shores in fall and winter. Such differences require differing fishery management strategies, and perhaps more importantly, point out the complexity of assessing impacts within rocky areas. Each species has adapted to a particular range of habitat requirements, occuring at different depths, seasons, substrates, and requiring different prey as well as many other subtle needs. Overfishing alone has been known to be detrimental to some fish (e.g., lingcod), therefore, we must carefully evaluate the effects of all our activities so that we maintain biological diversity as reflected in the genus Sebastes, the rockfishes.

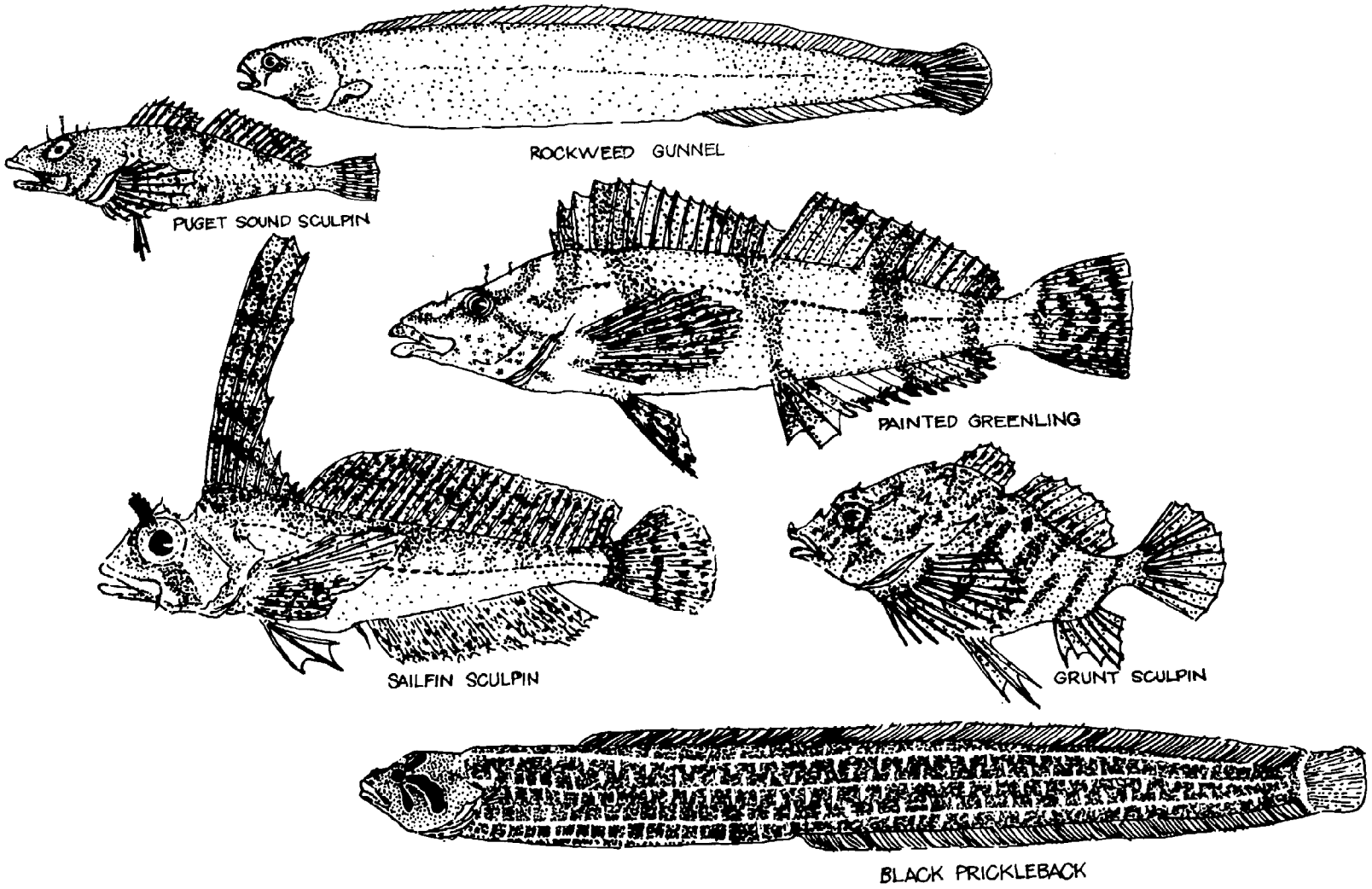

ROCKWEED GUNNEL
PUGET SOUND SCULPIN
PAINTED GREENLING
SAILFIN SCULPIN
GRUNT SCULPIN
BLACK PRICKLEBACK

Table 631-2
Characteristic Fish of Rocky Shores

Common Name	Scientific Name	Economic Value	Comment
Spiny dogfish	*Squalus acanthias*	C	
Ratfish	*Hydrolagus colliei*		
Pacific herring	*Clupea harengus pallasi*	C,R	Valuable baitfish
Pink salmon	*Oncorhynchus gorbuscha*	C,R	Salmon are frequently fished
Coho salmon	*O. kisutch*	C,R	nearshore off
Chinook salmon	*O. tshawytscha*	C,R	rocky shores
Northern anchovy	*Engraulis mordax*	C	Populations reduced
Eulachon	*Thaleichthys pacificus*	C,R	Also called candlefish
Threespine stickleback	*Gasterosteus aculeatus*		
Tube-snout	*Aulorhynchus flavidus*		
Shiner perch	*Cymatogaster aggregata*	R	
Striped seaperch	*Embiotoca lateralis*	C,R	
Pile perch	*Rhacochilus vacca*	C,R	
Northern clingfish	*Gobiesox maeandricus*		
Mosshead warbonnet	*Chirolophis nugator*		
Decorated warbonnet	*C. polyactocephalus*		
Ribbon prickleback	*Phytichthys chirus*		
Black prickleback	*Xiphister atropurpureus*		
Penpoint gunnel	*Apodichthys flavidus*		
Rockweed gunnel	*Xererpes fucorum*		
Wolf-eel	*Anarrhichthys ocellatus*		
Pacific sand lance	*Ammodytes hexapterus*	R	Eaten by many fish, birds, mammals
Blackeye goby	*Coryphopterus nicholsi*		
Silvergrey rockfish	*Sebastes brevispinus*	C,R	Rockfish are valuable
Copper rockfish	*S. caurinus*	C,R	commercial and recreational
Puget Sound rockfish	*S. emphaeus*	C,R	fishes. Sport catch alone

R = Recreational
C = Commercial

Table 631-2 (Continued)

Common Name	Scientific Name	Economic Value	Comment
Yellowtail rockfish	S. flavidus	C,R	estimated to be over 90,000 fish in 1977. Northeastern Pacific Coast commercial catch in 1976 over 126,000 metric tons. They are often referred to as rockcod.
Quillback rockfish	S. maliger	C,R	
Black rockfish	S. melanops	C,R	
Vermilion rockfish	S. miniatus	C,R	
China rockfish	S. nebulosus	C,R	
Tiger rockfish	S. nigrocinctus	C,R	
Canary rockfish	S. pinniger	C,R	
Redstripe rockfish	S. proriger	C,R	
Kelp greenling	Hexagrammos decagrammus	R	
Whitespotted greenling	H. stelleri	R	
Lingcod	Ophiodon elongatus	C,R	Highly prized
Painted greenling	Oxylebius pictus		
Scalyhead sculpin	Artedius harringtoni		Sculpins are a diverse group - Many are prey of several birds, mammals, and other fish. They are also referred to as bullheads.
Puget Sound sculpin	A. meanyi		
Spinynose sculpin	Asemichthys taylori		
Buffalo sculpin	Enophrys bison		
Red Irish lord	Hemilepidotus hemilepidotus		
Northern sculpin	Icelinus borealis		
Longfin sculpin	Jordania zonope		
Great sculpin	Myoxocephalus polyacanthocephalus		
Sailfin sculpin	Nautichthys oculofasciatus		
Saddleback sculpin	Oligocottus rimensis		
Grunt sculpin	Rhamphocotlus richardsoni		
Cabezon	Scorpaenichthys marmoratus	C,R	
Manacled sculpin	Synchirus gilli		
Northern spearnose poacher	Agonopsis emmelane		
Smooth alligatorfish	Annoplagonus inermis		
Speckled sand dab	Citharichthys stigmaeus	R	In patches of sand

R = Recreational
C = Commercial

unusual/rare/little known species

Many fish are unfamiliar to Washington residents simply because they occur beneath the water's surface. Other species are lumped into a large category such as "rockfish" because they appear to be one kind of fish. Commercial marketing practices do not help this situation since one never knows if "cod" in the package of fish in fish and chips is Pacific cod, copper rockfish, lingcod, or ? .

Other fish are simply uncommon, rare, or are so small that they are unnoticed by most people. Among the latter are several species which inhabit rocky shores and include the following:

Mosshead Warbonnet o

This four- to five-inch fish is a member of the family Stichaeidae, a group often mistakenly called eels. They occur under rocks at low tide within the intertidal.

Black Prickleback o

A relative of the warbonnets, the black prickleback grows to 12 inches and also occurs under rocks at low tide.

Rockweed Gunnel o

Gunnels are similar in appearence to the warbonnet and prickleback, but are within another family, Pholidae. As its name implies, the rockweed gunnel inhabits the Fucus, or rockweed zone within the intertidal.

Painted Greenling o

Relative of lingcod and kelp greenling, the painted greenling grows to ten inches. They hang vertically along steep rocky areas.

Puget Sound Sculpin o

A member of the large family of sculpins, Cottidae. Length to two inches, this small fish occurs from Port Orchard to Queen Charlotte Sound in British Columbia.

Sailfin Sculpin o

The sailfin sculpin is a small (length to eight inches) nocturnal species which swims mainly with its long dorsal fin. They have been observed hanging upside down along the roof of a rock crevice with the long fin extending in front of the head. They are known to eat crustaceans.

Grunt Sculpin o

When taken out of water, these three-inch sculpins grunt and hiss, hence the name, grunt sculpin. They are known to eat barnacle larvae. The long pectoral fins are used to crawl over rocks and seaweed.

Northern Spearnose Poacher o

The scales of poachers are replaced by rows of plates with spines, which create a very rigid outer structure. They occur on mud bottoms, but have been observed in rocky areas.

Use by Man

Historical Changes and Trends

Pacific Northwest Indians living adjacent to the coast relied heavily on food from marine waters. Approximately 40 species of shellfish and other invertebrates were used as food, many of which occur in rock beaches. The reliance on salmon, halibut, whales, and/or candlefish was so overwhelming it strongly dominated cultural development.

Since they first came to the Pacific Northwest, non-Indians have used rock beaches heavily for commercial fishing. Other activities, such as agriculture, industry, and construction of homes, tended to occur in protected waters where rock beaches only rarely occur, protected waters being more suitable for shipping related activities.

In the last 40 years, land transportation has developed to the point where formerly remote, exposed beaches are accessible from the land. As a result, activities such as logging and home construction have increased tremendously in the uplands adjacent to rock beaches.

Recreation Value

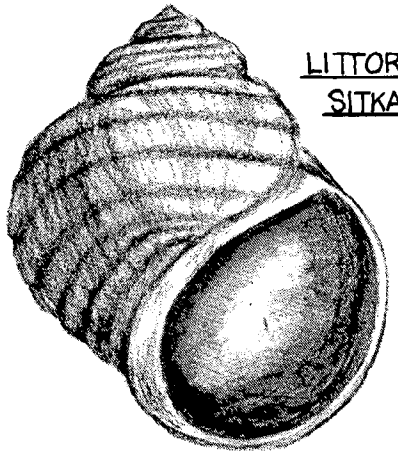
Rocky shores, especially in moderately or highly exposed situations, have an extremely high recreational value. Their rugged, untamed nature provides a strong attraction for people who do not normally encounter the awesome power of the sea. The high diversity of plant and animal life also makes these areas desireable for nonconsumptive appreciation of wildlife. As mentioned earlier, a plethora of birds

and mammals can be observed including such rare or unique species as Bald Eagles, Peregrine Falcons, Harlequin Ducks, Black Oystercatchers, Ravens, river otters, and occasionally grey whales and killer whales.

What is perhaps most unique about the rocky intertidal is that invertebrates are readily visible, unlike gravelly, sandy, or muddy beaches, and can be easily appreciated by many people. Several books have been written on the plants and animals occurring along Washington's coastline, with a definite emphasis on rocky beaches, where organisms are most easily observed. Tidepooling has become a popular activity and has been the subject of many magazine articles and pictorials. Photography is also popular, especially during periods of bird or whale migrations. For many people, just viewing the waves splashing against the rocks against the backdrop of a magnificent sunset is worth driving many miles to see.

The visibility and accessibility of organisms have also attracted a large number of scientists to study varying aspects of rocky intertidal communities. Rock beaches are by far the best studied beach type in Washington, and many of the basic principals of coastal ecology were first discovered studying rocky shores. Since they are so conducive to study, it is certain that continued work in the future will strongly mold our understanding of man's relationship with the entire coastal zone.

Rocky intertidal areas are also excellent educational facilities for students, providing an "open air classroom" where students can view many of the processes shaping the community. Many colleges and universities in Washington have marine laboratories located adjacent to rock beaches, and most other colleges and universities, and many high schools, offer classes in marine biology which feature field trips to rocky intertidal areas.



Although many of the plants and animals found on rocky shores are edible, relatively few species are collected as sources of food. Most notable are fishes, abalone, scallops, red rock crabs, oysters (when present), and occasionally shrimp, mussels, and sea cucumbers. Several of the fishes associated with rocky shores are highly sought by sport fishermen; salmon, many species of rockfishes, sea perch, kelp greenling, and lingcod are most popular.

Commercial Value

Most species of commercial value support only limited fisheries at present, and nearly all these are species predominately associated with shallow subtidal areas just offshore from the rocky intertidal. Included are urchins (whose gonads are considered a delicacy in Japan), octopi, rockfish, abalone, and scallops.

Adult salmon, which feed along rocky shores as juveniles, are commercially fished in shallow subtidal areas during migrations to their spawning areas. Herring, which use vegetation on rock and other beaches as a substrate for attachment of their eggs, also support commercial fishery in Washington. Intertidally, there are a few cases in Hood Canal where the Pacific oyster is abundant on protected rock beaches. In at least one of these areas (Pulali Pt. in Jefferson County) these oysters are commercially harvestable. In addition, a limited industry has existed in the past involving the sale of invertebrates (starfish, urchins, chitons, snails, and crabs) as curios. This industry is apparently extremely small or nonexistent at present. River otters which often rest and feed along rock beaches, are trapped commercially for their fur. Raccoons and mink, which occasionally forage on rocky shores are also trapped.

Several species of potential economic importance occur on rock beaches, including many species of algae (e.g., kelps, Iridaea, and Gigartina; see Class Nos. 628 and 629). Animals of potential value include welks (Thais spp.), mussels, limpets, goose barnacles, rockfishes, sea perch, large sculpins, rock crabs, shrimp, and sea cucumbers.

The greatest contribution of rock beaches, economically, is through indirect pathways. Increasing evidence on the high productivity of plants on rock substrates makes it apparent that most of the primary productivity is used through detrital food pathways. This pathway reaches large numbers of commercially valuable species, most of them eventually harvested in other areas. In addition, species such as juvenile salmon and herring are consumed by larger fish and birds after they leave rocky intertidal areas.

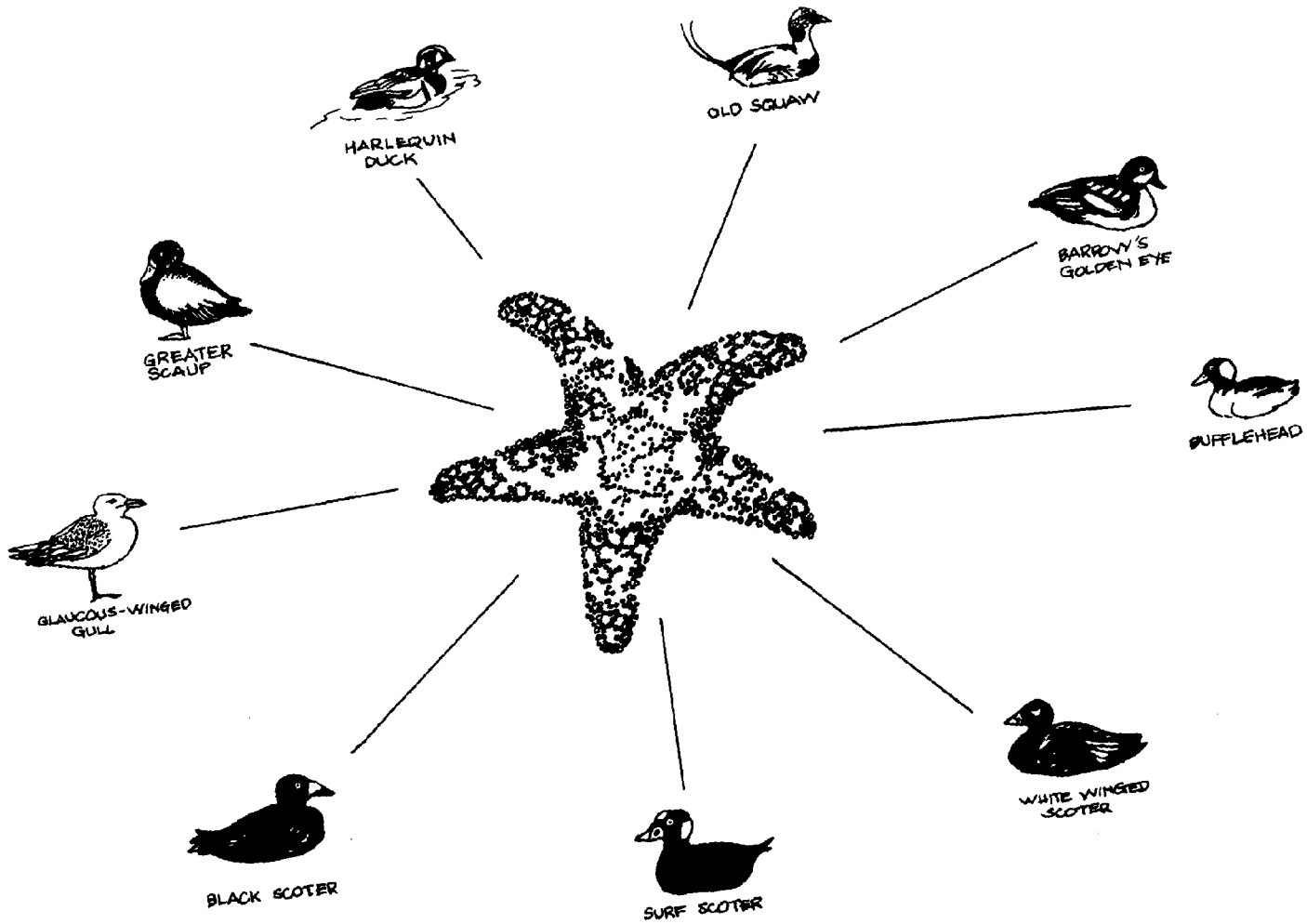
III. IMPACTS

Increased human activity on or adjacent to rock beaches, including intensive recreational use, tends to impact use of these beaches by extremely sensitive types of wildlife. Among these sensitive species are Bald Eagles, Peregrine Falcons, river otters, harbor seals, and sea lions. The species most sensitive are those which occur predominately only on rock beaches, such as Black Oystercatchers and Surfbirds.

Species such as the Bald Eagle, which use the interface between the uplands and the rock beaches are additionally impacted by the altering of adjacent upland areas. Development of these adjacent uplands can also severely limit recreational use of rock beaches by humans. Certain types of development destroy the esthetic value many persons attach to moderately or highly exposed rock beaches, while some types of development simply remove beaches from public access.

Intensive recreational use of rock beaches can also have other impacts, especially when the participants want to take home a few souvenirs from the beach. In the past, this amateur collecting has led to such severe depletion of certain organisms, that one would be hard pressed to find more than a few snails, and virtually no starfish, urchins, or chitons, on popular beaches. Collection of oganisms for commercial sale was a contributing factor to this depletion, although not to as great a degree. The problem became so severe that on some beaches in the states, signs have been posted forbidding the collection of any organisms. The Washington State Department of Fisheries requires anyone (even scientists) collecting nonfood organisms to obtain a special collector's permit, so the amount of collecting can be controlled. When overcollected, it can take many years for a beach to fully recover to its former state (if it ever does). Collection of certain "key" species, such as urchins or starfish, can result in the structure of the entire community being drastically altered.

STARFISH PREDATORS



To illustrate how sensitive rocky beaches can be, consider the small littorine snails. Many people walking over the shoreline will undoubtedly crush large numbers of snails without even realizing it. On popular beaches, the numbers of these snails can be drastically reduced. Yet these small snails are consumed by a large number of organisms (see Figure 631-4), all of which lose part of their food source when the snails are destroyed.

Another recreational activity that is impacting sensitive wildlife species is recreational boating. The impact is significant in areas such as the San Juan Islands where boating is exceptionally popular. Industrial pollutants actually pose the greatest threat to intertidal communities, however, as their impacts may reach over large areas. Most of these were discussed under Class No. 63 - Beach Substrates, as they apply to all types of substrates.

Logging activities, especially transport and storage of logs in marine waters or rivers, can cause a special type of impact on rock communities. Floating logs are often bashed against rock beaches during winter storms with such force that the organisms in the impacted area can be essentially scraped off the rock substrate. This occurs frequently enough that any particular spot on a moderately exposed beach on San Juan Island was found to have a 5 to 30 percent chance of being struck during a three-year period. Once a clearing is made, wave action can considerably enlarge its size. Up to 50 percent of the logs in the areas were cut, thus having originated from some type of logging or clearing activity, while for another 35 percent of trees the origins could not be determined. While this "denuding" of rock by logs is also a natural phenomenon, it appears to have been substantially increased through human activity. Succession appears to begin immediately in these cleared areas. In more remote areas, it was found that the number of logs resulting from human activity was greately decreased.

Any type of mining operation on rocky beaches will essentially destroy the plants and animals dependent on that particular beach. This includes impacts on animals which normally would migrate into the area to feed, and secondary impacts on organisms dependent upon the primary production of rock beaches. Possible reasons for mining are mineral extraction, or rock or gravel removal. However, these activities are currently confined to upland areas, and mining activity does not currently threaten rock beaches.

COBBLE (No. 632)

I. INTRODUCTION

This beach type consists primarily of uniform-sized cobbles between 2.5 and 10 inches (6.4 - 25.6 cm.) in diameter. Some sand or gravel may also occur on portions of the beach, or in some cases even cover the cobble seasonally, especially in the high intertidal zone.

A key feature of this beach type is wave energy strong enough to frequently roll the cobble about. These usually smooth cobbles have no (or very few) plants or animals (most notably barnacles, mussels, and algae) attached year-round. Cobble beaches are restricted to rather exposed sites, and are infrequently encountered.

In the lower intertidal portion of many beaches composed primarily of cobble, wave action is not as severe as in the mid- and high-intertidal, and cobble is not moved about appreciably. As a result, sand is present in these low areas, and algae and invertebrates appear on the surface of the cobble. The lower intertidal is more typical of a mixed coarse beach in this case (see Narrative No. 633), and far more productive than strictly cobble beaches. Examples of such beaches occur near Cherry Point in Whatcom County and Morse Creek in Clallam County. The Morse Creek cobble beach and others along the Strait of Juan de Fuca such as at Twin Rivers are influenced by the presence of a stream, with cobbles forming the major portion of the deltas.

II. SIGNIFICANT BIOLOGICAL FEATURES

Cobble beaches support species poor communities, with low densities of organisms, as well as low biomass. Shifting of the cobble as a result of wave action makes survival extremely difficult for algae and benthic invertebrates, and is responsible for the lack of organisms on the cobble surfaces, as well as the absence of clams. The dominant invertebrates are flatworms and amphipods (see Table 632-1). As a result of the impoverished benthic community, numbers of bottom-feeding fish species and their densities are low. However, large numbers of pelagic fish, such as Pacific herring and surf smelt may occur. These species do not depend on benthic organisms as a food source.

During the summer, when wave action is reduced, some ephemeral algae may occur on cobble. However,

macroscopic algae are not characteristic of cobble beaches, and the occurrence of microalgae is limited. Organisms are thus dependent on food energy produced offshore or in adjacent beach areas. Water birds reflect this dependence much as fish do. Since algae is greatly restricted, herbivores are not present and birds are primarily represented by fish-eating divers such as grebes, loons, and cormorants. Refer to Table 63-2 in the Beach Narrative (No. 63) for lists of characteristic birds and mammals of cobble beaches.

Areas offshore from cobble beaches are usually very productive, as wave action does not move about subtidal sediments to a significant extent. Kelp beds may be present in shallow subtidal areas, along with a rich assortment of fishes and birds. A productive salmon fishery can be expected offshore.

These offshore zones adjacent to cobble beaches provide areas shallow enough for bottom foraging birds and marine mammals to use and greatly increase the diversity of wildlife present. Numbers of species and individuals are high and comparable to those discussed in the Mixed Coarse Narrative. Our observations at cobble beach sample sites have shown they are much like mixed coarse beaches except in the high intertidal zones. Cobbles serve almost exclusively as rest areas for gulls along both beach types. However, mixed coarse beaches also provide open sandy or gravel patches in upper intertidal areas where shorebirds often feed. These patches also trap prey items for gulls and other beach scavengers such as raccoons and ravens. The clean, rather uniform upper intertidal of cobble beaches is much more sterile and provides limited feeding for these species. Killdeer were the only shorebird observed at our cobble beach sample sites and the significantly large numbers of gulls observed were generally at rest.

Nearshore and adjacent offshore waters of cobble beaches are often very productive. This was especially evident at a cobble beach along the Strait of Juan de Fuca at Twin Rivers (Clallam County). Extensive kelp beds offshore modify wave exposure, and shallow subtidal areas are comparable to those along mixed coarse beaches. Bottom feeding birds, those which feed in the water column, and surface feeders such as gulls, Bald Eagles, and Osprey were observed at this site. Numbers of species and total numbers of individuals were consistently as high or higher relative to cobble sites without kelp beds and exposed mixed coarse beaches as shown in Table 632-2. The total number of species observed on cobble beaches throughout our sampling period was highest (33 species) at Twin Rivers.

Cobble sites which lack kelp beds generally support fewer wildlife than areas such as Twin Rivers. However, schooling neritic fish are often present in large numbers and as a result marine bird and mammal predators are abundant. High counts of birds at South Beach (San Juan County) in October 1977 (Table 632-2) reflect this feature. Large numbers of murres and cormorants fed offshore on the day this count was taken and large numbers of gulls were attracted to prey brought to the surface by these diving birds. This is a common but irregular occurrence along South Beach and other cobble beaches and on many days very few species are observed as reflected by the November count of three birds in Table 632-2. Birds such as gulls and seabirds (Family Alcidae) respond to this patchy occurrence of schooling fish in several ways depending upon species. Fishermen also respond (in a manner much like the gulls) by watching the water for flocks of birds and moving to these feeding areas. Larger fish such as salmon are also attrached to these assemblages and are the reward for observant fishermen. Marine mammals also feed in these assemblages which attract fish, birds, and fishermen from long distances to cobble beaches.

III. IMPACTS

The only food organisms present in large numbers on cobble beaches are oligochaete worms and amphipods, both of which are small organisms. Toxins such as oil would impact these species heavily, thus destroying the only foods available to fish and birds. However, the high exposure of cobble beaches and large size of substrate particles would disperse pollutants rather quickly. Oligochaetes and amphipods are short-lived species, and if the source of the pollution was a one-time event (e.g., an oil spill) would tend to recolonize rather quickly, thus minimizing impacts to these beaches.

Impacts in low intertidal portions of cobble beaches, especially those with kelp beds, may be more severe. Organisms affected will be similar to those discussed in the Kelp (No. 628) and Mixed Coarse (No. 633) Narratives.

exposed
semi-protected

Table 632-1 CHARACTERISTIC ANIMALS OF COBBLE BEACHES

Common Name (Scientific Name)	Trophic Type	Zone(s) of Occurrences
INVERTEBRATES		
Flatworms (Platyhelminthes)		
(*Procerodes pacifica*)	Detr	H, M, L
(*Itaspiella armata*)	Detr	H, M, L
Nemerteans	Carn	H, M
Arthropods		
Beach hoppers (*Maera dubia*)	Detr	H, M, L
Sow bug (*Gnorimosphaeroma oregoneuse*)	Scav	L
Annelids		
Oligochaete worms	Dep	H
Polychaete worms		
(*Hemipodus borealis*)	Carn	M
(*Saccocirrus erotica*)		L

FISH Common Name	Scientific Name	Economic Value	Comment
Pacific herring	*Clupae harengus pallasi*	C, R	Valuable bait and food fish and prey of other fish, birds, and mammals.
Surf smelt	*Hypomesus pretiosus*	C, R	
Longfin smelt	*Spirinchus thaleichthys*	C, R	
Chinook salmon	*Oncorhynchus tshawytscha*	C, R	
Chum salmon	*O. keta*	C	
Pacific cod	*Gadus macrocephalus*	C, R	
Walleye pollock	*Theregra chalcogramma*	C	
Redtail surfperch	*Amphistichus rhodorus*	R	
Saddleback gunnel	*Pholisornata*		
Crescent gunnel	*P. laeta*		
Sharpnose sculpin	*Clinocottus acuticeps*		
Padded sculpin	*Artedius fenestralis*		
Buffalo sculpin	*Enophrys bison*		
Tadople sculpin	*Psychrolutes paradoxus*		
Pacific staghorn sculpin	*Leptocottus armatus*		
Ringtail snailfish	*Liparis rutleri*		
Rock sole	*Lepidopsetta bilineata*	C, R	
Starry flounder	*Platichthys stellatus*	C, R	

Table 632-2

TOTAL NUMBER OF BIRD SPECIES AND INDIVIDUALS PRESENT AT A COBBLE AND MIXED COARSE SAMPLE SITE ALONG THE STRAIT OF JUAN DE FUCA, AUGUST - DECEMBER 1977

	Aug	Sept	Oct	Nov	Dec	Mean
Species*						
Point Wilson (Mixed Coarse)	8	16	15	21	19	16
Twin Rivers (Cobble/Kelp)	15	15	15	11	16	14
South Beach (Cobble/No Kelp)	6	10	17	1		9
Individuals						
Point Wilson (Mixed Coarse)	201	269	94	101	142	161
Twin Rivers (Cobble/Kelp)	107	372	97	91	74	148
South Beach (Cobble/No Kelp)	102	150	279	3		134

*Total number of species observed at each site:

Point Wilson	31
Twin Rivers	33
South Beach	25

IN OPENING CUT ON THIS LINE
FRESH
CHUM SALMON
Fidalgo Island Packing Co.
KETCHICAN, ALASKA.

MIXED COARSE (No. 633)

INTRODUCTION

Mixed coarse beaches are as the name implies, comprised of a combination of different particle sizes. Cobble, gravel, and sand are always present in varying proportions, and boulders may or may not be present. In the most protected sites where mixed coarse beaches occur, some mud may also be present.

Mixed coarse is one of the more common beach types in Washington. They occur in pockets throughout the San Juan Archipelago, along the Strait of Juan de Fuca, and form extensive stretches along the mainland in northern Puget Sound, Hood Canal, and central Puget Sound. They also occur in southern Puget Sound, but are not as common there as in other inland waters. While ranging in occurrence from fairly high exposure areas to rather protected areas, mixed coarse beaches generally occur on moderately exposed shorelines.

Some mixed coarse beaches, particularly those in more exposed situations, undergo seasonal changes in composition of beach sediments. Sand and small gravel may wash up onto the upper beach during summer. This results in both a more level beach slope and a smaller average grain size in the upper beach. During winter, sand and small gravel is washed seaward, creating a steeper beach slope and leaving behind the larger gravel, cobbles, and boulders too heavy to be moved by waves and currents.

The slope of mixed coarse beaches is normally moderate to gentle. Typically, on beaches in northern Puget Sound, the substrate grades from sand and/or gravel in the upper portions to a more diverse composition of sand, gravel, and cobble and, occasionally, boulders and mud in the lower portions. In many protected areas, however, as in much of Hood Canal and southern Puget Sound, the opposite situation occurs. Scattered boulders among cobble, gravel, and sand form a strip along the middle and upper portions of the beach. This strip grades into a different beach substrate in the lower intertidal, usually sand or muddy sand.

Mixed coarse beaches often occur at the base of eroding bluffs composed of glacial till, which supply the source of sediments for the beach. As a result of longshore drift, finer sediments carried by waves and currents often supply the source materials for adjacent beaches.

Mixed coarse beaches are generally very productive, and contain diverse and complex biological communities. Many of the species they support are commercially or recreationally important, and many others of potential use are present.

Many of the significant biological features relevant to mixed coarse beaches (such as productivity and zonation) have already been discussed in the Rock Narrative (No. 631) and need not be repeated here. Additional information on the value of algae is found in the Kelp (No. 628) and Other Algal Communities (No. 629) Narratives. However, mixed coarse beaches do posses several unique attributes which distinguish them from rocky beaches.

SIGNIFICANT BIOLOGICAL FEATURES

Mixed coarse beaches have a high species diversity as a result of the variety of substrates present. While boulders and large cobbles support many of the species typical of rock beaches, pockets of sand or sand and gravel support animals typical of sand or mixed fine beaches. In addition, the undersides of rocks or crevices between boulders support several distinct species either not typical of other beaches or which occur in greatly reduced numbers elsewhere. A specialized locale within a larger habitat or community type, such as the bottom of a rock, a crevice, or the holdfast (or "root") of a kelp, within a mixed coarse beach, is called a microhabitat. Microhabitats often create a unique condition which is necessary for or conducive to the survival of certain species. In so doing, microhabitats tend to increase the diversity of an area. The presence of a variety of microhabitats on mixed coarse beaches are responsible for the high diversity of species. Mixed coarse beaches have the highest species diversity of any beach type, with the exception of moderately to highly exposed rocky beaches. Density and biomass are also high.

Characteristic Species

The plants and animals of mixed coarse beaches are generally similar to those of rocky beaches. Species listed in the Rock Narrative (No. 631) as occurring on highly exposed beaches of the outer coast, however, are not likely to be found on mixed coarse beaches. In addition, the diversity of algae on mixed coarse beaches is lower than on rocky beaches, and species such as starfish and chitons are fewer in number of species and/or abundance. Vertebrates of mixed coarse beaches are comparable to those discussed for rocky shores. Diversity of some groups, including shorebirds, is higher on mixed coarse beaches because of the variety of substrates. However, some species which prefer rocky shores, such as the Black Oystercatcher, are not as abundant. In addition, sea otters and other species restricted to the outer coast are absent or uncommon along mixed coarse beaches.

The high intertidal and splash zones of mixed coarse beaches normally do not have as complex or diverse communities as the corresponding zones of rocky beaches. This is especially true if sediments are unstable in the upper portion of the beach as a result of either small particle size or rough wave action. The upper beach is in this case, similar to a cobble (Narrative No. 632) or mixed medium (No. 634) beach, with a correspondingly impoverished flora and fauna. Table 633-1 lists species present on mixed coarse beaches.

Pockets of sand or sand and gravel on mixed coarse beaches provide habitat for a number of organisms, especially polychaete worms and clams which are not usually associated with rock beaches. The variety of polychates is great, and species present at any particular beach depend upon the amount of sand present, exposure, and salinity. Some typical species include herbivores such as *Nereis* and *Lumbineris*, the detrivores *Thelepus* (which usually occurs in sand covered by rock), *Cirratulus* and *Syllis*, the deposit feeders *Notomastus* and *Capitella*, and the carnivores *Hemipodus borealis* and *Glycinde picta*. Many of the clams which may be found are edible, including butter clams, native littleneck clams, Japanese littleneck or Manila clams, and soft-shell clams, as well as heart cockles. Also occurring are macoma clams, tiny transennella clams, and fat Pacific leptons. In the high intertidal and splash zone, large numbers of beach hoppers may occur, feeding on algal detritus cast upon the beach.

TABLE 633-1 CHARACTERISTIC PLANTS AND ANIMALS OF MIXED COARSE BEACHES
(Refer to Table 63-2 for Birds and Mammals)

Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
PLANTS				
Vascular plants				
Broad-bladed eelgrass (*Zostera marina*)	PP	L, SB		Important waterfowl food; many algae and invertebrates associated with eelgrass.
INVERTEBRATES				
Molluscs				
Mask limpet (*Notoacmea persona*)	HERB	H, M		
Screw snail (*Bittium eschrichtii*)	HERB	L		
Sitka periwinkle or littorine snail (*Littorina sitkana*)	HERB	SPL, H, M		
Checkboard periwinkle or littorine snail (*L. scutulata*)	HERB	SPL, H, M		
Dire whelk (*Searlesia dira*)	CARN	M, L		
Moon snail (*Polinices lewisii*)	CARN	L, SB		Edible
Rock oyster or jingle shell (*Pododesmus macroschisma*)	FF	M, L		Edible
Butter clam (*Saxidomus giganteus*)	FF	L	R, C	Edible; popular among clam diggers
Native littleneck clam (*Protothaca staminea*)	FF	M, L	R, C	Edible; popular among clam diggers
Heart cockle (*Clinocardium nuttallii*)	FF	M, L	R	Edible; popular among clam diggers
Japanese littleneck or Manila clam (*Tapes japonica*)	FF	M, L	R, C	Edible; popular among clam diggers
Soft-shell clam (*Mya arenaria*)	FF	H, M, L	R	Edible; supports commercial industry on East Coast
Tiny transennella clam (*Transennella tantilla*)	FF	M, L		
Fat Pacific lepton (*Mysella tumida*)	FF	M, L		
Macoma clams (*Macoma* spp.)	DEP	M, L		

Arthropods				
Beach hopper (*Orchestia traskiana*)	DETR	SPL, H		
Other amphipods	DETR, HERB	M, L		
Pill bug (*Exosphaeroma* spp.)	DETR	H, M, L		
Oregon pill bug (*Gnorimosphaeroma oregonense*)	DETR, SCAV	H, M, L		
Isopod (*Idotea wosnesenskii*)	HERB	M, L		
Hairy hermit crab (*Pagurus hirsutiusculus*)	DETR	H, M, L		
Hermit crab (*Pagurus granosimanus*)	DETR	M, L		
Purple shore crab (*Hemigrapsus nudus*)	SCAV-CARN	H, M		Prey of several marine birds. Raccoons also feed on shore crabs.
Hairy shore crab (*Hemigrapsus oregonensis*)	SCAV-CARN	H, M		
Porcellain crab (*Petrolisthes eriomerus*)	FF	M, L		
Black-clawed crab (*Lophopanopeus bellus*)	CARN	L		
Red rock crab (*Cancer productus*)	CARN	L, SB	R, PC	
Hairy cancer crab (*Cancer oregonensis*)	CARN	M, L		
Segmented worms (Annelids)				
Polychaetes				
Family Capitellidae				
(*Notomastus tenius*)	DEP	M, L		Prey of many commercially and recreationally valuable fish.
(*Capitella capitata*)	DEP	M, L		
Cirratulidae (*Cirratulus cirratus*)	DETR	M, L		
Glyceridae (*Hemipodus borealis*)	CARN	M, L		
Goniadidae (*Glycinde picta*)	CARN	M, L		
Lumbrineridae (*Lumbrineris* spp.)	HERB	M, L		
Nereidae (*Nereis* spp.)	HERB	M, L		
Onuphidae (*Onuphis* sp.)	HERB	M, L		
Opheliidae (*Armandia brevis*)	DEP	M, L		

TABLE 633-1 (Continued)

Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
Serpulidae				
(Serpula vermicularis)	FF	M, L		
(Spirorbis spp.)	FF	M, L		
Spionidae				
(Polydora spp.)	DETR	M, L		
(Spiophanes spp.)	DETR	M, L		
(Malacoceros glutaeus)	DETR	M, L		
Syllidae				
(Syllis spp.)	DETR	H, M, L		
Terebellidae				
(Thelepus crispus)	DETR	M, L		
Echinoderms				
Six-rayed sea star (Leptasterias hexactis)	CARN	M, L		
Mottle star (Evasterias troschelii)	CARN	L, SB		
Green sea urchin (Strongylocentrotus droebachiensis)	HERB	L, SB		Gonads edible
Red sea cucumber (Cucumaria miniata)	DETR	L, SB	R	Edible
White sea cucumber (Eupentacta quinquesemita)	DETR	L, SB		Edible
Burrowing sea cucumber (Leptosynapta clarki)	DETR	L		
Ubiquitous brittle star (Ophiopholis aculeata)	FF	L, SB		
Coelenterates				
Burrowing sea anemone (Anthopleura artemesia)	CARN-SCAV	M, L		

FISH

Common Name	Scientific Name	Economic Value	Comments
Spiny dogfish	(Squalus acanthias)	C	Edible
Pacific herring	(Clupea harengus)	C, R	Important bait fish
Pink salmon	(Oncorhynchus gorbuscha)	C, R	Salmon occur nearshore as juveniles and are caught offshore along mixed coarse beaches.
Chum salmon	(O. keta)	C	

Coho salmon	(O. kisutch)	C, R	
Chinook salmon	(O. tshawytscha)	C, R	
Cutthroat trout	(Salmo clarki)	R	
Surf smelt	(Hypomesus pretiosus)	C, R	
Plainfin midshipman	(Porichthys notatus)		Attach eggs to rocks
Northern clingfish	(Gobiesox maeandricus)		Adults attach to rocks with adhesive disc.
Tube-snout	(Aulorhynchus flavidus)		Nests in algae
Threespine stickleback	(Gasterosteus aculeatus)		
Shiner perch	(Cymatogaster aggregata)	R	
High cockscomb	(Anoplarchus purpurescens)	R	Cockscombs and prickleback are generally referred to as blennies. They are valued by those who enjoy tide-pool life. Also, are prey of other fish and marine birds.
Penpoint gunnel	(Apodichthys favidus)	R	
Crescent gunnel	(Pholis laeta)	R	
Saddleback gunnel	(P. ornata)	R	
Copper rockfish	(Sebastes caurinus)	C, R	Several rockfish may be present. All are valuable commercial and/or sports fish.
Black rockfish	(S. melanops)	C, R	
Kelp greenling	(Hexagrammos decagrammus)	R	
Lingcod	(Ophiodon elongatus)	C, R	
Buffalo sculpin	(Enophrys bison)	R	Sculpins are caught by young fishermen. Also prey of many other fish, marine birds and mammals.
Pacific staghorn sculpin	(Leptocottus armatus)	R	
English sole	(Parophrys vetulus)	C, R	

LEGEND:

[1]Trophic type

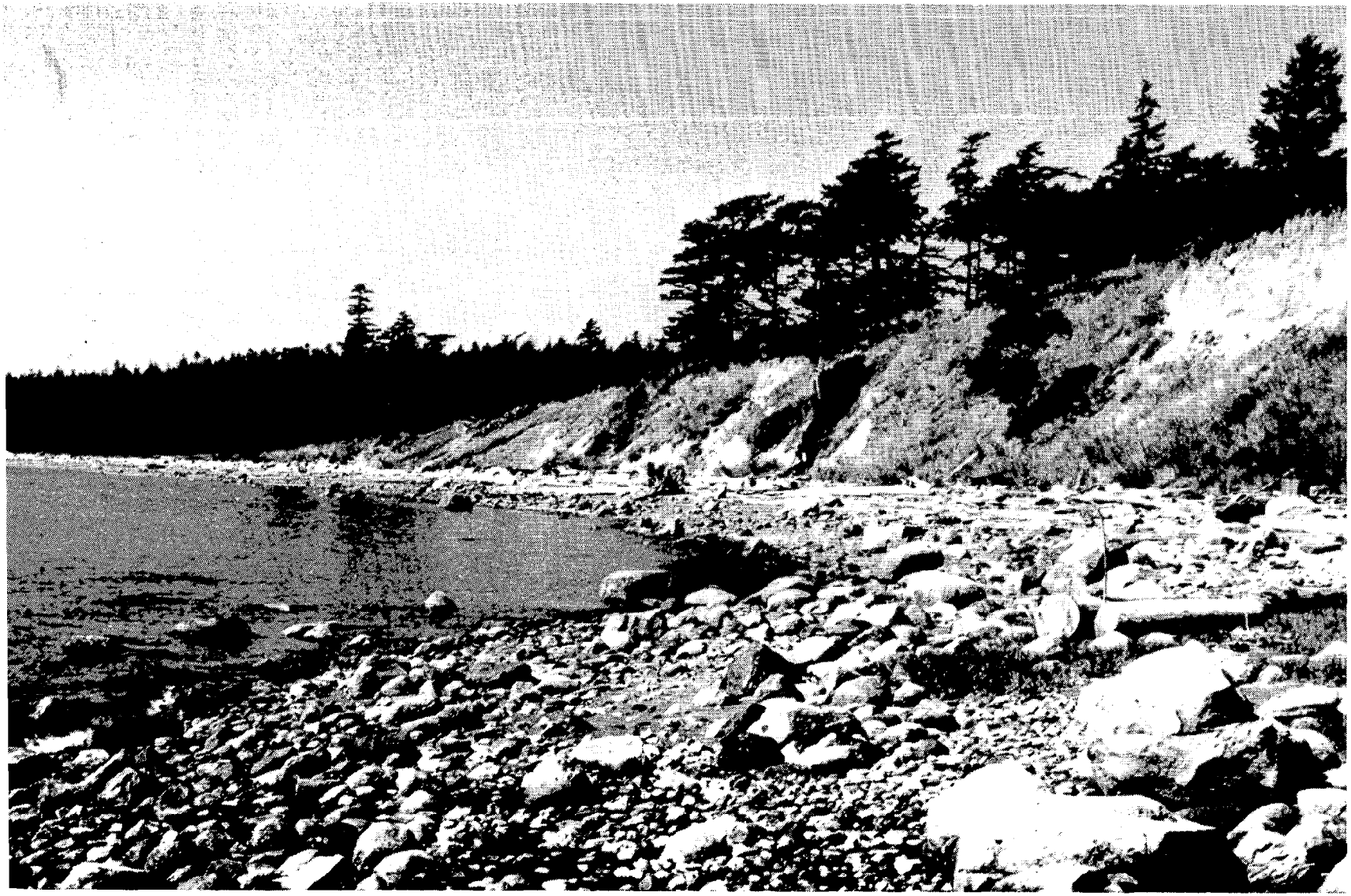
PP = Primary Producer
FF = Filter Feeder
DEP = Deposit Feeder
SCAV = Scavenger
CARN = Carnivore
DETR = Detritivore
OMNI = Omnivore
HERB = Herbivore

[2]Zones of Occurrence

H = High Intertidal
M = Mid-Intertidal
L = Low Intertidal
SB = Shallow Subtidal

[3]Economic Value

C = Commercial
R = Recreational
PC = Potential Commercial



In more protected mixed coarse beaches, broad-bladed eelgrass sometimes occurs on pockets of sand. The presence of eelgrass increases productivity of the beach and increases the diversity of species by creating a new microhabitat [a distinct flora and fauna are associated with eelgrass; refer to the Seagrass Narrative (No. 627), for further information].

Several species which occur on rocky beaches are found in greater abundance on mixed coarse beaches. These species are primarily more abundant because of the refuge from predators they obtain by spending much of their time, especially during low tides, under rocks. Several species of crabs, such as purple shore crabs, porcelain crabs, and hairy cancer crabs frequently hide under cobble-sized rocks. Young red rock crabs are also common. The six-rayed or brooding starfish is the most common starfish of mixed coarse beaches, and green sea urchins reach their highest densities on this beach substrate. Isopods and amphipods are often the most numerous invertebrates under rocks, with cobble-sized rocks sometimes harboring hundreds of individuals. A few species of fish adapted totally to intertidal life also seek protection under rocks at low tides. These include northern clingfish, pen-point gunnels, and high cockscomb. Sculpins will also commonly be found under rocks or in shallow tidepools.

Fish species diversity is generally high, especially when adjacent to kelp beds or when dense algae or eelgrass is present. Species listed in Table 633-1 inlcude many which also occur along rock beaches. Those discussed below are representative of the variety of fish inhabiting mixed coarse beaches:

Representative Fish of Mixed Coarse Beaches:

High Cockscomb

This eel-like inhabitant of mixed coarse beaches is abundant beneath rocks in the mid- and low intertidal zones. The high cockscomb (once referred to as cockscomb prickleback) is able to slip between and beneath rocks because of its slender body. Here it seeks shelter and food. Eggs are also laid beneath rocks and are deposited in small depressions or in empty clam shells. Prey of the high cockscomb includes a variety of invertebrates which also occur beneath rocks. Food also includes a high percentage of algae and invertebrates which inhabit growths of algae. The high cockscomb is unusual in that few other fish consume algae directly. Sea lettuce and unidentified red algae comprised the highest percentage (32%) of food items noted in a recent study of this fish in British Columbia.

Garter snakes have been reported to prey on the high cockscomb at low tide. Other predators thought likely to consume cockscombs include rockfish, greenling, sculpins, Red-necked Grebes, and Pigeon Guillemots.

Penpoint Gunnel

The penpoint gunnel looks much like the high cockscomb and several other fish commonly referred to as "blennies". Many persons also call them eels because they are long and slender. Collectively, this group of fish are common inhabitants of mixed coarse beaches and have evolved a body shape suited to life among rocks and algae. They are preyed upon by a wide variety of fish, marine birds, and by raccoons and river otters. The penpoint gunnel is one of the large blennies, growing to 18 inches (46 cm). It is further distinguished by the absence of pelvic fins and the presence of a spine at the head of the anal fin which is shaped like a pen nib. They occur in mid- to low intertidal zones.

Northern Clingfish

The clingfish is another inhabitant of mixed coarse beaches which is often found beneath rocks. Its name is derived from the presence of an adhesive disc on the fish's underside. This disc is formed within the flexible pelvic fins and is used to cling to rocks. They are known to feed on small crustaceans and molluscs. Along with blennies, clingfish are important recreational fish for those who enjoy turning over rocks in the intertidal zone.

Copper Rockfish

The copper rockfish is one of several fish which overlap in occurrence along rock and mixed coarse beaches. Other rockfish, kelp greenling, and ling cod are also among this group which includes many inhabitants of kelp beds associated with mixed coarse and rocky shores.

Copper rockfish are the most numerous of rockfish reported from inland waters and are valuable commercial and recreational food fish. Copper rockfish are highly regarded by sports fishermen who catch them intentionally (along with other bottom fish), and accidentally while salmon fishing. The firm flesh of these rockfish is excellent baked, or prepared as fish and chips.

Chinook Salmon

The chinook or "king" is one of the salmon which occur along mixed coarse beaches as juveniles. Here they feed and grow rapidly as they move into more open waters. When mature, they are often caught by commercial and sport fishermen adjacent to mixed coarse beaches. Chinooks are the largest salmon, attaining weights over 100 pounds (45.5 kg). Fish in the 20-40 pound range are not uncommon during summer when thousands of sport fishermen pursue the king salmon. A popular winter sport fishery also attracts many persons. Winter and smaller chinooks are referred to as "blackmouths" and average 5-10 pounds.

Combined commercial and sports catches of several million pounds (454 metric tons equal one million pounds) of chinook salmon are landed each year. These substantial catches have been adversely affected by construction of dams and other impacts on spawning rivers. Hatchery and salt water pen-rearing culture have contributed to enhancement of this valuable salmon, but natural habitat must also be available to maintain chinook populations.

Representative Birds and Mammals

Birds and mammals associated with mixed coarse beaches include many of those discussed for rock beaches. These species forage here on rocky surfaces and among the many spaces between cobbles and algae. Patches of sand and other nonrocky substrate also provide foraging areas. Thus, species associated with a variety of beach substrates often occur. For example, shorebirds of mixed coarse beaches include Black Oystercatchers (rock inhabitant) and Sanderlings (sand inhabitant). The following are examples of other inhabitants of mixed coarse beaches: (Refer to Table 63-2 for a list of other species which may be present.)

Common Goldeneye

In Hood Canal and other protected waters, mixed coarse beaches often form a narrow strip relatively high in the intertidal. This zone is a favored feeding area of Goldeneyes. Here they dive and pick invertebrates such as shore crabs and the tiny but numerous littorine snails from among the rocks.

In more exposed areas, Goldeneyes also forage along mixed coarse beaches which are often covered with dense growths of algae. A related diving duck, the Bufflehead is often observed in close association with Goldeneyes in both situations. However, they have been observed to feed at different depths along mixed coarse beaches and the two species may be avoiding food competition in this way.

White-winged Scoter

Three scoters are present along mixed coarse beaches, Surf, Black, and White-winged. During our studies, the White-winged Scoter was most often observed close to shore feeding in the same general areas as Common Goldeneyes, where both divers consume large numbers of shore crabs. Surf and Black Scoters were typically further offshore as illustrated in Figure 633-1.

Red-necked Grebe

Red-necked Grebes are one of five species of grebes observed along mixed coarse beaches during our studies. They were frequently seen diving nearshore at protected and exposed locations and are among the many recreationally valuable marine birds of our coastal zone. The rufous neck which distinguishes this diving duck is only worn during summer months. At other times, they may be drab in comparison to many water birds, but grebes dive gracefully and are a pleasure to observe throughout the year.

Heermann's Gull

The Heermann's Gull is one of several gulls which may rest on rocks at low tide, feed nearshore, or perch on kelp beds along mixed coarse beaches. The bright red bill and slate black wings of adults contrast sharply with their white head and sets them appart from other gulls. They are also unlike most other gulls in that they are one of few birds which are reverse migrants. Breeding in the south, including islands in the Gulf of California, they fly north in late summer, when they may be seen along our coast.

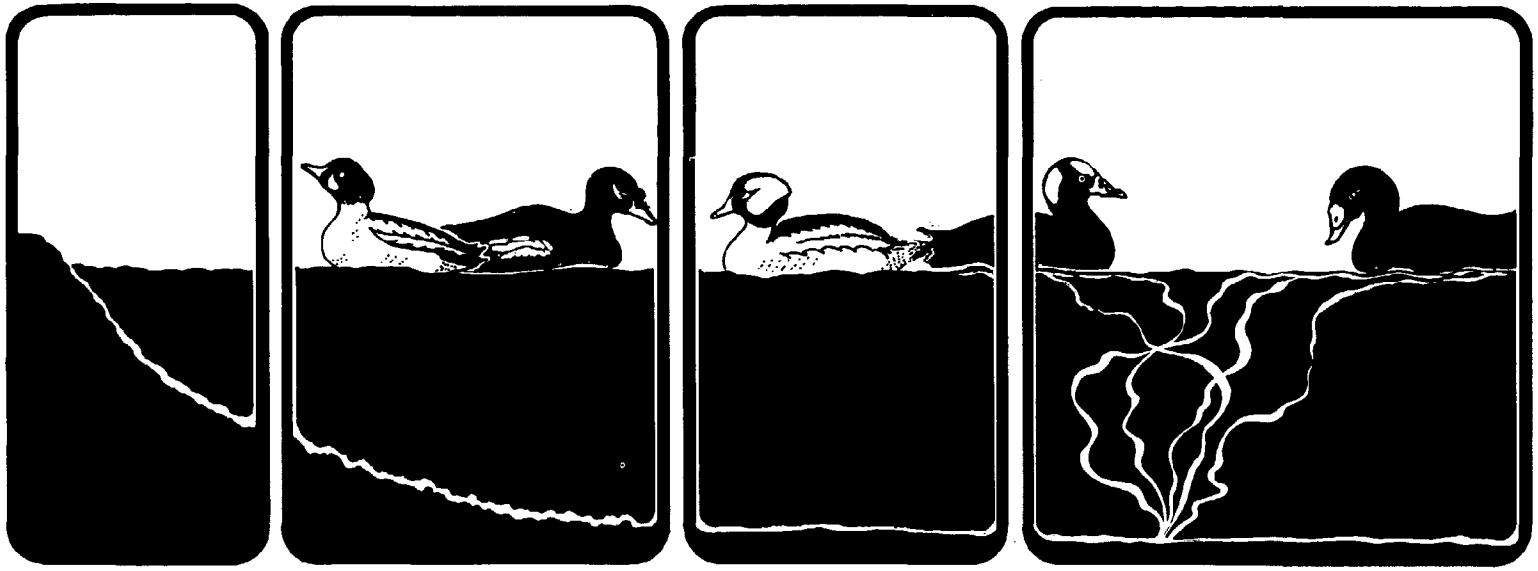
Raccoons

A ubiquitous shoreline forager, the raccoon often feasts along mixed coarse beaches. Under rock inhabitants such as shorecrabs and blennies are among their prey. Raccoons are enjoyed by many persons who often befriend these curious mammals. They are also trapped for their fur and hunted by persons who raise dogs specifically for the chase.

Use by Man

Mixed coarse beaches provide many benefits to man. The production of algae (and occasional eelgrass) in intertidal and shallow subtidal regions provides detrital foods which indirectly feed most species of fish and shellfish commercially harvested in nearshore areas. Many fish which are harvested farther offshore such as many salmon and English sole, spend a part of their life cycle feeding along mixed coarse beaches. Several rockfish (rock cod), as well as ling cod and kelp greenling, are recreationally fished in subtidal areas just offshore from mixed coarse beaches. Commercial and recreational salmon fishing frequently occurs here, especially where kelp beds are present. Ling cod, several species of rockfish, and herring all lay eggs in lower intertidal and shallow subtidal areas. Surf smelt may spawn on mixed coarse beaches in the high intertidal zone if the substrate consists of sand and gravel.

Figure: 633-1 *Diving Duck Distribution Along A Mixed Course Beach*
(several other species are also often present. those depicted generally feed at different depths as shown.)



mixed medium | mixed course | silty sand (mud)

Mixed coarse beaches may contain any of several recreationally important shellfish. Butter clams are often present, but native or Japanese littleneck clams, soft-shell clams, or heart cockles may be more abundant. Some mixed coarse beaches, particularly in Hood Canal, support populations of Pacific oysters. In parts of Dabob Bay, oysters are commercially harvested from mixed coarse substrates. Red rock crabs which are every bit as palatable as Dungeness crabs, are common, especially younger individuals. Shrimp often move into mixed coarse beaches during high tides to forage for food.

Waterfowl, which help support a valuable hunting industry in Washington, frequently use mixed coarse beaches, especially if eelgrass is present. Species commonly found during portions of the year include Brant and American Wigeon.

Many species of potential use by man occur in mixed coarse beaches. Edible species not popularly harvested include, for example, a large number of algae, edible or bay mussels, sea cucumbers, whelks, and shiner perch.

Nonconsumptive uses of mixed coarse beaches include bird-watching and use as an educational facility. The diversity of birds is high along mixed coarse beaches during fall and spring migrations, especially if kelp beds occur offshore. Marine mammals can also be seen quite close to shore along mixed coarse beaches. Harbor seals and sea lions are the more commonly observed examples, but porpoise and larger whales should be looked for. This is especially true along more exposed shores such as Point Wilson in Jefferson County. Kelp beds occur just offshore at this beach which is within Fort Worden State Park. The rich intertidal zone of the mixed coarse beach at Point Wilson attracts many persons who enjoy watching offshore wildlife and observing tidepool life beneath their feet.

IMPACTS

Mixed coarse beaches near large population centers, such as Seattle and Tacoma, undergo intensive recreational use. As a result of clam digging, beach combing, and movement of rocks, populations of plants and animals are usually reduced compared to more remote areas.

Structures such as jetties, groins, bulkheads, or revetments tend to interfere with longshore drift. As stated earlier, mixed coarse beaches are often associated with eroding bluffs. The finer sediment from the bluff, particularly sand, are moved along the beach by current and wave action. These sediments are often the source material maintaining adjacent beaches. Structures which cut off the flow of sediments to adjacent beaches often cause these beaches to undergo erosion.

Toxic substances which kill the animals of mixed coarse beaches tend to have fairly long-term effects, even if the exposure is only for a short time. Many of the species, such as clams, mussels, or anemones, are long-lived. Thus, it may take populations several years to reestablish their former density and age structure. In addition, some of these long-lived species do not spawn on a regular, yearly basis. Poor conditions for spawning in adjacent areas may further delay recovery of a population. Mixed coarse beaches are also used quite heavly by fish for spawning (e.g., Pacific herring, tubesnouts, several species of sculpins, rockfish, and, occasionally surf smelt, among others, spawn on mixed coarse beaches). Eggs or newly hatched juveniles are most sensitive to pollutants, and populations of these species could be greately impacted. Indirect impacts would also occur to species which spend a portion of their life feeding on mixed coarse beaches through a loss of food resources or protective cover.

The presence of bivalves (clams, oysters, and mussels) pose problems in areas where nontoxic, low levels of pollution occur. Bivalves are capable of concentrating pollutants such as heavy metals to hundreds-of-thousands of times their concentration in surrounding sea water. The bivalves can survive well enough with fairly high concentrations of most of these toxins, but the danger is for animals (including man) which feed on clams.

MIXED MEDIUM (No. 634)

I. INTRODUCTION

Mixed medium beaches occur in moderately to highly exposed sites, and the substrate consists of pure gravel or a mix of gravel and coarse sand. The slope is fairly steep, thus the intertidal zone is narrow. Mixed medium beaches most commonly form small indentations in the shoreline, often only 100 feet (30 m) in length, between rock outcrops. They are a common feature along rocky shores in the San Juan Islands such as at Deadman Bay on San Juan Island. Mixed medium substrates also form a narrow fringe in high intertidal areas throughout Puget Sound and Hood Canal, but this situation is discussed in the Mixed Fine Narrative (No. 635) as these protected beaches change to typically productive mixed fine beaches in the mid- and lower intertidal.

As with cobble beaches, wave energy is high enough to constantly roll the gravel-sized fragments about. This movement eliminates the survival of organisms which would attach to the surface of the gravel (most notably barnacles, mussels, and algae). Abrasive action of the gravel also minimizes the number of invertebrates surviving under or between gravel particles.

II. SIGNIFICANT BIOLOGICAL FEATURES

Mixed medium beaches are biologically unproductive and sparsely inhabited. Primary production is limited to the few microalgae which can survive among the constantly shifting sediments. Thus, the relatively few animals which can survive in this environment are largely dependent upon energy imported to the area by tides and waves.

The invertebrate community is dominated by small organisms (amphipods, flatworms, and oligochaete worms; see Table 634-1) and is detritus-oriented in its feeding. No clams and very few polychaete worms are present. The community has low numbers of species, low densities of organisms, and negligible biomass. The organisms are extremely patchy in their distribution.

Offshore, where sediments are more protected from wave exposure, and thus less subject to movement, the environment may be far more stable and productive. When this occurs, there may be high numbers and high densities of fishes using mixed medium beaches. However, the fish community has a greater pelagic component than bethic component as a result of the lack of production on these beaches. Common pelagic fish include Pacific herring and surf smelt. Surf smelt spawn in the upper intertidal of some mixed medium beaches. The most common demersal (bottom-feeding) fish are shiner perch, Pacific staghorn sculpins, crescent gennels, and juvenile English sole. English sole, surf smelt, and Pacific herring are commercially important species, although all are generally harvested in other areas.

Because mixed medium beaches most often occur in small pockets between rock ourcrops, birds and mammals associated with these areas are often those of rocky shores. Refer to Table 63-2 in the Beach Substrate Narrative, No. 63, for a list of characteristic birds and mammals. A notable shorebird which occasionally uses mixed medium beaches is the Black Oystercatcher. Oystercatchers feed on rocky substrate, but nest in patches of gravel just above the intertidal zone. Nesting is known to occur on Protection Island in Jefferson County, Smith Island in Island County, in the San Juans, and on offshore islands along the outer coast.

As with fish, there is also a greater component of relatively pelagic or offshore birds and mammals than those which feed near shore or on the beach at

low tide. These species are mostly dependent on fish or invertebrates produced in deeper water off mixed medium beaches or along adjacent rocky shores and kelp beds.

Very few birds or mammals will occur on the beach itself except to rest or feed on food items washed ashore. This was apparent in five monthly observations at Deadman Bay on San Juan Island. During this time, the only birds seen on the beach were two immature gulls feeding on a fish head. Total numbers of individuals and species observed were also low in other portions of the bay. Most birds (63 percent of all species observed) were in shallow subtidal areas or further offshore. These species were primarily diving birds which prey on schooling fish, or gulls and terns. Bottom feeding diving birds which are more dependent on invertebrates living on the beach substrate were few in numbers and generally occurred in more productive low intertidal or shallow subtidal areas.

Other birds and mammals which occur along mixed medium beaches use the protected nearshore waters as rest sites. They also feed along the rocky "shoulders" of the bays or rest on kelp plants which may float out over the gravelly substrate. Birds of prey such as Bald Eagles have been observed over these small bays and will prey on water birds seeking a sheltered rest area. Mammals known to occur within or along mixed medium beaches include river otter and killer whales. As with birds, these marine mammals feed mainly on fish or other organisms produced outside the immediate environment of mixed medium beaches.

III. IMPACTS

The moderate to high exposure of mixed medium beaches and the coarseness of the sediments would tend to disperse pollutants such as oil from the beach rather rapidly. The small organisms living on the beach would be highly susceptible to such pollutants, but would tend to re-inhabit the area quickly. Sublethal doses of toxins such as heavy metals and pesticides are of concern, however, due to the large numbers of fish which can be present along these beaches. Birds and mammals which feed on these fish would also be threatened by these pollutants. Oil may pose a greater threat to birds than other organisms since they often rest on the water's surface in small sheltered bays.

Table 634-1 CHARACTERISTIC PLANTS AND ANIMALS

Common Name (Scientific Name)	Trophic[1] Type	Zone(s) of[2] Occurrences
INVERTEBRATES		
Flatworms (Platyhelminthes)		
(Procerodes pacifica)	Detr	H, M, L
(Itaspiella armata)	Detr	H, M, L
Nemerteans		
Ribbon worm (Amphiporus sp.)	Carn	H, M, L
Nematodes	Detr	H, M, L
Arthropods		
Beach hoppers (Amphipod)		
(Maera dubia)	Detr	H, M, L
Sow or pill bug	Scav	L
(Gnorimosphaeroma oregonense)		
Annelids		
Oligochaete worms	Dep	H, M, L
Polychaete worms		
Spionidae (Malacocerus glutaeus)	Detr	L
Capitellidae (Capitella capitata)	Dep	L
Cirratulidae (Cirratulus cirratus)	Detr	L
Opheliidae (Armandia brevis)		L
Archiannelid (Saccocirrus erotica)		L

LEGEND

1. Trophic Type:

   Detr = Detritivore
   Carn = Carnivore
   Scav = Scavenger
   Dep = Deposit Feeder

2. Zone of Occurrence:

   H = High Intertidal
   M = Mid-Intertidal
   L = Low Intertidal

1. Economic Value:

   C = Commercial
   R = Recreational

Common Name	Scientific Name	Economic Value[1]	Comment
FISH			
Pacific herring	Clupea harengus pallasi	C, R	Herring and smelt are valuable bait and foodfish for humans and wildlife.
Surf smelt	Hypomesus pretiosus	C, R	
Walleye pollock	Theregra chalcogramma	C	
Pacific cod	Gadus macrocephalus	C, R	Also known as "true" cod.
Shiner perch	Cymatogaster aggregata	R	
Striped seaperch	Embiotoca lateralis	C, R	
Whitespotted greenling	Hexagrammos stelleri		Examples of species "overflowing" onto mixed medium substrates from adjacent rocky beaches or kelp beds
Copper rockfish	Sebastes caurinus	C, R	
Yellowtail rockfish	S. flavidus	C, R	
Padded sculpin	Artedius fenestralis		
Silverspotted sculpin	Blepsias cirrhosus		
English sole	Parophrys vetulus	C, R	Occur in adjacent sandy areas.

MIXED FINE (No. 635)

INTRODUCTION

Description and Distribution

Mixed fine beaches consist of a combination of gravel, sand, and mud. This substrate type is very common in central and southern Puget Sound, but outside this area it is restricted to bays, inlets, and lagoons. In extremely protected areas such as southern Puget Sound, the substrate will contain a high percentage of mud. The more protected the environment, the greater will be the amount of mud present. In such areas the beach substrate often grades into a salt marsh or bluff at its upper end. In more exposed areas, such as central Puget Sound and Hood Canal, the substrate consists of gravel and coarse sand in the upper intertidal, with fine sand and often some mud replacing the coarse sand in the lower intertidal zone. These more exposed beaches are usually bounded by a bluff or beach grassland at their upper margin.

Mixed fine beaches are limited to fairly protected situations. Although pure gravel or mixed gravel and coarse sand beaches do occur in moderately to highly exposed areas, the substrate is unstable due to movement by wave action. This results in an entirely different fauna associated with these beaches, as was discussed in the Mixed Medium Narrative (No. 634).

Mixed fine beaches, expecially in less protected areas, are intimately associated with eroding bluffs, which provide the source material for the beach. The eroding sediments are necessary to replace sediments which are moved away from the beach by longshore currents resulting from wave and current action. The beach slope may vary from one to two degrees to greater than 25 degrees. Usually the slope is greater in the upper intertidal zone, expecially on less protected beaches, and becomes more gradual in the mid and lower intertidal zones. Where mud is present, the slope is usually gradual. In these situations shallow tidepools may occur; which provide refuge for small fish and invertebrates during low tides, may occur.

Mixed Fine beaches are among the most popular recreational beaches, particularly for clam digging. They also support many other valuable marine invertebrates as well as fish, birds, and marine mammals. Eelgrass is generally present, adding greatly to the productivity. Refer to the Seagrass Narrative (No. 627) for information specific to eelgrass and the following discussions for other important features of mixed fine beaches.

SIGNIFICANT BIOLOGICAL FEATURES

Productivity

Productivity of mixed fine beaches is related to the amount of vegetation present. While there is little data on productivity specifically for mixed fine beaches, productivity appears to be very high in protected areas where sea lettuce is abundant in the spring, summer, and fall. In southern Puget Sound, where eelgrass and kelp beds and rock beaches are scarce or absent, mixed fine beaches may be the most productive beach type. Outside of southern Puget Sound, eelgrass often occurs in the lower intertidal zone of mixed fine beaches, thus enhancing their productivity.

Microscopic algae (mostly diatoms) also contribute to productivity. Their relative contribution becomes more important on beaches where there is little macroalgae present. Where salt marshes or beach grassland occur at the upper edge of the beach, beach production is further enhanced.

The mud component of mixed fine beaches provides an excellent medium for bacteria. These microbes, many of which are not actually "primary" producers, play an important role in shoreline ecology. A major function of bacteria is the breakdown of organic matter, which is an essential step in the recycling of nutrients. In addition, the detritivores and deposit feeders which feed on this organic matter are in many cases more dependent upon the bacteria for nutrition than upon the organic matter itself. Studies have shown that as bacteria increase in numbers on detritus particules (small particles of organic matter) the nitrogen and protein content of the particles increase. Certain bacteria are also important in maintaining water quality by breaking down pollutants (such as hydrocarbons) and maintaining an active sulfur cycle. Bacteria are reported to have a high productivity (up to ten grams per cubic foot per day).

Habitat

The fine sand and mud present in mixed fine beaches, especially in the lower intertidal zones, is an important component of this environment. Some important properties of these fine sediments are: 1) small particles have a greater total surface area than larger particles, thus more nutrients (and pollutants) adhere

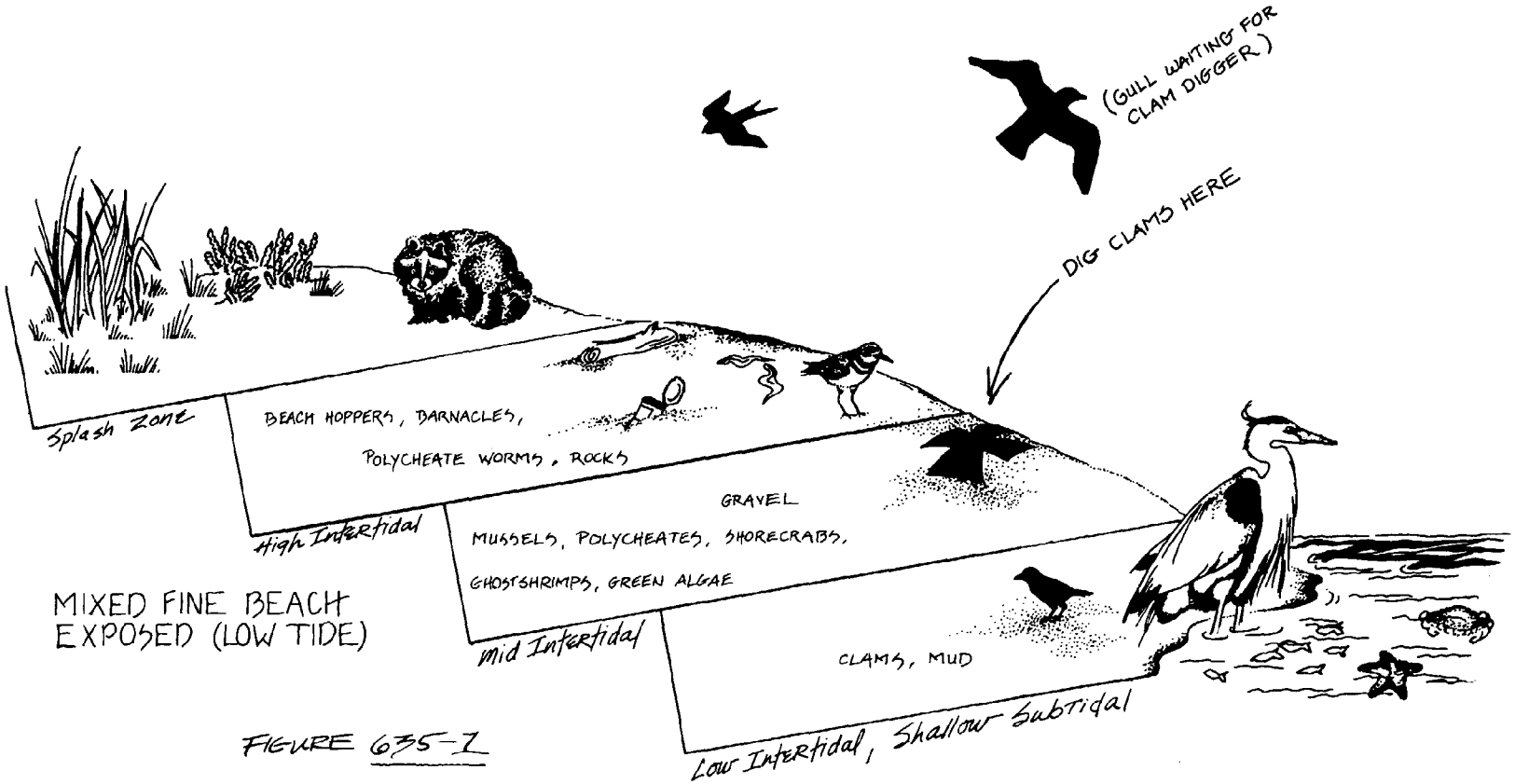

(GULL WAITING FOR CLAM DIGGER)
DIG CLAMS HERE
Splash Zone
BEACH HOPPERS, BARNACLES,
POLYCHEATE WORMS, ROCKS
High Intertidal
GRAVEL
MUSSELS, POLYCHEATES, SHORECRABS,
GHOSTSHRIMPS, GREEN ALGAE
Mid Intertidal
CLAMS, MUD
Low Intertidal, Shallow Subtidal
MIXED FINE BEACH
EXPOSED (LOW TIDE)

FIGURE 635-1

to the sediments, 2) capillary action holds more water in the sediments during low tides, thus protecting organisms from drying out, and 3) a greater amount of organic matter is present (wherever an area is protected enough for fine sediments to settle on the substrate, small detrital particles also settle out). The presence of gravel is also important, and makes the fauna of this beach type distinctive from those of sand, muddy-sand, or mud. Broken shells and their fragments also contribute to the unique structure of mixed fine beaches.

Structural dominants (those species which provide refuge for small animals from exposure to sun, waves, currents, or predation) include algae such as sea lettuce, eelgrass, bay mussels, clams, and the burrowing ghost and mud shrimp. Algae, eelgrass, and mussels provide habitat for numerous small crustaceans and polychaete worms. The clams and burrowing shrimp often host very specific organisms in their burrows, such as pea crabs and scale worms. The burrowing shrimp actually perfer muddy-sand to mixed fine sediments, but as many mixed fine beaches contain a muddy sand strip densely populated by shrimp, they deserve mention.

The abundance of prey on mixed fine beaches provide excellent feeding areas for fish and crabs. They also provide a nursery area for juvenile flatfish and salmonids and are frequented by larvae of herring, sandlance, and candlefish. These beaches are the preferred spawning areas for surf smelt and where algae and eelgrass occur, they are often used by herring as a substrate for attachment of their eggs.

Mixed fine beaches also provide valuable habitat for birds and mammals. Beaches exposed at low tide are used as forage and rest sites by birds, which feed on algae or eelgrass, including Brant, American Wigeon, and other waterfowl. Killdeer, several gulls, and crows forage for invertebrates when the tide is out and along the upper margins of the beach at high tide. Tidepools provide additional foraging areas for these species and terrestrial wildlife such as raccoons and skunks. Deer, weasels, and coyotes are also known to forage on mixed fine beaches during low tide.

Beaches submerged at high tide and nearshore habitats at all tidal stages are used by many of the species which forage on exposed beaches plus a wide variety of aquatic wildlife. Thus, gulls feed on the beach and on the surface of the water. Great Blue Herons stalk exposed beaches with shallow water or tidepools and wade nearshore. A number of diving birds and some marine mammals feed nearshore, and are particularly abundant when eelgrass is present. Some of the more common species include White-winged Scoters, Common Loons, Red-necked Grebes, and harbor seals.

There is very little information on how the different species of marine birds and mammals divide the resources available on mixed fine beaches. However, each species has its own special requirements which must be protected to insure their continued presence. For example, Killdeer only feed on exposed portions of the beach, Great Blue Herons mostly in shallow water, and scoters only in submerged areas. We also know that some species feed nearer to shore than others and that some feed selectively on one or two prey items. Thus, Arctic Loons feed offshore on schooling fish while Common Loons often feed on sculpins in the intertidal. Brant are well known for their dependence on eelgrass and are often seen along mixed fine beaches where other waterfowl feed on eelgrass and algae such as sea lettuce. Still others, such as weasels and raccoons, forage on the beach and retreat to wooded areas nearby for cover.

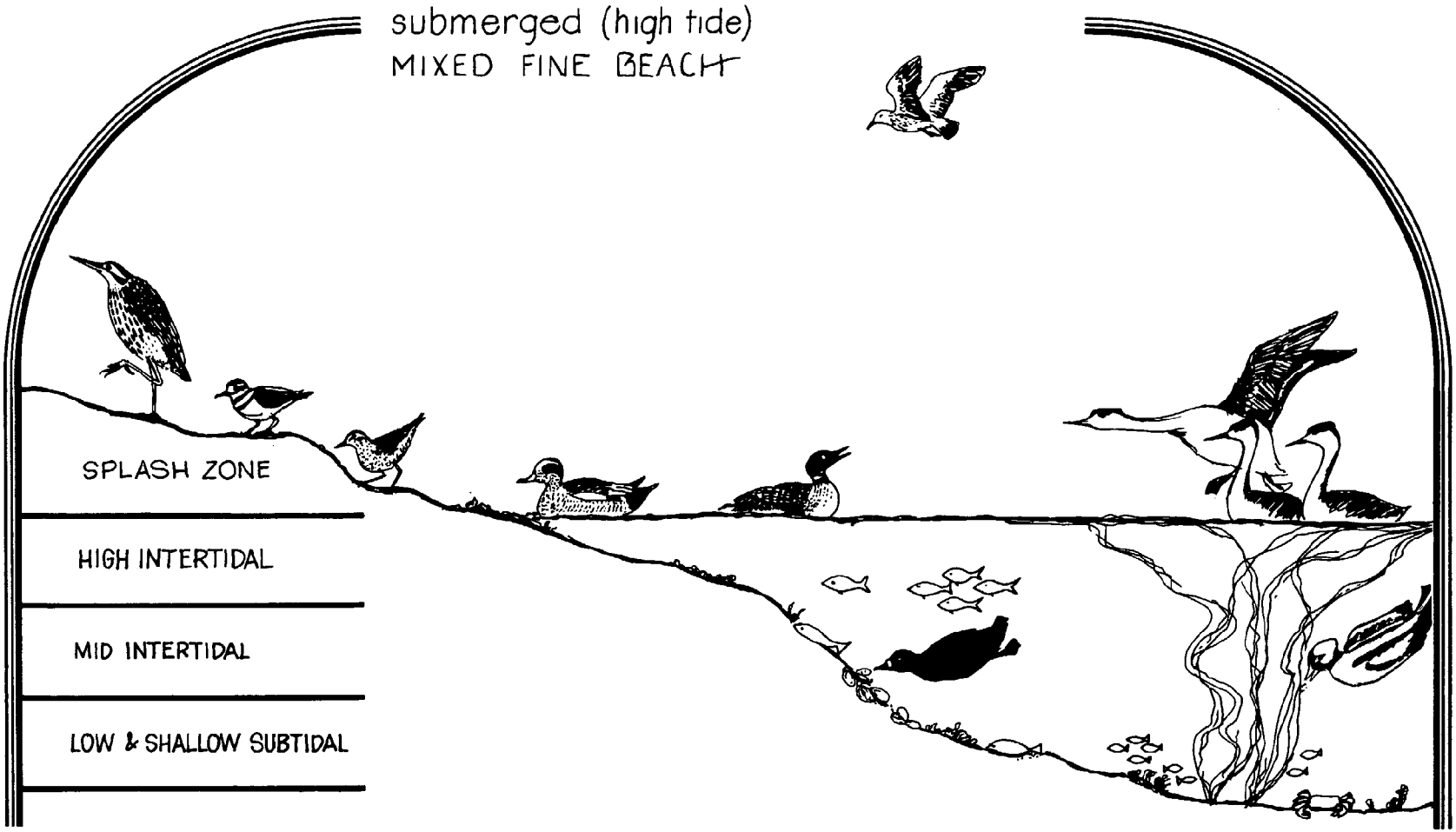
These examples demonstrate the variety of requirements of wildlife which use mixed fine beaches. We are continually becoming more aware of specific needs for each species and know now that a large number of wildlife depend on the substrate and relatively undisturbed adjacent habitats. Therefore, it is important to protect the quality of mixed fine beaches and adjacent habitats to maintain the diversity of species which occur here.

Characteristic Plants and Animals

Plants and Invertebrates

Intertidal zonation of mixed fine beaches is not as clearly defined as on rock beaches, but is present. Diversity and abundance increase as the amount of mud and organic debris present increases.

FIGURE 635-2


submerged (high tide)
MIXED FINE BEACH
SPLASH ZONE
HIGH INTERTIDAL
MID INTERTIDAL
LOW & SHALLOW SUBTIDAL

See Figures 635-1 and 2 for a representative cross-section of a mixed fine beach and characteristic species in each zone at high and low tides. Table 635-1 provides a list of characteristic species, many of which are discussed below:

splash zone

The splash zone is limited in extent, as this beach type is restricted to fairly protected areas. Where mixed fine beaches are bordered on their upland side by eroding bluffs the splash zone is not characterized by a distinct biological community. Where there is no bluff behind the beach, salt marsh (see Narrative No. 623) or beach grassland vegetation (No. 312) usually occupy the "splash" zone. In highly protected sites, the splash zone is essentially nonexistent.

high intertidal zone

The high intertidal zone is characterized by low diversity of organisms and low biomass, especially in less protected areas where there is essentially no mud present. Virtually no vegetation is present (unless marsh vegetation occurs), and the invertebrates are dominated by oligochaete and polychaete worms, nematodes, and small crustaceans (especially amphipods). In protected areas, small individuals of barnacles, limpets, and littorines (*Littorina*), may be scattered on the larger gravel-sized rocks. Detritus which accumulates on less protected sand and gravel beaches may support insect larvae as well as the familiar beach hoppers.

TABLE 635-1. Characteristic Plants and Animals of Mixed Fine Beaches.

SPECIES Common Name (Scientific Name)	Trophic Type	Zone(s) of Occurrence	Economic Value	Comments
PLANTS				
Green Algae				
Sea lettuce (*Ulva lactuca*)	PP	M,L	PC	Edible; high productivity
(*Ulva* spp.)	PP	M,L	PC	Edible
(*Enteromorpha* spp.)	PP	H,M,L	PC	Edible; often in brackish water
(*Monostroma* spp.)	PP	M,L	PC	Edible
Brown Algae				
Rockweed (*Fucus distichus*)	PP	H,M,L		
Blister wrack (*Laminaria bullata*)	PP	L,SB	PC	
Sugar wrack (*L. saccharina*)	PP	L,SB	PC	Edible
Seersucker (*Costaria costata*)	PP	L,SB		
(*Sargassum muticum*)	PP	L,SB	PC	Has been used for pig fodder.
Color changer (*Desmarestia ligulata*)	PP	L,SB		Plant cells contain sulfuric acid.
Whip tube (*Scytosiphon lomentaria*)	PP	L		
Red Algae				
(*Neoagardhiella baileyi*)	PP	L,SB	PC	Edible
(*Gigartina papillata*)	PP	H,M,L	PC	Contains carrageenan
Red or purple laver, nori (*Porphyra perforata*)	PP	M,L	PC	Supports large industry in Japan related to culture as food.
(*Gracilariopsis sjoestedtii*)	PP	L,SB	PC	Edible
(*Gracilaria verrucosa*)	PP	L,SB	PC	Edible
(*Polysiphonia* spp.)	PP	L,SB		
Other Algae				
Diatoms	PP	H,M,L,SB		

TABLE 635-1. Characteristic Plants and Animals.

SPECIES Common Name (Scientific Name)	Trophic Type	Zone(s) of Occurrence	Economic Value	Comments
Vascular Plants				
Eelgrass (*Zostera marina*)	PP	L,SB	PC	Seeds edible; Blades consumed by waterfowl.
INVERTEBRATES				
Molluscs				
Native little neck clam (*Protothaca staminea*)	FF	M,L,SB	C,R	
Japanese littleneck clam (*Tapes japonica*)	FF	M,L	C,R	
Soft shell clam (*Mya arenaria*)	FF	H,M,L	PC,R	Supports commercial industry on east ocast; prefer brackish water.
Washington or butter clam (*Saxidomus giganteus*)	FF	L,SB	C,R	
Horse clam (*Tresus capax* and *T. nuttallii*)	FF	L,SB	C,R	
Goeduck (*Panope generosa*)	FF	L,SB	C,R	Rare in intertidal
(*Transennella tantilla*)	FF	M,L		
(*Mysella tumida*)	FF	M,L		
Cocle (*Clinocardium nuttallii*)	FF	H,M,L,SB	R	
Bent-nose clam (*Macoma nasuta*)	DEP	M,L		Edible
Bay mussel (*Mytilus edulis*)	FF	M,L	C	Commercially cultured on rafts
Pacific oyster (*Crassostrea gigas*)	FF	M,L	C,R	
Variegated limpet (*Notoacmea persona*)	HERB	M,L		Edible
Plate limpet (*Notoacmea scutum*)	HERB	M,L		Edible
Littorine or periwinkle (*Littorina* spp.)	HERB	H,M,L		
Moon snail (*Polinices lewisii*)	CARN	L,SB		Edible
Chink shell (*Lacuna variegata*)	HERB	L,SB		

TABLE 635-1. Characteristic Plants and Animals.

SPECIES Common Name (Scientific Name)	Trophic Type	Zone(s) of Occurrence	Economic Value	Comments
Echinoderms				
Brittle star (*Amphipholis squamata*)	HERB	L		
Mottled star (*Evasterias troschelii*)	CARN	L,SB		Probably controls lower limit of mussels and oysters on mixed fine beaches.
Arthropods				
Acorn barnacle (*Balanus glandula*)	FF	H,M,L		
Horse barnacle (*B. cariosus*)	FF	M,L		
Hairy shore crab (*Hemigrapsus oregonensis*)	SCAV-CARN	M,L		
Dungeness crab (*Cancer magister*)	CARN-SCAV	L,SB	R,C	
Red rock crab (*C. productus*)	CARN-SCAV	L,SB	R,PC	
Pea crab (*Pinnixa faba*)	COMM	L,SB		Live in horse clams; feed on food collected by the clams
(*P. littoralis*)	COMM	L,SB		
Hairy hermit crab (*Pagurus hirsutiusculus*)	DETR-SCAV	M,L		
Hermit crab (*P. granosimanus*)	DETR-SCAV	M,L		
Ghost shrimp (*Callianassa californiensis*)	DETR	M,L,SB	PC,C	Edible; collected for sale as fish bait
Mud shrimp (*Upogebia pugettensis*)	DETR	M,L,SB	PC	Edible
Broken-back or gray shrimp (*Crangon* spp.)	CARN	L,SB,T	PC	Formerly commercially harvested
Oregon pill bug (*Gnorimosphaeroma oregonensis*)	SCAV	H,M		
Isopod (*Idotea wosnesenskii*)	HERB	M,L		
(*Exosphaeroma* spp.)	DETR	M		
Amphipod (*Corophium acherusicum*)	DETR	H,M		
Other gammarid amphipods	DETR	H,M,L,SB		
Caprellid amphipods	CARN	M,L,SB		
Tanaids (*Leptochelia* spp.)	FF	H,M,L		
Cumacean (*Cumella vulgaris*)	DETR	M,L		
Harpacticoid copepods	DETR	H,M,L		

TABLE 635-1. Characteristic Plants and Animals.

SPECIES Common Name (Scientific Name)	Trophic Type	Zone(s) of Occurrence	Economic Value	Comments
Annelids				
Syllidae (*Syllis* spp.)	DETR	H,M		
(*Exogone* sp.)	DETR	M,L		
Capitellida (*Mediomastus* sp.)	DEP	H,M,L		
(*Notomastus* sp.)	DEP	H,M,L		
Lumbrineridae (*Lumbrineris* spp.)	DEP	H,L		
Opheliidae (*Armandia* sp.)	DEP	L		
Nereidae (*Platynereis* sp.)	HERB	L		
(*Nereis* spp.)	HERB	M,L	R	Used as bait for fishing
Spionidae (*Polydora* spp.)	DETR	M,L		
(*Spio* spp.)	DETR	M,L		
(*Spiophanes* spp.)	DETR	M,L		
Cirratulidae (*Tharyx* sp.)	DETR	M,L		
Polynoidae (*Harmothoe* sp.)	CARN	L		
Hesionidae (*Ophiodromus* sp.)	CARN	L		
Oligochaetes	DEP	H,M,L		
Nematodes	DETR	H,M,L		
Nemerteans	CARN	H,M,L		
Phoronids				
(*Phoronopsis harmeri*)	FF	L,SB		

Legend:

Trophic type -
- PP = Primary Producer
- FF = Filter Feeder
- COMM = Commensal
- DETR = Detritivore
- CARN = Carnivore
- SCAV = Scavenger
- HERB = Herbivore

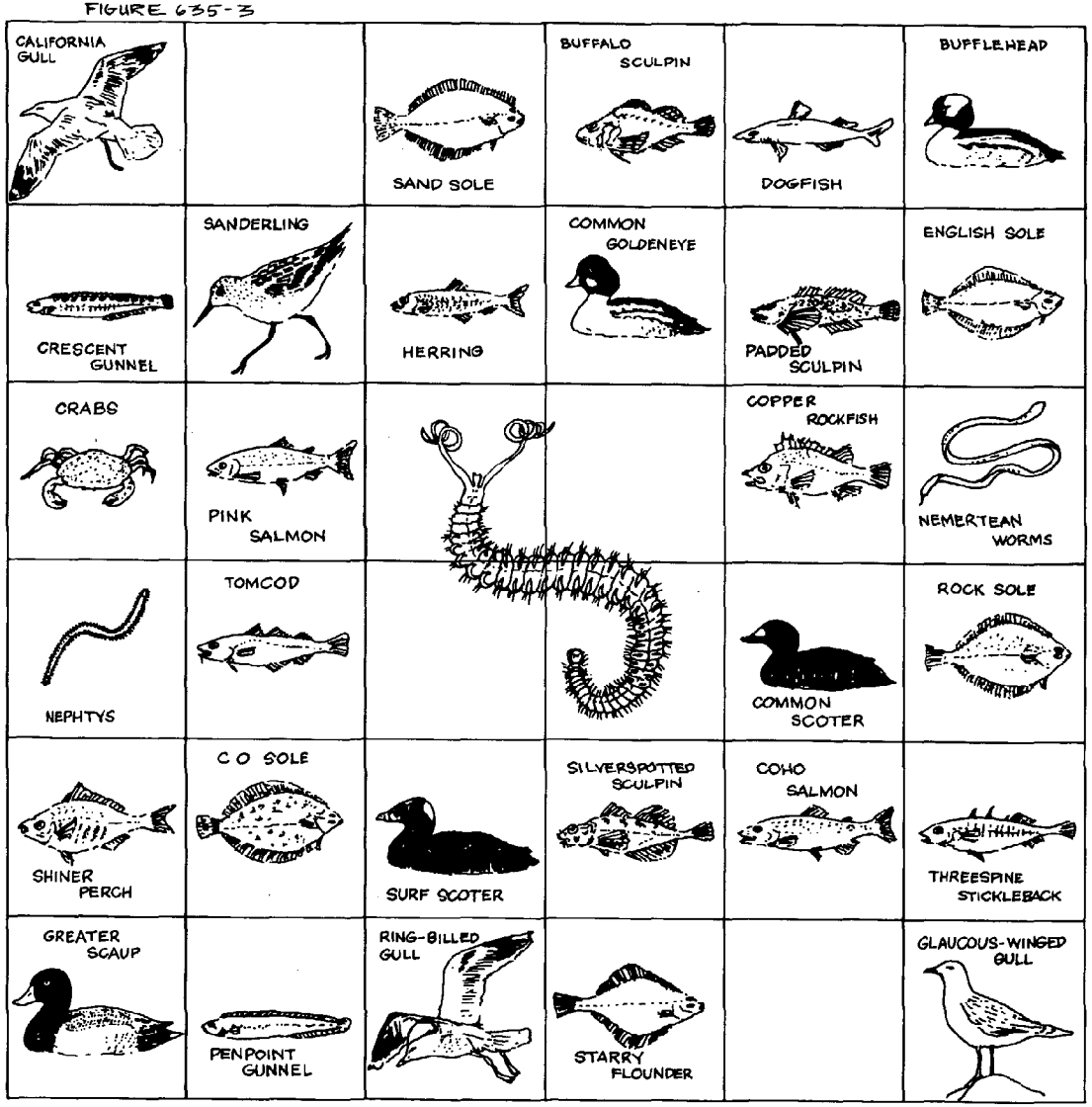
Zone of Occurrence -
- H = High Intertidal
- M = Mid-Intertidal
- L = Low-Intertidal
- SB = Shallow Subtidal
- T = Tidepool

Underlined zone denotes zone of greatest abundance.

Economic Value -
- R = Recreational
- C = Commercial
- PC = Potential Commerical

POLYCHAETE PREDATORS

FIGURE 635-3



mid-intertidal zone

The mid-intertidal zone is stongly dominated by filter feeding bivalves, most of which are also dominant in the lower intertidal zone. Most common are native and Japanese littlenecks, cockles, butter clams, horse clams, Transennella tantilla, and Mysella tumida. Softshell clams and the detritus-feeding bent-nose clam may be abundant where mud content of the substrate is higher. The distribution of these clams is usually quite patchy. In Hood Canal and central and southern Puget Sound, bay mussels often occur in large patches, especially on the alluvial fans formed by small creeks flowing across the beach.

Polychaete worms are the most diverse group of organisms in mixed fine sediments, particularly when mud is present. Most species encountered are deposit or detritus feeders, while a few are either carnivorous or herbivorous. The dominant species will vary depending upon the amount of organic matter and mud in the substrate. The importance of polychaetes as food for a myriad of species is illustrated in Fig. 635-3

Small crustaceans are also an important part of the fauna in the mid-intertidal.

Barnacles are usually fairly abundant on the pebbles of mixed fine beaches. In southern Puget Sound the hairy shore crab may reach densities of hundreds per square meter. These crabs seem to benefit from the presence of ghost and mud shrimp, into whose burrows they often scramble during low tides on hot summer days.

Algae are patchy in distribution in this zone, with rockweed occasionally attached to pebbles, mussels, or sticks. In low salinity areas, such as near creek mouths, Enteromorpha is usually found attached to mussels or pebbles.

lower intertidal zone

Many of the clams which occurred in the mid-intertidal zone are even more abundant in the lower intertidal. Bay mussels, however, become very uncommon due to predation by the mottled starfish and possibly crabs. Small crustaceans (harpacticoid copepods, isopods, amphipods, cumaceans, and tanaids) become extremely numerous, and the polychaete worms again show high diversity and abundance. Dominant species of these groups vary from site to site according to the amount of mud present. Larger crustaceans, such as crabs and shrimp, move into this zone during high tides to feed on small invertebrates.

The amount of vegetation present may increase quite dramatically in this zone in comparison to the higher intertidal zones. Eelgrass may occur, along with the many species of plants and animals associated with it (see Narrative No. 627). It is more likely, however, to find dense growths of green algae in well protected areas. See lettuce is the most abundant gree algae, but Monostroma and Enteromorpha also occur. Red algae such as Neoagardhiella baileyi often attach to small pebbles or clam shells, and the delicate Polysiphonia may attach to the siphon of horse clams. Several large brown algae may occur in the lower portions of the zone, such as seersucker, sea collander, sugar wrack, blister wrack, and Sargassum muticum, but these algae are more abundant just below the low water mark in the shallow subtidal zone.

Fish

A large number of fish species are often associated with mixed fine beaches. For example, the highest number of species were captured in recent oil baseline beach seine samples along the Strait of Juan de Fuca at a mixed fine beach. The presence of eelgrass and location in a protected bay were thought to be contributing factors. Since eelgrass and moderately protected locations are often present, a species rich fish community may be typical throughout the coastal zone at mixed fine beaches.

In more exposed situations, the fish associated with mixed fine beaches include many which also occur in rockier habitat. This is particularly true in the San Juan Islands, where rocky shoulders protect small bays with mixed fine and gravel substrate.

Many of the fish which feed along mixed fine beaches and in adjacent eelgrass and algae beds are highly valuable commercially and recreationally. These include salmon, English sole, herring, and sea-run cutthroat trout. Oil baseline sampling indicated the importance of protected mixed fine to these species, particularly English sole and herring which were caught in large numbers. Mixed fine beaches are known to be important nursery areas for English sole and recent sampling indicates their value for adults. Thus, maximum biomass of English sole recorded was at the mixed fine site owing to the large number of adults captured in winter.

Other fish which occur are valuable indirectly to man or directly to other wildlife. Several of these species and commercially valuable fish associated with mixed fine beaches are discussed below and listed in Table 635-2.

Staghorn Sculpin

The staghorn sculpin is to salt water as the robin is to lawns. They appear to be everywhere, but are especially abundant along mixed fine beaches throughout the year. The abundance, ubiquity, and occurrence close to shore make them one of the most valuable prey species for nearshore wildlife as indicated by their known predators shown in Figure 635-4.

These sculpins grow to 18 inches, but schools of much smaller staghorns are frequently seen at the water's edge. There, they may bury themsleves, all but the eyes, in bottom sand. They seem to come from nowhere if you disturb this hiding place by walking along shore. Sculpins feed on a large number of organisms, just as they are prey of so many others. Known prey include Gammarid amphipods, polychaetes, parasitic nematodes, shrimp including crangonids and ghost shrimp, shiner perch, shore crabs, and mysids.

Figure 63b-4

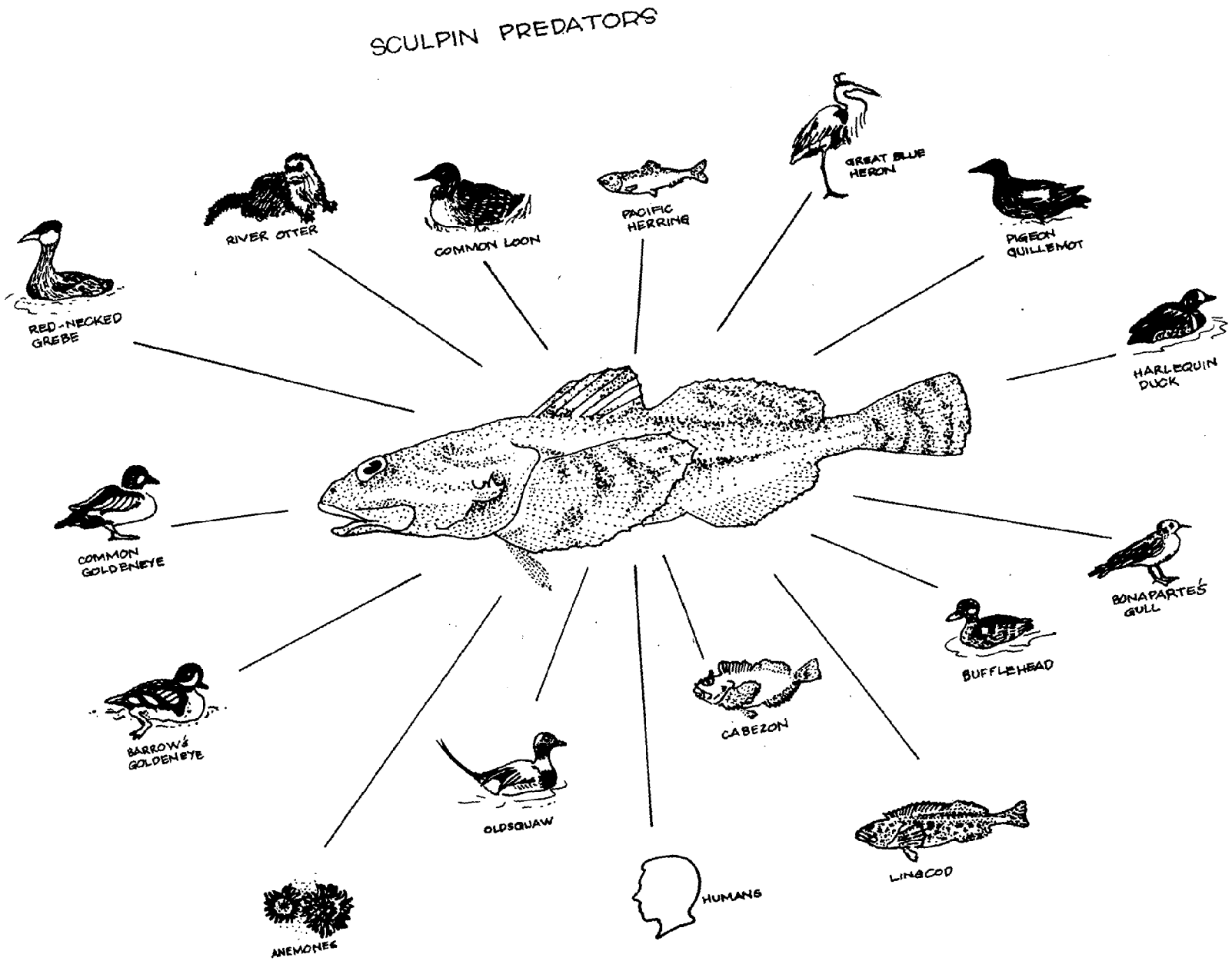

SCULPIN PREDATORS
RED-NECKED GREBE
RIVER OTTER
COMMON LOON
PACIFIC HERRING
GREAT BLUE HERON
PIGEON GUILLEMOT
HARLEQUIN DUCK
COMMON GOLDENEYE
BONAPARTE'S GULL
BUFFLEHEAD
BARROW'S GOLDENEYE
CABEZON
OLDSQUAW
LINGCOD
HUMANS
ANEMONES

TABLE 635-2. FISH ASSOCIATED WITH MIXED FINE BEACHES, A PARTIAL LIST

Spiny dogfish (*Squalus acanthias*)
Starry skate (*Raja stellulata*)
Pacific herring (*Clupea harengus*)
Pink salmon (*Oncorhynchus gorbuscha*)
Chum salmon (*O. keta*)
Coho salmon (*O. kisutch*)
Chinook salmon (*O. tshawytscha*)
Cutthroat trout (*Salmo clarkii*)
Surf smelt (*Hypomesus pretiosus*)
Plainfin midshipman (*Porichtys notatus*)
Pacific cod (*Gadus macrocephalus*)
Pacific tomcod (*Microgadus proximus*)
Walleye pollock (*Theragra chalcogramma*)
Threespine stickleback (*Gasteresteus aculeatus*)
Tube-snout (*Aulorhynchus flavidus*)
Bay pipefish (*Syngnathus griseolineatus*)
Rockfish (*Sebastes species*)
White spotted greenling (*Hexagrammos stelleri*)
Lingcod (*Ophiodon elongatus*)
Sharpnose sculpin (*Clinocottus acuticeps*)
Buffalo sculpin (*Enophrys bison*)
Staghorn sculpin (*Leptocottus armatus*)
Great sculpin (*Myoxocephalus polyacanthocephalus*)
Cabezon (*Scorpaenichthys marmoratus*)
Roughback sculpin (*Chitonotus pugetensis*)
Sturgeon poacher (*Agonus acipenserinus*)
Shiner perch (*Cymatogaster aggregata*)
Striped seaperch (*Embiotoca lateralis*)
Pile perch (*Rhacochilus vacca*)
Snake prickleback (*Lumpenus sagitta*)
Crescent gunnel (*Pholis laeta*)
Saddleback gunnel (*P. ornata*)
Pacific sandlance (*Ammodytes hexapterus*)
Speckled sanddab (*Citharichthys stigmaeus*)
Pacific sanddab (*C. sordidus*)
Rock sole (*Lepidopsetta bilineata*)
English sole (*Parophrys vetulus*)
Starry flounder (*Platichthys stellatus*)
C-O sole (*Pleuronichthys coenosus*)
Sand sole (*Psettichthys melanostictus*)

English Sole

English sole are members of the family Pleuronectidae, the righteye flounders. These flatfish are known variously as flounders and sole and usually have the eyes and dark coloration on the right hand side of the fish. Halibut are also in this family and are perhaps the best known of the commercially valuable bottom fish. English sole are also commercially harvested and are intimately associated with mixed fine beaches, especially as juveniles. Filet of sole has long been a popular and valuable food, and several millions of pounds of English sole are harvested annually by U.S. and Canadian fishermen. English sole also provide sport fisherman with an excellent fresh fish dinner; the continuance of which depends on protection of the quality of the nearshore environment. Recent evidence in Elliot Bay has shown high incidences of tumors and lesions on English sole. High levels of pollutants such as Polychlorinated bi-phenyls (PCB) entering the Duwamish River and Elliot Bay from municipal and other wastes are suspected causes.

Prey of the English sole include Gammarid amphipods, polychaetes, cumaceans, tanaids, harpacticoid copepods, mysids, crangonid shrimp, and clam siphons.

Shiner Perch

The shiner perch or "pogey" is the smallest member of the surfperch family (Embiotocidae), growing to about 6 inches. They are schooling fish which often occur in abundance along mixed fine beaches. Gammarid amphipods are favored food items of shiners which also consume harpacticoid copepods, calanoid copepods, polychaetes, mussels, and algae.

Shiner perch are an important prey of Caspian Terns in Grays Harbor and are also consumed by other marine birds, harbor seals, and river otters. They are also used by humans in a variety of ways. Children often catch "pogeys" from piers in the spirit of fishing for fun. Other people use them as bait for rockfish, and although small are occasionally brought home and eaten as fresh fish.

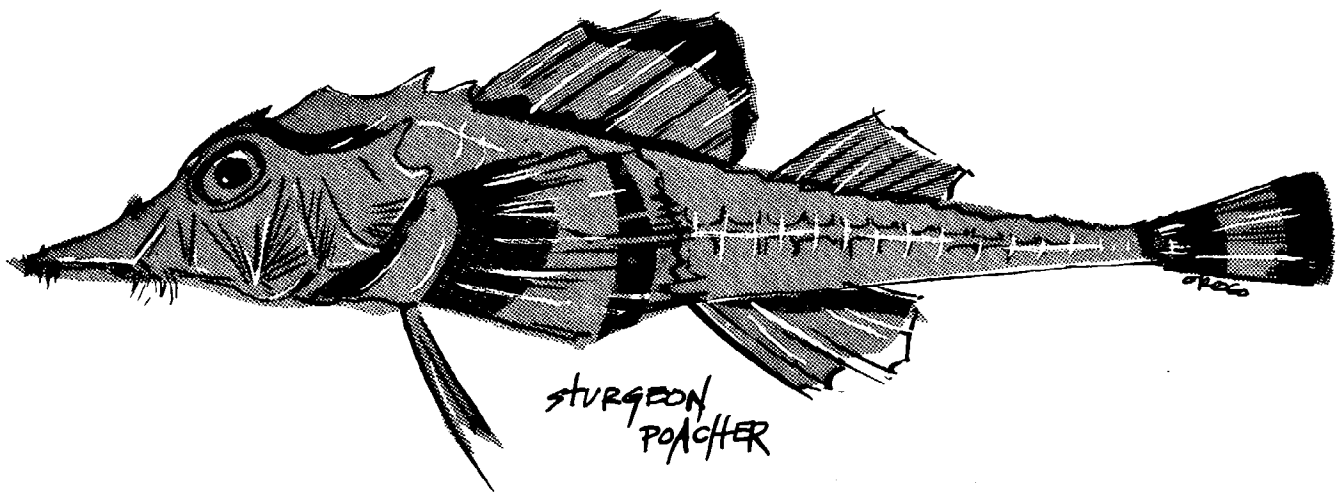
Shiner perch are unusual in that they are one of the fish which gives birth to live (as opposed to eggs) young. The tiny young are born tail first, most often in May or June.

Sturgeon Poacher

These intriguing fish are sometimes abundant nearshore along mixed fine beaches. The sturgeon poacher is a bottom dweller, as its downward directed mouth and somewhat flattened head suggest. They do look like sturgeon, but grow to only about 12 inches. Like their namesakes, the sturgeon poacher also has nighly modified "scales". While sturgeons have a scattering of bony plates replacing scales, the poacher has rows of spinous plates covering much of the body. The plates greatly restrict the fish's flexibility, limiting all but stiff lateral movements. The importance of the large pectoral fins for swimming has been noted, and is apparently a trade-off for the stiff but protective armor covering of plates. Prey of sturgeon poachers include cumaceans, gammarid amphipods, harpacticoid copepods, shrimp and polychaetes.

Pacific Herring and Coho Salmon

These two fish are discussed together because of the important relationship between them, especially to the thousands of sports fishermen of Washington. Pacific herring are often abundant along mixed fine



beaches where they spawn in eelgrass beds and reside as juveniles. Herring juveniles are almost exclusively planktivores, consuming copepods, mysids, and crab zoea (larvae which are planktonic). Herring are, in turn, consumed by a wide variety of birds, marine mammals, and other fish including Coho salmon. Coho, however, feed on a wide variety of other fish and invertebrates such as gammarid amphipods, cumaceans, insects, barnacle and crab larvae, euphausids, and squid.

Coho are a valuable sports fish and are renowned for their fighting ability. They may be caught on herring, but are often fished near the surface with an artificial lure known as the Coho fly.

Birds

A wide variety of birds and mammals use mixed fine beaches, especially as feeding areas. Some species occur throughout the year, while others are seasonal visitors. Refer to Table 635-3 for a listing of potential species and the following discussions for more detailed information on some of the more characterisitic species:

Mew Gull

Mew Gulls are small gulls distinguished by their relatively short, unmarked yellow bill and the large patch of white at the tip of their wing which contrasts sharply with the black separating this patch from the otherwise grayish wing.

Mew Gulls are present along mixed fine beaches throughout much of the year, and are especially common when eelgrass is exposed at low tide. They also feed over submerged beaches and subtidally, where they are often observed picking at the water's surface. Prey on exposed beaches includes polychaetes, while offshore they probably consume small schooling fish and a variety of invertebrates while surface picking.

Glaucous-winged Gull and Common Crow

Anyone who has dug clams along mixed fine beaches is aware of the expectant beach scavengers which most often include crows and the ubiquitous Glaucous-winged Gull. Both of these birds capture live prey, but feed extensively as beach scavengers. Broken clams, polychaete worms, crabs, and essentially all "bite-sized" invertebrates uncovered by the clam digger will be taken by gulls and crows. They also scavenge the beaches and adjacent uplands.

Crows and gulls seem not to be affected as yet by the many pollutants which are concentrated as they are transferred through various food chains. However, other predators such as Peregrine Falcons and harbor seals have been shown to be adversely affected.

Belted Kingfisher

Kingfishers are familiar, raucous callers along the beach and often frequent in mixed fine areas. Their large head, long and stout bill, crest, and blue color separate the Kingfisher from all other local birds. The band across their white breast is also distinctive. The female is identified by the presence of a rufous band below this bluish-grey one which is on both sexes.

Kingfishers seek their prey, often small sculpins, in shallow water. They perch on pilings overhanging branches from which they may plunge directly when a fish is spotted. They also fly out over the water and hover in mid-air before diving for a fish. Their five to eight eggs are placed in long tunnels excavated in steep bluffs alongshore.

Killdeer and other shorebirds

The Killdeer is probably the most familiar shorebird in Washington. They are about the size of a Robin and distinctively marked with two black breast bands. Killdeer are well known for their broken wing display which distracts would-be predators from the nest or young. Both parents incubate and care for the young, so males or females might be the one leading you away if this behavior is observed.

Killdeer were the most frequently observed shorebird on mixed fine beaches during our studies. Other species are infrequently observed and include those which more typically feed on rocky or muddier beaches. For example, Wandering Tattlers and Black Turnstones which usually prefer rocky areas, were observed and a Greater Yellowlegs, which is more common in tidepools on mudflats was seen along Sequim Bay on a mixed fine beach. Sanderlings and Spotted Sandpipers were also observed, both feeding along high intertidal areas which graded into mixed medium and coarse sand.

European Wigeon and American Wigeon

The European Wigeon occurs in small numbers, most often among a flock of the similar and abundant American Wigeon. The primary physical trait separating the two species is the fox red of the European's head which is much unlike the green-tinged head of the American Wigeon. Both have a creamy white crown, which has led to the popular name "Baldpate" often applied to the American Wigeon.

TABLE 635-3 BIRDS OBSERVED AT MIXED FINE BEACHES DURING THE COASTAL HABITAT INVENTORY

SPECIES	BEACH[1]	NEARSHORE[2]	OFFSHORE[3]
Common Loon		X	X
Arctic Loon			X
Red-throated Loon			X
Red-necked Grebe		X	X
Horned Grebe		X	X
Eared Grebe		X	X
Western Grebe			X
Pied-billed Grebe		X	
Double-crested Cormorant		X	X
Brandt's Cormorant			X
Pelagic Cormorant		X	X
Great Blue Heron	X	X	
Brant	X	X	X
Mallard	X	X	X
Pintail		X	X
European Wigeon		X	
American Wigeon	X	X	X
Canvasback			X
Greater Scaup		X	X
Lesser Scaup		X	X
Common Goldeneye		X	X
Barrow's Goldeneye		X	X
Bufflehead		X	X
Oldsquaw			X
White-winged Scoter		X	X
Surf Scoter		X	X
Black Scoter			X
Hooded Merganser		X	X
Red-breasted Merganser		X	X
Common Merganser			X
Sharp-shinned Hawk	X		
Bald Eagle	X	X	X
Osprey			X
Turkey Vulture	X		
Merlin	X	X	X
Killdeer	X		
Black Turnstone	X		
Spotted Sandpiper	X		
Greater Yellowlegs	X		
Wandering Tattler	X		
Sanderling	X		
Glaucous-winged Gull	X	X	X
Thayer's Gull	X	X	X
Western Gull			X
California Gull	X	X	
Mew Gull	X	X	X
Bonaparte's Gull			X
Heermann's Gull	X	X	X
Common Tern		X	X
Pigeon Guillemot		X	X
Marbled Murrelet			X
Rhinoceros Auklet			X
Common Murre			X
Belted Kingfisher		X	
Barn Swallow	X	X	
Common Crow	X		
Winter Wren	X		
Song Sparrow	X		

1 Exposed surface at high or low tide.

2 Submerged intertidal and shallow subtidal to approximately 20 to 30 feet relative to MLLW.

3 Shallow subtidal areas to approximately 300 yards offshore.

Both species feed along mixed fine beaches, consuming eelgrass, see lettuce, and Enteromorpha.

White-winged Scoter

The White-winged Scoter is one of three scoters which occur in Washington waters and is perhaps the most frequently observed near to shore. They were observed at all mixed fine beaches during our studies, often in flocks which also include Surf Scoters and scaups. White-winged Scoters, not surprisingly, are distinguished by the white patch (speculum) on the wing of both sexes. The male is otherwise all black with a striking white eye patch that curves back and up. Females are dark brown with two light cheek patches.

White-winged Scoters are often persecuted because they do feed on commercially harvested clams. However, they feed on a variety of other organisms including oyster drills, littorine snails, limpets, shore crabs, barnacles, sea urchins, starfish, sand dollars, and eelgrass. Where they are a problem to commercial clam harvesters, they can be scared away since they feed mostly by day.

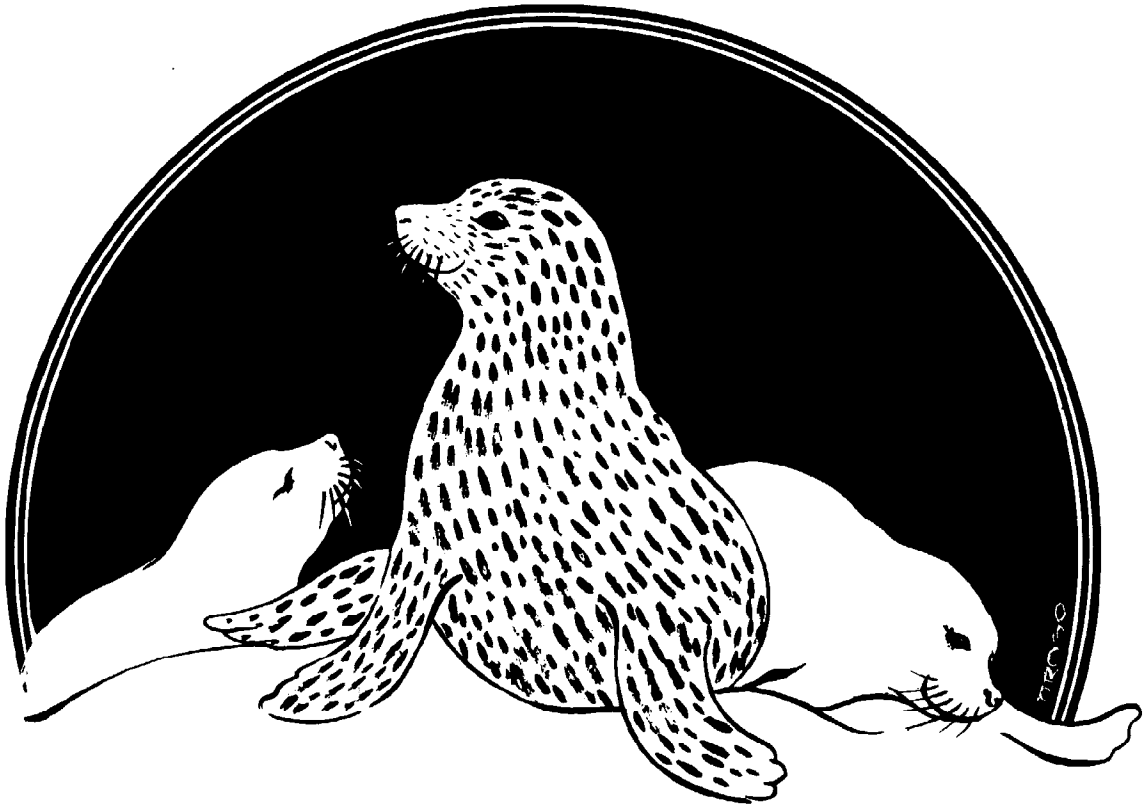
Mammals

Raccoon

The raccoon is a widely known mammal, largely because it is so observable. Raccoons are often seen crossing the highway, begging food from campers or in the backyard, and while they scavenge food along beaches.

Favored natural prey include a wide varity of items, but along beaches is often limited to shorecrabs and beach hoppers. Beach hoppers (sand fleas) are a surprisingly consistent and important prey of raccoons because of their small size. However, they are often quite abundant along mixed fine beaches where they feed on detritus in the high intertidal. We have often found sign of raccoon suggesting that an entire meal was composed of these tiny amphipods.

Figure 635-5



Prey of Harbor Seals

PACIFIC COD
ROCKFISH
SQUID
LAMPREY
HERMIT CRABS
DUNGENESS CRAB
STAGHORN SCULPIN
TOMCOD
GHOST SHRIMP
BLENNIES
SAND LANCE
FLATHEAD SOLE
SALMON
PACIFIC HERRING
SHORECRABS
SHINER PERCH
CRANGONID SHRIMP

Harbor Seal

The harbor seal often feeds close to shore along mixed fine beaches and has also been observed mating in shallow water at an isolated mixed fine beach. These seals are our only "earless" seal, family Phocidae; sea lions and fur-seals being members of the family Otariidae, or eared seals. Harbor seals are not really without ears, but do lack the external features of ears which are also quite reduced in sea-lions. Harbor seals are further distinguished by their short fore-flippers and dog-like face which often pops up to watch you walk the shore or glide by in a boat. The fur is spotted and color varies from whitish to dark gray, but most often is bluish gray with black spots and irregular white rings and loops.

Harbor seals are relatively nonmigratory and spend about half their time ashore at favorite haul out spots which include sand bars, isolated rock outcrops, rock islands, and islets, and artificial islands such as log rafts. Small groups or individuals may be somewhat scattered for much of the year, but there is a gathering in at the start of the early summer pupping season, to what are thought to be traditional pupping and breeding sites. These sites include year-round haul out areas such as the major Puget Sound site at Gertrude Island.

There appear to be no territorial conflicts while on land, which is quite unlike the fierce interactions between bull sea lions and fur-seals. Pupping occurs from late June to early September with local variations in timing of birth, weaning, and the beginning of the breeding season. Pups are about 12 pounds at birth and double this weight when they are weaned at four to six weeks from the rich diet of milk containing 45% fat and 9% protein. Adult weights vary from about 180 to 300 pounds.

Breeding begins soon after pups are weaned and following fertilization, there is a delay of implantation which retards development of the fetus for approximately two months so that the total gestation period is nine to ten months. Harbor seals have apparently evolved this mechanism to coincide the timing of mating in late summer (when males and females are together on the pupping sites) with the optimum time the following spring for birth and survivial of pups.

The harbor seal most often feeds in shallow water, although dives of 300 feet and dive durations of up to 25 minutes have been observed experimentally. Prey of the harbor seal is quite varied as illustrated in Figure 635-5.

They do consume salmon and occasionally are entangled in fishermen's nets. Fishermen respond at times by killing harbor seals, despite the fact that they are protected by the Marine Mammal Act. The only other major predator of harbor seals in Washington is the killer whale.

Other mamals observed on or adjacent to mixed fine beaches during our studies were : coyote, striped skunk, long-tailed weasel, river otter, deer, and killer whale.

Use by Man

Recreational Use

Historically, the major use of mixed fine beaches by man has been for recreational (and to much lesser extent for commercial) clamming. In fact, this beach type is one of the most popular for use by humans for gathering food. Native and Japanese littlenecks, butter clams, and horse clams are the most popular species sought. Goeducks, the largest bivalve in Washington, are considered a 'prize' catch, but are unncommon in intertidal areas. Even when found, a determined clammer may have to dig a hole over three feet deep to obtain a geoduck.

Cockles are also eaten, although they are not as popular as other species.

Soft shell and bent-nose clams are also edible, but are not commonly collected by clam diggers. Soft shell clams are extremely popular on the east coast, but are only beginning to show signs of becoming acceptable on the West coast. Bent-nose clams are unpopular because of their habit of feeding by vacuuming off the top layer of sediment and detritus with their siphon. Thus, they contain large amounts of sand and mud in their digestive tracts although it is expelled if the clams are left to soak in fresh salt water. Bay mussels are becoming a popular food item in some restaurants in western Washington. However, bay mussels are only rarely collected recreationally as a food source.

In portions of Hood Canal, where the Pacific Oyster is well established, oysters are collected recreationally. However, the number of public beaches where oysters occur is very limited. Dungeness crabs and, to a lesser extent, red rock crabs are also sought recreationally at mixed fine beaches. Crabbing is usually most lucrative in areas where eelgrass or algae are present.

Recreational fishing is also popular along mixed fine beaches, including pursuit of sea-run cutthroat trout which are most often caught in shallow nearshore waters. Salmon, flatfish, and Pacific cod are also fished in these areas, although in slightly deeper waters. Other recreational activities include bird watching, swimming, and quiet strolls along the beach. The latter being a pleasant activity enjoyed throughout Puget Sound where mixed fine beaches provide firm and yet not too rocky substrate.

Commercial Use

Natural populations of littleneck, butter, and horse clams are all currently harvested commercially from intertidal beaches in Washington. The harvest of goeducks, however, is presently limited to subtidal areas. In some areas, such as in the San Juan Islands, beaches have been seeded with young littleneck clams in hopes of increasing the commercial harvest. This method of culture is comparable to the seeding of oyster beds, which has long been used in Washington's waters. Mixed fine beaches are also often conducive to the commercial farming of oysters. Commercial harvest of bay mussels is presently limited to where they have been cultured on rafts. Considering the large numbers of mussels which occasionally occur on mixed fine beaches, there is a potential for harvest in intertidal areas. However, predators of mussels could pose a serious threat to an intertidal population.

Species of potential commerical value include various species of algae and shrimp. Some of the algae which occur on mixed fine beaches are edible (e.g., sea lettuce and Neoagardhiella) and closely related algae are popular foods in other parts of the world. Crangonid shrimp were harvested commercially in Puget Sound before the more profitably pandalid shrimp industry developed. Ghost shrimp, which are both edible and extremely palatable, provide another poten-

tial species for commercial harvest. There currently is a limited fishery for ghost shrimp as a bait for fishing. Surf smelt, which lay their eggs in the high intertidal zone of gravel and sand beaches, support a commercial fishery in Washington. Herring, which attach their eggs to marine plants, and juvenile flatfish, are commercially harvested species which occur on mixed fine beaches. Such beaches are reputed to be preferred feeding areas for juvenile chinook, coho, and chum salmon, where these species feed mainly on small crustaceans. Candlefish larvae, which also frequent mixed fine beaches, historically play an important role in Northwest Indian Culture, as the oil of the fish had a wide variety of uses. Candlefish, herring, and smelt are important food items for larger carnivorous fish and birds, including adult salmon.

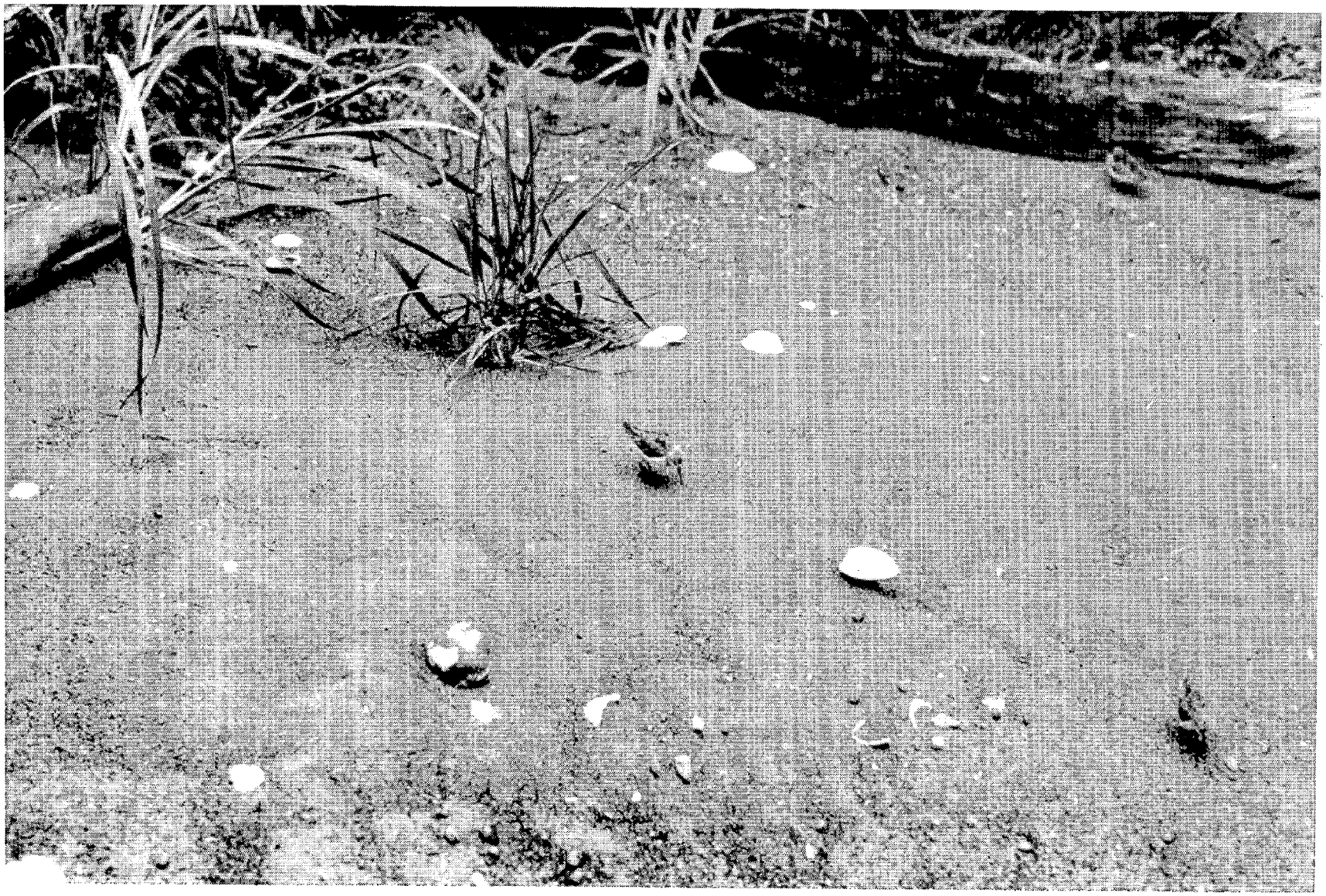
III. IMPACTS

The relationship of mixed fine beaches to protected environments largely determines their ability to deal with various pollutants. In general, reduced water circulation and wave action in protected areas tend not to disperse pollutants, thus they accumulate in these areas.

This problem is further compounded in mixed fine beaches, where bivalves (clams and mussles) form the foundation of heavy recreational and commercial use. Bivalves tend to concentrate many pollutants to phenomenal extents - as high as one million times the concentration in the surrounding water. Heavy metals, e.g., copper, mercury, and lead, are the worst offenders. However, organic wastes can also cause problems. Human sewage containing bacteria which enters the water is responsible for many areas of the state being closed to the commercial harvest of shellfish. Shellfish also concentrate some of these bacteria, which can cause hepatitis or other diseases if ingested by humans.

Perhaps the most widespread impact on mixed fine beaches has been the result of recreational clam diggers. There are some studies from the east coast which indicate young clams are not severely impacted by digging when precautions are taken (such as filling clam holes back in). However, mortalities to other types of animals can be very significant if caution is not observed. This is important in view of the many fish, birds, and crabs which feed upon these other organisms.

Development of adjacent uplands areas is another widespread impact on mixed fine beaches. Wildlife affected by such an impact are sensitive species, such as Great Blue Heron, harbor seals, river otters, and Pintail Ducks, as well as those dependent on the waterland interface, such as Bald Eagles and Belted Kingfishers which roost in trees along the shoreline and feed nearshore.



SAND (No. 636)

INTRODUCTION

Definition and Distribution

Sand beachese consist of particles ranging from .15 to 2.0 mm in diameter. They can be divided into either of two categories: 1) exposed or 2) protected. Exposed sand beaches are associated with high wave, wind, and current action. They occur extensively along the Pacific coast of Washington, especially south of Point Grenville. On relatively calm days on these beaches, the waves are usually 3-6 feet (1-2 meters) high. Also included among exposed beaches are those somewhat protected from direct pounding by oceanic waves, but which still have high wind, wave, or current action. Such beaches occur at the mouth of Grays Harbor and Willapa Bay, and in small bays north of Point Grenville, occasionally along the north side of the Olympic Peninsula (e.g., Kydaka Beach), the southwest shoreline of San Juan Island (e.g., Eagle Cove), and the west side of Whidbey Island. These semi-protected beaches have many features in common with fully exposed sand beaches, but some important faunal differences are evident.

Protected sand beaches are scattered throughout the inland waters of the state, especially at lower tidal levels and near the mouths of bays. Waves are usually less than 0.5 m in height. Specific examples occur at False Bay on Sand Juan Island, on the west side of Hood Canal north of Port Gamble, along King County shorelines, and at Birch Bay in Whatcom County. It is common to find some gravel mixed in with the sand in upper tidal levels.

SIGNIFICANT BIOLOGICAL FEATURES

Sand Beaches as Stressful Environments

Sand beaches, most notably those in exposed situations, provide a highly stressful environment. Stressful properties of these beaches include the following:

1. Sand holds little moisture when the tide is out, especially in coarse sand, and thus affords little protection from dessication (drying out).
2. Sand particles hold little detritus and few nutrients.
3. Sand particles are subject to movement by wind, waves, and currents, and thus provide a constantly shifting substrate. This substrate instability is not restricted to exposed areas, as sand bars in protected bays can shift considerably. In addition, some beaches are accreting while some are in the process of eroding. Thus, plants and invertebrates are either constantly being buried by sand, or constantly being uncovered. To further complicate matters, some beaches will erode during summer and accrete during winter.
4. Exposed sand beaches are subjected to constant, intense battering by the surf.
5. There is limited primary production on exposed sand beaches relative to other beach types.

Protected sand beaches tend to exhibit these stressful properties on a much reduced scale. For example, wave shock is greatly reduced, thus sediments are not shifted about as extensively. In addition, fine sand particles are present, and the ability of the substrate to retain water during low tides increases, affording inhabitants of sandy beaches greater protection. Algae and eelgrass may be present, which increase stability of the sediments and provide habitat for additional animals. Certain types of benthic diatoms which secrete mucilage are also effective in stabilizing sand sediments, as are small tube-dwelling invertebrates. Broad sand beaches in Puget Sound, Hood Canal, Grays Harbor, and Willapa Bay tend to form sand "waves" resulting from wind, current, and wave action. The low spots, or troughs, between waves tend to remain moist at low tides, sometimes even forming small tidepools. These pools not only protect small fish and crustaceans during low tides, but often support eelgrass and other algae.

Habitat

Sand beaches provide an excellent feeding area for fishes, diving birds, marine mammals, and invertebrates which move into the area during high tides. Fishes commonly feeding along sand beaches include sand sole, English sole, shiner perch, and staghorn, sharpnose, and tidepool sculpins. These fish feed primarily on crustaceans (harpacticoid copepods, mysids, cumaceans, tanaids, isopods, amphipods, and shrimp). Surf perch are also present on Pacific coast beaches. Juvenile coho salmon feed along sand beaches (from July to October), as do pink, chum, and chinook salmon. Sand beaches provide the primary nursery areas for English sole, and surf smelt often spawn in the upper intertidal zone. Herring also spawn on sand beaches but are dependent on the presence of vegetation. Crabs and shrimp are also abundant on sand beaches at high tide. They in turn provide food for a variety of fishes, birds, and marine mammals. Neritic fishes (those feeding on organisms in the water column) such as herring and smelt are present on sand beaches at high tide. Diving birds include loons, scoters, and grebes. Harbor seals and river otters feed along sandy beaches, while larger marine mammals, such as gray and killer whales and northern sea lions may cavort offshore.

When uncovered by the tide, sand beaches are frequented by Great Blue Herons, several gull species, and shorebirds. These birds use sand beaches for both feeding and resting. Terrestrial mammals which may occasionally wander onto beaches to gather food are raccoons, skunks, and bobcats. Deer have also been observed along sandy beaches in protected areas during our studies.

Productivity, Diversity, and Abundance

The diversity and abundance of plants and animals on exposed sand beaches is low compared to protected sand beaches or other substrate types such as rock, mixed coarse, mixed fine, and muddy sand. Vegetation is restricted to benthic or interstitial microscopic plants (mostly diatoms), as there is no stable substrate on which macroscopic plants can attach. Thus, productivity is low, and animals are largely dependent on food brought in by the surf (diatoms and decaying plant or animal material). The stressful environment limits the number of animals which can successfully survive, and exposed beaches may have only a dozen species of invertebrates which occur in abundance. Because of this, numbers of organisms may fluctuate greatly. Razor clams, for example appear to produce a successful set of juveniles only once every several years. They are one of the most abundant organisms throughout much of the area where they occur, and have a great impact upon the total number of animals present. Biomass of exposed sand beaches is very low when razor clams are absent.

Bird species diversity is also typically lower on exposed sand beaches, largely because of the impoverished invertebrate fauna. However, where exposed sand beaches occur near protected mudflats, birds, and particularly shorebirds, can be very abundant. This is especially true during spring and fall migrations when ocean sandy beaches are often covered with a seemingly indistinguishable variety of flocking shorebirds. Thousands of other migratory birds also occur in nearshore waters along exposed sandy beaches. These birds may feed intertidally, rest just offshore, or fly by in large flocks during migration. There is evidence that fish species diversity and density may be lower along exposed sand beaches relative to other

beach substrates and more protected sand locations. Recent nearshore fish studies have attributed low densities at exposed sand sites to direct exposure to wave surge and the unstable sand substrate.

Protected sand beaches show a much greater diversity and abundance of both plants and animals than exposed sand beaches, due to the less stressful conditions. In addition to benthic and interstitial microalgae, eelgrass and occasional bits of algae usually occur. However, production is still lower than in other beach substrates (with the exception of cobble and mixed medium) because macroscopic vegetation is usually sparse. Thus, there is still a dependence upon energy imported by tides, waves, and currents. The presence of plants increases the food resources and habitat diversity available to animals. The presence of tidepools may also increase diversity. In general, the density and diversity of animals increases as the tidal elevation gets lower.

The diversity of fishes and birds is strongly affected by the proximity of adjacent beach types. Where different substrates occur nearby, a greater diversity of vertebrates use the sand beaches due to "spillover" from these other areas. In general, the diversity and biomass of fishes is lower at sand beaches, even though the number of fish of each species may periodically be high.

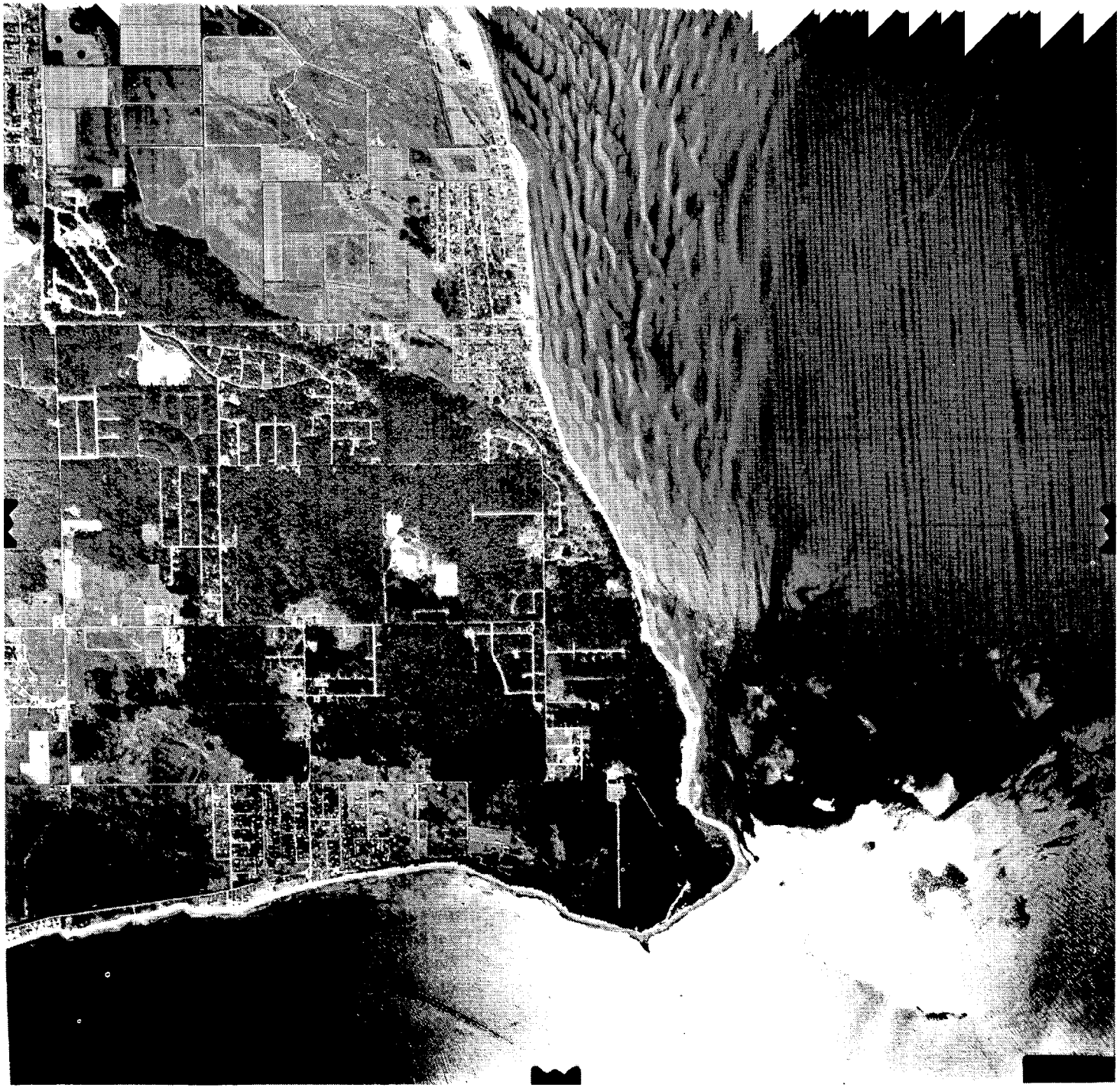
Birds of protected sandy beaches reflect the increase in available food and adjacent habitats within which they can feed. For example, waterfowl which feed on eelgrass and algae are more abundant, and a wider variety of other birds is often present. Diversity may be high in comparison to more exposed areas, but birds are not necessarily more abundant and some uncommon species are restricted to the exposed outer coast sandy beaches. These uncommon species include the Snowy Plover which is discussed in more detail in the Sand Dune Narrative (No. 722). Likewise, gray whales are abundant during migration along exposed sand beaches quite close to shore, but seldom occur in our protected waters.

Characteristic Plants and Animals

The splash zone of exposed sand beaches usually consists of extensive sand dune areas. Sands carried from the beach by wind and wave action are responsible for the gradual build-up of the dune. Sand dunes are discussed in detail in a separate narrative (No. 722). Along less exposed sand beaches, the splash zone typically forms a narrow strip of beach grassland (see narrative No. 312) and pure sand. Accumulations of driftwood are sometimes present, moved about only by a combination of storms and extreme high tides. Sand beaches are often bounded by bluffs at their upper end in Hood Canal and Puget Sound. In such situations, there is usually no strip of beach grassland present.

Plants

If macroscopic vegetation is present, it is only likely to occur on protected sand beaches. Narrow-bladed or European eelgrass, introduced to the west coast, is present in the upper part of the mid-intertidal in portions of Willapa Bay, Grays Harbor, Hood Canal, and northern Puget Sound. Broad-bladed eelgrass is restricted to the lower intertidal zone, and often forms a narrow band which continues into shallow subtidal areas. Where broad sand flats occur, such as in Boundary or Birch Bays in Whatcom County, sediments tend to form a wave pattern which is readily visible from the air. The low spots between waves often form small tide-pools, in which broad-bladed eelgrass is frequently present. Eelgrass tends to be less dense in sand than in muddy-sand substrates. Algae are scarce on sand beaches having only broad-bladed eelgrass, occassional pebbles or clam shells, worm tubes, or clam siphons upon which to attach. Examples of algae which may occur are sea lettuce (Ulva) and Entermorpha spp., both green algae, the red algae Neoagardhiella baileyi, and the brown algae Sargassum muticum and Laminaria bullata. Microscopic algae consisting primarily of diatoms, may become so numerous during certain seasons as to form a visible mat or film on the sediment surface.



Pt. Roberts, Whatcom County

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Invertebrates

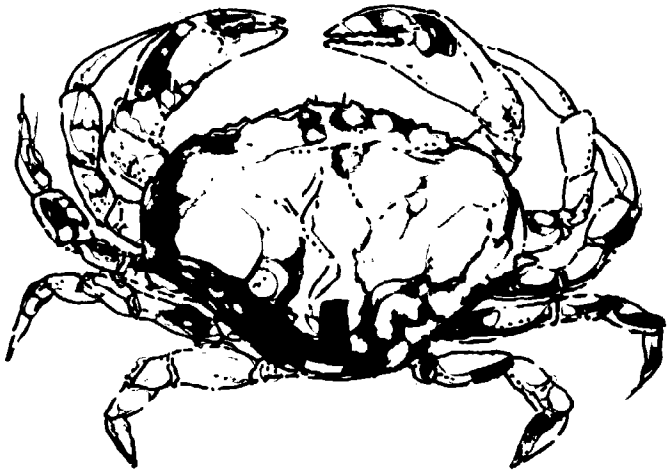
high intertidal

The invertebrates most conspicuous in the high intertidal zone of exposed sand beaches is the familiar beach hopper or sand flea (mostly Orchestoidae californiana). In less exposed areas, another beach hopper (Ochestia traskiana) becomes more abundant. These small crustaceans (which are amphipods) are usually associated with algal detritus, upon which they feed. Beach hoppers are fairly restricted in the high intertidal, but occasionally are found higher on the beach among driftwood. Other animals likely to be present are opossum shrimp and pillbugs, both of which also occur in lower zones as they largely follow the surf line, other amphipds, and deposit feeding oligochaete worms.

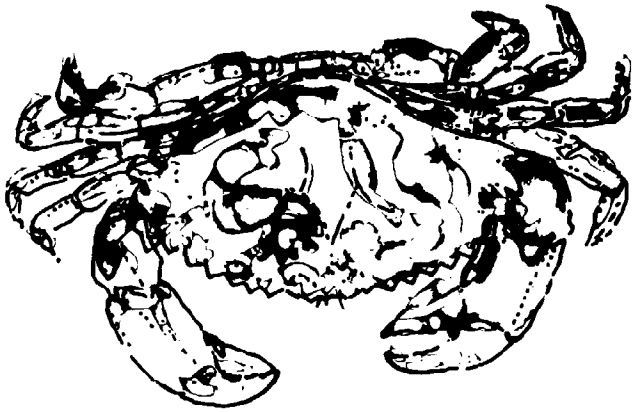
mid-intertidal

Exposed sand beaches

As a result of a lack of moisture and nutrient retention by sand, most of the invertebrates on sand beaches are concentrated in the mid-and lower intertidal zones. Mid-intertidal zones of exposed beaches are marked by the presence of the filter feeding razor clam. The razor clam, which is more abundant in the lower intertidal zone (and shallow subtidal zone), is an important recreational resource to the people of Washington State. Conspicuous polychaete worms include the blood worm, which when present forms a narrow strip parallel with the water's edge along Pacific coast beaches, and the large, carnivorous worm, Nephtys. The ribbon worm can be distinguished by the absence of segments typical of polychaete worms, as well as by its orange color. The ribbon worm preys on small polychaete worms, and can reach lengths of 30 cm. The amphipod Eohaustorius washingtonius, which is related to the beach hopper, is one of the most abundant species on Pacific Coast beaches. Another amphipod, Dogielinotus loquax, also occasionally occurs in abundance.



DUNGENESS CRAB



ROCK CRAB

Protected sand beaches

Razor clams and blood worms do not inhabit sand beaches which are not exposed to the full force of the Pacific Ocean, thus they do not occur in the Strait of Juan de Fuca, Hood Canal, or Puget Sound. Ribbon worms and the polychaete worm Nephtys, on the other hand, occur in the most protected of sand beaches. The number of polychaete worm species increases in more protected situations with the lugworm being one of the more obvious organisms. The lugworm forms characteristic fecal mounds on the sediment surface which signal its presence. Burrowing species such as the lugworm are responsible for turning over marine sediments, much as earthworms do in gardens. Small tube-dwelling invertebrates, such as the polychaete worm Polydora, can be important in stabilizing sand sediments through construction of their tubes. In situations where the tube interferes with shoreline sediments, a gradual build-up of the beach can occur. This phenomenon has reportedly occurred on the northwest side of Jetty Island in Snohomish County. Small crustaceans, especially amphipods, cumaceans, and harpacticoid copepods, are also dominant and important components of semi-protected and protected sand beaches and are important food sources for benthic-feeding fishes. The only large clam of these beaches is the white sand clam, which differs from most other clams by being a deposit feeder rather than a filter (or suspension) feeder. Usually more abundant but much smaller in size, is the little transennella clam.

Two species related to sea urchins and starfish are at times common on protected sand beaches. One is the sand dollar which feeds on detritus. Sand dollars are capable of becoming so dense that not only do they seem to form a solid mat of partially buried individuals, but they form a strip

which is visible on aerial photographs. Sand dollars also occur on exposed sand beaches, but are rarely found in the intertidal, preferring the more protected shallow subtidal areas. Much less conspicuous when present is the burrowing sea cucumber. Both sand dollars and burrowing sea cucumbers are widespread in Hood Canal and Puget Sound. The burrowing sea anemone is misnamed, as it does not actually burrow in the sand. Instead, it lies partially buried in the sand attached to gravel or shell fragments. It is usually found in sand adjacent to beaches which contain cobble or gravel.

lower intertidal

Virtually all the species mentioned as occurring in the mid-intertidal zone are also present in the lower intertidal zone, usually in greater abundance. Several additional species which are rare in the mid-intertidal also occur. The beautiful purple olive shell is restricted to exposed beaches of the Pacific Coast. Semi-protected beaches are again dominated by a variety of polychaete worms and small crustaceans, which are also numerous on protected sand beaches. The largest intertidal snail in Washington, the moon snail, is sometimes found on protected sand beaches, along with one of its food items, the cockle shell. Both of these animals are more common on muddy-sand sediments, however. Occasional visitors to the intertidal (from the subtidal zone) include the vermillion star and the striped sea slug. More commonly invading the intertidal during high tides to forage for food are Dungeness and red rock crabs and a variety of shrimp (e.g., Crangon, Pandalus, Eualus, and Heptacarpus).

Fish

Several of the nearshore fishes which occur along sandy beaches are widely distributed on our coast. Some, like salmon, migrate great distances and occur seasonally and during various life stages in sand habitat. Many others occur along a variety of beach substrates duscussed in separate narratives and readers should refer to other fish sections, particularly in the Mixed Fine Narrative (No. 635) as well as literature suggested at the end of this narrative.

Recent baseline fish sampling suggests that the number of species associated with sand beaches is relatively low compared to other beach substrates. However, the frequent occurrence of eelgrass in more protected areas increases the diversity of the habitat and these areas often support a greater variety of fish than exposed sites. Demersal fish (bottom dwellers) may be abundant at either exposed or protected sites and are often regarded as characteristic inhabitants of sandy nearshore waters. Representative species include English sole, sand sole, rock sole, c-o sole, and the Pacific staghorn sculpin. Refer to Table 636-1 for a listing of these and other characteristic fish of sand beaches, some of which are discussed in more detail below.

Rock Sole

Despite its name, this flatfish frequently occurs on sand substrates and has been reported from much of Puget Sound and the Strait of Juan de Fuca. Clams, clam siphons, polychaetes, shrimp, crab, sand lance, and brittle stars are known prey of the rock sole. They are present down to 200 fathoms (1,200 ft. or 366 meters), but are considered scarce below 100 fathoms. Rock sole are known to move into shallow water during the summer.

The rock sole is a highly regarded food fish, and in Canada it is the most used of the smaller flatfish. Total annual production in the Canadian fishery in 1970 was reported to be 4.5 million pounds of rock sole. They are also fished commercially in Washington and often taken by recreational bottom fishermen. Another important flatfish of sand substrates is the English shole which is discussed in the Mixed Fine Narrative.

Chum Salmon

Small schools of juvenile chum salmon were reported in sandy nearshore areas during recent baseline sampling in the San Juan Islands. These observations were made during early summer when young salmonids often feed nearshore. Chum salmon are known to remain in nearshore waters throughout the summer after leaving freshwater soon after hatching in early spring. Food of young chums include insects and copepods and following movements to open waters, foods include euphausids, squid, amphipods, and crab larvae. Chum salmon are the latest of Pacific coast salmon to spawn and spawning populations occur in large rivers as well as some of our smallest coastal streams.

Chum salmon have been a traditional favorite of Northwest Coast Indians because they smoke well. They are infrequently caught by sportsfishermen, but are an important commercial species.

Sand Sole

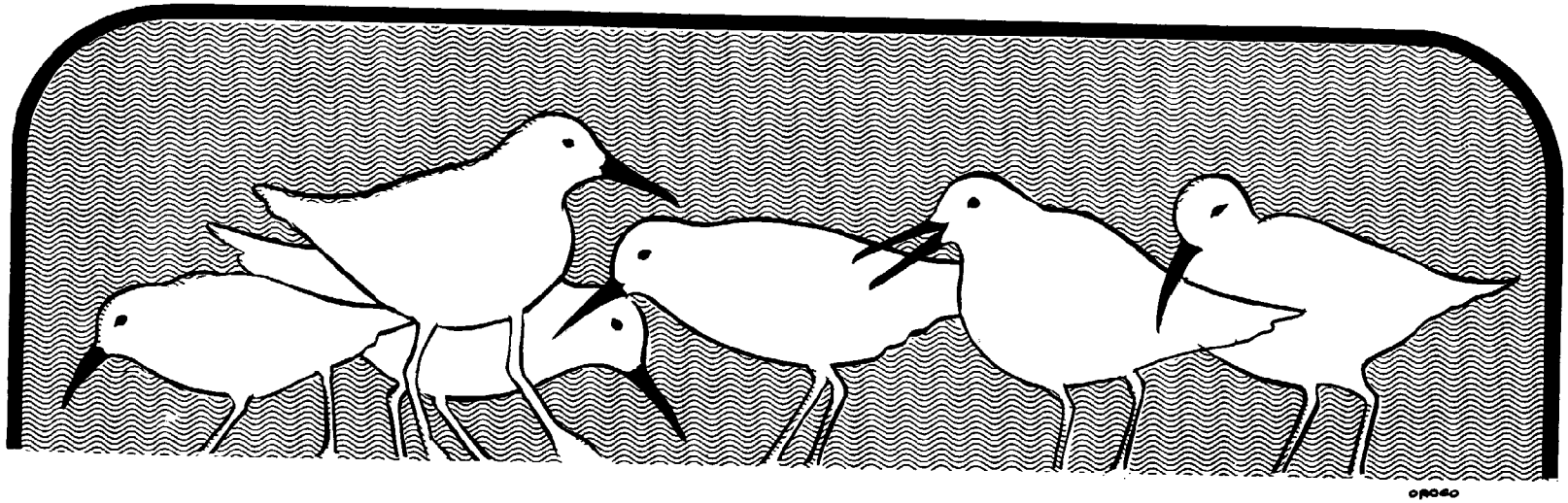
Sand sole are another of the many flatfish which may occur on sand substrate. They were consistently captured as juveniles in San Juan baseline studies, occurring in every sample taken in sand habitats where eelgrass was present. They were also taken at more exposed sites although not as frequently. Their food includes other flatfish, herring, anchovies, crustaceans, and molluscs.

Birds and Mammals

The most characteristic of the various wildlife inhabiting sandy beaches are the sandpipers, and, appropriately enough, the most typical sandpiper on sand beaches is the Sanderling. Sandpipers belong to a larger group of birds referred to as shorebirds, which also include plovers, Black Oystercatchers, American Avocets, and phalaropes.

Flocks of sandpipers are mystifying as they fly in tight formation, each turning in unison, then plopping down together and running in and out with the tide. Chances are good that the very light colored, small sandpiper seen running in and out at the water's edge is a Sanderling. However, there are several species of sandpipers and other shorebirds. Many of these occur along the extensive sandy beaches of the outer coast and on isolated sandy beaches of the inland waters. Some of the more familiar of these inland locations where concentrations of shorebirds occur are along Dungeness Spit in Clallam County, Birch Bay in Whatcom County, False Bay on San Juan Island, and at Cultus Bay in Whidbey Island.

Throughout the coastal zone, shorebirds will often be observed in mixed species flocks, especially while resting on the upper beach, on sand bars, spits, or in beach grass and marshes. However, they have different feeding strategies which is reflected in the variety of bill shapes and sizes,



and leg length. Generally, the larger bill is for probing deep in the substrate, while shorter billed sandpipers pick at the surface or turn over bits of algae in search of prey. Larger shorebirds generally take larger prey and tend to be more selective foragers in terms of food size than smaller shorebirds. However, there is quite a bit of overlap in the prey taken and several species can often be seen feeding together. A closer look will often show that the birds are feeding in a slightly different habitat or using different feeding strategies. For example, the Greater Yellowlegs often feeds in tidepools while Western Sandpipers feed in diatom and silt covered depressions between sand waves. Other examples and more detailed discussions of characteristic wildlife occurring on sandy beaches follow. Refer also to Table 63-2 in the Beach Substrate Narrative (No. 63) and other beach narratives for information on more widely distributed species (see especially the Sand Dune Narrative, No. 722 for upper beach zone discussions).

Sanderling

Large numbers of shorebirds migrate along the sandy beaches of Washington and small sandpipers like Sanderlings can often be seen in flocks of one hundred or more birds during spring and fall. This flocking behavior in shorebirds is partially a response to predation by birds of prey. This was demonstrated in a recent study on Bolinas Lagoon in California, where 13 percent of the Sanderlings wintering on the lagoon were estimated to have been preyed upon by Merlins and other raptors. Sanderlings and other numerous shorebirds are also prey of raptors along our coast. It is important that we maintain the large numbers of shorebirds which are required to support populations of less abundant, and in some cases, rare birds of prey.

Sanderlings winter as far south as Argentina and southern Chile and breed in the Arctic tundra. They may be found at the water's edge at low tide in mixed flocks of Dunlins and Black-bellied Plovers. They also feed in upper intertidal zones

where the sand is compact and dry, even when the tide is out. Prey of Sanderlings in a study at Cultus Bay on Whidbey Island was primarily (97%) amphipods, including beach hoppers and Corophium sp. Isopods, shrimp, and small numbers of molluscs were also consumed. Along the outer coast, razor clams are often a prominent food item.

Greater Yellowlegs

The Greater Yellowlegs was frequently observed during our studies in the coastal zone. Along sandy beaches they often feed in tidepools where their long legs serve them well. Within these tidepools, eelgrass often appears at relatively high intertidal elevations. These scattered pools of eelgrass are rich feeding areas for the yellowlegs and several other birds such as Bonaparte's, Mew, and Ring-billed Gulls.

Northern Phalarope

The phalaropes are examples of the diversity of feeding strategies employed by shorebirds. Northern Phalaropes may be seen ashore in "typical" shorebird habitat, but the usual feeding area is in open water. They often occur miles from shore where they feed by swimming in a circular spinning motion which apparently brings small organisms to the surface. Northern Phalaropes have also been observed feeding at the edge of shore in the gentle surf near Kydaka Point in Clallam County. At that location they were picking unidentified small prey from the water with a small flock of Bonaparte's Gulls. Ferry riders can observe these intriguing shorebirds as they feed on the surface in open water during late summer migrations. Thousands of Northern Phalaropes can be observed during spring migration along the outer coast.

Gray Whale

Several mammals frequent sand beaches, but one of the most impressive, and certainly one of the largest is the gray whale. Once greatly reduced in numbers by whalers, the gray whales along our coast have responded to international protection afforded them in 1947. There are indications that gray whales have recovered to an original population size estimated to be about 15,000 animals in the eastern North Pacific. Western North Pacific populations are nearly extinct and there is historic evidence of a Northern Atlantic Ocean population which is extinct. A recent report on marine mammals of northern Puget Sound and the Strait of Juan de Fuca by Robert Everitt of the National Marine Fisheries Service should be referred to for more details on gray whales and other marine mammals along our coastal zone.

Use by Man

Recreational

Sand beaches are extremely popular for recreational use. Most popular are the exposed sand beaches of the Pacific Coast south of Point Grenville. One of the primary attractions of this area is the famous razor clam. On a weekend low tide during clamming season, as many as 100,000 people, some of whom travel hundreds of miles to seek their prey, crowd the beaches in search for this tasty clam. The razor clam is considered by many to be Washington's most palatable clam; it is certainly one of the most challenging to dig as it is the only clam in Washington capable of digging as fast as, or in some cases faster, than its human predator.

Other attractions of the Pacific Coast beaches are the fresh air, the presence of the ocean and the constant pounding of the surf, the wide open spaces, and the change in atmosphere from heavily populated areas. Recreational fishing for salmon and other species offshore is another major attraction. Beachcombing, an activity which has increased in popularity recently as a result of the publication of several books and magazine articles, also draws a number of people to ocean beaches. These factors are responsible for the growth of tourism to a multimillion dollar industry along the outer coast.

Sand beaches in protected areas also support high recreational use. These are usually the most popular beaches for swimming, sunbathing, and picnicking, and beachcombing of a different type than occurs on the outer coast (looking for shells, sand dollars, etc. instead of glass floats, and Japanese bottles). During low tides, Dungeness and red rock crabs are collected for eating, especially where eelgrass is present. Moon snails and white sand clams are rarely eaten by humans, but are both edible. White sand clams are deposit feeders, however, so their digestive tract is usually filled with sand which detracts from their use as food.

Certain Indian tribes use shells of various types in making jewelry. The purple olive shell, for example, which is restricted to the outer coast, is frequently used by the Makah Indians in their jewelry.

Several species of fishes which frequent sand beaches are sought recreationally by fishermen. Included are salmon, surf perch, English sole, starry flounder, sand sole, herring, and smelt.

Sand beaches are also among the most popular for bird watching, particularly along the outer coast where thousands of birds can be observed as they pass in migration. Spring trips to the coast are

especially rewarding because of the weather, a chance to dig razor clams or the thrill of observing gray whales on their northern migration. Gray whales can often be seen just off the breakers which pound sandy ocean shore. Their vertical spout is often the only glimpse one gets, but that is a rewarding sight for many whale watchers.

Gray whales were once hunted commercially and neared extinction along our coast until granted international protection in 1947. They were captured by shore stationed whalers and were once hunted by Northwest Coast Indians. The Makahs were among those who developed strong traditions surrounding the equipment, rituals, and skilled huntsmen who set out from coastal villages to capture gray whales. The last whale hunt by these people, who today still live close to the sea, occurred early in this century. A museum in Neah Bay now houses, among other relics from an archaeological dig near Ozette, reminders of Northwest Coast whaling activities.

Commercial

Razor clams support a limited commercial industry in Washington. They are the principle commercial species actually harvested from sand beaches as food. Other species which use sand beaches that are usually harvested in other areas include Dungeness crabs, Pandalid shrimp, salmon, English sole, sand sole, starry flounder, herring, and smelt. Crangonid shrimp supported a commercial fishery in Puget Sound at one time.

Some sand inhabitants, such as sand dollars and moon snails, have in the past supported a limited industry based on their sale as curios.

Pacific oysters are occasionally cultured on sand beaches, however, culture is much more prevalent on beaches with varying amounts of mud present in the substrate. Hardshell clams, such as littleneck and butter clams, are also rarely, if ever, harvested from sand beaches. However, it is not because these clams cannot grow on sand beaches; there are some studies which indicate they will grow well on protected sand beaches. It appears that without the gravel present in the sediments where these clams normally grow, they are much more susceptible to predation by birds and fishes. If predation were controlled, it appears hardshell clams could successfully be cultured on sand beaches.

Sand beaches have occasionally been used in the past as a source of sand for road construction or industrial purposes. This has several deleterious ramifications, however, which will be discussed in the next section.

River otters and raccoons are commercially trapped in Washington. There is a substantial market for the fur of these mammals which occur on sand beaches.

While not occurring intertidally, scallops may be found in offshore sand areas at depths of greater than 50-60 feet.

IMPACTS

Please refer to the beach substrate narrative (No. 63) for general information on impacts.

Recreational Impacts

The popularity of sand beaches as recreational areas has had a definite impact on their use by wildlife and by many persons who seek the solitude of the beach. To fully appreciate the magnitude of this impact, one needs to be present at Birch Bay or the sand beaches in King and Snohomish County during a warm summer day, or at Ocean Shores during a weekend low tide. Some consequences are:

1. Invertebrates such as sand dollars, moon snails, and crabs are collected as souvenirs. Collection usually results in depleted populations which also reduces the food available for birds and fishes which feed on these invertebrates. Discussions with long-time residents of Birch Bay indicate that a drastic reduction in the number of sand dollars has occurred in conjunction with increased recreational use of the beaches.

2. Human activity on the beaches, including use of motor vehicles where permitted or just walking, can impact organisms living at or next to the sediment surface. Small crustaceans which are important as food for shorebirds and fishes are very susceptible to such activities. The decrease in numbers of sand dollars at Birch Bay may in part be a result of being crushed by human feet.

3. Displacement of birds and mammals from feeding and/or resting areas is a major consequence of intensive recreational use. Displaced animals have fewer sand beaches to retreat to because of the increasing popularity of these areas.

4. The popularity of razor clams has led to the possibility of over-exploitation of the resource. In recent years, populations of clams have been severely reduced in some areas. The limit of clams which can be dug has been reduced, a in 1978 part of the Long Beach Peninsula was closed to the digging of clams. This problem is compounded by the irregular, unpredictable nature of razor clam spawning. The clams may reproduce little for several years before having a highly successful year. This pattern may result from changes in the food source or some physical factor(s) such as temperature. The uncertainty of clam reproduction makes management of such a highly used resource extremely difficult.

5 The attraction of sand beaches has resulted in associated development of adjacent upland areas. Examples are the Long Beach Peninsula, Ocean Shores, Birch Bay, and many beaches in King and southern Snohomish County which have become popular vacation spots or desirable residential and day use areas. Development of adjacent upland areas has the greatest impact on birds and mammals which use sand beaches.

Interference with Sediment Drift

The combined action of wind, waves, and currents on sand beaches has the effect of moving sand particles predominantly in one direction. This process is called shoreline drift, and is an important feature maintaining the integrity of the beaches and adjacent dependent land features. As the exposure of sand beaches increases, so does the volume of sediment subject to movement. The two main sources of sediments on beaches are eroding bluffs and river borne sediments. The existence of areas such as spits, sand dunes, and beach grassland, are dependent upon shoreline drift to supply sand sediments. The sand beaches themselves are vulnerable to interference with shoreline drift and may undergo largescale erosion or accretion. Projects which interfere with shoreline drift include jetties, groins, and construction of dams on rivers which are important sources of beach material.

Dependence on Adjacent Areas

Since sand beaches are dependent on adjacent areas for part of the energy used, their fate is partially dependent on impacts to those adjacent areas such as eelgrass beds.

TABLE 636-1

CHARACTERISTIC PLANTS AND ANIMALS
OF SAND BEACHES
(see Table 63-2 in Beach Substrate Narrative for Birds and Mammals)

Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
PLANTS				
Green Algae				
Sea lettuce (*Ulva* spp.)	PP	M, L	PC	Edible; important waterfowl food.
(*Enteromorpha* spp.)	PP	H, M, L	PC	Edible; important waterfowl food.
Red algae				
(*Neoagardhiella baileyi*)	PP	L, SB	PC	Edible
(*Gracilaria verrucosa*)	PP	L, SB	PC	Edible
(*Polysiphonia*)	PP	L, SB		
(*Gigartina tepida*)	PP	L, SB		
(*Gracilariopsis* sp.)				Edible
Brown Algae				
(*Sargassum muticum*)	PP	L, SB	PC	
Blister wrack (*Laminaria bullata*)	PP	L, SB	PC	
Sea Colander (*Agarum fimbriatum*)	PP	L, SB	PC	
Seersucker (*Costaria costata*)	PP	L, SB		
Sugar wrack (*Laminaria saccharina*)	PP	L, SB	PC	Edible
(*Leathesia difformis*)	PP	L, SB		
(*Scytosiphon lomentaria*)	PP	L, SB		
Other algae				
Benthic diatoms	PP	H, M, L		
Vascular plants				
European or narrow-bladed eelgrass (*Zostera noltii*)	PP	H, M, L		
Broad-bladed eelgrass (*Zostera marina*)	PP	L, SB		See Seagrass Narrative (No. 627) for further information.
INVERTEBRATES				
Moluscs				
Razor clams (*Siliqua patula*)	FF	M, L, SB	R, C	Recreationally and economically important; restricted to Pacific Coast; edible.
White sand clam (*Macoma secta*)	DEP	M, L		

TABLE 636-1 continued

Transennella clam (Transennella tantilla)	FF	M, L		
Tellin clams (Tellina spp.)	DEP	M, L		
Heart cockle (Clinocardium nuttallii)	FF	H, M, L, SB	R	Edible; occasionally dug recreationally
Soft-shell clam (Mya arenaria)	FF	H, M, L	R, PC	
Purple olive shell (Olivella biplicata)	SCAV	M, L		Restricted to Pacific Coast; used for Indian jewelry
Moon snail (Polinices lewisii)	CARN	L, SB		Edible (although rarely eaten)
Striped sea sluge (Armina californica)	CARN	L, SB		
Arthropods				
Harpacticoid copepods	DETR	H, M, L		Important prey of fish including juvenile salmon
Cumaceans	DETR	M, L		
Tanaids	DETR	M, L		
Beach hoppers or sand fleas (amphipods)				Prey of several fish and birds; restricted to expsed beaches
(Orchestoidea californiana)	DETR	H		
(O. pugettensis)	DETR	H		
(Orchestia traskiana)	DETR	H		
(Eohaustorius washingtonius)	DETR	H, M, L		
(Dogielinotus loquax)	DETR	M, L		
(Maera dubia)	DETR	H, M		
(Paraphoxus milleri)	DETR	H, M, L		
(Ampelisca spp.)		M, L		
(Corophium acherusicum	DETR	M, L		
(Anisogrammarus spp.)	OMNI	H, M, L		
Pillbugs or sowbugs (isopods)				
(Cirolana kincaidi)	SCAV	H, M, L		
(Gnorimosphaeroma orgonense)	SCAV	H, M		
(Exosphaeroma spp.)	DETR	M		
Opossum shrimp (mysids)				
(Archaeomysis grebnitzskii)	DETR	H, M, L		
(Mysis spp.)	DETR	L, SB		
(Neomysis spp.)	DETR	L, SB		
Gray or broken-back shrimp (Crangon spp.)	CARN	L	PC	Formerly supported commercial industry in Puget Sound
Pandalid shrimp (Pandalus spp.)	CARN	L, SB	R, C	
Other shrimp				
(Eualus spp.)	CARN	L, SB		
(Heptacarpus spp.)	CARN	L, SB		
(Sclerocrangon spp.)	CARN	L, SB		
Ghost shrimp (Callianassa sp.)	DETR	M, L		Edible, sold commercially as fish bait
Dungeness crab (Cancer magister)	CARN-SCAV	L, SB	R, C	Important recreationally and commercially; highly prized seafood
Red rock crab (C. productus)	CARN-SCAV	L, SB	R, PC	Also consumed as seafood, but in smaller quantities than C. magister

TABLE 636-1 continued

Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
Segmented worm (Annelids)				
Oligochaetes	DEP	H, M		
Polychaetes				Important prey of several fish and birds
Capitellidae				
(Notomastus)	DEP	M, L		
(Mediomastus)	DEP	M, L		
Abarenicolidae				
(Abarenicola)	DEP	M, L		
Goniadidae				
(Glycinde)	CARN	M, L		
Nephtyidae				
(Nephtys)	CARN	M, L		
Opheliidae				
(Euzonus)	DEP	M		
Orbiniidae				
(Scoloplos)	DETR	L		
(Haploscoloplos)	DETR	L		
Paraonidae				
(Paraonella)	DEP	M, L		
(Paronis)	DEP	M, L		
Spionidae				
(Polydora)	DETR	M, L		
(Scolelepis)	DETR	M, L		
(Spio)	DETR	M, L		
(Spiophanes)	DETR	M, L		
(Pygospio)	DETR	H, M		
Syllidae				
(Syllis)	DETR	H, M, L		
Nemerteans				
Ribbon worm (Cerebratulus californiensis)	CARN	M, L		
Other nemerteans	CARN	H, M, L		
Echinoderms				
Sand dollars (Dendraster excentricus)	DETR	M, L		Often collected by beachcombers
Burrowing sea cucumber (Leptosynapta clarki)	DETR	M		
Vermillion star (Mediaster aequalis)	CARN	L, SB		
Coelenterates				
Burrowing sea anemone	CARN-SCAV	M, L		
Nematodes	DETR, CARN, HERB	H, M, L		

TABLE 636-1 continued

FISH

Common Name	Scientific Name	Economic Value[3]	Comments
Spiny dogfish	Squalus acanthias	C	
Ratfish	Hydrolagus colliei		
Pacific Herring	Clupea harengus	C, R	Important bait fish
Pink salmon	Oncorhynchus gorbuscha	C, R	Salmon are among our most highly prized fish
Chum salmon	O. keta	C, R	
Coho salmon	O. kisutch	C, R	
Chinook salmon	O. tshawytscha	C, R	
Cutthroat trout	Salmo clarki	R	Year-round sportsfish
Dolly varden	Salvelinus malma	R	
Surf smelt	Hypomesus pretiosus	C, R	
Longfin smelt	Spirinchus thaleichthys	C, R	Anadromous
Plainfin midshipman	Porichthys notatus		
Pacific cod	Gadus macrocephalus	C, R	Important commercial foodfish
Pacific tomcod	Microgadus proximus	R	
Walleye pollock	Theragra chalcogramma	C	
Tube-snout	Aulorhynchus flavidus		
Threespine stickleback	Gasterosteus aculeatus		Eaten by larger fish, marine birds, and mammals
Bay pipefish	Syngnathus griseolineatus		
Shiner perch	Cymatogaster aggregata	R	Prey of several fish, river otters, seals, birds
Striped seaperch	Embiotoca lateralis	C, R	
Pile perch	Rhacochilus vacca	C, R	
Snake prickleback	Lumpenus sagitta		
Penpoint gunnel	Apodichthys flavidus		
Crescent gunnel	Pholis laeta		
Saddleback gunnel	P. ornata		
Pacific sand lance	Ammodytes hexapterus		Important prey of seabirds, other fish.
Padded sculpin	Artedius fenestralis		Sculpins are a diverse groups of fish also known as bullheads. They are preyed upon by many other fish, birds, and mammals.
Sliverspotted sculpin	Blepsias cirrhosus		
Roughback sculpin	Chitonotus pugetensis		
Sharpnose sculpin	C. acuticeps		
Buffalo sculpin	Enophrys bison		
Soft sculpin	Gilbertidia sigalutes		
Pacific staghorn sculpin	Leptocottus armatus		

TABLE 636-1 continued

Common Name	Scientific Name	Economic Value[3]	Comments
Great sculpin	Myoxocephalus polyacanthocephalus		
Sailfin sculpin	Nautichthys oculofasciatus		
Tadpole sculpin	Psychrolutes paradoxus		
Sturgeon poacher	Agonus acipenserinus		
Pygmy poacher	Odontopyxis trispinosa		
Slipskin snailfish	Liparis fucensis		
Showy snailfish	L. pulchellus		
Pacific sanddab	Citharichthys sordidus	C, R	Sanddabs, flounders, and soles are known collectively as flatfishes and are well known as seafood in the form of filet of sole.
Rock sole	Lepidopsetta bilinaeta	C, R	
Slender sole	Lyopsetta exilis	R	
English sole	Parophrys vetulus	C, R	
Starry flounder	Platichthys stellatus	C, R	
C-O sole	Pleuronichthys coenosus	C, R	
Sand sole	Psettichthys melanostictus	C, R	

LEGEND:

[1]Trophic type

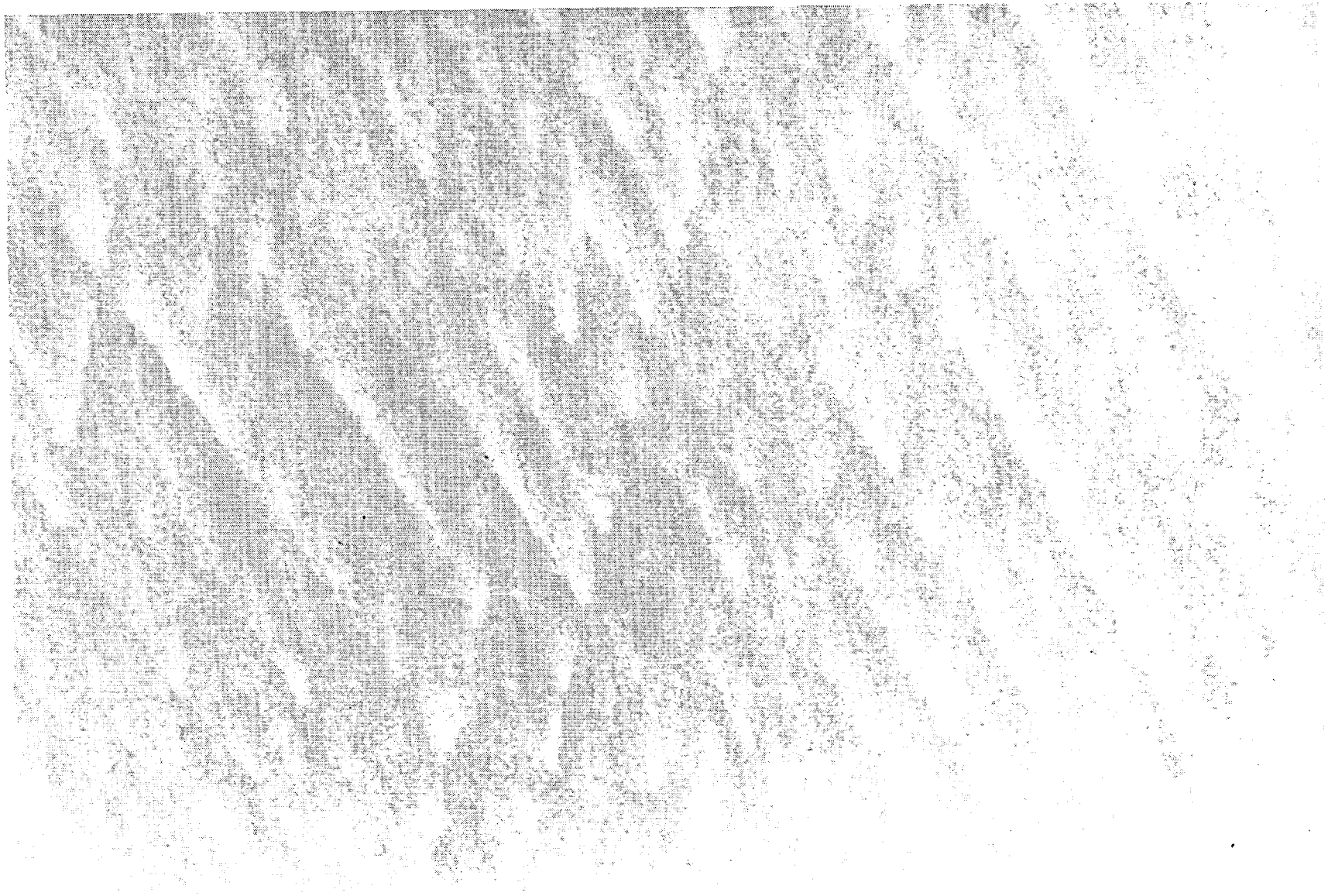
PP = Primary Producer
FF = Filter Feeder
DEP = Deposit Feeder
SCAV = Scavenger
CARN = Carnivore
DETR = Detritivore
OMNI = Omnivore
HERB = Herbivore

[2]Zones of Occurrence

H = High Intertidal
M = Mid-Intertidal
L = Low Intertidal
SB = Shallow Subtidal

[3]Economic Value

C = Commercial
R = Recreational
PC = Potential Commercial



MUDDY SAND (No. 637)

INTRODUCTION

This beach type consists of sediments composed of a mixture of mud (silt and/or clay) and sand. These sediments at first appear to contain a large amount of mud, but if picked up and rubbed between one's fingers, are found to contain a large percentage of sand. When walking through muddy sand, one's feet will sink only a couple of inches into the sediment.

Muddy sand beaches usually occur in the lower and mid-intertidal regions, with a beach type such as mixed fine (see Narrative No. 635), mixed coarse (No. 633), or sand (No. 636) in the higher zone(s). This pattern results from greater wave action in the upper intertidal zones which prevents mud from settling down on the substrate.

Muddy sand beaches typically are gently sloping, and in some areas, for example Padilla Bay, Grays Harbor and Willapa Bay, form extensive tidal flats. Numerous tidal channels, which are extremely important as feeding areas for some fishes, dissect these broad tidal flats.

Muddy sand beaches are restricted to areas protected from wave or current exposure. They are also associated with the presence of eelgrass (refer to Narrative No. 627), which reaches its greatest density in muddy sand. The protected locale and presence of eelgrass make muddy sand beaches an extremely stable environment for the species which reside in them.

SIGNIFICANT BIOLOGICAL FEATURES

Muddy sand beaches have high diversities and densities of organisms, as well as high biomass. A major reason for this is the protected, stable nature of the environment. The lack of wave or current action allows fine sediments and decaying organic matter to settle out of the water column, making this beach type extremely rich in detritus. The decaying organic matter provides food for a large number of detritus and deposit feeding organisms, and the nutrients are necessary for plants. The vegetation of muddy sand beaches further reduces wave and current action.

The mud present in the sediment holds large amounts of water by capillary action during low tides, protecting many of the smaller organisms living in the substrate from drying out. The gentle slope of most muddy sand beaches, as well as the presence of eelgrass, often maintains a thin layer of water over the tide flats during low tide, which protects invertebrates living on the surface of the substrate as well as small fishes.

Another reason for the high diversity, density, and biomass on muddy sand beaches is the high productivity. Muddy sand provides the optimal habitat for eelgrass in all areas of the state except southern Puget Sound (south of the Tacoma Narrows), where eelgrass is scarce or absent. The high productivity of eelgrass and its role in providing food and habitat is discussed in the seagrass narrative (see No. 627). Another species of eelgrass, narrow-bladed or European eelgrass, often occurs in the mid- and high intertidal zones, especially if the sediment contains little mud.

Macroscopic algae also grow on muddy sand beaches, but their presence is somewhat limited by the amount of suitable substrate available. Algae grow attached to pebbles, clam shells, worm tubes, eelgrass, and, in some cases, even clam siphons. Some filamentous green algae form mats of intertwining filaments which cover the tide flats. Certain other green algae, such as sea lettuce, continue to thrive while floating, after waves, currents, or grazing by invertebrates have detached them from the substrate. These floating algae tend to accumulate in protected areas, such as in muddy sand beaches, especially if eelgrass, in which they get tangled, is present. Here these algae may continue to grow or they die and decompose, adding additional nutrients and detritus to the community.

Microscopic algae, especially diatoms, also contribute to primary production. During portions of the year, microscopic algae become so abundant as to form a visible layer over the sediment surface.

The presence of bacteria on muddy sand beaches is another factor which contribute to high density and biomass of organisms. Bacteria are reported to thrive at high rates of production on an aereal basis. In addition, bacteria which break down

dead plant and animal tissue provide highly nutritional food for deposit and detritus feeding organisms. It has been shown that some detritivores use only the bacteria growing on decaying organic matter as food, passing the detritus through their digestive system unaltered.

When macroscopic vegetation is abundant, the production of muddy sand beaches exceeds the energy requirements of the community. When this occurs, large amounts of energy are exported to other areas, mostly in the form of detritus. This energy is extremely important in areas such as the offshore subtidal environment, as there is little or no primary production in these reas. Thus, they are totally dependent on imported energy. Also exported to other areas are large numbers of planktonic zoospores released by algae and planktonic larvae released by many benthic invertebrates. These zoospores and larvae are so abundant that they are an important component of the diet of many filter feeding organisms (such as clams, oysters, and some fish) in adjacent areas.

The abundance of organisms and productivity of muddy sand beaches provides a rich feeding area for a variety of fish, birds, crabs, and shrimp. Intertidal vegetation is used by herring as a substrate for attachment of eggs. English sole and starry flounder use these beaches as nursery areas. Many other small fishes and invertebrates use the vegetation which provides refuge from predators.

Tidal channels, when present, are important and heavily used feeding sites for juvenile salmonids, and contain large numbers of Pacific staghorn sculpins, shiner perch, and sticklebacks. Tidal channels are also feeding areas for ducks, gulls, and shorebirds. Wading shorebirds such as the Greater Yellowlegs are often observed stalking in shallow tide channels and Bonaparte's Gulls forage on small fish and shrimp which swim or get washed by. Eelgrass often grows in the channels and may extend rather high on the beach because of relatively deep water in these tidal streams. Waterfowl concentrate here and feed on eelgrass plants while predators such as Great Blue Herons snatch sculpins from among the plants.

Much of the shorebird feeding activity in the coastal zone is concentrated on silty sand and muddy beaches in relatively nonvegetated zones. Thousands of migrating and over-wintering shorebirds descend on these flats to feed as tides recede. Invertebrates consumed by the shorebirds are largely dependent on detritus produced within adjacent eelgrass beds even though feeding occurs primarily above the eelgrass zone. Adjacent salt marshes also contribute significant amounts of detritus to the beaches and as tides rise, shorebird feeding often extends up into the low marsh.

Intertidal and shallow subtidal vegetation provides food and foraging areas for large numbers of birds, especially waterfowl. Diving birds feed on fish and invertebrates during high tides and along the water's edge, while other birds feed on invertebrates and stranded fish when tidal flats are exposed during low tides. Occasionally, terrestrial mammals such as raccoons, deer, and skunks forage on muddy sand beaches. Nearshore, or when high tides cover the tidal flats, aquatic mammals such as harbor seals and river otters feed along these beaches. The presence of eelgrass strongly influences the use of muddy sand beaches by wildlife, and since so much of the activities of fish, birds, and mammals is concentrated in the eelgrass zone, readers are urged to refer to the Seagrass Narrative (No. 627). Many of the characteristic birds and mammals of muddy sand beaches listed in the general beach narrative (No. 63) are discussed in the Seagrass Narrative. Characteristic fish of muddy sand beaches are listed in Table 637-1 in this narrative.

It has already been stated that the protected environment of muddy sand beaches and the presence of vegetation causes sediment and detritus particles to settle out of the water onto these beaches. The result of this is that there tends to be a gradual buildup of the tideflats. Eventually on some of the more protected muddy sand beaches, the elevation of the beach can build up to the level where marsh plants could colonize. This process would be most likely to occur on broad tide flats such as those in Grays Harbor, Willapa Bay, and Padilla Bay. Strong evidence of this process is apparent in Skagit Bay, where salt marsh plants can be seen invading the tideflats.

TABLE 637-1 CHARACTERISTIC PLANTS AND ANIMALS

Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
PLANTS				
Green Algae				
Sea lettuce (Ulva spp.)	PP	M, L	PC	Edible; abundant seasonally; important waterfowl food.
(Enteromorpha spp.)	PP	H, M, L	PC	Edible; abundant seasonally; important waterfowl food.
(Monostroma spp.)	PP	M, L	PC	Edible; abundant seasonally; important waterfowl food.
(Rhizoclonium sp.)				
Brown algae				
Red algae				
(Neoagardhiella baileyi)	PP	L, SB	PC, R	Edible
Other algae				
Benthic diatoms	PP	H, M, L		Abundant seasonally
Vascular plants				
Broad-bladed eelgrass (Zostera marina)	PP	L, SB		Important waterfowl food; increases diversity of habitat.
European or narrow-bladed eelgrass (Z. noltii)	PP	H, M		Important waterfowl food.
INVERTEBRATES				
Moluscs				
Bent-nose clam (Macoma nasuta)	DEP	M, L		Edible, but usually contains sand and mud in stomach, therefore not popular.

TABLE 637-1 continued

Common Name (Scientific Name)		Zone(s) of Occurrence[2]		Comments
Macoma clam (*M. inquinata* = *M. irus*)		H, M, L		
Macoma clam (*M. balthica* = *M. inconspicua*)		H, M		
Heart cockle (*Clinocardium nuttallii*)		H, M, L		Muddy sand is optimal habitat
Soft-shell clam (*Mya arenaria*)		H, M, L		Introduced; supports commercial harvest on East Coast; in brackish water areas.
(*Cryptomya californica*)		M, L		Commensal of ghost and mud shrimp
Tiny transennella clam (*Transennella tantilla*)		M, L		
Pacific oyster (*Crassostrea gigas*)		M, L		Supports large industry in Washington
Atlantic oyster (*C. virginica*)		M, L		Rare; relic of former commercial industry
Moon snail (*Polinices lewisii*)		L, SB		Edible, rarely eaten; more often taken by beachcombers
(*Batillaria attramentaria*)		M, L		Introduced; not widespread but abundant where present
(*Aglaja diomedea*)		M, L		
Arthropods				
Leptostracan (*Nebalia pugettensis*)		H, M, L		
Harpacticoid copepods		H, M, L		Important food for juvenile salmon
Cumaceans		M, L		
Tanaids (*Leptochelia* spp.)		M, L		
Pill bug (*Gnorimosphaeroma orgonense*)		H, M, L		In brackish water areas; largely under debris on beach
Amphipods (*Corophium acherusicum*)		M, L		

TABLE 637-1 continued

Common Name (Scientific Name)	Zone(s) of Occurrence[2]	Comments
Amphipods (Continued)		
(*Corophium salmonis*)	H, M, L	Abundant in low salinity areas; very important food for shorebirds and juvenile fish
(*Anisogrammarus confervicolus*)	H, M, L	In brackish water; often under debris on beach
(*Ampithoe* spp.)	M, L	
Gray or broken-back shrimp (*Crangon* spp.)	L	Formerly harvested commercially in Puget Sound
Ghost shrimp (*Callianassa californiensis*)	M, L	Edible, used as fish bait
Mud shrimp (*Upogebia pugettensis*)	M, L	Edible, used as fish bait
Pea crabs (*Pinnixa* spp.)	M, L	Commensal in larger clams and in ghost and mud shrimp burrows
Hairy shore crab (*Hemigrapsus oregonensis*)	H, M, L	
Dungeness crab (*Cancer magister*)	L, SB	Supports large commercial industry in Washington
Red rock crab (*Cancer productus*)	L, SB	
Segmented worm (Annelids)		
Oligochaete worms	H, M, L	
Polychaete worms:		
Abarenicolidae lugworms (*Abarenicola pacifica*)	M, L	Prey of many fish and birds important in turning over tideflats sediments
Capitellidae		
(*Notomastus tenuis*)	M, L	
(*Capitella capitata*)	M, L	
(*Mediomastus* spp.)	M, L	
Cirratulidae (*Cirratulus cirratus*)	M, L	

TABLE 637-1 continued

Common Name (Scientific Name)	Zone(s) of Occurrence[2]	Comments
Dorvilleidae (*Dorvillea rudolphi*)	L	
Glyceridae		
(*Glycera rugosa*)	M, L	
(*Hemipodus borealis*)	M, L	
Goniadidae (*Glycinde picta*)	M, L	
Hesionidae (*Ophiodromus pugettensis*)	M, L	
Lumbrineridae (*Lumbrineris* spp.)	M, L	
Maldanidae		
Jointed-tub or bamboo worm (*Axiothella rubrocincta*)	M, L	
Nereidae (*Platynereis bicanaliculata*)	L	
Opheliidae (*Armandia brevis*)	M, L	
Paraonidae (*Paraonella* sp.)	H, M, L	
Phyllodocidae (*Eteone longa*)	H, M, L	
Spionidae		
(*Malacoceros glutaeus*)	M, L	
(*Pygospio*)	H, M, L	
(*Polydora*)	M, L	
(*Spiophanes*)	M, L	
Syllidae (*Exogone lourei*)	L	
Terebellidae		
(*Eupolymnia heterobranchia*)	M, L	
(*Pista brevibranchiata*)	L	
Echinoderms		
Sand dollars (*Dendraster excentricus*)	M, L	Often collected by beachcombers

TABLE 637-1 continued

Common Name (Scientific Name)	Zone(s) of Occurrence[2]	Comments
Burrowing sea cucumber (*Leptosynapta clarki*)	M	
Vermillion star (*Mediaster aequalis*)	L, *SB*	
Ribbon worms (Nemerteans)		
(*Paranemertes peregrina*)	M, L	
Nematodes	H, M, L	
Anemones (Coelenterates)		
Brooding sea anemone (*Epiactis prolifera*)	H, M, L	
(*Edwardsiella*)	H, M	
(*Edwardsia*)	H, M	

FISH

Common Name	Scientific Name	Comments
Spiny dogfish	*Squalus acanthias*	
Pacific herring	*Clupea harengus pallasi*	Spawn on eelgrass and algae
Chum salmon	*Oncorhynchus keta*	Juvenile salmon feed nearshore and in eelgrass beds.
Coho salmon	*O. kisutch*	
Chinook salmon	*O. tshawytscha*	
Cutthroat trout	*Salmo clarki*	
Surf smelt	*Hypomesus pretiosus*	
Longfin smelt	*Spirinchus thaleichthys*	
Plainfin midshipman	*Porichthys notatus*	Attach eggs to rocks

TABLE 637-1 continued

Common Name	Scientific Name	Comments
Pacific tomcod	Microgadus proximus	
Threespine stickleback	Gasterosteus aculeatus	
Bay pipefish	Syngnathus griseolineatus	Bay pipefish are one of many fish which are primarily associated with eelgrass along muddy sand beaches (see also characteristic species for eelgrass)
Shiner perch	Cymatogaster aggregata	
Snake prickleback	Lumpenus sagitta	
Saddleback gunnel	Pholis ornata	
Pacific sand lance	Ammodytes hexapterus	Prey of many other fish, seabirds and mammals
Sharpnose sculpin	Clinocottus acuticeps	
Pacific staghorn sculpin	Leptocottus armatus	
Cabezon	Scorpaenichtys marmoratus	
Sturgeon poacher	Agonus acipenserinus	
Pacific spiny lumpsucker	Eumicrotremus orbis	
English sole	Parophrys vetulus	Primary nursery area
Starry flounder	Platichthys stellatus	
Sand sole	Psettichthys melanostictus	

LEGEND:

[1]Trophic type

PP = Primary Producer
FF = Filter Feeder
DEP = Deposit Feeder
SCAV = Scavenger
CARN = Carnivore
DETR = Detritivore
OMNI = Omnivore
HERB = Herbivore

[2]Zones of Occurrence

H = High Intertidal
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SB = Shallow Subtidal

[3]Economic Value

C = Commercial
R = Recreational
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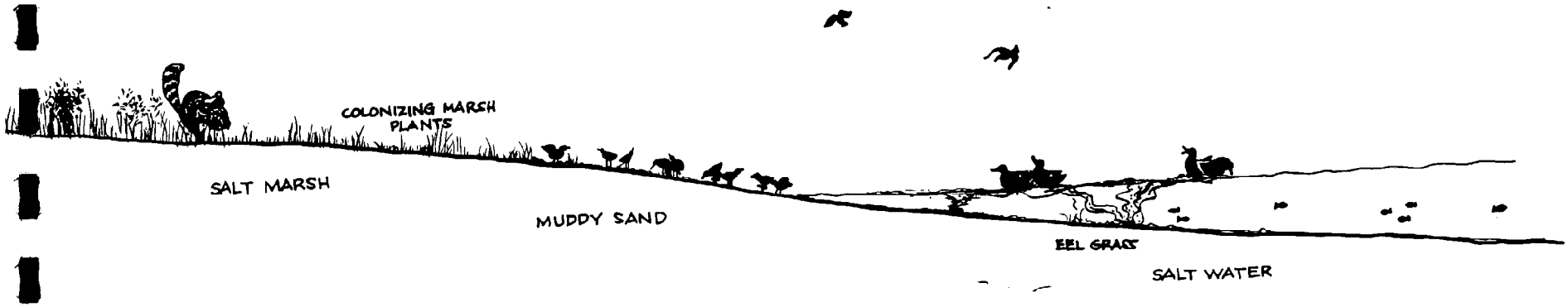


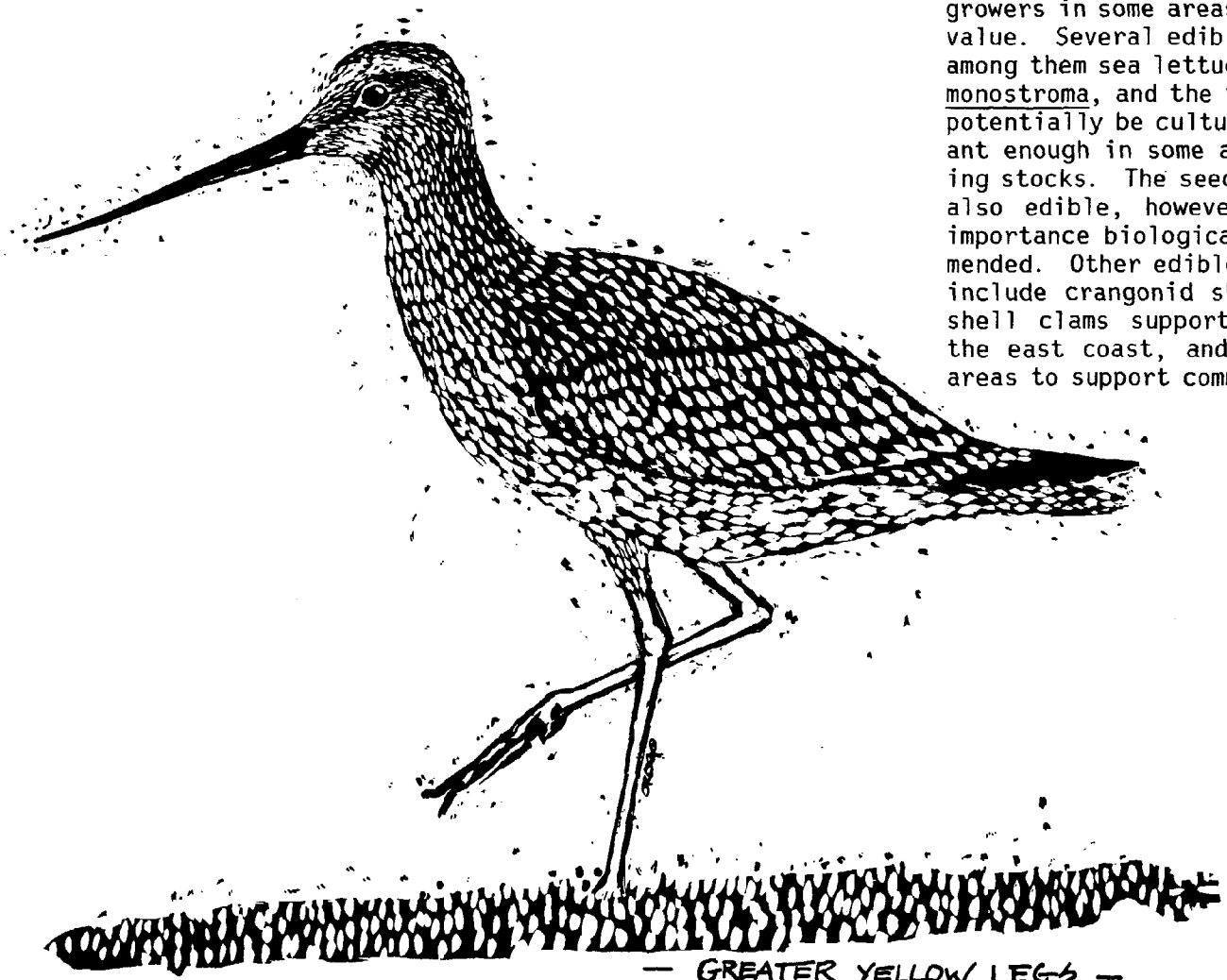
Use by Man

Recreational use of muddy sand beaches is fairly high. These beaches are noted for their excellent crabbing, especially when eelgrass is present. On some of the beaches where tideflats are broad, waterfowl are heavily hunted. Occasionally cockles or soft-shell clams are dug. Many of the fish which spend a portion of their life on muddy sand beaches such as salmon, cutthroat trout, English sole, and starry flounders attract attention from hopeful anglers. Fishermen often use ghost shrimp collected on muddy sand beaches for bait. Bird watchers can usually find a wide assortment of bird-life to enjoy, especially in the fall and spring during migratory seasons. Deer and elk, which are infrequent visitors to beaches, are hunted heavily in western Washington.

The commerically harvested species of muddy sand beaches are led by the Pacific oyster. Harvest of oysters is perhaps more prevalent on muddy sand beaches than on any other beach type. Oyster culture is a major industry in the state of Washington. The only other species commercially harvested on muddy sand beaches is the ghost shrimp, which supports a very limited industry as a source of bait for fishermen.

Several species which use muddy sand beaches as nursery, nesting, or feeding areas are commerically harvested in other areas. Among them are salmon, English sole, starry flounder, Dungeness crabs, and pandalid shrimp. Raccoons, which are frequent visitors to beaches at night, are trapped for their fur.

Several plants and animals present on muddy sand beaches are potentially important commercial or recreational species. Ghost and mud shrimp, which can reach amazing densities, are edible and quite tasty. In addition, they are a nuisance to oyster growers in some areas, so harvest would have double value. Several edible algae of muddy sand beaches, among them sea lettuce, the green algae Enteromorpha monostroma, and the red algae Neoagardhiella, could potentially be cultured. Sea lettuce may be abundant enough in some areas to allow harvest of existing stocks. The seeds of broad-bladed eelgrass are also edible, however, eelgrass is of such great importance biologically that harvest is not recommended. Other edible animals of muddy sand beaches include crangonid shrimp and moon snails. Soft-shell clams support an extensive industry along the east coast, and are abundant enough in some areas to support commercial harvest in Washington.



— GREATER YELLOW LEGS —

IMPACTS

The fine sediments which occur on muddy sand beaches tend to hold pollutants on these beaches. Oil products, heavy metals, pesticides, and herbicides tend to bind to the surface of the mud, thus becoming incorporated into the sediments. The lack of strong wave or current energy reduces the chance that pollutants will be washed away. Muddy sand sediments near sources of pollution consistently have pollutants present in them, as does the biota. Activities such as dredging and disposal resuspend these polluted sediments in the water column, exposing them to possible uptake by animals and plants. The presence of pollutants on muddy sand beaches are of concern to man as many commercially important species frequent these beaches.

Any human activity which affects the primary producers of muddy sand beaches, especially those affecting eelgrass, will greatly reduce the high biological value of the beaches. Species affected would include juvenile salmonids, English sole, Pintail, Wigeon, Brant, Dungeness crabs, and shrimp. Many other important nearshore animals which use energy exported from muddy sand beaches would also be affected. Excessive dumping of sewage effluents, changes in water temperature, increased siltation, and many types of industrial effluents can all decrease primary productivity.

Activities which lower the dissolved oxygen content of water on those muddy sand beaches where the tidal flats are extensive can cause great stress to the organisms inhabiting them. These beaches naturally have stressfully low oxygen content during part of the year, due largely to the presence of decaying organic matter. Additionally, on warm days during incoming tides the seawater advancing over the tideflats can reach 70°F. (21°C.). The stress caused is not usually directly fatal, but organisms affected are more likely to fall subject to predation or disease.

Processes which interfere with the natural build-up of sediments, and subsequent invasions of the tideflats by marsh plants, will actually decrease the extent of marshes adjacent to muddy sand beaches. Activities such as dredging of the flats (for navigation or clams) will prevent the build-up of sediments, preventing colonization of marsh plants. The marsh will continue, however, to develop into a terrestrial environment at its upland edge (see Salt Marsh Narrative No. 623), and will gradually be reduced in size.

MUD (No. 638)

INTRODUCTION

Muddy beaches have been the most misunderstood and abused beach type in Washington. Mudflats sometimes release a foul odor, are a hinderance to navigation, and cannot easily be walked upon by man. As a result, mudflats have historically been considered wastlands. Filling of beaches to create agricultural or urban land, and dredging for the creation or expansion of port and marine facilities have occurred more often on mud than on any other beach type. This is largely related to the extensive use of protected estuarine areas where sediments are likely to contain mud.

The nearby presence of man has also been responsible for heavy pollution of mudflats as pulp and paper mills, saw mills, food processing plants, and other types of industries have been constructed. In addition, sewage effluents have been dumped in marine waters with little or no preliminary treatment. This alteration and pollution of mudflats has been unfortunate since they are now known to be important areas both in terms of biological function and commercial/recreational use by man.

Mud sediments consist predominantly of fine silt and clay particles, although some sand may be present. Only those beaches occurring in the most protected portions of bays and estuaries are able to retain these fine sediments. Usually varying amounts of small wood fragments similar to saw dust are also present in the sediments. Mud flats can be extremely difficult and even dangerous to walk across, particularly if there is no sand in the sediments; one may easily sink well past the knees in soft mud. Salt marshes are usually associated with mud beaches, and produce much of the energy which is consumed on the mudflat itself. In areas where salt marshes are absent or form only a narrow finge in the high intertidal, the narrow upper portions of mud beaches are often steeper and contain some gravel mixed in the substrate. This is especially true if a bluff is present along the shoreline.

Usually located near rivers and streams, most mudflats receive considerable freshwater influence. Some mudflats, however, occur in areas such as the San Juan Islands, where salinities remain fairly high throughout the year. Mud beaches typically form broad, almost level tideflats, with occasional tidal channels created by water draining off the flats at low tide. Examples of mud beaches are found at Mud Bay (Thurston County), Fidalgo Bay (Skagit County), Drayton Harbor (Whatcom County), and just north of Bowerman Air Field in Grays Harbor (Grays Harbor County). Mud beaches are rich in numbers of organisms and where salinities remain fairly high, diversity of organisms is also great. Food webs are large and complex, and affect many species of commercial importance to man.

SIGNIFICANT BIOLOGICAL FEATURES

Mud beaches occur in areas protected from waves and currents, and are a relatively stable environment. Protection from waves and currents allows small particles of silt, clay, and organic matter (detritus) to settle out of the water, forming the mudflat. Considerable organic matter is present due to the nearness of the mudflats to marshes and/or rivers. Eelgrass and algal beds are also sometimes present on the tideflats and contribute organic matter. Thus, mudflats are an organically enriched system, providing a food base for many animals. In addition, many nutrients bind to small silt and clay particles, and as these particles settle onto the mudflats, nutrients are available for use by plants and animals.

Fine sediments and organic matter hold large amounts of water, largely by capillary action and maintain a thin layer of water over the mud at low tide. This moisture helps protect the many small organisms which live within or at the surface of the mud.

Bacteria

Mudflats provide an excellent environment for bacteria (or microbes, as they are often called). These microbes are extremely important in the ecology of mudfalt communities. Mud typically has a shallow (usually less than 1 inch or 2.5 cm thick) oxygenated layer at the surface, which is a brownish color. Below this layer is a black anoxic layer of sediments. Digging into this black layer releases small amounts of hydrogen sulfide (H_2S) gas, which has an order reminiscent of rotten eggs. This gas is produced by anaerobic bacteria which derive chemical energy from sulfur compounds. This energy is used in much the same manner that plants use the energy in sunlight to produce organic matter. These anaerobic bacteria thus contribute to the primary production of mudflats.

Other types of bacteria are essential for breaking down dead plant or animal matter into detritus which is fed upon heavily by other marine organisms, especially in mudflats where large amounts of detritus settle. For many detritivores (detritus feeding organisms) these bacteria are analogous to

the bacteria in the rumen of a cow; they break down organic matter not digestible by the animals into a form which is digestible. The bacteria themselves are also often digested as a food source, and as they become more numerous on the detritus upon which they grow have been shown to increase the nutritional value to detritivores of the detritus bacteria complex. Other detritivores digest and receive nourishment from only the bacteria growing on the detritus. The actual detrital particles are passed through the digestive tract and back into the environment, where they will once again culture bacteria. Extensive mudflats are important in providing the needed surface area and the proper environment where organic matter can be converted to a form usable by animals higher in the food web, and where nutrients are made available for recycling by plants.

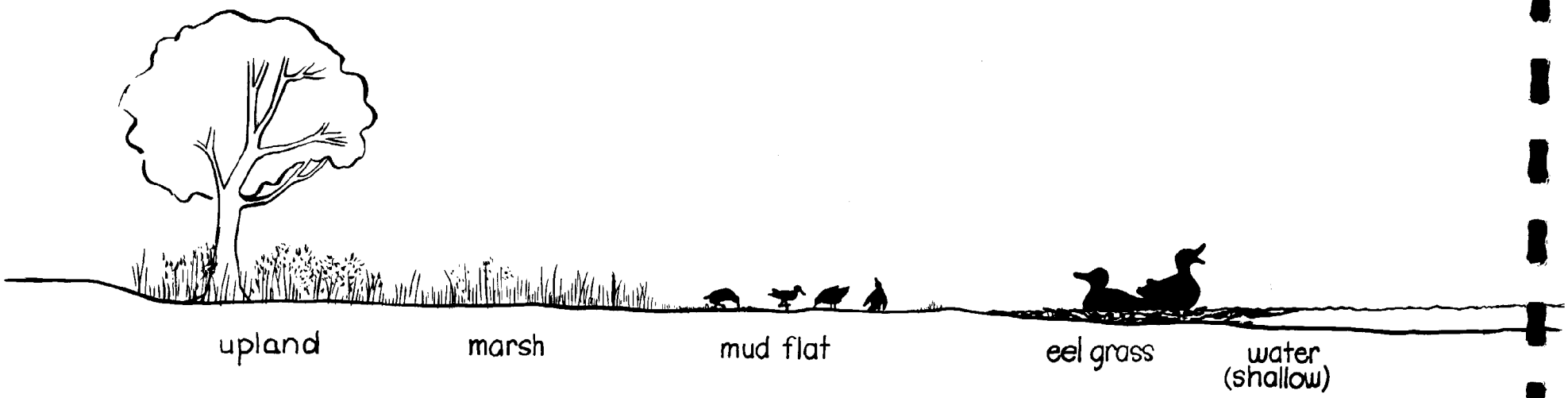
Bacteria are also important in the cycling of nutrients such as sulfur and nitrogen. It has been implied by some scientists that their importance in this respect reaches far beyond the mudflats in which the bacteria live, and may perhaps be of global importance. Bacteria are also valuable to man in breaking down certain pollutants, such as sulfur and sewage products.

Succession

Mudfalts are important in maintaining the salt marshes which are so often associated with them. As silt, clay, and detrital particles slowly settle onto mudflats, the elevation of the mudflat is gradually built up. As elevation increases, marsh plants colonize the upper portions of the mudflat. The result is that marshes tend to slowly advance seaward. This successional development on mudflats is important in maintaining marshes since a gradual buildup of soil creates an upland environment encroaching on marshes on the landward side.

Production

Mud beaches have high primary productivity, especially when salt marshes or eelgrass beds, or both, are present. (Refer to Salt Marsh Narrative, No. 623, and Seagrass Narrative, No. 627, for further information.) Algae such as sea lettuce (Ulva) also contribute to primary productivity when present. The occurrence of algae is partially limited by the absence of a firm substrate for attachment, although filamentous green algae may seasonally form thin mats over the mudflats without requiring a solid base for attachment. Some invertebrates promote the growth of algae on mudflats. The tube-building polychaete worm, Platynereis bicanaliculata, for example, is known to grab pieces of floating sea lettuce and attach them to its tube. The alga continues to grow while attached to the the tube, and the worm, which eats algae, has a constant supply of food available. Another source of primary production is benthic diatoms. These diatoms may form a visible "scum" on the mud surface during portions of the year.



Little work as been done on the productivity of bacteria. However, it has been estimated that the productivity of bacteria in intertidal mudflats is as high as .38 ounces (11 gm) per cubic foot per day. If this figure is accurate, bacteria are of far greater importance ecologically than ever thought before.

The high productivity of mudflat systems, supplemented by organic matter supplied by rivers and adjacent upland areas, supports large numbers of animals. The majority of these animals obtain food by eating detritus or preying on detritivores. In general, the detrital food pathway is more important than pathways involving direct grazing of vegetation.

Density and Diversity

The density of invertebrates on mud beaches is extremely high, and in the high intertidal is greater than at comparable elevations on any other substrate. This density is of tremendous importance to vertebrates, especially shorebirds, which feed on these invertebrates. High intertidal areas are exposed a large percentage of the time by low tides, greatly increasing the amount of time available for shorebirds to feed in comparison to mid- and lower intertidal zones. This is especially critical during winter when mean tidal levels are often increased by storms and high freshwater runoff. During these periods, the availability of feeding area is a critical factor for shorebirds. The birds become heavily dependent on these high elevation mudflats since they offer the greatest food resources. Mudflats are, therefore, extremely important in supporting shorebirds and shorebird predators such as falcons, especially during winter.

While the density of invertebrates is extremely high on mud beaches, the diversity varies in relation to fluctuations in salinity. Mudflats occurring in estuaries, where salinities change greatly according to season, typically have fewer species which can survive, and, therefore, have low diversity. Small organisms (primarily crustaceans and polychaetes), which may reach densities of greater than 9,300 per ft^2 (100,000 per m^2), usually dominate numerically. These small organisms provide the major sources of food for shorebirds, juvenile fishes, and crabs which forage on mudflats. Mud beaches which occur in areas where salinities remain fairly stable throughout the year (such as in the San Juan Islands) are also dominated numerically by small crustaceans and polychaetes; however, the diversity of species is extremely high.

Characteristic Species

Invertebrates

Larger invertebrates found on mudflats include red rock crabs, Dungeness crabs, hairy shore crabs, mud shrimp, macoma clams, soft shell clams, heart cockles, and occasionally, Pacific oysters. High salinity mudflats may also have moon snails, native littleneck clams, and Japanese littleneck or Manila clams, but these species are not "characteristic" of mudflats. Refer to Table 638-1 for a list of characteristic plants, invertebrates, and fish occuring on mud beaches and to Table 63-2 for lists of birds and mammals.

Fish

Large numbers and varieties of fish feed along mud beaches, particularly if eelgrass is present in lower intertidal and shallow subtidal areas. For example, in northern Puget Sound baseline sampling, mud/eelgrass habitats supported the richest, most abundant neritic (feed in the water column) fish assemblages. Fish which occur in this area include juvenile English sole and starry flounders, three-spine sticklebacks, Pacific staghorn sculpins, spiny lumpsuckers, snake pricklebacks, shiner perch, sharpnose sculpins, saddleback gunnels, surf smelt, and Pacific herring. Mudflats serve as nursery areas for juvenile English sole and starry flounder, especially when eelgrass is present. Tidal channels provide important feeding areas for juvenile chinook, chum, and coho salmon, as well as sculpins, starry flounder, and shiner perch. Representative examples of fish inhabitating mud substrates include the following:

TABLE 638-1 CHARACTERISTIC PLANTS AND ANIMALS

Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
PLANTS				
Green Algae				
Sea lettuce (*Ulva*)	PP	M, L	PC	Edible; important waterfowl food.
(*Enteromorpha* spp.)	PP	H, M, L	PC	Edible; important waterfowl food.
(*Monostroma* spp.)	PP	M, L	PC	Edible; important waterfowl food.
Diatoms	PP	H, M, L		Abundant seasonally.
Vascular plants				
Broad-bladed eelgrass (*Zostera marina*)	PP	L, SB		Important waterfowl food; increases diversity of habitat.
INVERTEBRATES				
Molluscs				
Soft-shell clam (*Mya arenaria*)	FF	H, M, L	R, PC	Introduced; harvested commercially on East Coast.
Heart cockle (*Clinocardium nuttallii*)	FF	M, L		
Bent-nose clam (*Macoma nasuta*)	DEP	M, L		Edible, but contains mud in stomach.
Macoma clam (*M. balthica* = *M. inconspicua*)	DEP	H, M		
Macoma clam (*M. inquinata* = *M. irus*)	DEP	H, M		
(*Cryptomya californica*)	FF	M, L		Commensal in ghost and mud shrimp burrows.
Tiny transennella clam (*Transennella tantilla*)	FF	M, L		
Pacific oyster (*Crassostrea gigas*)	FF	M, L	C, R	Supports large commercial industry in Washington.

Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
Molluscs (Continued)				
(Batillaria attramentaria)	CARN	M, L		Introduced with oysters.
(Aglaja diomedea)	CARN	M, L		
Arthropods				
Leptostracan (Nebalia pugettensis)	FF	H, M, L		
Ostracod	DETR	L		
Harpacticoid copepod	DETR	H, M, L		Important food for juvenile salmon.
Cumaceans (Cumella vulgaris)	DETR	M, L		
Tanaid (Leptochelia savignyi)	DETR	M, L		
Tanaid (Pancolus)	DETR	M, L		
Pill bug (Gnorimosphaeroma oregonenses)	SCAV-HERB	H, M, L		Usually under debris on beach.
Amphipods				
(Corophium acherusicum)	DETR	M, L		Abundant on high salinity mudflats.
(C. salmonis)	DETR	H, M, L		Abundant in low salinity mudflats; important food for shorebirds and juvenile fish.
(Anisogammarus confervicolus)	OMNI	H, M, L		Usually under debris on beach; important food for fish and shorebirds.
(Ampithoe spp.)		M, L		
Mud shrimp (Upogebia pugettensis)	DETR	M, L	R, PC	Edible, used as fish bait.
Hermit crab (Pagurus spp.)	DETR	M, L		
Hairy shore crab (Hemigrapsus oregonensis)	SCAV-CARN	H, M, L		
Dungeness crab (Cancer magister)	CARN	L, SB	R, C	Supports large commercial industry in Washington.

Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
Red rock crab (Cancer productus)	CARN	L, SB	R, PC	Edible.
Insect larvae (Paraclunio alaskensis)	HERB	H, M		
Segmented worm (Annelids)				
Oligochaete worms	DEP	H, M, L		
Polychaete worms				
Abarenicolidae				
lugworms (Abarenicola pacifica)	DEP	H, M, L		
Capitellidae				
(Capitella capitata)	DEP	H, M, L		
(Mediomastus ambiseta)	DEP	H, M, L		
(Notomastus tenuis)	DEP	H, M, L		
Dorvilleidae				
(Dorvillea rudolphi)		H, M, L		
Glyceridae				
(Hemipodus borealis)	CARN	M, L		
Goniadidae				
(Glycinde picta)	CARN	M, L		
Hesionidae				
(Ophiodromus pugettensis)	CARN	M, L		
Lumbrineridae				
(Lumbrineris)	HERB	M, L		
Nereidae				
(Platynereis bicanaliculata)	HERB	H, L		
Opheliidae				
(Armandia brevis)	DEP	H, M, L		
Orbiniidae				
(Scoloplos armiger)	DEP	H, M, L		
Phyllodocidae				
(Eteone longa)	CARN	H, M, L		
Sabellidae				
(Manayunkia pacifica)	DETR	H, M		
(M. aestuarina)	DETR	H, M		

Common Name (Scientific Name)	Trophic Type[1]	Zone(s) of Occurrence[2]	Economic Value[3]	Comments
Spionidae				
(*Polydora kempi japonica*)	DETR	H, M, L		
(*Polydora ligni*)	DETR	H, L		
(*Polydora socialis*)	DETR	M, L		
(*Streblospio benedicti*)	DETR	H, M, L		
Syllidae				
(*Exogone lourei*)	DETR	M, L		
Ribbon worms (Nemerteans)				
(*Paranemertes peregrina*)	CARN	M, L		
Nematodes	DETR, CARN, HERB	H, M, L		
Anemones (Coelenterates)				
(*Edwardsia*)		H, M, L		
(*Edwardsiella*)		H, M, L		
Phoronid				
(*Phoronopsis harmeri*)	FF	L		

FISH

Common Name	Scientific Name	Economic Value	Comments
Spiny dogfish	*Squalus acanthias*	C	
American shad	*Alosa sapidissima*	C, R	Introduced.
Pacific herring	*Clupea harengus pallasi*	C, R	Spawn when eelgrass present.
Northern anchovy	*Engraulis mordax*	C, R	
Pink salmon	*Oncorhynchus gorbuscha*	C, R	Juvenile salmonids feed over submerged mudflats.
Chum salmon	*O. keta*	C	
Coho salmon	*O. kisutch*	C, R	
Chinook salmon	*O. tshawytscha*	C, R	

Common Name	Scientific Name	Value	Comments
Cutthroat trout	Salmo clarki	R	
Surf smelt	Hypomesus pretiosus	C, R	
Longfin smelt	Spirinchus thaleichthys	C, R	
Three-spine stickleback	Gasterosteus aculeatus		Common prey of several other fish and birds.
Bay pipefish	Syngnathus griseolineatus		
Shiner perch	Cymatogaster aggregata	R	Prey of many fish, birds, and marine mammals.
Snake prickleback	Lumpenus sagitta		
Saddleback gunnel	Pholis ornata		
Pacific sand lance	Ammodytes hexapterus		Prey of many fish, birds and marine mammals.
Arrow goby	Clevelandia ios		
Padded sculpin	Artedius fenestralis		
Sharpnose sculpin	Clinocottus acuticeps		
Buffalo sculpin	Enophrys bison		
Pacific staghorn sculpin	Leptocottus armatus		
Tidepool sculpin	Oligocottus maculosus		
Tadpole sculpin	Psychrolutes paradoxus		

LEGEND:

[1]Trophic type

PP = Primary Producer
FF = Filter Feeder
DEP = Deposit Feeder
SCAV = Scavenger
CARN = Carnivore
DETR = Detritivore
OMNI = Omnivore
HERB = Herbivore

[2]Zones of Occurrence

H = High Intertidal
M = Mid-Intertidal
L = Low Intertidal
SB = Shallow Subtidal

Underline = Zone of greatest abundance

[3]Economic Value

C = Commercial
R = Recreational
PC = Potential Commercial

English Sole

Juvenile English sole are especially abundant on muddy beaches. The protective eelgrass habitat, which is often present, and an abundance of food are considered as major factors in supporting these and other muddy beach inhabitants. English sole are popular commercial and recreational food fish.

Salmon

Salmon are not generally thought of as inhabiting muddy shores. Adults are fished in open water far from shore or along more exposed beaches than mudflats. However, juvenile salmon frequent these protected mud substrates, retreating to stream and tidal channels when low tides drain the shallow mudflats. Mudflats are a dominant feature of the estuaries where large numbers of juvenile salmon first enter the marine environment. They feed on a variety of mudflat invertebrates including large quantities of insects and amphipods.

Shiner Perch

Shiner perch are often very abundant, and were noted as the predominant schooling fish at the San Juan Island mud and eelgrass site during recent baseline fish sampling. In Grays Harbor, shiner perch are a major prey of Caspian Terns which feed over the extensive, shallow waters submerging intertidal mudflats.

Pacific Staghorn Sculpin

The staghorn sculpin has been noted as one of the most common and abundant bottom dwelling fish on mud substrates in Washington waters. Staghorn sculpins tolerate wide ranges of salinity and may extend from the estuarine, mudflat environment to freshwater. They are prey of several other fish, birds, and mammals; Great Blue Heron, Kingfishers, Caspian Terns, river otters, and Common Loons are all known to feed on this ubiquitous sculpin. Staghorn sculpins also consume young of their own species. Other food items include stickleback, ghost shrimp, and a variety of other invertebrates.

Because they are so numerous, staghorns are important in energy transfer within mudflat communities. They consume small organisms (juvenile fish and invertebrates) which then become available to larger predators (adult fish and other vertebrates) which consume staghorns. These larger predators would not be able to take advantage of the tremendous quantities of smaller organisms on mudflats without the link in food pathways provided by mid-sized organisms like the sculpin. Thus, the Pacific staghorn sculpin should be regard as a major contributor to economically and recreationally valuable fish, birds, and mammals. Staghorns are not consumed by humans directly, but many species we eat or enjoy in other ways are sculpin predators.

Starry Flounder

Starry flounders are distinguished by the alternating light and dark banding on their fins and tail. The skin is rough due to small projections on the scales which are visible when examined closely. They grow to approximately 36 inches (91 cm) and may weigh up to 20 pounds (9.1 kg).

Birds

Dunlin

A wide variety of shorebirds depend on mudflats for feeding habitat, primarily during spring and fall mirgrations. Dunlins are one of the most common and abundant of this migrants and among those which also winter in Washington. Dunlin have been observed to prefer areas within mudflats at or near the water's edge and where a surface film of water persists when tides recede. They probe the surface layer with their slender bills and consume mostly invertebrates. Prey items also include seeds of salt marsh plants.

During studies of Dunlin at Grays Harbor, the amphipods Corophium sp. and Anisogrammarus confervicolus were major food items. Thousands (high counts of approximately 10,000 Dunlins were noted during the periods March-May and October-January) of Dunlin feed on these invertebrates within the Grays Harbor area each year. Elsewhere, Corophium and related invertebrates of mudflats also support migrant shorebirds as well as many other birds and commercially valuable fish. Other predators also consume these organisms which prey on mudflat invertebrates. Among these predators is the Peregrine Falcon [subspecies: Amercian Peregrine Falcon

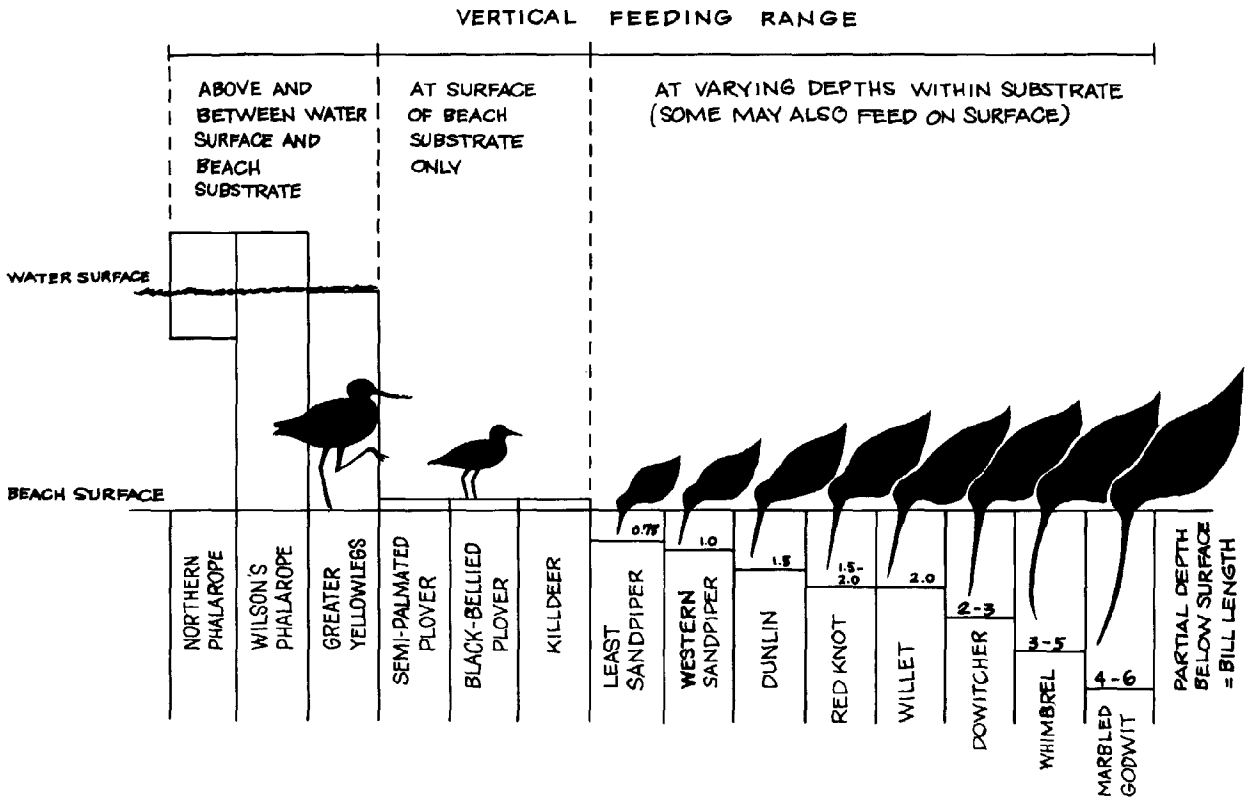
(Falco peregrinus anatum), is an endangered species]. A Peregrine Falcon was observed to use sites where shorebirds concentrated as a feeding area in Grays Harbor. The remains of eight Dunlin were assumed to have been left by a Peregrine at a roost site in the Harbor.

Western and Least Sandpipers

Both these birds are among the small sandpipers commonly referred to as "peeps." They are both quite small (both under 7 inches or 18 cm) and somewhat difficult to distinguish from a distance. Like other sandpipers, they are often regarded as indistinguishable, light-colored birds all belonging to the same species. However, as discussed in the Sand Narrative (No. 636), there are several species of shorebirds and each has a distinctive feeding area. Because Western and Least Sandpipers are so similar, the compete for much the same food items and feeding area. For example, a study in California noted that both these species shared many of the same kinds and sizes of prey. Feeding areas overlapped on mudflats, but Least Sandpipers tended to feed more often higher in the intertidal. They are able to co-exist on the same mudflats, partially because of this difference in distribution. They also migrate at different times of the year, thus, staggering arrival times as they pass along our coast. Perhaps more importantly, Western and Least Sandpipers are small. Because of their size, they are able to feed on the most numerous prey items available on mudflats [small invertebrates which reach densities of 9,300 per ft^2 (100,000 per m^2)]. These small organisms are so abundant that they are able to support many other predators (fish and birds) in addition to the large numbers of sandpipers which compete for food.

Larger shorebirds may also feed on the same food items as Western and Least Sandpipers, but in general they consume larger prey. These larger prey organisms are not as abundant and neither are their predators. Larger shorebirds include Whimbrels, Black-bellied Plovers, and Willets. These and other shorebirds have evolved physical traits and behavior which tend to segregate feeding areas and organisms more so than observed for Western and Least Sandpipers. The following diagram (Figure 638-1) adapted from a recent shorebird study illustrates distribution of feeding above and below the surface of beach and water surfaces.

FIGURE 638-1 *FEEDING DISTRIBUTION ON MUDFLATS AND NEWSHORE WATERS BY SELECTED SHOREBIRDS.*



Shorebirds are able to probe below the surface to varying depths according to bill length (the numbers indicate both length of bill and depth to which they can probe in inches). They also have varying leg lengths, and are able to wade in shallow water, as illustrated by the Greater Yellowlegs which feeds in tidalpools and shallow nearshore waters. Phalaropes generally feed while resting on the water's surface, while Plovers feed on organisms on the surface of beach substrates.

Green-winged Teal

The Green-winged Teal is one of several waterfowl which feed on mudflats. They may occur in shallow waters of submerged flats or on the mud surface at low tide. Teal are often concentrated along tidal channels and salt marsh margins where they may be joined by the larger Pintail. American Wigeon also occur with these ducks, but feeding habits and areas generally do not overlap. Teal and Pintails both consume more animal matter than wigeons, which feed primarily on eelgrass and algae. Green-winged Teal food items include seeds of salt marsh plants, insects, and amphipods.

Green-winged Teal are the smallest dabbling duck (surface feeders which include Mallards, Pintail, and other teal). They are abundant and often pursued by duck hunters. All who enjoy bird watching also seek the teal to observe its attractive coloration and aerial maneuvering. These small ducks are especially enjoyable to observe at close range so that one can hear their wings whistling as they fly past, or watch their dabbling feeding habits.

Canvasback and Ruddy Duck

Both Canvasback and Ruddy Ducks are diving ducks which were most often observed feeding over submerged mudflats during our studies. The larger Canvasback is distinguished from other ducks by its sloping crown to bill profile which gives the head (reddish brown in males) an elongated appearance. Ruddy Ducks are about the size of the more common Bufflehead with which they are confused from a distance. The bright blue bill of the male is distinctive, but it becomes black during fall and winter. Ruddy Ducks are not as abundant as they once were due to overhunting and loss of breeding habitat. Canvasbacks have also decreased in numbers and have been considered to be endangered by some authors because of a steady reduction of breeding habitat and excessive hunting mortality. Canvasbacks are considered uncommon in Washington waters and critical winter concentrations noted in the Coastal Zone Atlas include: North Padilla Bay and Samish Bay, Willapa Bay and Grays Harbor, Whidbey Island Basin Area, Dungeness Bay, and Elliot Bay. Other wintering areas noted during this study and others are Port Susan Bay, Drayton Harbor, Budd Inlet, Annas Bay, and Lynch Cove.

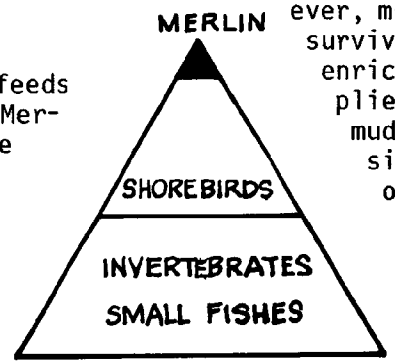
Canvasbacks are among several ducks noted to be susceptible to lead poisoning due to consumption of lead shot (from shotguns). Development of non-toxic steel shot for use by hunters might ease this problem. Protection of breeding habitat and winter feeding areas such as mudflats will also help enhance the survival of Canvasbacks.

Eared Grebe

Eared Grebes are also diving birds, but are not members of the duck family. They are very similar to the more common (on salt water) Horned Grebe which also occurs over submerged mudflats. The larger Red-necked and Western Grebes (all members of the family Podicipedidae) more commonly occur further off shore or along more exposed shores. Eared Grebes are uncommon in western Washington where known areas of concentrations include Willapa Bay, the Strait of Juan de Fuca, San Juan Archipelago waters, and Padilla Bay. Large numbers of Eared Grebes were observed on Mud Bay on Lopez Island during our studies.

Merlin

The Merlin is a small falcon which often feeds on shorebirds concentrated on mudflats. Merlins and other birds of prey require large numbers of shorebirds and are examples of predators at the pinnacle of marine food webs. One of viewing these food webs is as a pyramid of numbers as depicted in Figure 638-2:



pyramid of numbers

Fewer species and individuals are represented in each level of the pyramid. Top level consumers are far less common than secondary consumers such as the shorebirds and many are threatened by reductions in prey populations (loss of shorebirds and amphipods affects Merlins) and by loss of habitat (loss of marsh and mudflats eliminate prey of shorebirds and amphipods as well as roost sites for Merlin).

Mammals

Like humans, other mammals generally use organisms produced on mudflats in other areas. A few mammals such as raccoons and river otters feed on a variety of fish and invertebrates on the flats. However, many more mammals benefit from organisms which occur on mudflats during part of their life cycle and move offshore at later stages. For example, marine mammals including harbor seals, sea lions, and killer whales feed on fish which use mudflats as nursery areas.

Use by Man

Mud beaches support many species which are recreationally or commercially important. Pacific oysters which support a valuable industry are commercially harvested on mud beaches primarily in southern Puget Sound and Willapa Bay. However, mud beaches can pose problems for the survival of oysters, despite the organic enrichment which assures adequate food supplies. Constant siltation in protected muddy areas and the danger of oysters sinking can result in smothering of the oysters. Thus, some mud beaches have been modified by dumping gravel over the mud to minimize problems of oysters smothering. In addition, cement walls to retain sea water and sprinkler systems have been employed to protect oysters from excessive temperatures during low tides.

Waterfowl, particularly Pintails, American Wigeons, and Green-winged Teal are common along mud beaches as migrants and winter visitors. Thousands of these birds frequent mudflats, especially those adjacent to salt marshes where they are sought by duck hunters and bird watchers.

Most of the species of direct value to man spend only a portion of their lives on muddy beaches and are harvested in other areas. Chinook, coho, and

chum salmon, English sole, starry flounder, Dungeness crabs, surf smelt, and Pacific herring are all harvested in offshore areas. Many of the mammals which occasionally use mud beaches for feeding or resting such as river otters, deer, raccoons, and mink are harvested by man for food or for their fur. All these species are also valued by all who enjoy watching wildlife.

Ghost and mud shrimp, soft-shell clams, and sea lettuce are all edible and represent species of potential use by man. Ghost shrimp are the only species currently harvested for commercial use, and are sold as bait. This is an extremely small industry in Washington at present. Soft-shell clams were harvested commercially for a short period in Port Susan and Skagit Bays, but this industry is not currently in operation.

The high diversity of birds associated with mud beaches, particularly during spring and fall migrations, makes them popular bird-watching areas. This is especially true for areas which do not have extensive urban development nearby. Bird-watching has become an important industry in Washington during the last decade, contributing a large percentage of the several hundred million dollars added to the State's economy each year by nonconsumptive wildlife users.

IMPACTS

Although biologically productive and containing large numbers of organisms, mudflats provide many stresses to the organisms inhabiting them. Often they occur near areas where rivers or streams meet marine waters. Thus, salinity is between that of salt and fresh water, and usually varies signficantly with the amount of freshwater flow. Temperatures reach extremes which further stress organisms. During summer, when hot weather corresponds with daytime low tides, water can be heated in excess of 21°C. (70°F.) as tides bring water in over sun-warmed mudflats. During winter, low tides occur during night when temperatures are coldest, thus occasionally exposing tideflats to freezing weather. Another stress on mudflat organisms is the decreased level of dissolved oxygen. Since decaying organic matter is abundant on mudflats, and this process requires oxygen, dissolved oxygen levels are normally low on mud beaches. During summer, the problem is compounded, as warm water holds less oxygen than cold water.

Because of these stresses, mudflat communities, especially those in estuaries, are sensitive to activities which alter their environment. For example, activities which affect dissolved oxygen can greatly impact the number and variety of invertebrates occurring in the mudflat. Organic wastes, such as sewage effluents, food processing plant wastes, and large amounts of wood chips, require oxygen to

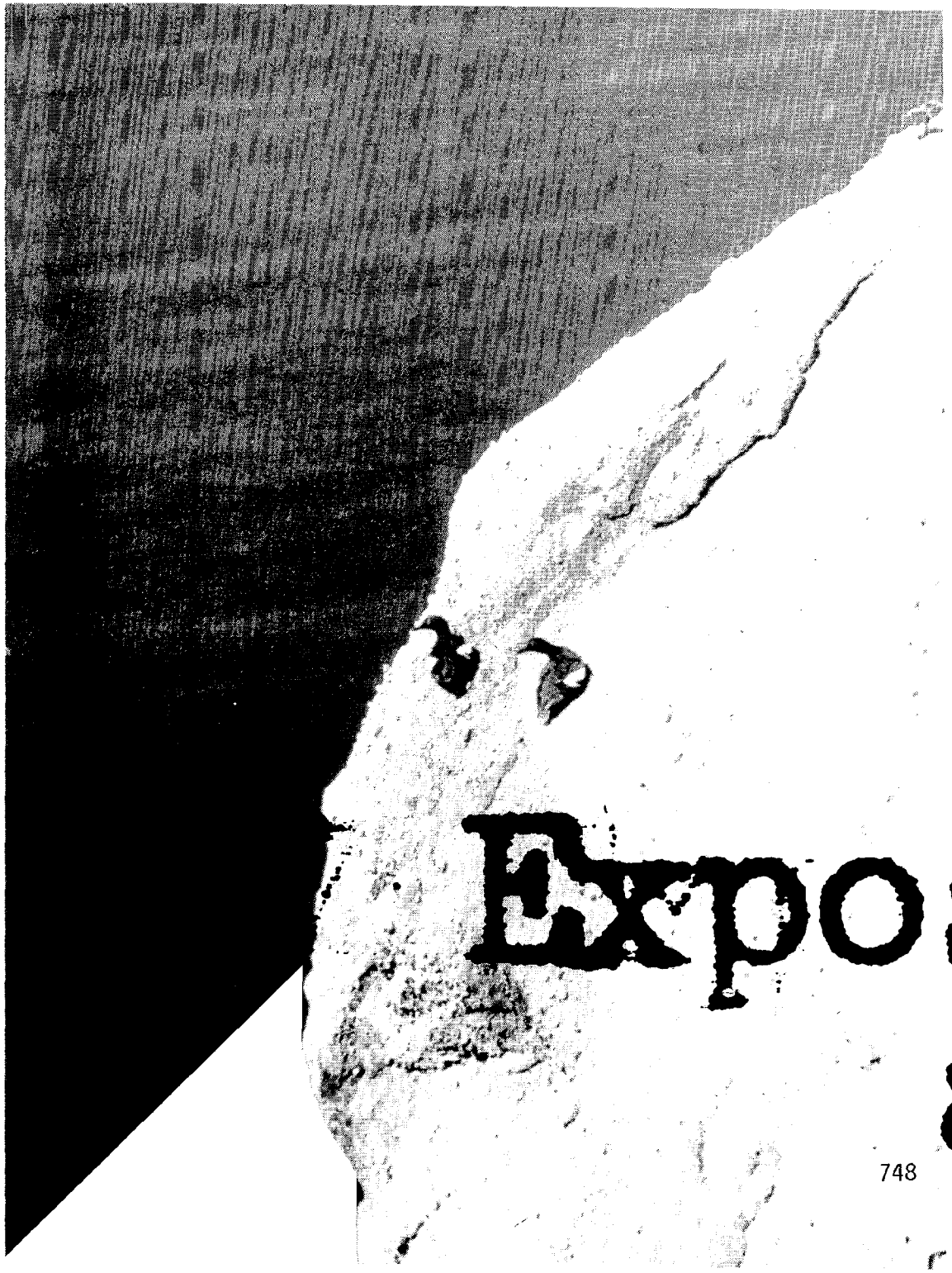
decompose, and thus tend to lower oxygen content in the water. The number of animals using the mudflats can be reduced drastically as a result.

Storage of logs in intertidal areas not only produces wood debris which requires oxygen to decompose, but also represents another type of impact; that of smothering and crushing benthic invertebrates. A study in Everett Bay, Snohomish County, indicated that the number of invertebrates was significantly reduced by log rafting. However, most of the invertebrates in the study area were small, short-lived species capable of reestablishing their population within a short period (two months) after removal of the logs. Thus the impact can be rather ephemeral if storage is not a long-term event. If, on the other hand, storage occurs in an area where longer-lived invertebrates reside (such as soft-shell clams), or during a critical time period (such as during migration of juvenile fish), the impacts can have longer-lasting repercussions.

The fine sediments present in muddy substrates tend to bind with inorganic materials, such as nutrients, as stated earlier. By the same means, toxins bind to fine sediment particles, so that mud beaches, especially those near sources of inorganic pollutants (e.g., heavy metals), are

likely to accumulate toxins. Some of these toxins are incorporated into the biota of the area, while some remain bound to the sediments. Disturbance of the sediments through activities such as dredging, poses the threat of making these toxins available to the biota once again. Reworking of the sediments by burrowing organisms (such as ghost and mud shrimp) will result in a long-term, slow release of toxins.

The problem of toxins in areas where the substrate is primarily mud poses another problem. Such areas are normally very protected, with restricted movement of water. As a result, toxins in the water stay in the area longer, and are not diluted as quickly. In parts of southern Puget Sound, water takes in excess of 20 years to completely turnover. Thus, pollutants discharged into the water in small but constant quantities can accumulate to extremely high levels over long periods of time and pollutants remain in the water for long periods of time after the source of pollution is cut off. This is true for organic wastes as well. In southern Puget Sound, oyster farmers in several small embayments are threatened by the continual release into the water of small amounts of sewage from septic tanks. The buildup of coliform bacteria can make it unsafe for humans to consume oysters in these areas, thus jeopardizing the existence of the oyster industry in these areas.



Exposed and

EXPOSED AND OTHER LANDS (No. 7)

The exposed and other lands classification includes features which are treated in greater detail in the geology maps of the Coastal Zone Atlas. Significant formations which have important biological values are Rock (No. 71), Sand (No. 72), Spits (No. 74), and Bluff (No. 76). Rock islands or emergent rocks often too small to be designated in the Coastal Zone Atlas are important areas for seabirds and harbor seals.

Other Lands

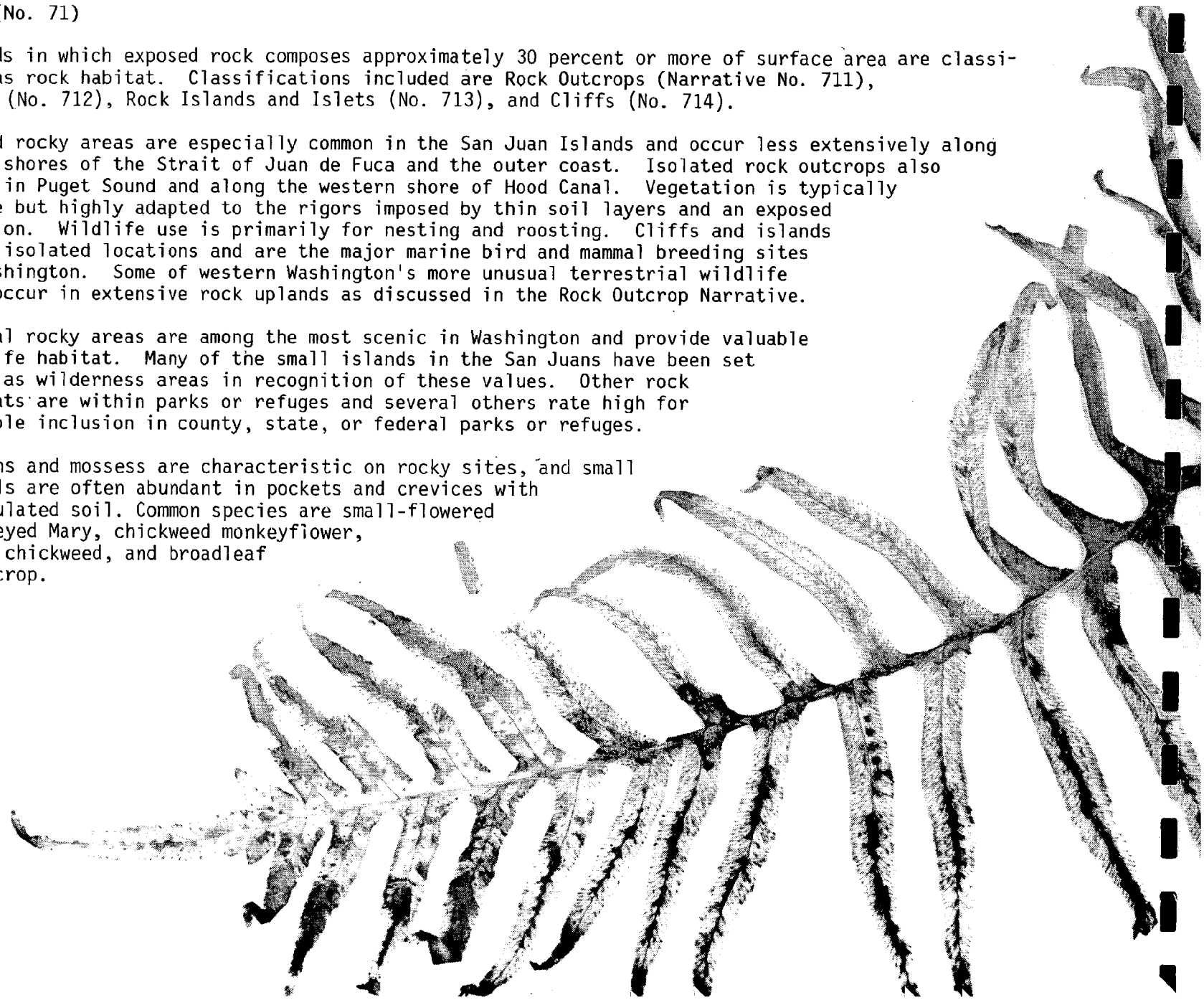
ROCK (No. 71)

Uplands in which exposed rock composes approximately 30 percent or more of surface area are classified as rock habitat. Classifications included are Rock Outcrops (Narrative No. 711), Talus (No. 712), Rock Islands and Islets (No. 713), and Cliffs (No. 714).

Upland rocky areas are especially common in the San Juan Islands and occur less extensively along rocky shores of the Strait of Juan de Fuca and the outer coast. Isolated rock outcrops also occur in Puget Sound and along the western shore of Hood Canal. Vegetation is typically sparse but highly adapted to the rigors imposed by thin soil layers and an exposed location. Wildlife use is primarily for nesting and roosting. Cliffs and islands offer isolated locations and are the major marine bird and mammal breeding sites in Washington. Some of western Washington's more unusual terrestrial wildlife also occur in extensive rock uplands as discussed in the Rock Outcrop Narrative.

Coastal rocky areas are among the most scenic in Washington and provide valuable wildlife habitat. Many of the small islands in the San Juans have been set aside as wilderness areas in recognition of these values. Other rock habitats are within parks or refuges and several others rate high for possible inclusion in county, state, or federal parks or refuges.

Lichens and mossess are characteristic on rocky sites, and small annuals are often abundant in pockets and crevices with accumulated soil. Common species are small-flowered blue-eyed Mary, chickweed monkeyflower, field chickweed, and broadleaf stonecrop.



ROCK OUTCROP (No. 711)

I. INTRODUCTION

Rock outcrops occur primarily as rocky projections scattered throughout the coastal zone, particularly in the San Juan Archipelago. Not suprisingly, these outcrops are most often associated with rocky intertidal areas where they typically form a narrow fringe between the salt water and vegetated uplands. Rock outcrops sometimes have a very steep profile, in which case they may be mapped as cliffs, but most often rock outcrops are gentle slopes.

Rock outcrops are usually quite small; in many areas smaller than the minimum map size of the Coastal Zone Atlas. These outcrops are a dominant feature of the San Juan shoreline, but also occur along the western shore of Hood Canal, the outer coast, and the Strait of Juan de Fuca.

Occasionally, rock outcrops cover more extensive areas as on the west slope of Mount Dallas. These extensive rocky slopes provide a striking contrast to the typically wet and forested coastline of Washington. Rainfall is much lower on Mt. Dallas than in most of the coastal zone, which in combination with the rocky substrate produces desert-like conditions, providing habitat for uncommon and rare plants and animals. Much of the rock outcrop area on the west side of Mount Dallas on San Juan Island was mapped as cliff. It was difficult in this area to draw a line between cliff and rock outcrop. Since one cover type grades into another, the entire west Mount Dallas area should be regarded as a matrix of cover types on a rock substrate, the entire area being an extrememly complex rocky slope.

Appearing bare from a distance, closer examination of the rock outcrops reveals unique associations of plants and animals. Plants emerge from and produce cracks in the rocks; examples include saxifrage which literally translated means "rock breaker", and gold-back fern.

Patches of grasses and wildflowers occur on soil accumulated in shallow depressions, while scattered marshes and small ponds unexpectedly occur in deeper depressions. Shrub and tree cover is sparse, and grades into the more open slopes creating an inseparable matrix of exposed rock woodland, shrub, and grassland. The overall plant and animal diversity of the area increases as additional cover types are considered. It is, however, the presence of a rocky substrate (the rock outcrops) which sets this site apart as one of the truly unique coastal features of Washington.

Historically, rocky areas have been regarded as nonproductive. Crops do not fare well on rocky soils and construction is difficult. However, rocky shorelines are becoming increasingly popular because of their high esthetic value. Recreational values are especially high, and many persons have chosen rocky shorelines as home sites despite inherent difficulties of living on the rocks. Human activities, particularly housing, now pose a serious threat to rocky areas including Mount Dallas and other San Juan sites.

II. SIGNIFICANT BIOLOGICAL FEATURES

Rock outcrops most often rise from the rocky intertidal as small patches but occasionally extend over several acres of upland habitat.

Nearshore

Kelp forests often dominate the nearshore areas adjacent to rock outcrops. Smaller marine algae occur above the tidal zone where salt spray splashes the rocks. An abrupt change from marine to upland vegetation often occurs on rock outcrops, however, spray may influence the sparse rock vegetation quite high above the waters edge. For example, at Eagle Point on San Juan Island, seashore salt grass occurs in large patches 30 to 40 feet above the water's surface. Encrusting lichens cover the rock surfaces and grasses, other than seashore saltgrass, also occur in addition to fat-hen, grindelia, and occasionally peppergrass. Most of these species are also found on salt marshes in protected muddy bays.

It is on these grass-covered rock outcrops along the edge of rocky shores that much marine bird nesting occurs. Glaucous-winged gulls sometimes nest on rock outcrops on the main islands in the San Juans and perhaps on the mainland. However, major colonies of nesting gulls occur primarily on the more isolated small islands scattered throughout the San Juan Archipelago (See Rock Island Narrative, No. 713, for more detailed information).

The river otter is another species which makes extensive use of rock outcrops at the shore's edge. Otters come ashore on outcrops to roll and play on grass which is matted down and sometimes dug up in the process. They also defecate here, leaving evidence of their presence. The recurring sign and presence of otters on the rock outcrops is evidence of outcrop importance to these intriguing mammals which are adapted to life on land, freshwater, and the marine environment.

Higher Ground

Above the strong influence of salt spray, upland vegetation begins to appear on the rock outcrops and in the shallow soil between the rocks. Typical plant species pioneering on bare rock include lichens (*Physcia stellanis*, *Umbilicaria* spp., *Verrucaria* sp. and *Caloplaca* spp.) and mosses. The mosses *Polytrichum piliferum*, *Polytrichum juniperum*, *Hedwigia ciliata*, *Rhacomitrium canescens* and *Grimma* spp. colonize cracks and minute accumulations of soil, and eventually through death and decay contribute to the slow build up of soil. Vascular plant species typically occurring on the rock outcrops include selaginella, little hairgrass, Lemmon's needlegrass, pine bluegrass, small-flowered blue-eyed mary, Menzies' larkspur, field chickweed, sheep sorrel, chickweed monkey flower, and broadleaf sedum. Lanceleaved stonecrop (*Sedum lanceolatum* var. *nesioticum*) occurs in the San Juan Archipelago in this and similar exposed rock habitats (e.g., cliffs and rock islands) Several ferns are characteristically found in the crevices of rock outcrops or cliffs in the driest areas of the coastal zone, including gold-back fern, maidenhair spleenwort. parsley fern, and aspidotis. Aspidotis is a reliable serpentine rock indicator. Although occasionally occurring on other rock types, it is always present on serpentine.

Plants found in deeper soil between rock outcrops usually include the grassland species discussed in the Open Grassland Narrative (No. 313). Camas (*Camassia* spp.), death-camas, tomcat clover, Pomo-celery lomatium, California poppy, sea thrift, and small flower fringecup are common spring-blooming wildflowers. Throughout the rain shadow area of the northern Puget Trough occurs perhaps the most unexpected member of our coastal flora, brittle cactus. The main distribution of this cactus is east of the Cascade range, but a small disjunct population survives in San Juan, Island, Whatcom, Jefferson, and Clallam counties. Characteristically occurring in rock outcrop or open grassland habitats, brittle cactus forms low mounds at the base of the outcrops or in the grassland.

At day light on the 18th of May we both weigh'd anchor and with light variable airs of wind and the assistance of the boats ahead we got out of Port Quadra by the channel to the Eastward of Protection on that Island, as Captain Vancouver was going to land on that Island to take some bearing & went with him to have another short stroll on that delightful spot and among other Plants & collected & was not surprised to meet with the Cactus opuntia thus far to the Northward, it grew plentifully but in a very dwarf state on the Eastern point of the Island which is low flat and dry sandy soil—

Trees may occur sporadically throughout areas mapped as rock outcrop. Garry oak, madrona, Douglas fir, lodgepole pine, and Rocky Mountain juniper are the usual species, but on the west side of Mt. Dallas, big-leaf maple occurs in this very atypical habitat.

Representative Plants and Animals of Rock Outcrops

Gold-back fern

This is one of a few ferns that are essentially restricted to rock crevices. Gold-back ferns derive their name from the presence of a golden powder (the spores) on the lower surface of the frond.

As with all ferns, the gold-back produces numerous spores (some ferns producing as many as 52 million spores on a single leaflet). Spores are wind disseminated, and unlike flowering plants, do not develop directly into the "adult" form. Instead, the few which successfully germinate, develop into a stage known as a gametophyte. The gametophytes produce eggs and sperm which combine to give rise to new spore-producing plants (sporophytes, or the familiar "adult" form of the gold-back fern). Since the sperm actively swims to the egg, free surface water must be available for successful reproduction. Water which collects in small depressions among the rocks for brief periods in otherwise dry outcrops is, therefore, critical in the life cycle of these and other rock crevice ferns. Construction, trampling by hikers, and rock garden collectors pose a threat to these plants because of their restricted range and habitat requirements.

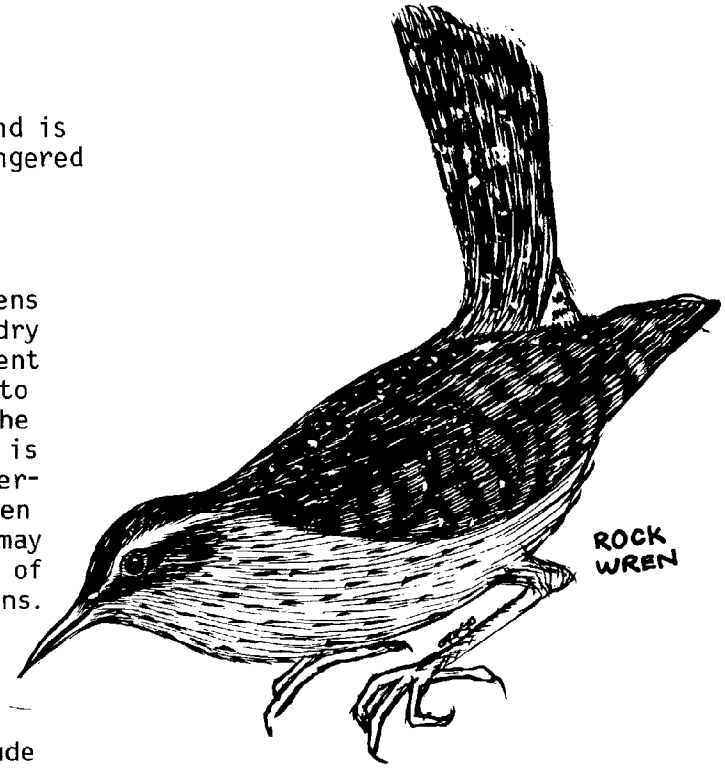
Stonecrops

The stonecrops are fleshy, thick leaved plants which are a distinctive part of rocky areas including outcrops and cliffs. The broadleaf stonecrop is our common species. The small (less than one inch long) leaves are individually wedge-shaped and arranged in rosettes. Small clusters of bright yellow flowers appear in May and June and add to the color of rock faces.

The lanceleaved stonecrop is far less common, and is being considered for proposal as a rare or endangered plant in Washington.

Rock Wren

Like the cactus of the San Juan Islands, Rock Wrens are an example of a unique species occurring in dry sites in the coastal zone. A more typical resident of eastern Washington, the Rock Wren is known to occur in the coastal zone in the vicinity of the west side of Mt. Dallas on San Juan Island. It is thought that populations might fluctuate considerably, however no thorough investigation has been conducted of Rock Wrens in the San Juans. They may also be present on the open west slopes of parts of Orcas Island and other rocky areas in the San Juans.



Birds of Prey

Raptors which occur along rock outcrops include Bald Eagles, Golden Eagles, Merlins, and Red-tailed Hawks. Birds of prey hunt these open areas, and perch in nearby woodlands. Trees are often scattered throughout rock outcrops, however, and provide roost sites within the immediate area. This is evident at Dallas Mountain where an occasional maple or snag interrupts the rocky terrain. These trees diversify this sparsely vegetated habitat. Critical as roost sites, they also enhance the esthetic value of coastal rock outcrops. Small pockets of shrub and grassland which support the small mammal prey of raptors also occur in outcrops.

III. IMPACTS

Coastal rock outcrops are valuable esthetically and as unique habitat which supports some of the most uncommon species in western Washington. Small outcrops are numerous and are often occupied by a single landowner along private rocky beaches. Extensive rocky areas are rare in the coastal zone and include the area along the west side of Mount Dallas on San Juan Island which is perhaps the finest example of a rock upland and one of the most unique sites in the coastal zone. The area also encompasses extensive patches of open woodlands, cliffs, and small marshes. These habitats support several uncommon species including Rock Wrens, Burrowing Owls, and giant fawn-lily (Erythronium oregonum) a proposed rare/endangered plant species. It has also been designated as a critical area for Bald Eagles. Unfortunately, housing threatens Mount Dallas and several other rocky areas in the coastal zone.

Despite their solid, unbreakable appearance, all rock outcrops are fragile areas which contain microhabitats easily destroyed. In many cases, heavy use by persons walking through outcrops can trample vegetation or disrupt breeding birds. Thin soil layers are easily disturbed by trampling, off-road vehicles, or by construction activities.

Because of the open nature of rock outcrops, they generally lack vegetated buffers which tend to isolate animals from noise or sight of human activities. Therefore, human activity quite some distance away poses a threat to several species. Increasing boat traffic along shore will displace nesting marine birds as well as mammals, such river otters, from small coastal outcrops. In more extensive inland outcrops, such as at Mt. Dallas, this effect is caused by vehicles, construction, and large numbers of people walking through the area. Houses and associated activity are, therefore, especially destructive to the unique fauna of rock outcrops since the sphere of potential impacts extends far beyond the immediate vicinity of the building. For example, Bald Eagles are certain to be displaced by disturbance occurring at greater distances from them than in forested areas.

Esthetic values are also easily diminished because of the open nature of rock outcrops. Buildings, or in many cases, one building, can effectively destroy an area visually. Thus, human and wildlife values are extremely sensitive to any impacts occurring in rock outcrops. We urge the preservation of Mount Dallas and suggest that other valuable rocky areas be identified for possible preservation. One such area is on the east side of Massacre Bay on Orcas Island.

TALUS (No. 712)

Talus was mapped in very few locations within the coastal zone. Locations include slopes near Deception Pass in Skagit County, at Point Disney on Waldron Island, and along the west side of Lummi Island. Talus slopes are piles of rock fragments which drop from cliffs and accumulate in uniform masses at the base.

No information is available concerning biological features of coastal Washington talus slopes, however, vegetation and wildlife is somewhat similar to that described in the Cliff (No. 714) and Rock Outcrop (No. 711) Narratives. Major differences would result from the relative instability of the substrate. When rock slides recur frequently an improverished flora and fauna is to be expected. Stable talus slopes will be more completely vegetated and provide suitable crevices for nesting birds and small mammals.

ROCK ISLANDS (713)

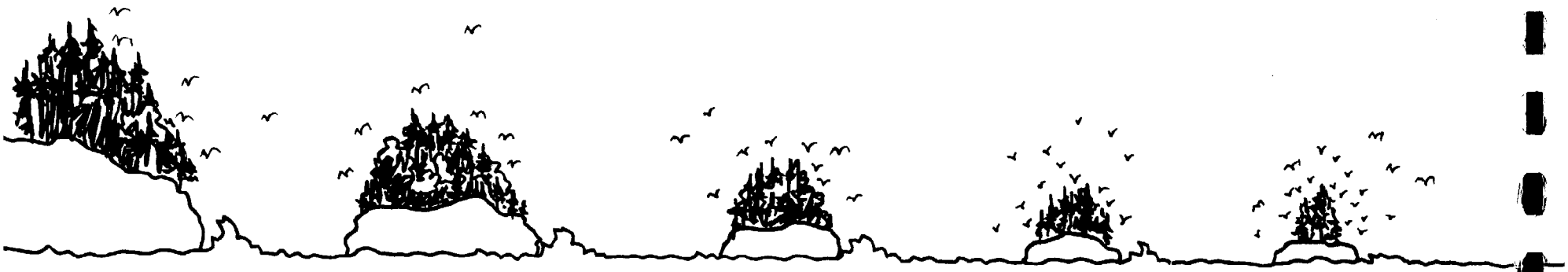
INTRODUCTION

All areas mapped rock island (713, 7131, 7132, 7133) in the Coastal Zone Atlas were 50 acres or smaller. This was an arbitrary size chosen because of the unique features of smaller islands and islets. The following discussion includes all islands, although small, non-peopled islands are emphasized because of their significant value for wildlife. Refer to the Sand Island Narrative (No. 721) for specific information restricted to that class. Otherwise, the information below is relevant to islands of varying substrate and size. Refer also to specific narratives describing the vegetative cover on islands (e.g., See Conifer Narrative No. 41 for information on No. 7133 Island, Conifer).

Islands occur throughout the coastal zone of Washington and are an exclusive feature within the San Juan Archipelago. The San Juans extend into the Canadian Gulf Islands and into Washington counties other than San Juan (e.g., Lummi Island in Whatcom County, Williamson Rocks in Skagit County). These islands are thought to be a submerged extension of the Olympic Mountains and include approximately 457 islands and rock islets at high tide, of which 175 are named. Sizes vary from small rock islets barely exposed at high tide, to 57 square mile Orcas Island, the largest in the group. Other major San Juan Islands include San Juan, Lopez, Blakely, Stuart, Lummi, Cypress, and Sucia.

Small islets and islands are less numerous outside the San Juan Archipelago. Among these is Protection Island in Jeffereson County which is a major seabird nesting area. Several large islands are prominent features in Washington's coastal zone. Whidbey, Bainbridge, Vashon, Anderson, and Hartstene are all distinguished by varying degrees of isolation afforded to islands. These large islands, as with most sizeable San Juan islands, are populated today by people who reflect an interesting history of change in island life. Early occupation of islands was difficult because of water barriers, however, European settlement quickly paved a way with power boats, ferries, highways and bridges. The early day sense of isolation is now largely restricted to small, non-ferry trafficked islands, or to the non-tourist season.

Just as some people seek solitude on islands, other animals and plants also seek isolation or have been isolated on islands. Herein lies the unique value of islands to plants and animals. Charles Darwin visited the Galapagos Islands in the 1800's and observed several qualities peculiar to islands. His observations form the basis of present island biogeographical research which has led to many basic concepts of evolution and ecological relationships.



A coastal island's value as a resting and breeding site usually corresponds to its degree of isolation and lack of disturbance.

Islands have served as natural research laboratories principally because they are isolated. Island flora and fauna are restricted and often much different from mainland populations. The uniqueness results from the isolation, modified competition, space limitation, and special climates characteristic of islands. Major factors affecting colonization of islands are size and distance from the mainland.

Another feature which affected Pacific Northwest islands was glaciation. Once thought to have been a land refuge, the San Juans are now believed to have been completely covered with ice during the last glaciation. Therefore, terrestrial life has had to re-invade the islands in the past 12-13,000 years over water barriers of varying distance from the mainland. In general, the degree of colonization or similarity to the mainland increases with island size and nearness to the mainland. Thus, Whidbey Island flora and fauna is fairly indistinguishable from the mainland while that of Orcas Island reflects its insular situation and life on tiny Williamson Rocks is very unique although quite limited.

Smaller islands are much less like the mainland and are further distinguished by the protection afforded by the water barrier. The smaller and more isolated islands can not support terrestrial predators and thus are extremely valuable breeding and resting sites for marine birds and mammals. Numbers of species may be limited on most small islands, but densities are quite high because of limited space and the limited number of undisturbed islands. Humans can and have severely impacted many islands, which further restricts present populations on remaining islands. It is essential that future development be restricted and activities limited on small islands to insure the continued existence of species which rely on the natural protection of islands.

SIGNIFICANT BIOLOGICAL FEATURES

Islands are extremely valuable and unique areas for wildlife, particularly as breeding and rest sites for marine birds and mammals. This results from several features discussed in more detail below:

Isolation

Island flora and fauna are restricted by the water barrier separating them from mainland sources of potential colonizers. This tends to reduce the number of species present and varies with island size and distance from the mainland.

The San Juan Islands provide an excellent example of the effect of insularity. As on most islands, there are a few terrestrial mammals, many of which have been introduced. According to a recent study, 24 terrestrial mammals are known to occur. Of these, nine were introduced, eight are native, and seven are bats. Terrestrial mammals reported from the San Juan Islands are listed in Table 713-1. At least fifteen species of marine mammals have been recorded for the area and include:

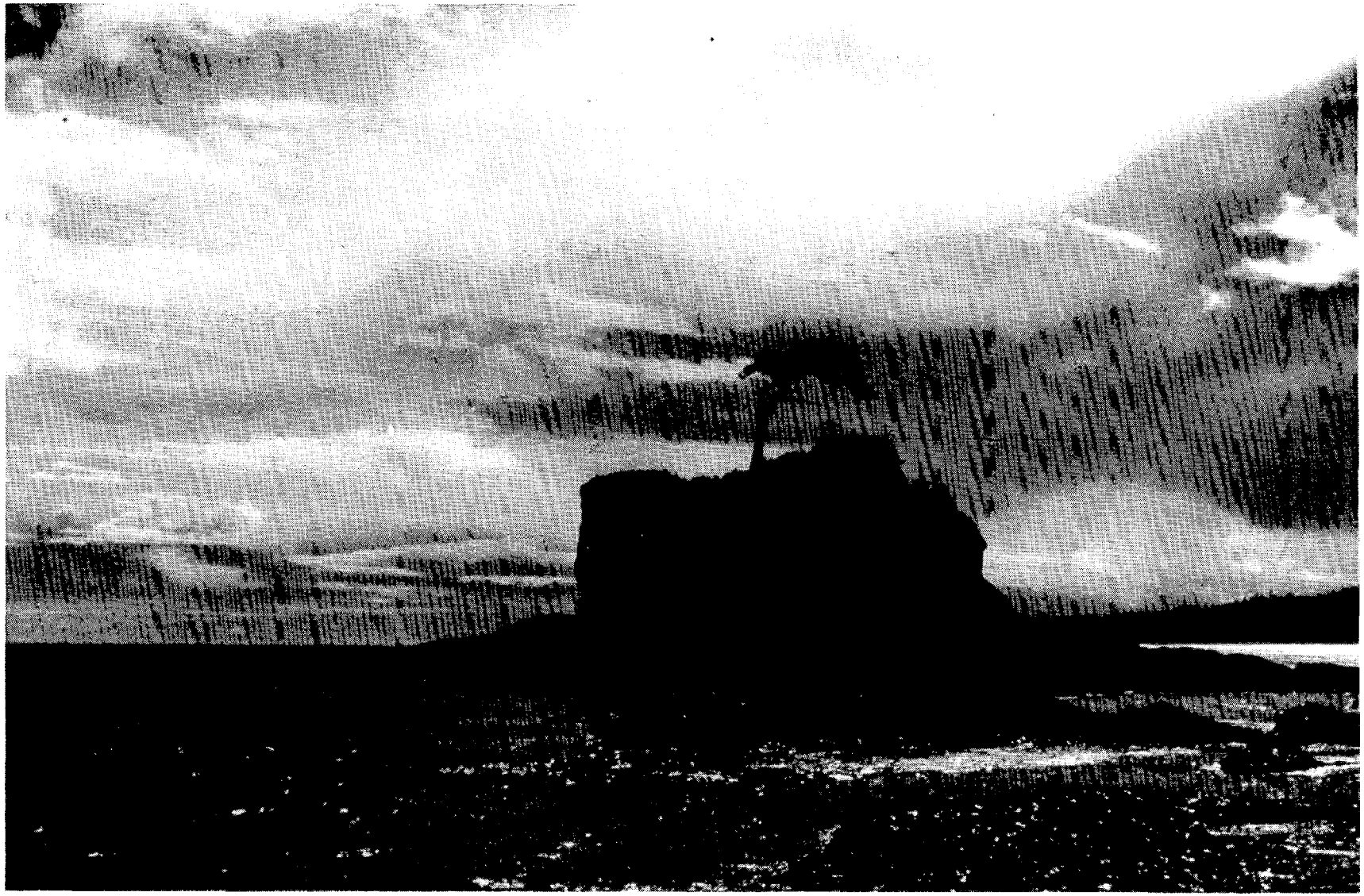
Northern Fur Seal	Goose-beaked Whale	Short-finned Pilot Whale
California Sea Lion	Dall Porpoise	Harbor Porpoise
Northern Sea Lion	Humpbacked Whale	Pacific White-sided Dolphin
Harbor Seal	Sperm Whale	Minke Whale
Common Dolphin	Fin Whale	Killer Whale

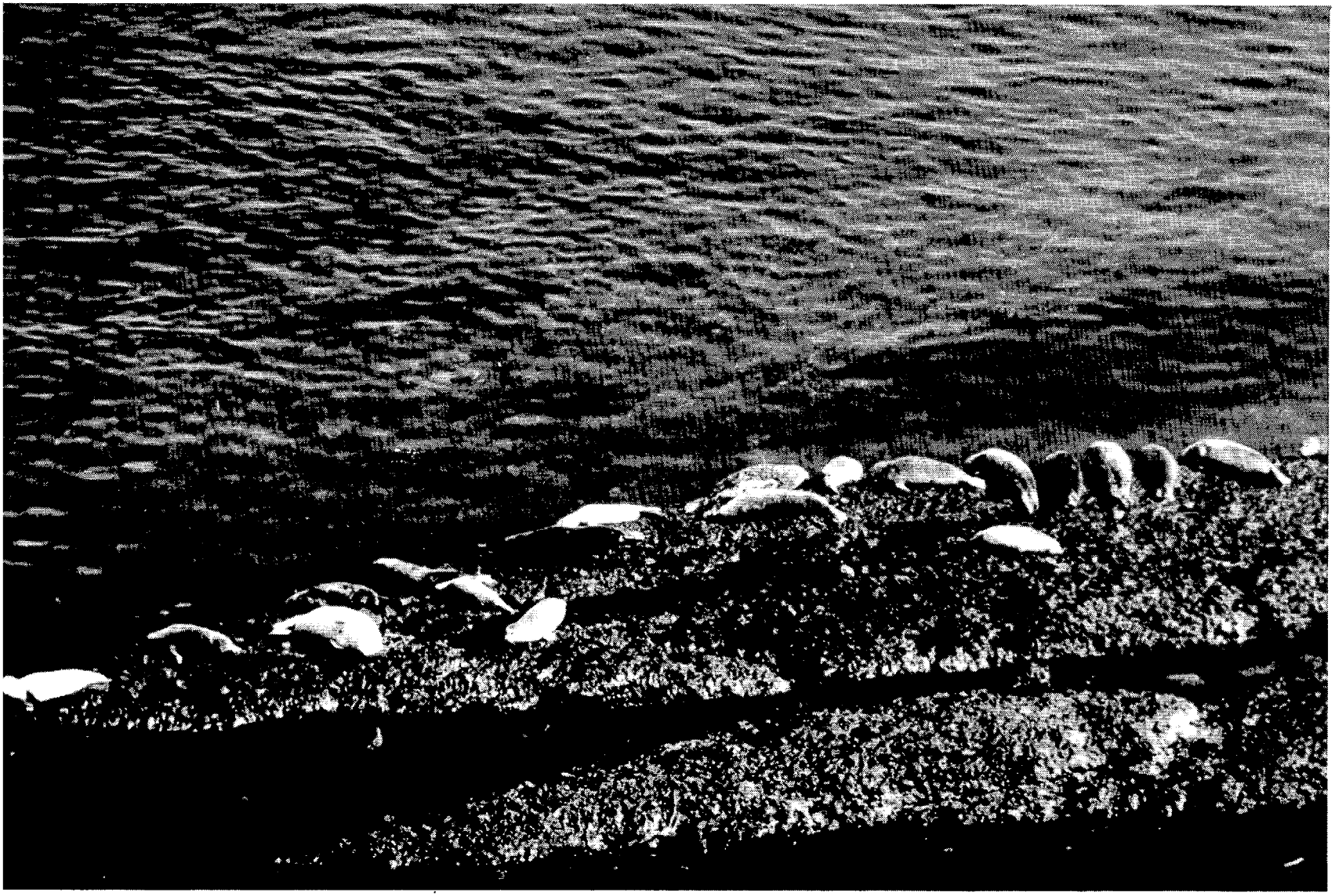
Reptiles and amphibians are also limited on islands because they face the same barriers to colonization as most mammals. The following species are known to occur in San Juan County:

Rough-skinned Newt	*Taricha granulosa*
Western Toad	*Bufo boreas*
Pacific Tree Frog	*Hyla regilla*
Red-legged Frog	*Rana aurora*
Northern Alligator Lizard	*Gerrhonotus coeruleus*
Northwestern Garter Snake	*Thamnophis ordinoides*
Western Terrestrial Garter Snake	*Thamnophis elegans*
Common Garter Snake	*Thamnophis sirtalis*

Birds are more sucessful colonizers than terrestrial mammals with the exception of bats. However, the bird species recorded from the islands are fewer than for western Washington as a whole. A 1964 listing of San Juan Archipelago birds included 216 species as compared to an approximate figure of 325 species which have been recorded for western Washington. See Table 713-2 for a listing of birds recorded from the San Juan Islands. Species occurrence on a given island varies greatly, largely in response to island size and presence of suitable habitat. In this respect, islands are no different from, and in fact provide an excellent model for mainland "islands" of isolated pockets of differing habitat types. Thus, a one acre shrub covered island may have one isolated pair of nesting White-crowned Sparrows, while a one acre patch of shrub surrounded by a mainland forest may also have an isolated pair of nesting White-crowned Sparrows.

Another island analogy is the continuous fragmentation and isolation of natural vegetation due to urbanization. These pockets of vegetation surrounded by urban development are becoming more widespread in the coastal zone (See Figure 713-1). The significant difference, however, between mainland and "true" islands is the presence of the water barrier which surrounds "true" islands. Water acts as a barrier to terrestrial predators and the rich, rocky intertidal zone surrounding small islands creates ideal habitat for marine birds and mammals. Thousands of migrating birds roost on small islets and islands, while breeding birds nest in numbers varying from a single isolated pair of gulls on an unnamed San Juan rock islet to the estimated 17,108 breeding pairs of Rhinoceros Auklets which nest in burrows on Protection Island. A summary of northern Puget Sound and Strait of Juan de Fuca marine bird breeding populations are listed in Table 713-3. This information is adapted from a recent study of northern Puget Sound marine birds which should be consulted for more detailed discussions of seasonal distribution and abundance of birds in northern Washington waters. The northern





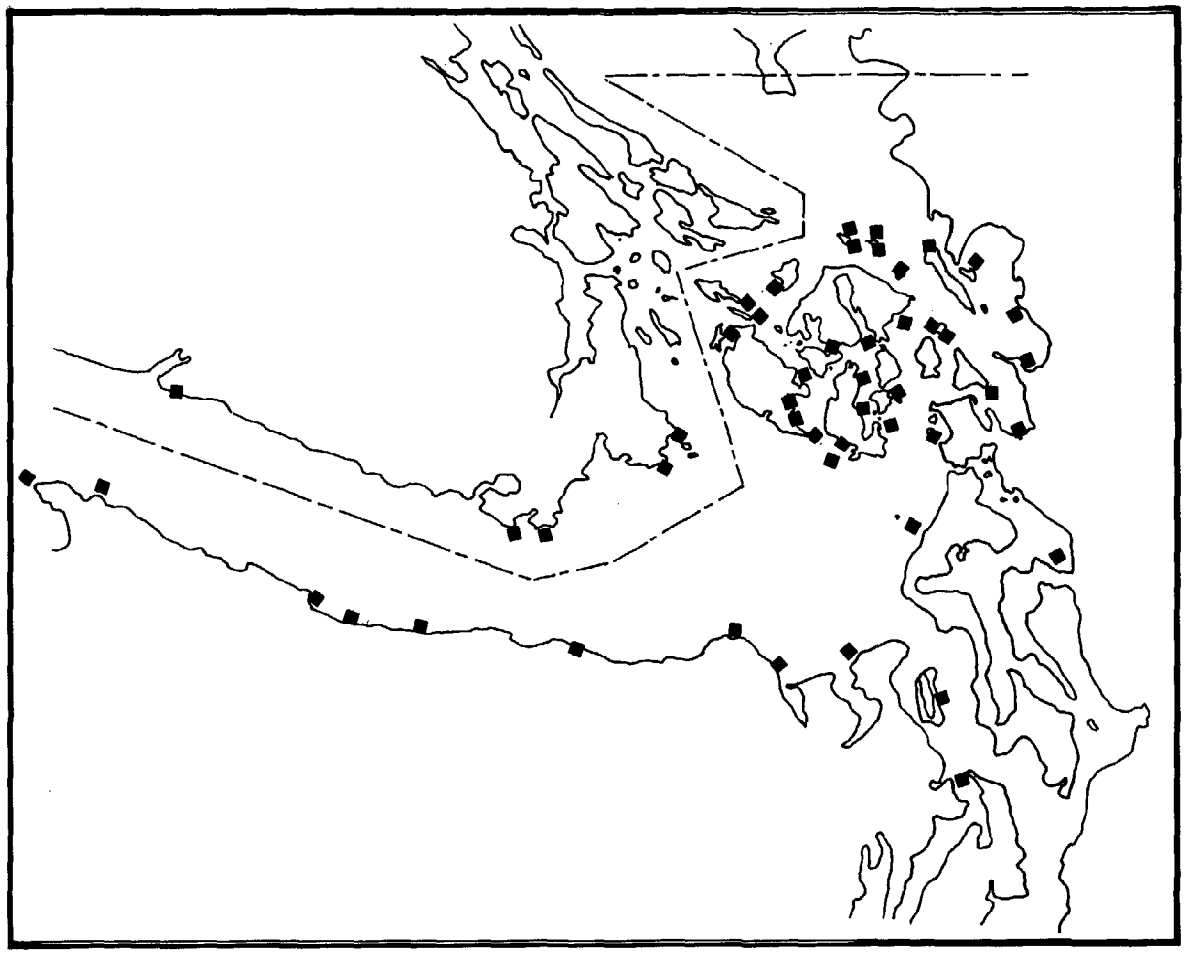


FIGURE 713-2

Northern Puget Sound and Strait of Juan de Fuca Harbor seal haul out sites. Sites identified during recent study: Everitt, Robert D., Clifford H. Fiscus, and Robert L. DeLong, 1979. Marine mammals of Northern Puget Sound and the Strait of Juan de Fuca. NOAA Tech. Memo. ERL MESA-41.

Puget Sound report also contains a listing of species and numbers of breeding pairs which occur on each island censused during recent studies. Species which nest on two major breeding islands, Smith and Protection, are listed in Table 713-4. This table also includes a summary of breeding species which nest on the numerous islands in the San Juan Archipelago.

Islands identified in recent nesting surveys are critical areas for those species which breed in Washington's coastal zone. All other small islets and islands are also critical as rest and feeding areas for many more species which nest elsewhere in Washington or in more distant areas. Examples of some of these species were discussed in the Rocky Intertidal Narrative (No. 631) and include Harlequin Ducks, Peregrine Falcons, Bald Eagles, Heermann's Gulls, Bonaparte's Gulls, Wandering Tattlers, and Black Turnstones. Year-round protection must be afforded islands since required use includes nesting, feeding, roosting, and molting sites for some species throughout the year. Refer to the Characteristic Species section of this narrative for representative examples of the varied use of islands by both birds and mammals.

Marine mammals feed nearshore along rocky islands and several species require the protected shores of small islands as haul out and nursery sites. The harbor seal is the most common marine mammal which rests on small islands in Washington. Sea lions, sea otters, and river otters also depend on these protected rest sites. Islands supporting large numbers of harbor seals include Protection Island, Smith and Minor Islands, Sucia Island, Bare Island, Ripple Island, Sentinel Island, White Rock, and Gertrude Island. Map locations of harbor seal haul-out sites identified during recent studies in northern Puget Sound are illustrated in Figure 713-2. Refer to the study by Everitt, et al., cited in Figure 713-2 for detailed information on harbor seal and other marine mammal populations, including use of islands by seals and sea lions.

Large concentrations of breeding seabirds and the protective isolation of islands also make them ideal habitats for birds of prey. Coastal islands are critical areas for the very few nesting Peregrine Falcons in Washington and also support migrant populations of peregrines. For example, recent observations of the Peregrine Falcon have been made on Protection Island and further attest to the significant wildlife value of this threatened island. Bald Eagles are also dependent on several islands for nesting and as roost or feeding sites throughout the year. The San Juan Islands are especially noted for concentrations of nesting eagles and support appproximately 50 percent of the total nesting Bald Eagles in Washington. Golden Eagles are among the other birds of prey which occur on islands and are one of the rarest nesting birds in western Washington.

Fig. 713-1

Isolation has also historically affected man's impacts on islands although modern technology now allows us to quickly cross water barriers. Islands are still relatively inaccessible and, as a result, many reflect near pristine conditions. Most of the smaller islands in Washington are roadless and not peopled. Several are included in a protected status as part of the National Wildlife Refuge System or as Wilderness Areas. Wilderness status has been recently afforded to more than 80 islands in the San Juan Archipelago. Wilderness status recognizes their unique values for wildlife and human intrusion is strictly limited; all are closed to the public. Others have been set aside as State and County parks or preserves. Many of these islands reflect conditions present throughout the coastal zone prior to massive settlement. The presence of large, undisturbed seabird colonies is one example of this isolation effect. Another is the presence of old growth forests, the most extensive in the coastal zone being on Long Island in Willapa Bay. This approximately 560 acres of old growth has withstood the near total elimination of virgin forest along the coast and stands as the finest example of pristine conditions outside National Park boundaries. Scattered old growth conifers also occur on islands in the San Juans. Most of these are small stands or isolated trees, but are nonetheless valuable for many reasons including their use by Bald Eagles.

Climate/Substrate Effects

Small islands are predominantly rock which supports a unique flora and fauna discussed in several narratives:

Open Grassland;	No. 313
Shrub/Exposed Rock;	No. 323
Open Woodlands;	No. 44
Rock Outcroppings;	No. 711

The unusually dry climate in the San Juan Islands, when combined with the rocky substrate, produces even more unusual conditions for a western Washington location. These areas support brittle cactus and birds such as Burrowing Owls and Rock Wrens which are more typical of eastern Washington deserts.

Commercial/Esthetic/Recreational Benefits

Larger islands which do support human populations are among the most popular recreational areas in Washington. The San Juan Islands in particular are reknowned for boating, fishing, camping, diving, and other outdoor pursuits. The feeling of "leaving it all behind" is especially felt when one is surrounded by water and the unique climate of the San Juans further heightens this island appeal.

The pleasantly dry climate in the San Juans also attracts permanent residents and, as stated, most of the larger islands are inhabited. Island living is very appealing even without the dry climate as exhibited by the popularity of homes on Bainbridge, Mercer, or Vashon Islands. A distant location protects the San Juans from the extreme overcrowding occurring on these satellites of Seattle, but overflowing ferry docks attest to the popularity of the San Juan Islands throughout the summer months. Many island residents are dismayed by the great influx of summer visitors each year, although for others, tourism simply means more business. It is essential, however, to restrict development and recreational activities on many of the islands to protect breeding seabirds, marine mammals, and other unique biological features of islands.

In general, islands without ferry service should be regarded as unique natural areas which can not sustain short- or long-term human occupation. Most crucial seabird colonies are posted by the U.S. Fish and Wildlife Service and are closed to the public. Those not posted should also be considered as sensitive areas and avoided if possible. There is a limited number of islands which means a limited amount of space for nest and rest sites. Continued disruption of any island could, therefore, result in permanent displacement of those species which depend on island rest or nest sites.

Characteristic Species

Several narratives discuss species which occur on islands; refer to the appropriate aquatic and terrestrial associations (e.g., Open Grassland No. 313 for grass covered island). Some of the nesting species are discussed in the Cliff Narrative (No. 714) and others include:

Tufted Puffin

The Tufted Puffin is one of our most spectacular seabirds. Also called the sea parrot, puffins are members of the Alcidae family, commonly referred to as Auks. All auks are highly adapted to an aquatic life and, like the Rhinoceros Auklet, Tufted Puffins only come ashore in the breeding season when they lay their single egg in a burrow nest.

The Tufted Puffin is mostly black and similar in appearance to the Rhinoceros Auklet during winter. In spring, its white face, yellowish tufts and large, bright orange-red bill distinguish the puffin from all near relatives and suggest a relationship with tropical forest parrots. Puffins are very much water birds, however, and may dive as deep as one hundred feet in pursuit of fish and invertebrate prey.

Tufted Puffins nest in large numbers in British Columbia and Alaska, and are primarily restricted to the outer coastal islands in Washington. Like other alcids, Tufted Puffins are very vulnerable during oil spills. Tufted Puffin populations have seriously declined as indicated in recent northern Puget Sound marine bird censuses. These studies note that large populations once nested on Bare Island, Waldron Head, Flattop Island, Smith Island, and Protection Island with smaller numbers occurring throughout the San Juand Islands. The only substantial populations now nesting in northern Washington are at Tatoosh and Protection Islands. Reasons suggested for decline include a decrease in herring populations and increased human disturbance in the San Juan Islands.

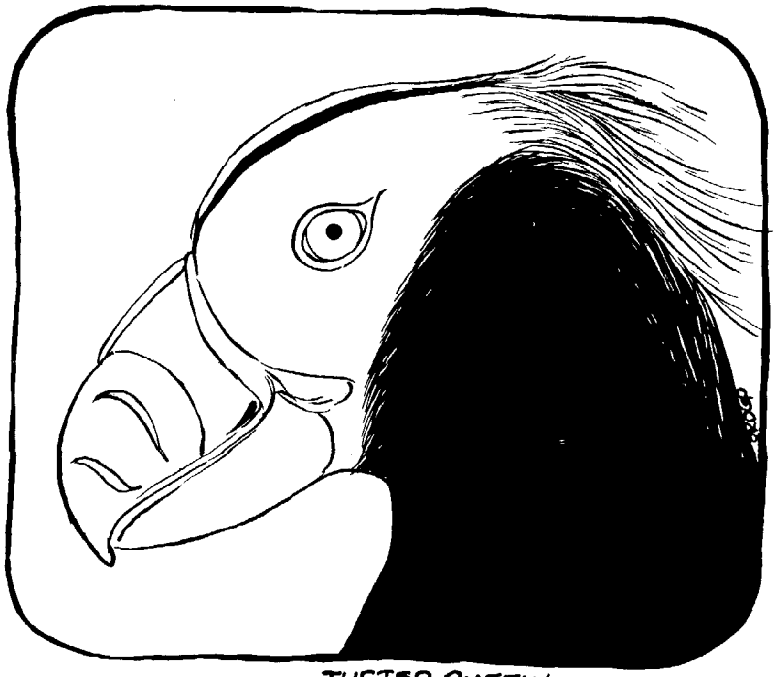
Rhinoceros Auklet

The Rhinoceros Auklet, or "rhino", is named for the hornlike projection at the base of its bill. This dark-colored alcid is a relative of the more colorful Tufted Puffin and also excavates a burrow nest. Rhinos feed at varying distances from their breeding islands and return at night with a bill load of fish and an occassional squid to feed the nestlings.

They require breeding sites with a substrate loose enough for burrowing and yet stable enough to prevent collapse. The gently sloping vegetated bluffs on Protection Island provide these requirements and are ideal nest sites for Rhinoceros Auklets. Protection Island supports a major percentage of Washington's breeding population, other important colonies being at Smith Island and Destruction Island. As with many birds, Rhinoceros Auklets are flightless when they undergo a molting period during late summer. They are especially vulnerable to oil at this time as well as when large numbers are concentrated near breeding colonies or at feeding sites.

Glaucous-winged Gull

Glaucous-winged Gulls are the most frequently observed "seagulls" in western Washington and suffer a bit in popularity because they are so common. However, on close examination, like the ubiquitous robin, these gulls are extremely beautiful birds. Immatures are a dull grey-brown, but the adult in breeding plummage is an immaculate white bird with subtle grey back and wings which show a white "window" at the tip. The yellow bill has a bright red spot on the lower mandible and the feet are pink. A lack of any black in the wing separates the Glaucous-winged from most large gulls, although hybrids do occur, particularly with the darker Western Gull, which confuses identification of them.



TUFTED PUFFIN

Like other large gulls, they scavenge beaches, open water, shoreline restraunts, and garbage dumps for a variety of foods. Natural prey includes crabs, sculpins, chitons, and mussels.

Nesting is usually in colonies such as on the eastern spit of Protection Island which is the largest colony in our inland waters, with about 1,500 pairs. They have also been known to nest on pilings and on roofs of buildings. Territories are defended around the nest which generally contains two to three eggs by the second week in June. Both parents incubate the eggs which hatch in about four weeks. Many young do not survive the nestling period due to predation, delayed hatching, and attacks by other gulls when territorial bounds are crossed by chicks. On the average, slightly more than one chick is fledged (successfully leaves the nest) by each breeding pair of gulls. The young grow quickly and at about eight weeks of age are fully grown and begin to leave the nesting island. Young and adults gradually disperse, some remaining together into the winter while others go their own way soon after fledging. Most adults return to favored foraging areas which are usually less than 100 miles from the nest island.

Their foraging and rest sites are scattered throughout the coastal zone and allow anyone with an interest to observe animal behavior at close hand. Get to know these familiar gulls, and it is likely you might also become acquainted with an individual or pair that might return year after year to the same location for as long as 20 years. Once you have distinguished a Glaucous-winged Gull from other "seagulls," the more subtle traits which differentiate individuals may be looked for. Like humans, they are all different

- even though all gulls might look the same. We know that gulls recognize their own offspring and that mates identify one another. You might use different clues than gulls to identify individuals, but it is still possible to separate one from the crowded flock. They have all adapted to a variety of environmental features and reflect a complex array of genetic differences. Watch the gull or gulls in your neighborhood or at a favorite beach. They are all generally alike, but one might prefer a certain rock or piling, while another prefers to feed just offshore. Some become tame enough to hand feed and most gather quickly when clams are being dug or fish are cleaned.

The gulls are long-lived and learn their surroundings and accompanying activitites well in their lifetime. If this preferred habitat is lost because of development, chances are that the gulls will survive. This is not true for most species because of their specialized habitat requirements. Glaucous-winged Gulls are one of a few native species benefiting from humans in that we throw out enough garbage to subsidize an excess population. However, their breeding islands are critical habitat for their survival and if the breeding site is destroyed, that segment of the gull population will be lost. Islands are at a premium and most, if not all, breeding space is already taken. This is true for gulls and for other island nesters. Small islands, therefore, are critical limiting factors which must be preserved to maintain populations of Glaucous-winged Gulls and several other marine species.

IMPACTS

Islands are very susceptible to human disturbance because much of their value to wildlife depends on isolation. In recognition of this value several islands have been designated as Wilderness areas and are closed to the public. Other islands lack the official designation as Wilderness, but still require protection from most human activities. Some of the threats unique to islands are discussed below, but it should be remembered that many activities relevant to other areas will have pronounced impacts on islands.

Introduced Species/Predators

Island flora and fauna have evolved in the absence of many species present on the mainland. The result is a dynamic balance among species that are present which is easily upset by the introduction of any exotic (introduced from adjacent islands, mainland, or distant area) organism. The most dramatic example is the presence of the European rabbit in the San Juans as discussed in the Open Grassland Narrative (No. 313).

Man is another exotic on most Washington islands and we should respect those areas unsuitable for our presence (e.g., Wilderness Areas in the San Juan Archipelago). Intentional and accidental introductions which occurred in the past are reminders that we have visited many islands and left our mark in many ways. Examples have varied and include the presence of Norway rats on Lopez Island, Peacocks on Protection Island, red fox on Henry Island, European polecats on San Juan, and domestic animals on several islands. Dogs, cats, sheep, and rabbits are the most common of the domestic animals which represent significant predation and competition threatening native plants and animals.

Efforts should be made to remove exotics from island communities now affected by their presence and further introductions should not take place except under strict control. Unfortunately, such control is lacking in most cases and intentional introductions meant to control other species have often failed. Thus, foxes were introduced on San Juan Island to control rabbits to no avail. Perhaps the old lesson of Prevention is indeed the best cure.

Boating

The tremendous increase in pleasure boating in recent years poses a special threat to islands. We might all wish to escape to our own private island retreat, but the same values

Table 713-1. MAMMALS REPORTED FROM THE SAN JUAN ISLANDS

Vagrant Shrew (*Sorex vagrans*)
Yuma Myotis (*Myotis yumanensis*)
Long-legged Myotis (*Myotis volans*)
California Myotis (*Myotis californicus*)
Little Brown Myotis (*Myotis lucifugus*)
Silver-haired Bat (*Lasionycteris noctivagans*)
Townsend's Big-eared Bat (*Plecotus townsendii*)
Big Brown Bat (*Eptesicus fuscus*)
* European Rabbit (*Oryctolagus cuniculus*)
Deer Mouse (*Peromyscus maniculatus*)
Muskrat (*Ondatra zibethica*)
Townsend's Vole (meadow mouse) (*Microtus townsendii*)
* House Mouse (*Mus musculus*)
* Norway Rat (*Rattus norvegicus*)
* Black Rat (*Rattus rattus*)
* Douglas Squirrel (*Tamiasciurus douglasii*)
* Fox Squirrel (*Sciurus niger*)
* Townsend's Chipmunk (*Eutamias townsendii*)
* Red Fox (*Vulpes fulva*)
Raccoon (*Procyon lotor*)
Mink (*Mustela vison*)
River Otter (*Lutra canadensis*)
Black-tailed Deer (*Odocoileus hemionus*)

* Introduced

of isolation that attract humans are what necessitate the exclusion of our presence. Most small islets and islands are critical habitat for resting or breeding birds and mammals and require complete protection from human disturbance. Many islands are posted by the U.S. Fish and Wildlife Service as being closed to the public. Boaters should respect these and other small islands by steering a wide course around them. Likewise, isolated coves on larger islands are often important marine bird and mammal feeding sites and occasionally are adjacent to Bald Eagle nest trees. Boating disturbances will be minimized if anchorage is restricted to established marinas and state park moorage sites. Studies should be conducted to determine the carrying capacity of boating in Washington waters, especially in island areas. Additional boats, boating activities, and associated marinas and other facilities are a threat to islands and ultimately to the entire marine environment of Washington. Limiting the numbers of marinas, moorage sites, and other boating facilities will decrease impacts on wildlife while enhancing the value of the boating experience.

Construction

A limited amount of building related activity, such as navigational markers, radar equipment, lighthouses, and homes and businesses, on larger islands must occur. However, many islands are unsuitable for any construction activity. The most crucial sites which will not tolerate buildings and associated activity are those used as marine bird and mammal breeding or rest sites as well as those supporting Bald Eagles or unique plant communities.

Several narratives (see especially Rock Outcrops, No. 711; Open Grassland, No. 313; and Oak Savannah, No. 441) address unique communities associated with islands. We advise careful consideration of natural values discussed in these sections and in the previous discussions in the Island Narrative before proceeding with construction activities. If construction must take place, consult with responsible individuals or agencies concerning timing to minimize disruption during critical seasons. Real estate development on Protection Island deserves special mention here since this seabird nesting site is perhaps the most imminently threatened island in Washington. Natural values of this island have been discussed in this and other narrative sections (see especially Open Grassland, No. 313). A brief review includes the presence on Protection Island of the largest known Glaucous-winged Gull Colony in our inland waters, the majority of Washington's breeding population of Rhinoceros Auklets, nesting Black Oystercatchers, Tufted Puffins, Pelagic Cormorants, and Pigeon Guillemots, and the use by many other species including Peregrine Falcons, harbor seals, and Harlequin Ducks. A part of the island is set aside as the Zella M. Schultz Sea Bird Sanctuary. However, various plans to develop the island have been proposed. Present use of the island is mostly by summer visitors who have been constructing cabins and adding house trailers to the island at an increasing rate. Human presence on Protection Island is incompatible with the high wildlife values and sensitivity of many of the species present. However, the island is inhabited and compromises must be made by all concerned individuals and agencies. Landowners should reconsider their plans for future activities on the island. Those wishing to remain should respect breeding requirements of nesting birds and minimize disruptive activities. This would include care in not trampling auklet burrows and avoidance of gull colonies during the breeding season. Others may wish to sell or donate land to be added to the Sea Bird Sanctuary.

County and State agencies responsible for management decisions on the island should carefully evaluate the negative impacts of further encroachment while

negotiating with landowners to minimize wildlife losses. Landowners willing to sell or donate land should be encouraged to do so, but all attempts to escalate real estate speculation should be averted. A lack of water has been a key factor in modifying island development plans of professional real estate developers. Further development of the area must be prevented because of the high wildlife values of Protection Island. We suggest that all parties involved meet and agree upon a plan of action which will eventually preserve Protection Island as a wildlife sanctuary.

Oil Spills

The threat of oil spills is discussed in other sections; the impact section of the Rocky Beach Substrate Narrative (No. 631) is especially relevant to island shorelines. Oil is mentioned here because of the potentially disastrous effects of a spill on colonial nesting marine birds. The most vulnerable birds to oil are divers and include the highly aquatic members of the Alcidae family such as the Tufted Puffin, Rhinoceros Auklet, and Common Murre. These colonial nesters are especially vulnerable to oil spills for several reasons:

1) Nesting islands are near major shipping lanes and proposed oil terminals. For example, Protection Island is in the vicinity of Port Angeles.

2) Alcids spend most of their time on the water, coming ashore only to nest. They are frequently exposed to even minor spills because of their continual presence on the water.

3) Local spills in distances from the colony (which vary with species) could wipe out a majority of the breeding population. This could happen directly if adults are oiled or indirectly if hatching success is affected. For example, adults with small amounts of oil on their plumage might coat their eggs with oil, an event which has been shown to result in a failure of eggs to hatch.

4) If populations are reduced, many years would be required to rebuild populations because alcids have a very low reproduction potential. For example, it has been estimated that 53 years are required for a population of Common Murres to double its population.

Islands are also extensively used by other marine birds and mammals as rest sites and are, therefore, vulnerable throughout the year to the threat of oil. Harbor seals, river otters, and sea otters are all affected by oil in varying degrees and use islands throughout the year. Harlequin Ducks are flightless during much of the time they roost on or near islands and are especially vulnerable in late summer. Gulls and cormorants can fly to avoid spills, but feed on the water and would suffer losses of food and feeding areas. All other island inhabitants would also be affected in varying degrees by oil spills.

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Table 713-2. BIRDS REPORTED FROM SAN JUAN ARCHIPELAGO

Common Loon
Artic Loon
Red-throated Loon
Red-necked Grebe
Horned Grebe
Eared Grebe
Western Grebe
Pied-billed Grebe
Short-tailed Albatross
Fulmar
Sooty Shearwater
Fork-tailed Petrel
Double-crested Cormorant
Brandt's Cormorant
Pelagic Cormorant
Great Blue Heron
American Bittern
Mallard
Pintail
Green-winged Teal
Blue-winged Teal
Cinnamon Teal
American Wigeon
European Wigeon
Gadwall
Wood Duck
Canvasback
Greater Scaup
Lesser Scaup
Common Goldeneye
Barrow's Goldeneye
Bufflehead
Oldsquaw
Harlequin Duck
White-winged Scoter
Surf Scoter
Black Scoter
Ruddy Duck
Hooded Merganser
Common Merganser
Red-breasted Merganser
Canada Goose
Brant
Snow Goose
Turkey Vulture
Goshawk
Sharp-shinned Hawk
Cooper's Hawk
Red-tailed Hawk
Rough-legged Hawk
Swainson's Hawk
Marsh Hawk
Osprey
Peregrine Falcon
Merlin
American Kestrel
California Quail
Bobwhite
Mountain Quail
Chukar
Gray Partridge
Blue Grouse
Ruffed Grouse
Ring-necked Pheasant
Sandhill Crane
Virginia Rail
Sora
American Coot
Black Oystercatcher
American Golden Plover
Black-bellied Plover
Semi-palmated Plover
Killdeer
Rock Sandpiper
Surfbird
Black Turnstone
Ruddy Turnstone
Whimbrel
Spotted Sandpiper
Wandering Tattler
Greater Yellowlegs
Lesser Yellowlegs
Baird's Sandpiper
Least Sandpiper
Short-billed Dowitcher
Long-billed Dowitcher
Western Sandpiper
Sanderling
Dunlin
Pectoral Sandpiper
Northern Phalarope
Red Phalarope
Pomarine Jaeger
Parasitic Jaeger
Skua
Glaucous-winged Gull
Western Gull
Herring Gull
California Gull
Ring-billed Gull
Mew Gull
Bonaparte's Gull
Heermann's Gull
Sabine's Gull
Red-legged Kittiwake
Black-legged Kittiwake
Common Tern
Caspian Tern
Common Murre
Pigeon Guillemot
Marbled Murrelet
Rhinoceros Auklet
Tufted Puffin
Band-tailed Pigeon
Rock Dove
Mourning Dove
Barn Owl

Screech Owl
Great Horned Owl
Snowy Owl
Pygmy Owl
Burrowing Owl
Saw-whet Owl
Common Nighthawk
Black Swift
Vaux's Swift
Rufous Hummingbird
Belted Kingfisher
Common Flicker
Pileated Woodpecker
Lewis' Woodpecker
Red-breasted Sapsucker
Hairy Woodpecker
Downy Woodpecker
Willow Flycatcher
Western Flycatcher
Dusky Flycatcher
Western Wood Pewee
Skylark
Horned Lark
Violet-green Swallow
Tree Swallow
Rough-winged Swallow
Barn Swallow
Cliff Swallow
Purple Martin
Steller's Jay
Common Raven

Common Crow
Chestnut-backed Chickadee
Black-capped Chickadee
Bushtit
Red-breasted Nuthatch
Brown Creeper
House Wren
Winter Wren
Bewick's Wren
Long-billed Marsh Wren
Rock Wren
Sage Thrasher
American Robin
Varied Thrush
Hermit Thrush
Swainson's Thrush
Western Bluebird
Townsend's Solitaire
Golden-crowned Kinglet
Ruby-crowned Kinglet
Water Pipit
Cedar Waxwing
Loggerhead Shrike
Northern Shrike
Hutton's Vireo
Solitary Vireo
Warbling Vireo
Orange-crowned Warbler
Nashville Warbler
Yellow Warbler
Yellow-rumped Warbler

Black-throated Gray Warbler
Townsend's Warbler
Hermit Warbler
MacGillivray's Warbler
Yellowthroat
Wilson's Warbler
House Sparrow
Western Meadowlark
Red-winged Blackbird
Brewer's Blackbird
Brown-headed Cowbird
Western Tanager
Black-headed Grosbeak
Evening Grosbeak
Purple Finch
House Finch
Cassin's Finch
Pine Siskin
American Goldfinch
Red Crossbill
Rufous-sided Towhee
Savannah Sparrow
Vesper Sparrow
Dark-eyed Junco
Chipping Sparrow
White-crowned Sparrow
Lincoln's Sparrow
Golden-crowned Sparrow
White-throated Sparrow
Fox Sparrow
Song Sparrow

TABLE 713-3

-SUMMARY OF MARINE BREEDING BIRD POPULATIONS-
NORTHERN PUGET SOUND AND STRAIT OF JUAN DE FUCA, WEST TO TATOOSH ISLAND.

(adapted from: Manuwal, David A., Terence R. Wahl, and Steven M. Speich, 1979. Seasonal distribution and abundance of marine bird populations in the Strait of Juan de Fuca and Northern Puget Sound in 1978. U.S. NOAA, MESA Puget Sound Project, Unpublished Manuscript.)

Island or Area	Total Breeding Population Estimated (Pairs)	Comment
San Juan Islands	5,192	Marine bird nesting occurs on numerous small islands and isolated sites on larger islands.
Smith & Minor Islands	842	Major breeding site - Island County
Protection Island	19,137	Refer to Table 713-4 and Text.
Northern Areas	653	
Port Angeles Bay	38	
Seal and Sail Rocks	60	
Tatoosh Island	2,194	Several other outer coast nesting islands occur south of Tatoosh.
Other - (totals of Pigeon Gillemots & Marbled Murrelets which nest in scattered locations.)	1,807	Breeding populations of Murrelets & Guillemots more widely distributed than other species and include mainland locations.
Total	29,204	

TABLE 713-4

MARINE BIRD BREEDING POPULATIONS OF PROTECTION AND SMITH ISLANDS, INCLUDING A SUMMARY OF SAN JUAN ISLANDS.
(From: Manuwal, et al., 1979 and Wilson, Uhlrich, 1977.)

Species	Smith Island (includes Minor Island) Number of Breeding Pairs	Protection Island Number of Breeding Pairs	San Juan Islands Number of Breeding Pairs	Comment
Pelagic Cormorant	100	295	297	Refer to Cliff Narrative
Double-crested Cormorant			182	Major nest sites subject to boating disturbance and are along oil route.
Black Oystercatcher	6	4-6	27	Refer to Rocky Beach Narrative
Glaucous-winged Gull	106	1,500+	3,987	See Text, this narrative
Pigeon Guillemot	30	180	580	Refer to Kelp Narrative
Marbled Murrelet			116	Refer to Forest Narrative
Rhinoceros Auklet	600	17,108		See text, this narrative
Tufted Puffin	(Present)	50	3	Has declined recently; see text this narrative
Total	842	19,137	5,192	

CLIFFS (No. 714)

INTRODUCTION

Cliffs are vertical or near vertical rock walls which occur most often at or near the water's edge along rocky shorelines. They are distinguished from bluffs, which are sometimes vertical walls, but are composed of sand and mixed substrates. We distinguish cliffs from rock outcrops; however, it is often difficult to separate the two. At Mt. Dallas on San Juan Island, the extensive rocky areas defy separation into clearly defined areas based on slope. Therefore, areas mapped as cliff on Mt. Dallas are not entirely sheer rock walls, but also include more gently sloping and flat rock substrate. The entire west Mount Dallas area is an extremely diverse site, with rock as a major factor influencing physical and biological features.

Elsewhere, most cliffs are more clearly distinguishable, such as along Sares Head, near Tongue Point, the south end of Lumimi Island, and Lawrence Point on Orcas Island. These and other cliffs generally lack the partial soil layer present on rock outcrops.

Much of the information discussed in the Rock Outcrop Narrative (No. 711) is relevant to cliffs. However, plants are often restricted to encrusting lichens and those capable of growing in rock crevices and shallow soil, including stonecrop and saxifrage.

SIGNIFICANT BIOLOGICAL FEATURES

Flora

The flora of rocky cliff faces is composed of species adapted to the dry conditions typical of this habitat. Whatever the exposure (north, south, east, or west) shallow soil limited to pockets or ledges insures that water availability will be a factor limiting

which plant species can survive. Cliff faces positioned directly above exposed shores may be subjected to salt spray, further increasing drought stress and influencing which species will occur within the spray zone. Succession on cliff faces is relatively simple, limited to pioneering lichens and mosses, and succeeded by the climax community dominated largely by perennial herbs. Many species are quick-growing, flowering early in the spring and remaining dormant through the summer. Occasionally trees and shrubs may become established, especially Douglas fir, grand fir, madrona, and ocean spray. These species are typically dwarfed, and rarely if ever dominate the plant community. W. C. Meunscher, in The Flora of Whatcom County, mentions the following species as common on cliffs and ledges along the seashore:

Field chickweed, broadleaf stonecrop, smallflower fringecup, pomo-celery lomatium, shooting star, large-flowered blue-eyed Mary, dwarf owlclover, and rosy plectritis. Other species common on cliff faces throughout the coastal zone include Wallace's selaginella, licorice fern, small-leaf alumroot, Sitka valerian, checker lily, and naked broomrape.

Due to their inaccessibility, and because cliff habitat is a relative uncommon type in coastal Washington, little study has been devoted to the composition and dynamics of cliffside plant communities. As a result, spoonwort a small mustard apparently restricted to the salt spray zone on cliffs along the outer coast, has been reported only rarely in western Washington; this may reflect the activities of local botanists more than the true distribution and abundance of the species. Three plant species with very restricted distributions in Washington occur on seacliffs. Pigmy-weed has been reported from the cliffs at Deadman Bay, San Juan County, seacliff bluegrass from the seacliffs near Ilwaco, Pacific County, and Tracy's mistmaiden from Clallam and Pacific counties. All three species are being considered for rare or endangered status.

Fauna

Vegetation is often sparse due to the lack of horizontal surfaces and extensive soil development and animals inhabiting cliffs are restricted by the lack of vegetation and a firm foothold. However, cliffs function much like islands because few predators can climb the "sea" of sheer rock. Several birds and an occasional mammal have adapted to the rigors of cliff dwelling in response to this protection, and perhaps to the competition for limited space on "true" islands. Mainland cliffs offer much the same protection as island cliffs, so these cliff nesters also are able to to use sites throughout the coastal zone where suitable breeding habitat occurs. However, islands still provide much of the cliff nesting habitat, perhaps because disturbance excludes use of some mainland cliffs as nest sites.

Cliff Nesters

Pelagic Cormorant

Pelagic Cormorants are the smallest of three Washington cormorants and are easily recognized in the breeding season by the presence of white patches on their flanks. The rest of the body is a green glossed black except for a red pouch just under the long, slender bill.

Pelagic Cormorants may nest on a more gentle slope, but of the three species, they are most likely to nest on a cliff face. When all three occur together, Pelagics nest on cliff faces, Brandt's on gentle slopes, and Double-crested on cliff tops. The narrow nest ledges offer little room and birds often land and take off facing the cliff, being unable to turn around.

Three to seven long, bluish eggs are laid in nests constructed mostly of seaweed. Preference for seaweed has been noted in several areas including Northern California where recent observation indicated use of seaweed even when vascular plants were available nearby.

Fork-tailed Storm Petrels

Petrels typically nest in burrows, however, Fork-tails have been observed nesting in natural rock crevices. Petrels are small, swallow-like birds, which are rarely seen in sight of land. Feeding occurs during daylight

at sea where they may move as far as 357 miles (600 km) on foraging trips. Because of their small size (8-9"), petrels are susceptible to predation at nesting colonies from several species, including gulls. They return to nests at night to avoid predation and it is thought that the musky smell of their burrows may guide the parent to the nest site. The only known nest sites in Washington occur along the outer coast where an estimated 1,900 pairs breed on the Bodelteh Island group.

Common Murre

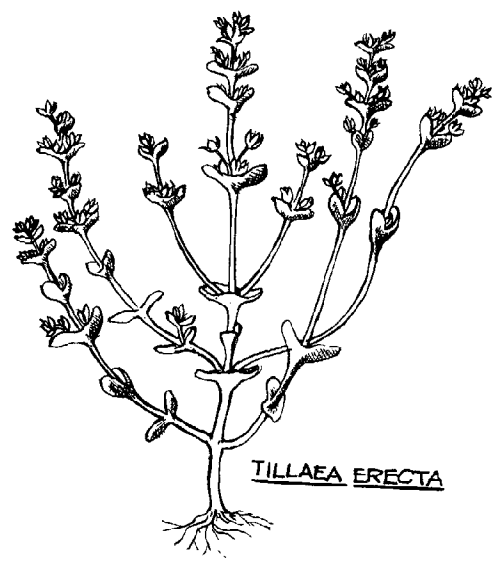
Common Murres occur throughout the coastal zone, but breeding islands are restricted to the outer coast, where approximately 12,000 pairs nest on several islands protected by the U.S. Fish and Wildlife Service. Despite the fact that these island are protected and nest sites are along inaccessible cliffs, Murres are particularly vulnerable to human disturbance.

Like other members of the family Alcidae, murres are highly adapted to an aquatic existence. Children often mistake them for penguins, but the mistake is an intuitive recognition of convergent features. In fact, murres and other alcids are the northern hemisphere's equivalent to the penquins of southern regions. You might, therefore, say that murres are northern penguins which have not lost the ability to fly. They even stand erect while on land, penguin-fashion.

The high degree of adaptability to water is expressed in the Murres' body shape; legs are set well back, wings adapted to swimming, and by the fact they only come ashore to breed. Because of this, they are highly susceptible to oil pollution and are often seen along the coast emersed in a deadly coat of oil, despite the lack of recent major spills. Oil is continually pumped from bilges and spilled in small quantities. Murres are continually on the water and often raft in large flocks. Contact with oil is, therefore, more frequent than for birds which roost ashore like cormorants, or are not as adapted to aquatic life such as gulls. Major oil spills pose a very serious threat to many marine birds; Common Murres are among those most highly threatened.

Pigeon Guillemot

Another member of the family Alcidae, Pigeon Guillemots nest in a variety of situations including rock cliffs. They are unlike most other alcids in their usual lack of colonial nesting. They are probably the only alcid which nests on the mainland, where they most frequently nest in shallow burrows along steep bluffs.



Cliff nests are placed in crevices where one or two white to greenish, dark spotted eggs are laid. Their bright, orange-red feet are a distinguishing feature of these black seabirds with white wing patches. Since they breed throughout the coastal zone, Pigeon Guillemots are the most observable nesting seabirds. The sight of orange feet amidst a blur of black and white flying into a cliff or bluff nest is a valuable wildlife experience which can be enjoyed from southern Puget Sound to the outer coast.

Guillemots feed close to shore near the nest site and can be observed at fairly close distances flying to and from the nest carrying single fish to their young.

Common Raven

Ravens nest in trees and on cliff faces where a stick nest is constructed. Breeding status along the coastal zone is not well known and should be investigated. Known or suspected nest sites should be reported to the Washington Game Department nongame species program.

Cliff Swallows

Appropriately named, the Cliff Swallow uses cliff faces as substrate to attach its gourd-shaped mud nest. Like Barn Swallows, they also nest on man-made structures. They are one of the very few organisms that have adapted to bridges and building, using the sides as nest sites. They may nest singly, but more often in colonies of up to several hundred.

Black Swift

Swallow-like, the swifts spend much of their time in flight and are highly adapted for aerial pursuit of insects. Their longer, sickle-shaped wings distinguish them from swallows. They feed on flying insects which are captured on the wing, sometimes incredible distances away from nestlings awaiting in protected cliff ledge nests. During summer storms, they might fly from nest sites several hundred miles until favorable weather is encountered. They return to the nest when the storm is over and feed the young which survive without food due to lower metabolism, an adaptation allowing the young to be raised in alternating periods of plenty and shortage.

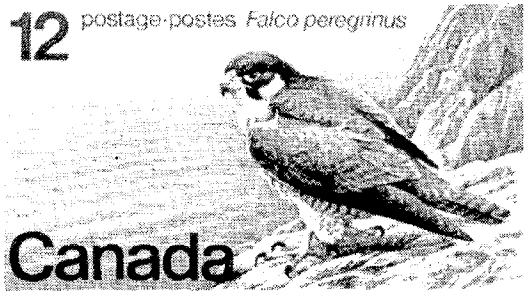
Black Swifts are known to nest under waterfalls, on mountain cliffs, and along coastal cliffs. Breeding status along the coastal zone is unknown, but they have been observed along cliffs near Tongue Point in Clallam County.

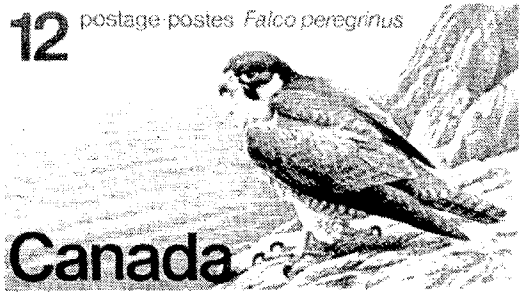
Peregrine Falcon

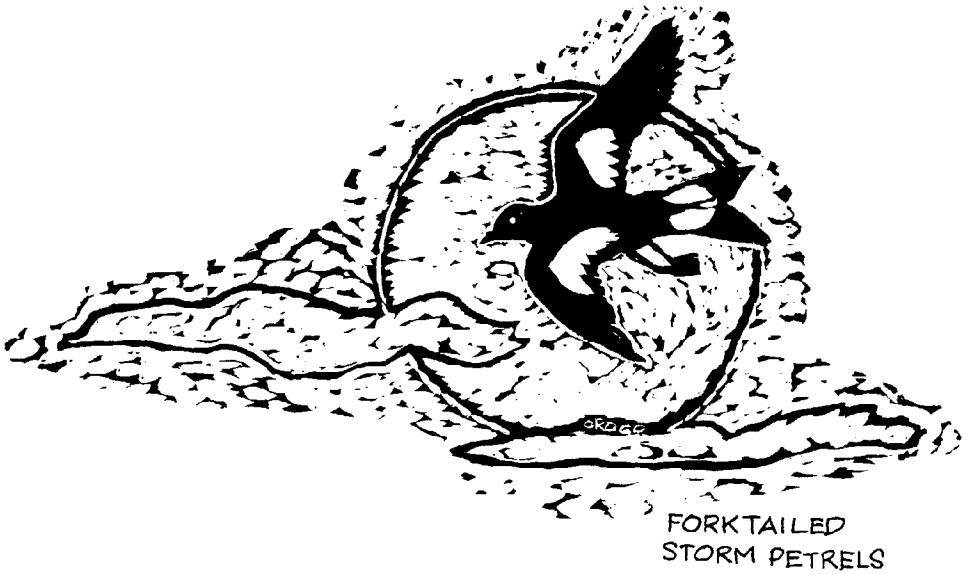
The Peregrine Falcon has long been a symbol of superior speed and power among those who practice the King's sport of falconry. Peregrines fly, then swoop dramatically on other birds which they literally knock out of the sky with clenched talons. Swirling, they often fly back to snatch their prey from mid-air before it falls to the ground.

Unfortunately, the Peregrine Falcon is an endangered species due to the accumulation of pesticides concentrated in prey species which include marine birds. A very few cliff nests are known in Washington, all of which require strict protection not only because they are rare but because falconers still seek these birds for sport.

Apart from the few breeding falcons in Washington, migrants also occur which require protection and suitable habitat. This includes protection of known roosting sites and wintering areas. All areas supporting Peregrines should be identified, however, much discretion is applied to release of information concerning this sensitive species. As stated, nests are especially vulnerable. Wintering or foraging sites are also vulnerable to a variety of potential impacts. In general, areas supporting large concentrations of water birds are potential Peregrine Falcon habitat. Seabird nesting islands are also favored falcon habitat. Protection Island in Jefferson County is an area where Peregrines have been observed. Several thousand seabirds nest here and offer potential prey. Unfortunately, development threatens much of the island and may limit use of the island by falcons.







IMPACTS

As illustrated by the examples of nesting birds, cliffs provide valuable and protected habitat for several species. All identified nesting areas require protection from most human activity, especially during the breeding season.

Little is known about breeding distribution of several species, therefore, all cliff areas should be regarded as potential nest sites and be provided adequate protection.

Cliffs are potential sites for rock quarries, however, coastal areas are too valuable for marine birds to allow rock extraction.

It is fairly common to find a road at the base of a cliff. This may have an impact on the plant community by providing access for collectors, and on the animal community if road activity is above the tolerance level of cliff dwelling species.

The principal value of cliffs does not lie in commercial exploitation, but rather in their esthetic values and wildlife habitat.

789

790 Deception Pass State Park, Whidbey Island

SAND (No. 72)

The sand classification was used for areas in which sand or aggregate comprises approximately 30 percent or more of exposed surface areas. These include Sand Islands (No. 721), Sand Dunes (No. 722), Slide (No. 723), and Sand and/or Gravel Bar (No. 724).

SAND ISLANDS (No. 721)

Includes: Vegetated Sand Island 7211
Nonvegetated Sand Island 7212

Sand Islands are generally small, nonrocky islands which occur in protected bays or estuaries. They differ from sand and gravel bars in that surface areas occur which are above mean high water.

Refer to the Rock Island Narrative (No. 731) for significant features of islands in Washington's coastal zone. Sand islands share a majority of these features. The following points distinguish sand islands from others, or are characteristic of notable sand islands:

- Sand islands typically occur in more protected locations than rock islands and are, by definition, composed of less stable material. They are often subjected to periodic shifting as a result, especially when they form at mouths of rivers. For example, Sand Island at the mouth of the Columbia River has shifted considerably to the north and east. Because of this natural instability and shifitng, considerable energy has been expended to control erosion and accretion processes in the Columbia River.

- Plant communities are generally restricted to beach grasslands. Refer to the Beach Grassland Narrative (No. 312) for a discussion of associated features and species.

- Animal species diversity is not as great as on rock islands because of the limited vegetative structure. However, the value of breeding and haul-out sites for marine mammals and nesting and resting areas for birds is significant. Sand Islands in Willapa Bay and Grays Harbor are excellent examples of major harbor seal hauling out areas and breeding grounds include

lower elevation shoals (sand and/or gravel bars). In Grays Harbor, as many as 1,400 harbor seals center their activity around the Sand Island shoals. This may be the largest harbor seal breeding colony in Washington and Oregon. Examples of breeding birds on sand islands in these areas are summarized in Table 721-1. These islands are especially important for Caspian Terns which have been considered as being potentially threatened with extinction in Washington.

Caspian Tern nesting colonies in eastern Washington, in Oregon, and in coastal California have already declined or disappeared due to human interference and development. It has been suggested that Caspian Tern nesting colonies be set aside as natural preserves and that controlled access to the islands be in effect during their breeding season, from March 15 to September 1.

Suggested References:

Penland,[1] Stephen T. 1976. The natural history and current status of the Caspian Tern (*Hydroprogne caspia*) in Washington State. Unpublished Master's Thesis, University of Puget Sound, Tacoma, Wn. 101 p.

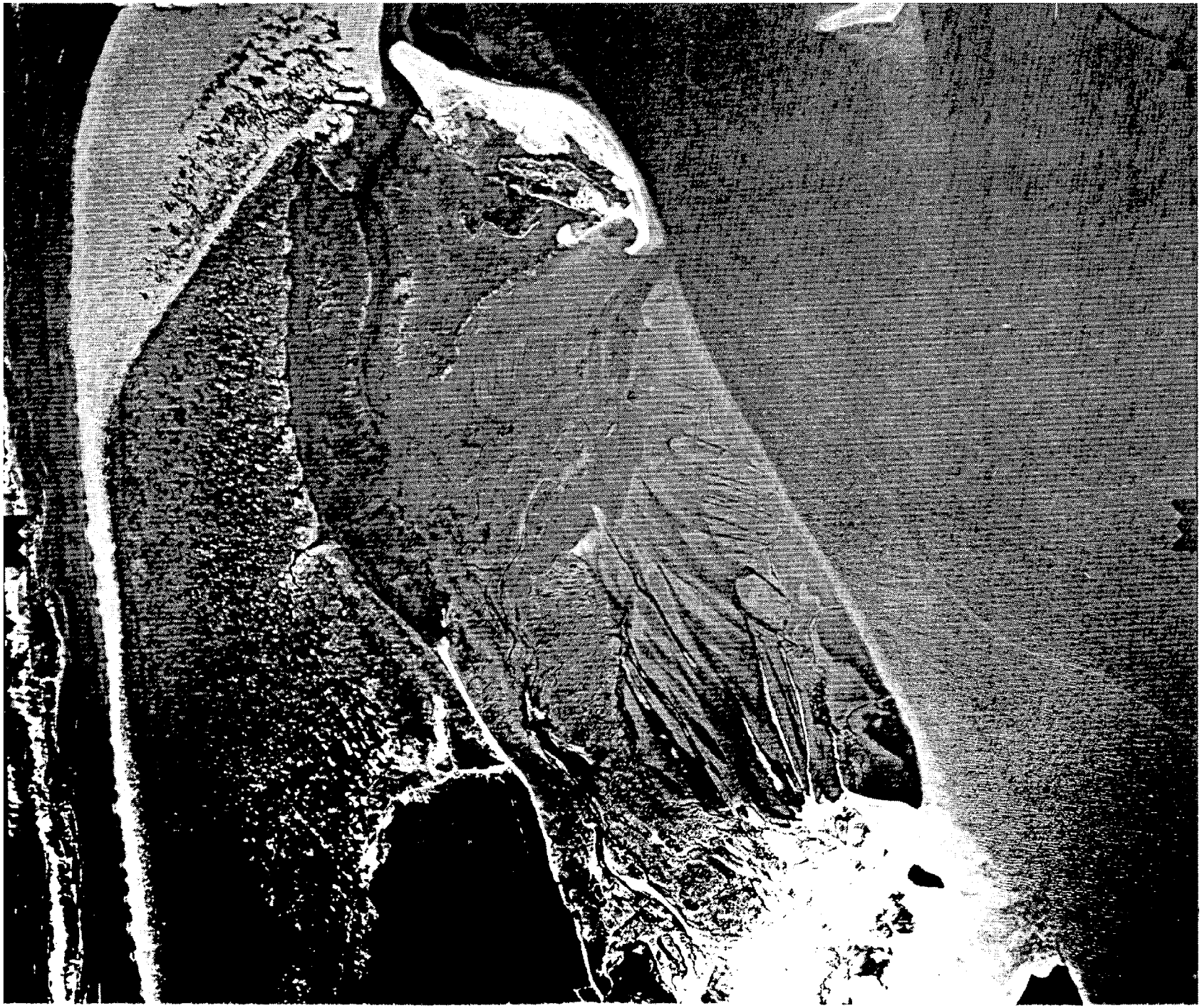
1. (Consult Penland's thesis for management recommendations and assessment of potential threats to Caspian Terns.)

Table 721-1

EXAMPLES OF BREEDING BIRD USE OF
SAND ISLANDS IN WASHINGTON'S COASTAL ZONE

Island	Location	Nesting Species Present	Comment
Whitcomb Island	Grays Harbor	Caspian Tern Glaucous-winged Gull Western Gull Hybrid Western X Glaucous-winged Gulls Ring-billed Gulls	Largest known Caspian Tern colony in Washington (an estimated 1,240 breeding pairs in 1976). Washington is the northern limit of breeding range of Caspian Tern in the Pacific Northwest. One of only two known nesting sites of Ring-billed Gulls in western Washington.
Goose Island	Grays Harbor	Glaucous-winged Gull Western Gull Hybrid Western X Glaucous-winged Gulls	Caspian Terns once nested on the island. (Approx. 1,000 pairs nested in 1973; birds were absent in 1976.) Gull competition and loss of nesting habitat due to erosion are proposed causes.
Sand Island	Grays Harbor	Caspian Tern Glaucous-winged Gull Western Gull Hybrid Western X Glaucous-winged Gulls	Terns first discovered nesting in 1976.
Unnamed Island on Ellen Sands	Willapa Bay	Caspian Tern Glaucous-winged Gull Western Gull Western X Glaucous-winged Gull Hybrids Ring-billed Gulls	First recorded nesting site of Ring-billed Gulls in western Washington (1976).

AERIAL PHOTO OF LEADBETTER POINT, PACIFIC COUNTY



SAND DUNES (No. 722)

INTRODUCTION

Sand dunes were mapped at only three locations along the coast (excluding Grays Harbor County): Cattle Point on San Juan Island (San Juan County), at Deception Pass on Whidbey Island (Island County), and on the Long Beach Peninsula (Pacific County). The Long Beach dunes are by far the largest, covering approximately 19 miles along the peninsula, the northernmost 3 miles of which are within the Willapa National Wildlife Refuge at Leadbetter Point. The Cattle Point site covers 98.6 acres (40 ha) and is within San Juan National Historic Park, and the 26.4 acre (10.7 ha) Whidbey Island site is in Deception Pass State Park.

Dunes are formed by the interaction of sediment supply, wind, and vegetation. The structure of dune formations may be quite complex, and numerous descriptive terms are used to define various areas as shown in Figure 722-1.

Long Beach Peninsula dunes are the best developed of the three sites and the formation here can be divided into three major zones:

1) Foredune
2) Unstabilized Dunes
3) Stabilized Dunes

A fourth zone, the dune forest, is often considered in accounts of dune communities and will be discussed in the Coniferous Forest Narrative (No. 41, Conifer Forest). Sand beaches are also an associated habitat which should be referred to (No. 63, Sand Beach). Specific zones present at each of the Washington sites are presented in Table 722-1.

Table 722-1. Zones of the Dune Community Present at Three Coastal Washington Sites.

	Beach	Foredune	Unstabilized Dunes	Stabilized Dunes	Dune Forest
Cattle Point	cobble		x		
Deception Pass	sand/gravel	x	x with wet hollows	x with wet hollows	x
Long Beach Peninsula	sand	x	x with wet hollows	x with wet hollows	x

The Deception Pass dunes also represent a well-developed dune formation. A dune wildrye-dominated foredune is present, and areas of unstabilized and stabilized dunes are interspersed with one another, the stabilized areas supporting small patches of forest. The impact of heavy use is obvious in some areas, although efforts are being made to minimize these disturbances through the construction of pathways and interpretive displays.

The San Juan Island site is highly unusual in that sediments are derived from upland, rather than marine sources. This site is severely altered by rabbits and will be discussed in more detail in the impacts section.

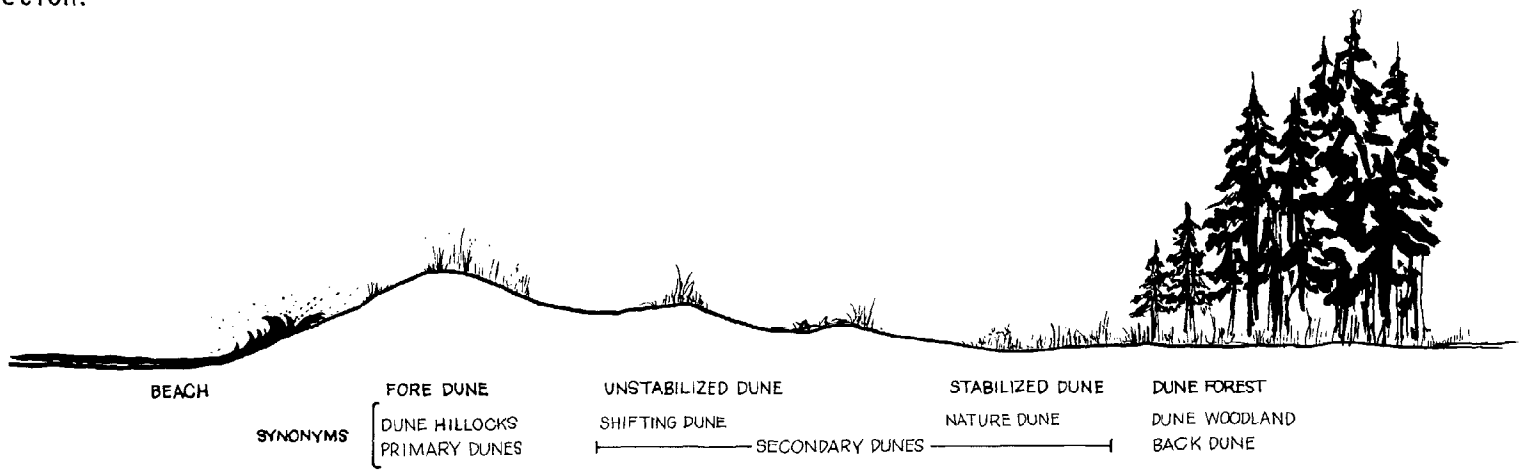


Figure: 722-1 Zonation and some physical characteristics of sand dune communities

SIGNIFICANT BIOLOGICAL FEATURES

Plant Communities

The characteristic role of vegetation in the dune system is stabilization. This role is effectively accomplished by the prostrate growth form of many of the species, and the binding of the upper sand layer by the network of roots and rhizomes. Another function is the acceleration of sand deposition as a result of reduced wind speed over the vegetated surface of dunes. Man-made barriers have been used in attempts to stabilize dunes, but often become buried by sand and cease to function. Dune vegetation, on the other hand, grows with the developing dune, and plant communities change as dune formation proceeds. The dune system may be divided into three major zones as depicted in Figure 722-1 and described below:

1) Foredune: Immediately above high tide line, environmental conditions are very unfavorable for plant growth. Unstable substrate, low nutrient supply, lack of water, salt spray, and abrasion from blowing sand are major selective factors, and only a few plant species have adapted to this harsh environment. Typical species found nearest the beach are dune wildrye, seashore bluegrass, European beachgrass, and sea rocket. As individuals become established, loose sand is stabilized by their extensive, spreading root systems, and blowing sand is deposited around the bases of the plants, slowly accumulating and forming low mounds. Beyond these embryo dunes, plant density increases, resulting in increased rates of deposition and stabilization, and environmental conditions are modified to the extent that several additional species become established.

2) Unstabilized Dunes: Beyond the foredune, beach strawberry, bighead sedge, sea purslane, beach morning-glory, sand verbena, and sandmat occur with all the previously mentioned species except sea rocket, which is usually restricted to the foredune. Vegetative cover is not dense enough to stabilize the sand, and dunes in this zone are constantly shifting, subjecting plants to burial or uprooting.

There are two major micro-environments in the unstabilized dune zone. One is the environment on the top and sides of each individual dune. Here, exposure is great, subjecting plants to strong winds, low water supply, and shifting substrate. The second is the area between the dunes, referred to as the dune hollow or dune slack. These low spots are usually at or near the water table and often have standing water for several months of the year. As a consequence, marsh and swamp species are characteristic of dune hollows, in striking contrast to the drought-tolerant species on the dune proper. Vegetation is sparse in these hollows as it is throughout the unstablized dunes, but includes pioneers of the wetland community that subsequently develops.

3) Stabilized Dunes: Between the unstabilized dunes and the dune forest lie the stabilized dunes. This is an area of nearly solid vegetation cover, supporting many plant species on the dune proper and in the dune hollows. In addition to previously mentioned species, seaside tansy, seashore lupine, red fescue, licorice fern, black knotweed, and sea thrift are common on the dunes. Kinnickinnick, a low, mat-forming shrub occurs near the forested upland. Environmental conditions may be modified sufficiently to allow upland species to become established. At Leadbetter Point, Western red cedar and red alder were both observed in the stablized dune area. Both species were dwarfed and had saltburned branch tips, reflecting the rigors of life in this exposed habitat.

Dune hollows support dense stands of slough sedge, rushes, and Pacific silverweed. Shrubs occurring in these wet spots include twinberry, spiraea, and Hooker's willow.

Tree seedlings become frequent at the inland margin of the stabilized dune. On the Long Beach Penninsula, shore pine was the only species observed. At Deception Pass, Sitka spruce, grand fir, and Douglas fir dominate the dune forest and seedlings of all three occur throughout the dunes.

Endemic Plant Species

The flora of Washington dunes and beach grasslands includes the following species endemic to the Pacific coast, and restricted to these habitats:

- yellow sand verbena (*Abronia latifolia*)
- pink sand verbena (*A. umbellata*)
- coastline bluegrass (*Poa confinis*)
- seashore bluegrass (*P. macrantha*)
- seashore lupine (*Lupinus littoralis*)
- beach peavine (*Lathyrus littoralis*)
- silver bursage (*Ambrosia chamissonis*)
- black knotweed (*Polygonum paronychia*)
- northern dune tansy (*Tanacetum douglasii*)

Fauna

Animals associated with Washington dunes follow much of the same changes as vegetation progresses from embryo dune to backdune areas. These changes are primarily in response to the increasing plant diversity, cover, and complexity in each of the three zones previously described. In general, there is an increase in numbers of animal species as zones change from embryo dunes, to stabilized dunes, to the highly diverse fauna of dune forests. Adjacent cover types, wet spots within the dunes, and other microhabitats unique to each site also add to faunal diversity within the dune environment. Major cover types and associated fauna are mentioned here, but are discussed in more detail in separate narratives. For discussion of the overlap and interrelationships between high intertidal beach zones, embryo dunes, and dune formations refer especially to the Conifer Forest Narrative (No. 41) for dune forest species, Freshwater Marsh Narratives (Nos. 621 and 622) for species associated with dune hollows, and the Sand Beach Narrative (No. 636).

Additional features of each of the three Washington sites create distinctive conditions for the variety of wildlife they share in common, and furthermore for species unique to each dune location. Long Beach Peninsula dunes, which include Leadbetter Point, are known as one of the most outstanding bird watching areas in Washington. Dune fauna at this site is strongly influenced by the ocean beach, extensive salt marsh, complex of dune forest, swamps, dune hollows, and the rich waters of nearby Willapa Bay. One of the unusual breeding birds is the Snowy Plover, which nests here and in Grays Harbor County. These restricted dune nest sites are the northernmost breeding sites of these shorebirds along the Pacific Coast and the only known nest sites in Washington.

Other unusual breeding birds may include Ring-necked Ducks, Northern Shovelers, Blue-winged Teal, and Cinnamon Teal which are known to nest in dune hollows on the Oyehut Penninsula in Grays Harbor County. Studies have shown ponds in these dunes to be productive breeding sites for other waterfowl including Mallards and Green-winged Teal. Additional birds reported to occur at Leadbetter Point by the U.S. Fish and Wildlife Service are listed in Table 722-2.

Mammals in this area include Townsend's voles which are an abundant source of prey for Marsh Hawks and coyotes. Other mammals include black bears which forage on the dunes and retreat to dune forests for cover. Deer, raccoons, and deer mice also occur. Rabbit sign has also been noted at Leadbetter Point, however, they appear to be uncommon and not a threat to dune plant communities as the European rabbits are on San Juan Island.

The San Juan Island dune sites are adjacent to the open grassland which dominates the southern tip of the island. These two areas are structurally similar and fauna is typified by ground dwellers (rabbits) and birds of prey (Bald Eagles, Golden Eagles, Red-tailed Hawks and others). Rabbits have severely altered vegetation in the dunes as discussed in the impacts section.

Whidbey Island dunes lie between the Strait of Juan de Fuca, and Cranberry Lake, one of a very few lakes within the coastal zone (as defined in this inventory). This site is a fascinating wildlife area as a result of the diversity of upland, marine, and freshwater habitats present.

Characteristic Species

Many of the Leadbetter Point birds listed in Table 722-2 occur at other dune locations. Several of these species are characteristic of dunes and other open habitats such as grasslands, meadows, and sandy beaches. The list also includes species inhabiting dune forests and some which are restricted to open waters adjacent to the dunes. Others occur only in marshy areas of dune hollows. They are all included because of the interrelationships of each of these habitats and associated species. For example, Common Flickers are often thought of as forest birds, but are common on dunes where they forage on the ground, drift logs, and on shore pines. Bushtits forage and possibly nest in Hooker's willows in the dune hollows, and chickadees search for insects in willows and advancing shore pines. Open water birds and intertidal foragers such as shorebirds rest in dunes, fly by, or are preyed upon by other dune inhabitants.

Species most often associated with dunes are those which inhabit the more open and exposed foredunes. Some nest locally, while others are winter visitors from their northern tundra breeding grounds. Representative examples are discussed below:

Snowy Plover

Snowy Plovers are small (6-7"; 15-18 cm.) relatives of the familiar Killdeer. They are distinguished by their pale color which blends perfectly with the sandy habitat they choose for nest sites. Their distribution is worldwide, but occur only along river banks, on coral beaches, or in sand dunes. The northern breeding range extends along the Pacific Coast to Washington and our only known coastal nesting birds occur at Leadbetter Point and in Grays Harbor County. They are especially vulnerable to disturbance because of their restricted nesting habitat. The U.S. Fish and Wildlife Service has posted Leadbetter Point breeding habitat to prevent destruction of nest sites. Other dune areas should also be protected to preserve existing and potential nest sites of these uncommon shorebirds.

Lapland Longspur

These sparrow-like birds breed in arctic tundra and occasionally winter along our coast. They occur in flocks with Snow Buntings and Horned Larks and have been recorded as uncommon to rare at Leadbetter Point. They should be looked for at other dune sites.

Snow Bunting

Snow Buntings are also sparrow-like birds of the tundra which sometimes appear in mixed flocks along dunes and sandy beaches in winter. The summer male is all white except for a patch of black on its back. Both sexes are distinguished from similar birds in winter by their large white wing patches. Snow Buntings are considered uncommon at Leadbetter Point. Another bunting, McKay's, has recently been observed in the Ocean Shores vicinity. This was the first recorded sighting in Washington of this northern bird which nests on small islands in the Bering Sea.

Horned Lark

Horned Larks are more common than the species mentioned above and are characteristic birds of open habitats including dunes and open grasslands. They likely occur at all three dune sites, and are known to nest in open grasslands adjacent to the San Juan dunes. The birds occurring on the Long Beach Penninsula comprise a distinct subspecies, recognized by their redder beak and yellower face.

IMPACTS

Sand dune formations are dependent upon the deposition of erosion sediments by longshore currents for their source material. The San Juan Island dunes are an exception in that sediments here are derived from upland sources deposited during the last glaciation. The general area supplying sediments for the other sites discussed are:

Deception Pass Dunes: Sandy eroding bluffs to the south.

Long Beach Penninsula: Erosion sediments from the Columbia River.

As a result of this dependency, any action altering the supply of sediments will impact dune formations. Human activities on dunes with adequate sediment supply may also be destructive. All three Washington sites show the effects of overuse or abusive activities. Sand dunes are fragile areas, the stabilization afforded by vegetation easily disrupted, often with long-lasting effects. Destruction of the plant cover may cause succession to revert to its earliest stages, and can lead to the destruction of larger areas by changing wind flow patterns.

Recreation

Recreational use of the beach and dunes is very heavy on the Long Beach Peninsula, a popular resort area.

Hiking is a tolerable recreational use of the dune community, but trails should be established to avoid excessive trampling of vegetation. Construction of artificial walkways, as has been done at Deception Pass State Park, is desirable if large numbers of people visit a given dune location. The walkway will minimize trampling and can also be used as an educational pathway through the dune community.

Off-road vehicle use is not a tolerable use of dunes. Throughout the dunes, especially near populated areas, scenes similar to Figure 722-2 are common.

Such destructive activity is certainly facilitated by the fact that driving on the beach along the Long Beach Penninsula is permitted and encouraged by the maintenance of access sites. This off-road travel is also detrimental to razor clam beds, a potential hazard to beach recreation, and a disruption to wildlife. Especially vulnerable are the small numbers of nesting Snowy Plovers at Leadbetter Point.

Housing

Construction on the dunes is causing considerable destruction of large areas along the Long Beach Peninsula. Losses due to expanded resort and home construction is particularly regrettable in view of the fact that on the Long Beach Penninsula and south for 18 miles into Oregon is the only sizeable area on the Oregon and Washington coast with a parallel ridge dune system (sand ridges running parallel to the shore).

Introduced Species

Two introduced species which have had pronounced impacts on Washington dunes are European beachgrass and European rabbits.

European beachgrass (also referred to as "marram grass") is native to northwestern Europe and has been widely planted in the northern hemisphere because of its superior abilities as a sandbinder. Lateral root development is stimulated by the slow burial of aerial stems, making it especially well adapted to the embryo and unstabilized dune areas. Introduced in 1869, at San Francisco, European beachgrass has spread the length of our coast and is now abundant on the Long Beach Peninsula, less so at Deception Pass, and lacking at Cattle Point. The introduction of this exotic species has had a profound effect on the character of the dune flora. California studies show that species diversity is depressed on European beachgrass dominated foredunes, with adjacent wildrye dominated foredunes supporting twice as many species.

The European rabbit has greatly modified the San Juan Island dune site and plays a major role in maintaining and expanding existing dunes. Canada thistle and bracken fern, common weeds throughout western Washington, dominate the area and it appears that

rabbits are inhibiting the establishment of typical dune vegetation. Rabbits have been observed to create new dune areas along Cattle Point by removing vegetation and exposing sand soil layers. The sand is then shifted by the wind, thus creating active dunes which cover surrounding open grassland vegetation.

The San Juan rabbit population provides a substantial source of food for birds of prey including Bald Eagles, however, their destructive effects on plant communities must be considered in management decisions affecting the Cattle Point area.

Sand Removal On the Long Beach Peninsula, sand removal from the beach is a common practice, primarily for two purposes: For use as fill in the creation of cranberry bogs, building sites, and septic tank drainfields; and for the maintenance of an ocean view. In areas where large amounts of sand are removed, or sand removal continues for an extended period, recent studies indicate that growth of the foredune may be slowed in the vicinity. Removal of the foredune for view maintenance not only destroys the plant and animal community in the immediate area, but exposes the residence to winter storm waves and allows sand to blow through the opening, possibly to accumulate around buildings and roadways.

Driftwood Removal With the aid of chain saws and four-wheel drive vehicles, driftwood removal is undoubtedly proceeding at a faster rate than ever before. As driftwood is incorporated into the building foredune, it stabilizes the sand and as it slowly decays, adds organic matter to the slowly developing soil. The removal of driftwood exposes the foredune to wave action, and increases the vulnerability of the foredune to erosion by wind and waves.

Table 722-2 BIRDS OF LEADBETTER POINT

Species	Season/Relative Abundance[1] Spring	Summer	Fall	Winter	Known to nest in area (Leadbetter or Oyehut)
Western Grebe	c	r	c	c	
Northern Fulmar		r	r	u	
Pink-footed Shearwater			u		
Sooty Shearwater	u	c	a		
Short-tailed Shearwater	r			r	
Fork-tailed Storm-Petrel			r		
Brown Pelican			u	r	
Double-crested Cormorant	c	c	c	c	
Brandt's Cormorant	c	u	c	c	
Pelagic Cormorant	c	u	c	c	
Great Blue Heron	c	c	c	c	x
American Bittern	r	u	u	r	
Whistling Swan			c	c	
Trumpeter Swan			u	c	
Canada Goose	c	c	c	c	x
Brant	a		u	a	
Emperor Goose	r		r		
White-fronted Goose	u		u		
Snow Goose	u		u	u	
Mallard	c	c	c	c	x
Gadwall	c	r	c	c	
Pintail	c	u	a	c	x
Green-winged Teal	c	u	c	u	x
Blue-winged Teal	u	r	u	u	x
Cinammon Teal	r	r	r	r	x
American Wigeon	c	r	a	c	
Northern Shoveler	u	r	u	c	x
Wood Duck	u	c	c	u	x
Ring-necked Duck	u		c	u	x
White-winged Scoter	c	u	a	a	
Surf Scoter	c	u	c	a	
Common Merganser	u	u	u	c	
Turkey Vulture	r	u			
Goshawk	u	r	r	c	x
Sharp-shinned Hawk	u		u	c	
Cooper's Hawk	u	u	u	c	
Red-tailed Hawk	u	u	c	c	x
Swainson's Hawk	r	r			
Rough-legged Hawk	u		u	c	
Golden Eagle	r		r		
Bald Eagle	u	u	u	u	x
Marsh Hawk	u	u	c	c	x
Peregrine Falcon	u		u	r	
Merlin	r		u	u	
American Kestrel	u	r	u	c	
Osprey		u			

Ruffed Grouse	c	c	c	c	x
Ring-necked Pheasant	c	c	c	c	x
Sandhill Crane			r		
Virginia Rail	u	u	u	u	x
Sora	u	c	c		x
Semipalmated Plover	c	r	c	u	
Snowy Plover	u	u	r		x
Killdeer	c	c	c	c	x
American Golden Plover	u		u	r	
Black-bellied Plover	c	r	c	c	
Surfbird	u		u	r	
Ruddy Turnstone	u		u	r	
Black Turnstone	u		u	c	
Black Oystercatcher	u	r	u		
Common Snipe	c	u	c	u	x
Long-billed Curlew	u		u		
Whimbrel	c		c	u	
Spotted Sandpiper	c	u	c	u	
Wandering Tattler	u		u		
Willet	r		r	r	
Greater Yellowlegs	c	u	c	u	
Lesser Yellowlegs	c	u	c	c	
Red Knot	u	r	u	r	
Sharp-tailed Sandpiper	r		r		
Pectoral Sandpiper	u		c	u	
Baird's Sandpiper		u	u		
Least Sandpiper	a	u	a	a	
Dunlin	a	u	a	a	
Short-billed Dowitcher	u		u		
Long-billed Dowitcher	a	u	a	a	
Stilt Sandpiper	r		r		
Semipalmated Sandpiper	r		r		
Western Sandpiper	a	c	a	a	
Buff-breasted Sandpiper		r	r		
Marbled Godwit	r		u		
Sanderling	c	u	c	a	
Red Phalarope	r		r		
Wilson's Phalarope	r				
Northern Phalarope	u		u		
Parasitic Jaeger		r	u	u	
Long-tailed Jaeger			r		
Glaucous Gull	u	u		u	
Glaucous-winged Gull	c	u	c	c	
Western Gull	c	u	c	c	
Herring Gull	c	u	c	a	
Thayer's Gull	u		u	u	
California Gull	u	c	c	u	
Ring-billed Gull	c	u	c	c	x
Mew Gull	c	r	c	c	
Bonaparte's Gull	c		c	u	
Heermann's Gull	u	u	c	c	

Table 722-2 (Cont.) BIRDS OF LEADBETTER POINT

Species	Season/Relative Abundance[1] Spring	Summer	Fall	Winter	Known to nest in area (Leadbetter or Oyehut)
Black-legged Kittiwake	u		c	u	
Sabine's Gull	r		r		
Common Tern	r	u	c		
Arctic Tern	r		u		
Caspian Tern	u		u		
Common Murre	c	u	c		
Pigeon Guillemot	c	u	c		
Marbled Murrelet	r			r	
Cassin's Auklet	r				
Rhinoceros Auklet	r			r	
Tufted Puffin	r			r	
Screech Owl	c	c	c	c	x
Snowy Owl	r			r	
Common Flicker	a	a	c	c	x
Pileated Woodpecker	u	c	u	r	
Red-breasted Sapsucker	u	u	u	u	
Hairy Woodpecker	c	c	c	c	x
Downy Woodpecker	u	u	u	u	
Western Wood Pewee	u	u	u		
Horned Lark		u	u	r	
Violet-green Swallow	c	c	c		x
Tree Swallow	c	c	u	r	
Bank Swallow	u	u			
Rough-winged Swallow	c	c	u	r	
Barn Swallow	c	c	u		x
Cliff Swallow	c	c	u		x
Steller's Jay	c	c	c	c	x
Scrub Jay	r	r	r	r	
Common Crow	u	u	u	u	x
Black-capped Chickadee	c	u	c	c	x
Chestnut-backed Chickadee	c	c	c	a	x
Bushtit	u	u	u	u	x
Red-breasted Nuthatch	c	c	c	c	x
Brown Creeper	u	u	u	u	x
Winter Wren	c	c	c	c	x
Bewick's Wren	c	c	u	u	x
American Robin	q	c	c	a	x
Varied Thrush	c	u	c	a	
Hermit Thrush	u	u	u	u	
Swainson's Thrush	c	c	u		x
Western Bluebird	u	r	u	u	
Golden-crowned Kinglet	c	u	c	c	x
Ruby-crowned Kinglet	u		u	u	
Water Pipit	u		u	u	
Cedar Waxwing	c	u	c	u	x

Northern Shrike		u	u	c	
Starling	c	c	c	c	x
Hutton's Vireo	u	u	u	u	x
Solitary Vireo	u	u	u		x
Warbling Vireo	u	u	u		x
Oregon-crowned Wabler	c	u			x
Nashville Warbler	u	c	u		x
Yellow-rumped Warbler	c	c	c	u	x
Black-throated Gray Warbler	c	u	c		x
Townsend's Warbler	u				x
MacGillivray's Warbler	u	u			x
Common Yellowthroat	u	u	u		x
Wilson's Warbler	u	c	u		x
Western Meadowlark	c	c		u	x
Yellow-headed Blackbird	r		r		
Red-winged Blackbird	c	c	u	u	
Brewer's Blackbird	a	c	c	a	
Brown-headed Cowbird	c	c	u	c	x
Western Tanager	c	c			x
Black-headed Grosbeak	u	u			x
Evening Grosbeak	c	u	c	u	
Purple Finch	u	u	u	u	
House Finch	c	u	u	c	x
Common Redpoll	u			u	
Pine Siskin	c	u	c	a	x
American Goldfinch	a	u	c	a	x
Red Crossbill	c	u	u	c	x
Rufous-sided Towhee	u	u	c	c	x
Savannah Sparrow	u	c	u	r	x
Dark-eyed Junco	c	c	c	a	x
Chipping Sparrow	u		u	u	
White-crowned Sparrow	c	u	u	c	x
Golden-crowned Sparrow	c		u	c	
Fox Sparrow	u		u	c	
Song Sparrow	c	c	c	c	x
Lapland Longspur	u		u	r	
Snow Bunting			u		

1 a = abundant
c = common
u = uncommon
r = rare

FIGURE 722-2

Destruction of the vegetative cover by careless use of Off Road Vehicles, Long Beach Peninsula, Pacific County

Suggested References:

Boorman, L. A. 1977. Sand Dunes in: Barnes, R. S. K. (ed.) The Coastline. John Wiley & Sons. 161-197.

Carefoot, Thomas. 1977. Pacific Seashores - A Guide to Intertidal Ecology. University of Washington Press. 208 pp.

McHarg, Ian L. 1969. Design With Nature. Doubleday & Co., Inc. New York. 198 pp.

Phipps, James B. and John M. Smith. 1978. Coastal Accretion and Erosion in Southwest Washington. Wa/DOE/CA/78-12. 75 pp.

Wiedemann, A. M. et al. 1969. Plants of the Oregon Coastal Dunes. Oregon State University Bookstore Inc. Corvallis, Oregon. 17 pp.

Fred Stevens of San Juan Environmental Studies kindly provided information concerning San Juan rabbits.

SLIDE (NO. 723)

Slides are areas of sand or gravel substrates which drop from steep slopes, leaving a scar at the source and producing an accumulation of substrate at the base.

SAND AND/OR GRAVEL BAR (No. 724)

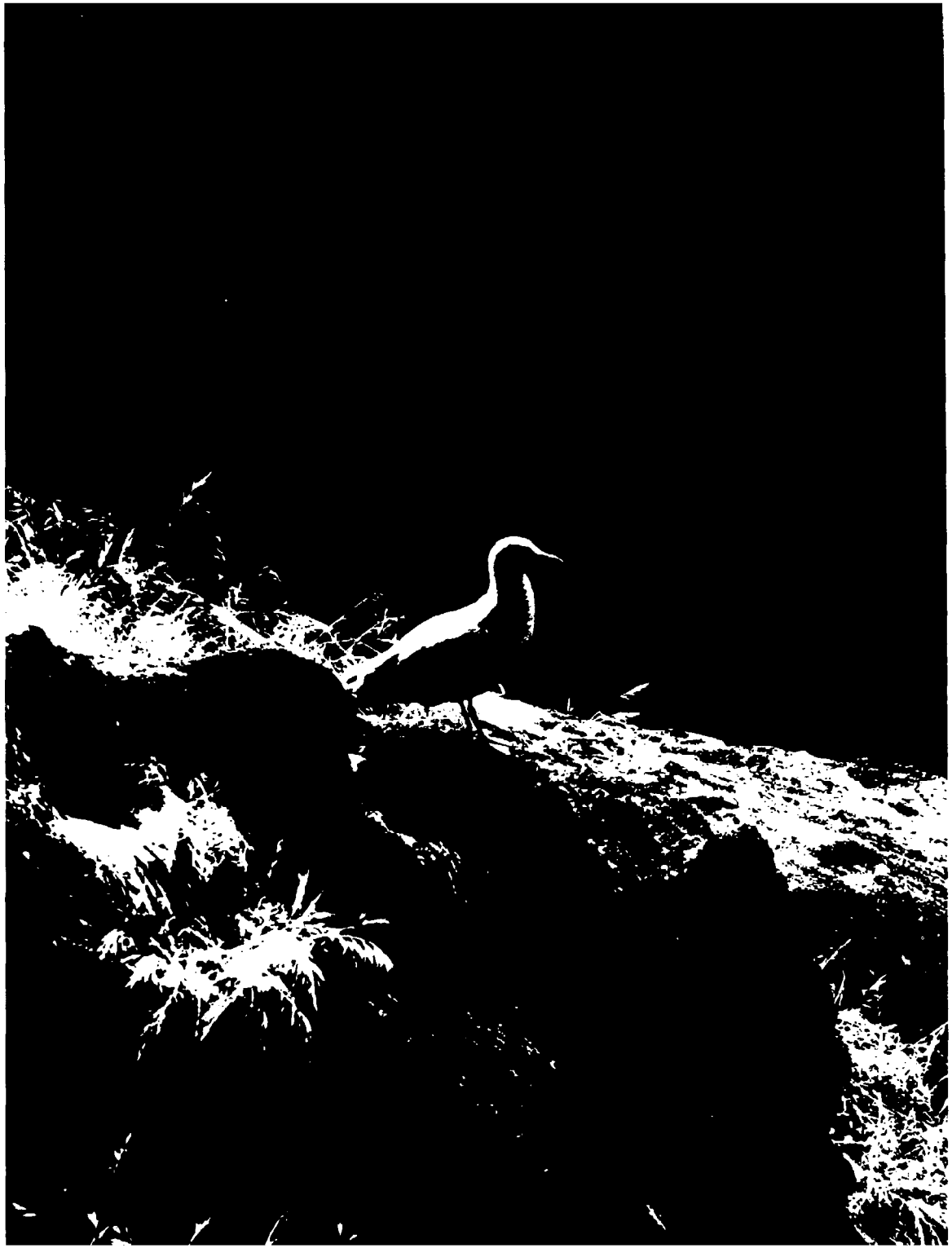
Sand or sand and gravel bars (also referred to as shoals) are intertidal deposits which are covered at mean high water. Sediments forming bars are deposited as a result of longshore drift, and tend to be unstable, particularly when no gravel is present. This instability results in a constant shifting of sand bars, and sand and gravel bars may shift if wave energy is strong enough. Most of this shifting assumes a seasonal pattern.

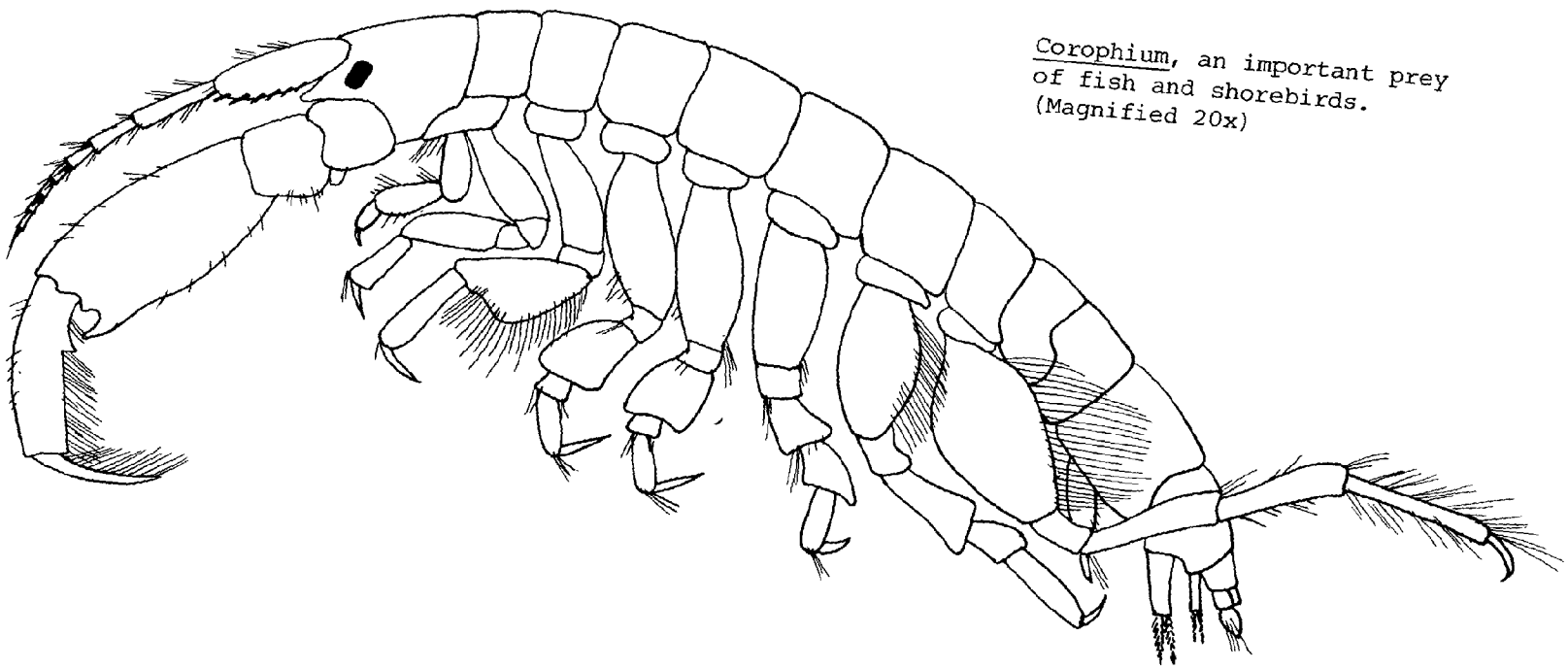
The constant shifting of sand bars creates harsh conditions under which few invertebrates and essentially no algae (except a few microscopic algae) can survive. Thus the few animals present must rely heavily on foods brought in by the tides.

Bars of sand and gravel, and occasionally some cobble, are more stable than pure sand bars, and tend to contain a greater diversity and abundance of invertebrates and, in some cases, seaweeds. Organisms present are typical of those found in mixed fine beaches (refer to Narrative No. 635), and often contain large numbers of littleneck, butter, and horse clams.

Use of sand or sand and gravel bars by birds and marine mammals is limited by the amount of time such bars are covered by water during high tides. However, they often provide extremely important resting areas when uncovered. For example, the bars within Grays Harbor centered around Sand Island are key haul-out sites for the largest known breeding population (approximately 1,400 animals) of harbor seals in Washington and Oregon. Harbor seals haul out on bars in many other locations throughout the coastal zone, including Skagit and Padilla Bays. In summer months seals may give birth to and nurse pups on these bars as well as using them as rest sites throughout the year.

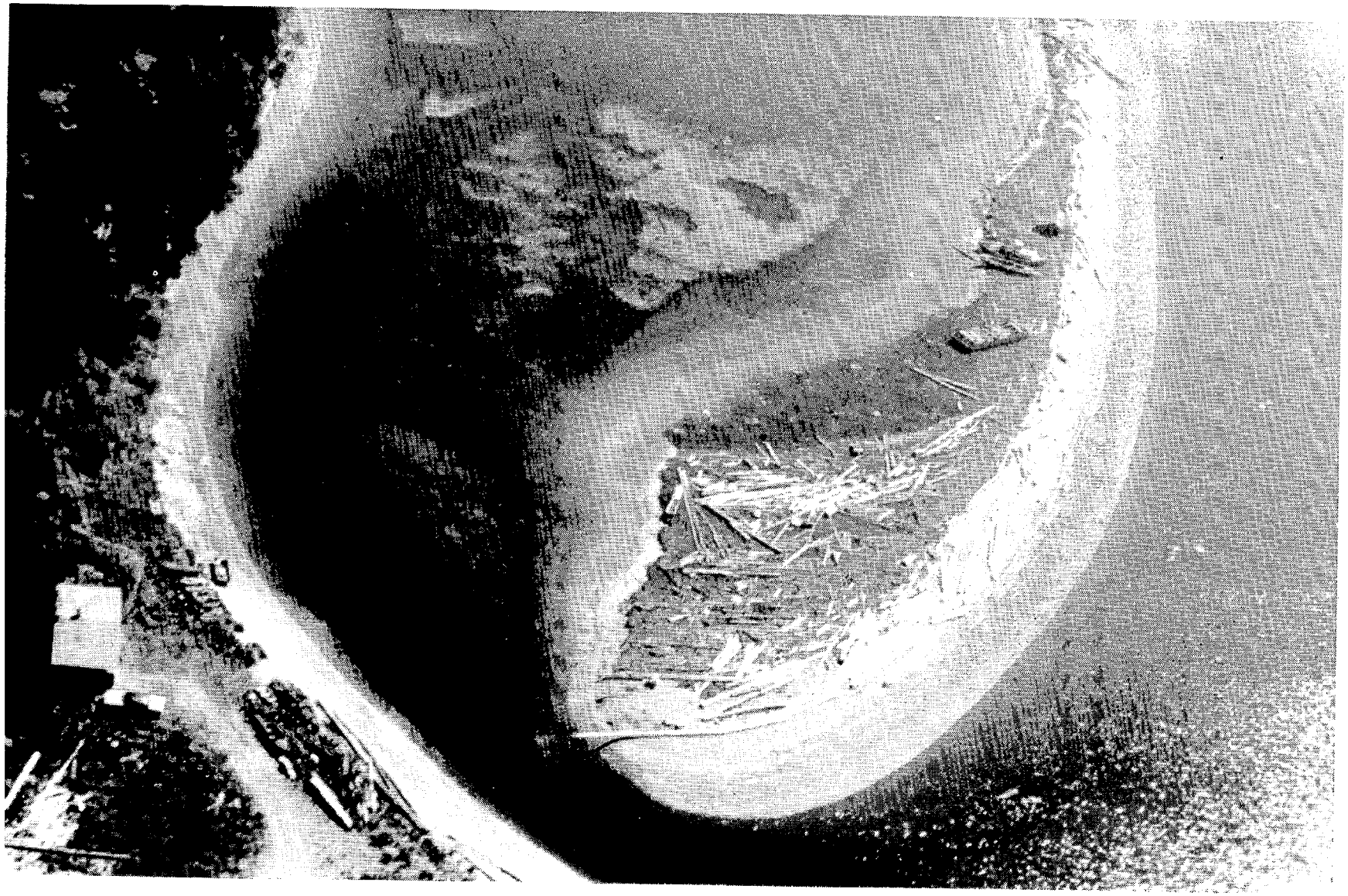
Bird use of sand or sand and gravel bars is not limited to resting. Gulls and shorebirds are among the more common birds which do loaf here, but many also feed on shoals, especially shorebirds.





Corophium, an important prey of fish and shorebirds. (Magnified 20x)

Spit in the northwest corner of Sequim Bay, Clallam County, enclosing Paradise Cove.



SPIT (No. 74)

includes: Vegetated Spit (No. 741)
Non-vegetated Spit (No. 742)

I. INTRODUCTION

Spits are shoreforms created when sediments are deposited by wind and water currents. Sources include sand or gravel eroded from bluffs and cliffs, and sediment transported by rivers. Spits are frequently curvilinear in shape with a wave-built berm and cobble or other coarse substrates on the outer (exposed) side, and a more gently sloping inner (protected) side. These protective barriers frequently provide conditions for mudflats, lagoons, and salt marsh complexes to develop. Readers are advised to refer to the Coastal Drift Sector narrative in each Atlas volume for further information on spit formation.

Vegetated portions of spits which are larger than minimum mapping size are designated by appropriate cover type, e.g., Beach Grassland (No. 312), Salt Marsh (No. 623).

II. SIGNIFICANT BIOLOGICAL FEATURES

Plant Communities

Beach grassland and salt marsh are the most commonly found habitat types associated with spits. Beach grassland usually occupies the exposed side of spits, beginning just above high tide line, and is well adapted to the harsh environment. On the inner side of spits, protected from wind and wave action, salt marsh vegetation often occurs. Both these plant communities help stabilize the spit substrate, the beach grassland forming a first line of defense against erosion by wind and waves. For complete discussions of salt marsh and beach grassland, refer to these narratives (Nos. 623 and 312, respectively). Refer also to Table 74-1 for a list of characteristic plants. Characteristic animals are also listed in Table 74-1 and discussed below.

Animals

Spits are a harsh environment for many invertebrates due to the instability of the substrate, poor moisture and nutrient retention, wind and wave exposure, and changing salinities.

On the higher (supra-littoral) parts of a spit, animal diversity is relatively low, dominated by arthropods. They are generally concentrated under driftwood and decaying algae. Also frequently occurring at this level are invaders from the upland, including flies, beetles, and arachnids. Invertebrate visitors from the sea that may be found here are amphipods (e.g., *Orchestoidea californiana* on exposed spits and *Orchestia traskiana* on protected spits) and isopods (e.g., *Allonicusus perconvexus* on exposed spits and *Porcellio scaber* on protected spits).

For invertebrate residents of the beach substrate on the spit, refer to the appropriate substrate types - e.g., Sand (No. 636), Mixed Fine (No. 635), etc.

TABLE 74-1 CHARACTERISTIC PLANTS AND ANIMALS

	Relative Occurrence[a]	Season[b]	Comments
PLANTS			
Beach wildrye (*Elymus mollis*)	C	Perennial	Beach grassland
Silver bursage (*Ambrosia chamissonis*)	C	Perennial	Beach grassland
Bighead sedge (*Carex macrocephala*)	C	Perennial	Beach grassland
Yellow Sandverbena (*Abronia latifolia*)	C	Perennial	Beach grassland
Beach peavine (*Lathyrus japonicus*)	C	Perennial	Beach grassland
Pickleweed (*Salicornia virginica*)	C	Perennial	Salt marsh
Saltgrass (*Distichlis spicata*)	C	Perennial	Salt marsh
Arrowgrass (*Triglochin maritimum*)	C	Perennial	Salt marsh
Glaux (*Glaux maritima*)	C	Perennial	Salt marsh
Creeping bentgrass (*Agrostis alba*)	C	Perennial	Salt marsh
Fungi			
Bacteria			
INVERTEBRATES			
Beach hoppers (amphipods)	C	Res	
Pillbugs (Isopods)	C	Res	
Insects	C	Res	
Spiders & mites (Arachnids)	C	Res	

BIRDS	Relative Occurrence[a]	Season[b]	Comments
Great Blue Heron	C	Res	Often rest on spits
Green-winged Teal	C	MW	Protected side
American Wigeon	C	MW	Protected side
Harlequin Duck	U	MW, S	Exposed areas
Bald Eagle	U	Res, MW	Day roost site
Marsh Hawk	U	Res	Hunt along beach grassland
Peregrine Falcon	R	Res	Endangered species
Merlin	U	Res	
American Coot	C	MW	
Killdeer	C	Res	Often nest here
Black-bellied Plover	C	MW	Many shorebirds use spit as rest site during high tides
Least Sandpiper	C	MW	
Dunlin	C	MW	
Western Sandpiper	C	MW	
Sanderling	C	MW	
Glaucous-winged Gull	C	Res	Gulls and, occasionally, terns nest on spits. They often rest here.
California Gull	C	MW	
Bonaparte's Gull	C	MW	
Common Tern	C	MW	
Belted Kingfisher	C	Res	
Common Flicker	C	Res	Feed on ground and drift logs
Horned Lark	U	MW	
Purple Martin	U	Sum	Nest in pilings
Common Crow	C	Res	Ubiquitous
Robin	C	Res	

	Relative Occurrence[a]	Season[b]	Comments
Water Pipit	C	MW	
Savannah Sparrow	C	Res	May nest
White-crowned Sparrow	C	Res	
Song Sparrow	C	Res	
Lapland Longspur	U	MW	
Snow Bunting	U	MW	
MAMMALS			
Vagrant shrew (*Sorex vagrans*)	U	Res	Beach grassland
Raccoon (*Procyon lotor*)	C	Res	Forage along spit
Mink (*Mustela vison*)	U	Res	Forage along spit
Striped skunk (*Mephitis mephitis*)	C	Res	Forage along spit
Deer mouse (*Peromyscus maniculatus*)	C	Res	Beach grassland
Townsend vole (*Microtus townsendii*)	C	Res	Beach grassland
Harbor Seal (*Phoca vitulina*)	U	Res	Use spit as rest site
REPTILES & AMPHIBIANS			
Garter snakes (*Thamnophis* spp.)	U	Res	

[a]C = Common
U = Uncommon
R = Rare

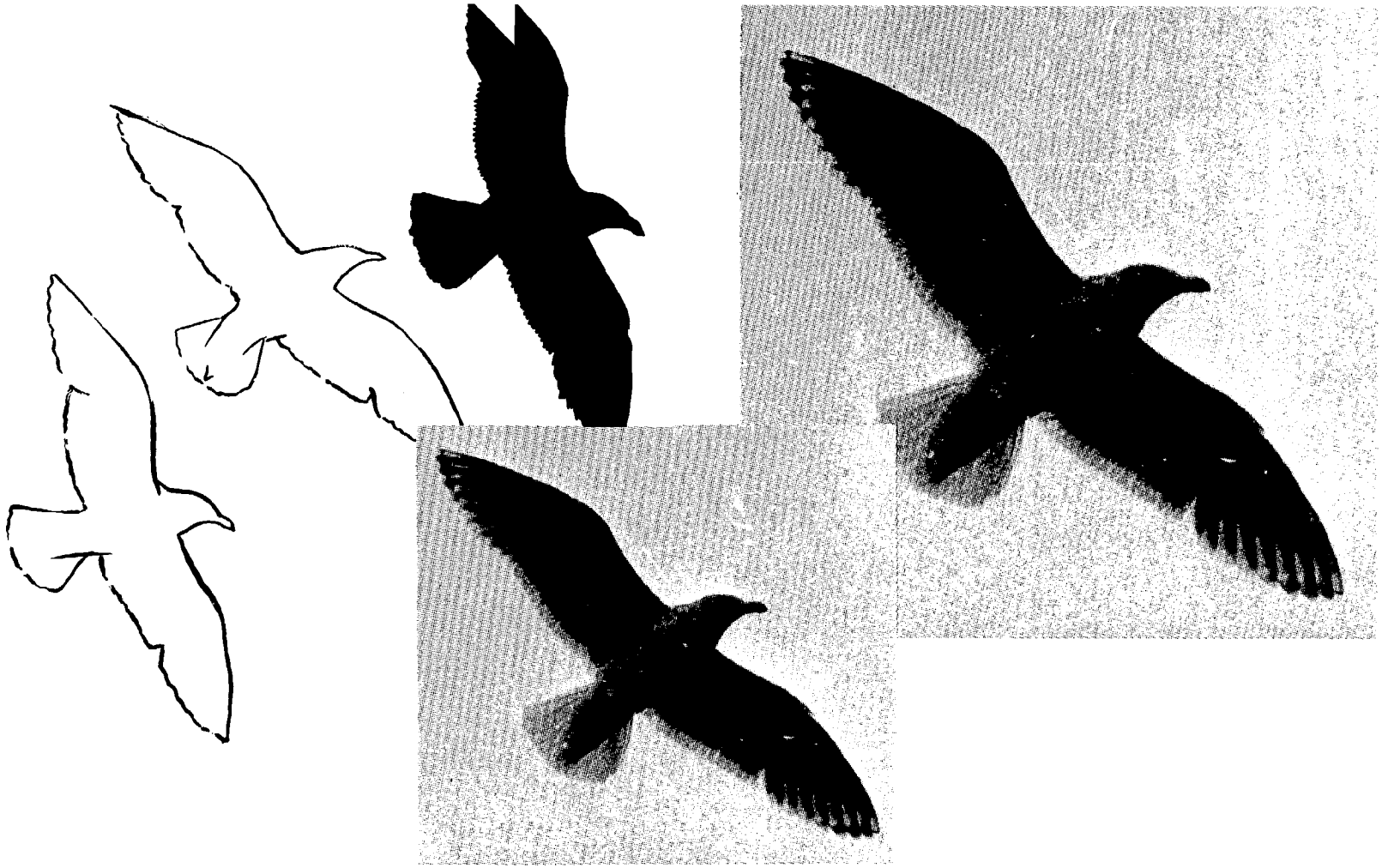
[b]R = Year Round Resident
MW = Migrant and/or Winter Resident
Sum = Summer Resident

Both vegetated and nonvegetated spits are used year-round by birds and mammals, although some species may be present only a short time during migration. A significant value of spits is their use as resting sites for large numbers of animals, particularly birds. Their isolation and unobstructed view make them especially important for safety and freedom from disturbance. Numerous shorebirds, gulls, terns, waterfowl, and harbor seals frequently can be observed on undisturbed portions of spits.

Spits with a minimum of disturbance are used as nesting sites by a number of birds. Groundnesting songbirds (Passerines) such as Savannah Sparrows frequently breed on vegetated spits. Shorebirds, gulls, terns and some seabirds have historically used, or are presently using, spits as their primary nesting territory. For example, the largest known colony of Glaucous-winged Gulls in the State's inland waters occurs on the Kanem Point spit on Protection Island in Jefferson County.

The use of spits as feeding sites is limited by low prey diversity. However, some animals are commonly observed hunting, particularly along vegetated spits. Insectivorous birds forage along drift log and beach grass areas, while raccoons and skunks regularly feed along the shorelines. Marsh Hawks, Red-tailed Hawks, and Merlins are frequently observed hunting along spits in search of small mammal or shorebird prey. Bald Eagles and other raptors also use posts and higher driftlogs on spits as perches during the day.

Dungeness Spit in Clallam County provides an example of the significant value of spits to wildlife. Karl Greubel of Port Angeles has been hiking the spit for several years and began monthly bird counts there in 1977.



"I have been hiking the Dungeness Spit for more than eight years and have been impressed by the constant changes that occur on it. Changes occur not only in the wildlife but in the ever-shifting nature of the spit itself."

Karl Greubel Jan. 1977

During two years of bird surveys along Dungeness Spit, Mr. Greubel walked over 288 miles and observed 96 species. Large numbers of shorebirds, waterfowl, gulls, and other marine birds were seen during his counts and several sightings of rare birds were also noted. The following list (Table 74-2) of shorebirds are representative of the thousands of birds observed by Mr. Greubel in one season:

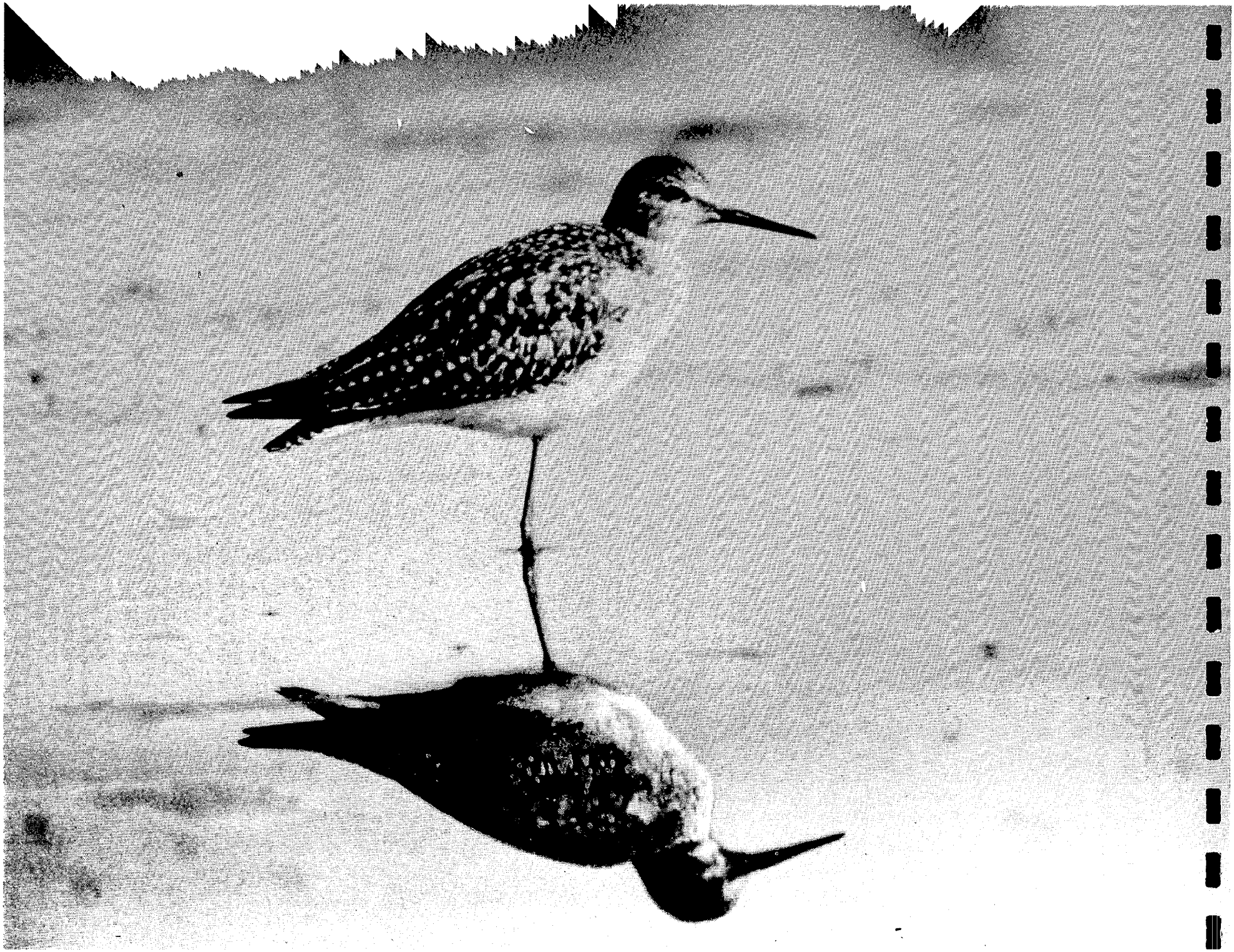


Table 74-2

SHOREBIRDS OBSERVED ON DUNGENESS SPIT,
SEPTEMBER - NOVEMBER 1977 AND 1978

Species	High Daily Count
Black Oystercatcher	5
Semipalmated Plover	50
Killdeer	23
Black-bellied Plover	100's
Ruddy Turnstone	15
Black Turnstone	38
Whimbrel	6
Greater Yellowlegs	4
Wandering Tattler	9
Willet	1
Surfbird	8
Red Knot	5
Sanderling	100's
Semipalmated Sandpiper	2
Western Sandpiper	100's
Least Sandpiper	17
Dunlin	1000's
Short-billed Dowitcher	100's
Marbled Godwit	2
Northern Phalarope	6

Other notable birds recently observed on Dungeness Spit by Mr. Greubel or other persons include Peregrine Falcons (a rare and endangered species), Snowy Owls, Bar-tailed Godwits (very rare in Washington), Bald Eagles (a threatened species), and Ruffs (shorebird rarely observed in Washington).

Many of the birds observed at Dungeness and other spits are directly dependent on the spit for a nest site. These and a wide variety of other species ranging from brant to oysters are indirectly dependent, since the spit is a key feature in the formation of other habitats as discussed below.

Functions

A salient feature of spits is the role they play in producing an environment suitable for the formation of other, biologically productive ecosystems. A spit, due to its location, often creates a lagoon on its protected side. These lagoons are frequently fed by streams incapable of flushing out all sediments settling in the lagoon. The lagoon acts as a sediment trap and slowly fills. As it does, a marsh develops and expands, eventually filling the entire lagoon. Lagoons (No. 56) and salt marshes (No. 623) are described in their respective sections.

At other times, spits may form a protected bay. In this protected situation, nutrient-enriched sediments are stable enough for marine vegetation and animals to become established. Thus, the bay becomes rich in algae (especially ulvoids and diatoms), eelgrass, benthic organisms, fish and birds. Dungeness Spit in Clallam County provides an example of this situation, with its extremely diverse habitats. The habitat diversity of the total system affords a synergistic value much greater than the sum of its parts, spits being a small but important aspect. With high diversity comes a seemingly unending array of wildlife: river otters and raccoons at the head of the bay formed inside the spit; Savannah Sparrows, and Song Sparrows along the beach grassland; Kingfishers, Great Blue Herons, Greater Yellowlegs, Western Sandpipers, Least Sandpipers, Black-bellied Plovers, Common Terns, Bonaparte's Gulls, Whimbrels, and several other shorebirds on the mudflats and near shore along the inner margin; White-winged Scoters, Common Loons, Red-breasted Mergansers, and Buffleheads in the bay; Rhinoceros Auklets, Red-throated Loons, Common Murres, Western Grebes, Bonaparte's Gulls, Heermann's Gulls, and harbor seals offshore along the outer margin.

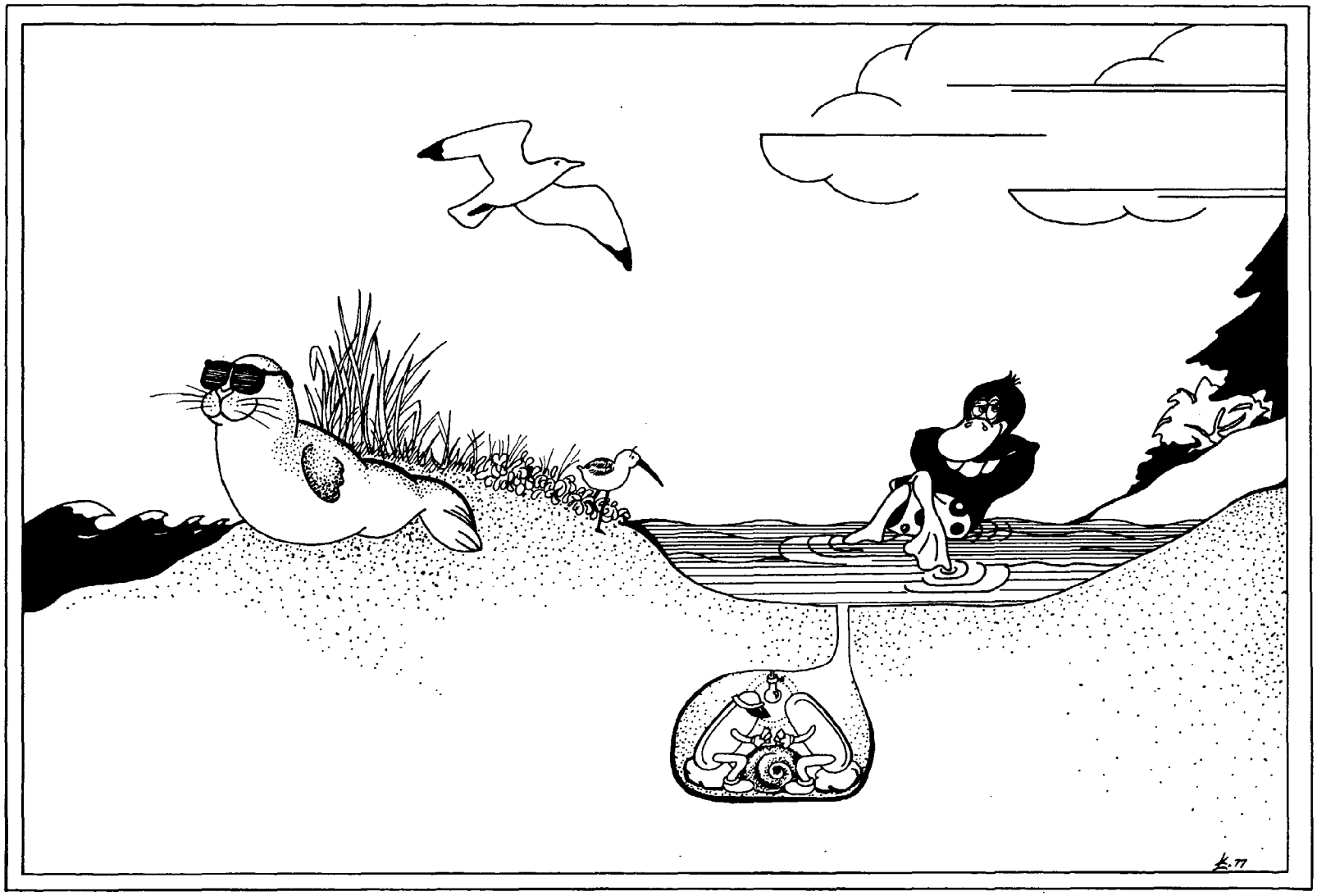
III. IMPACTS

Spits, formed as they are by wind, current, and wave action are inherently unstable and dynamic. Thus, any action that alters the equilibrim of accretion and erosion can generally be counted on to change the character of the spits themselves.

Man's activities can affect this equilibrium in a variety of ways. Coastal Zone Atlas users will want to refer to the Drift Sector discussions in the Atlas for details describing spit formation and disturbances. Bulkheads, highways, or railroads along the base of feeder bluffs will reduce the supply of sediments which originally formed and presently help maintain the spit. Dam construction also reduces the amount of materials available for maintenance. Without a constant supply of sediments, spits may deteriorate, which in turn affects the many dependent biological and physical features previously described. Groins, jetties, revetments, or piers along a beach can interfere with longshore drift, consequently affecting the supply of substrate material to dependent spits.

Careless logging and agricultural practices in adjacent habitats can increase river-borne sediments and thereby smother life in intertidal parts of spits. This increased sedimentation may also hasten the development of marshes in lagoon areas.

Construction in the vicinity of, and on spits can have numerous and far reaching effects on wildlife use. The immediate loss of vegetation and wildlife occurs at the construction site by direct covering of organisms. Adjacent areas are severely disturbed by construction equipment and roads. The loss of stabilizing vegetation can result in wind and water erosion of the spit itself. Sea walls and revetments intended to reverse this process result in additional wildlife losses in the intertidal regions of the spit.



An adjunct to construction on spits is the accompanying increase in human and pet activity. The loss of nesting Caspian Terns and gulls from Damon Point in Grays Harbor County apparently can be attributed to development at nearby Ocean Shores. Recreational activities and potential development on Protection Island in Jefferson County currently threatens nesting birds and harbor seals.

Recreational activities have the obvious impact of frightening (or, in some cases, destroying) wildlife in the vicinity, and if frequent enough, may result in their leaving permanently. This, in effect, is a virtual loss of habitat. A more insidious impact is the cumulative result of countless human feet treading on vegetation and substrate. This seemingly innocuous activity eventually can result in the disappearance of species intolerant of such abuse (e.g., most plant species in the beach grassland cover type), and the existence of dependent animals may be threatened, or at least negatively modified. Impacts can be moderated by avoidance of vegetated portions of spits and limiting access to spits with breeding bird colonies or otherwise sensitive areas.

BLUFF (No. 76)

Refer to the Forested Bluff Narrative (No. 47) for discussion of all bluff classifications.

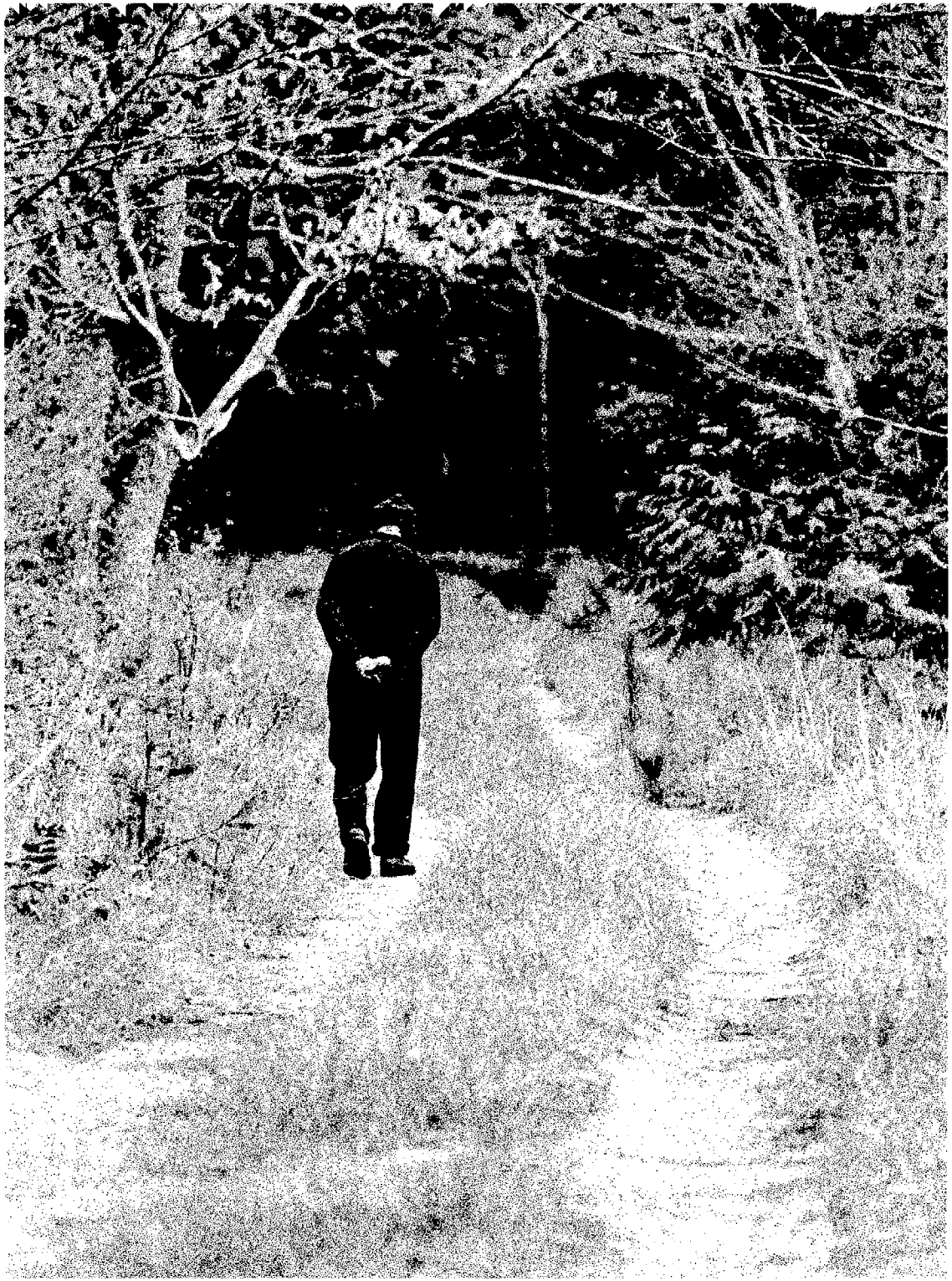
HENRY HALVORSON

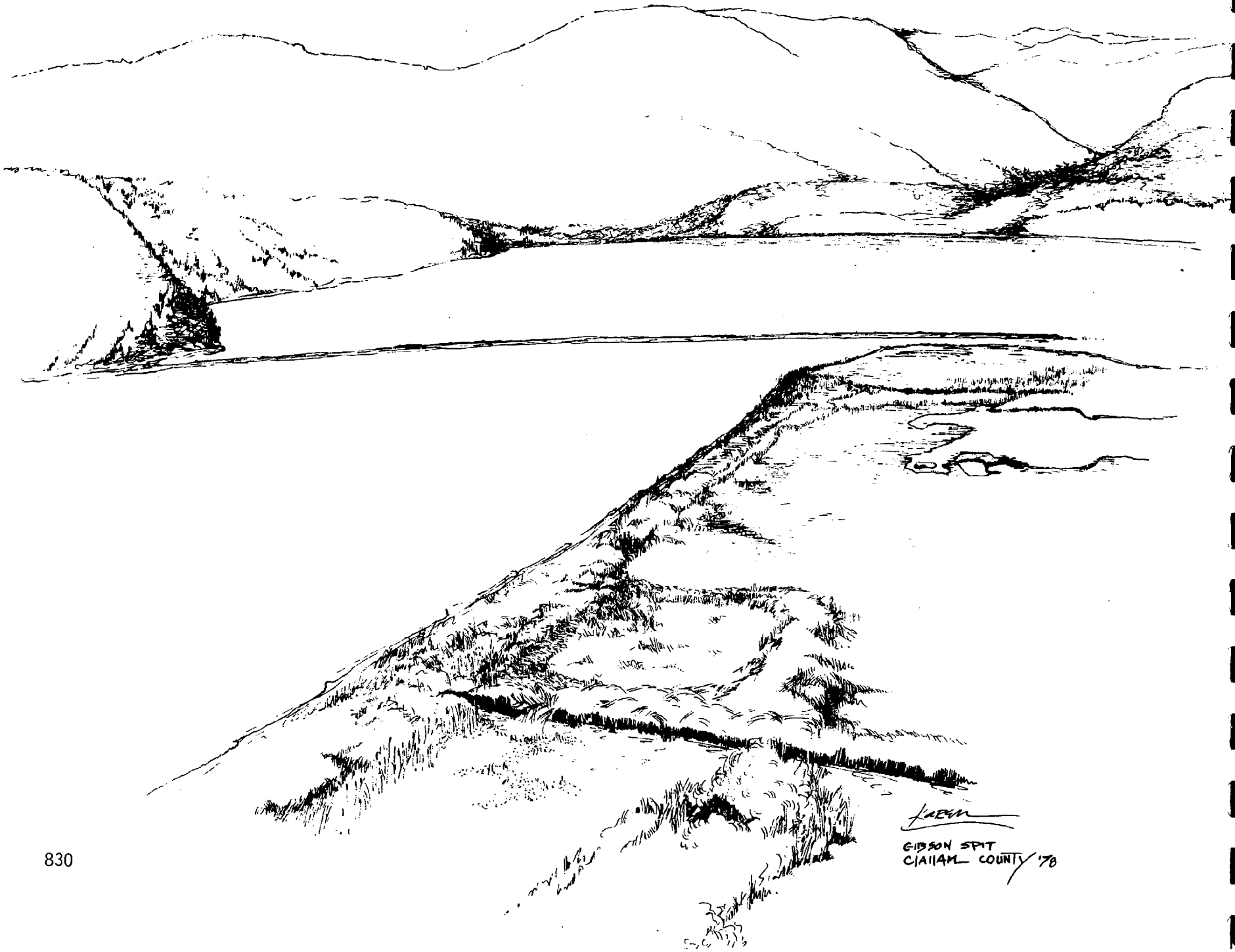
We had come to visit Thorndyke Bay and a part of our hello was as always, a talk with Henry. He had walked down from his cabin and sat with us along the beach. An osprey circled the bay and Henry sampled the oysters we cooked over an open fire. Behind us were woods older than me, almost as old as my dad. Henry had been here when this forest was cut, some of the trees for the first time. He'd worked in logging camps most of his 80 plus years of living along Hood Canal. He told us about that time in his second generation Swedish/American tongue.

Thousands and Thousands of salmon. Ducks darkening the sky. Trees cut high above the base to take only the best. The straight, clear grain of old growth. Black bears along the creek. Deer and deer hunting. Logging camp cooks. His eyes twinkling, hands clasped behind his back, Henry also told us about more recent days. It had been his birthday and friends surprised him with a party up the canal a mile or two at the Trails End Tavern. Somebody broke into his cabin while he was away and took his two best shirts. He looked across the bay and told us of how more people were moving in and that he'd heard that plans were underway to develop Thorndyke Bay. He said he didn't want to be around when that happened.

About one year later Henry got sick and a relative brought him to Port Townsend for medical attention. He left his old grey pickup, his cabin and his life on Thorndyke Bay. Away from Hood Canal, he died. I'd always thought that Henry's presence somehow protected Thorndyke, its salt marsh, and dependent animals. He'd been there when it was first touched by axes, roads and human interests. He saw it grow back a bit and for a long time he was the only year-round human resident on the bay. Now he's gone. I don't know about Thorndyke.

Ron Hirschi, May 1980




GIBSON SPIT
CLALLAM COUNTY '78

APPENDIX I

The following is a list of coastal plants presently under consideration for rare, threatened, or endangered status in Washington. None of these species currently enjoy official status, but as more information becomes available, many will surely be proposed for official listing by the U. S. Fish and Wildlife Service.

The habitats listed for each species are not exhaustive, and similar land cover types may also provide suitable habitat. For example, if freshwater swamp is listed, the possibility of the species occurring in other freshwater wetland habitats should not be excluded.

Information on these species is still being compiled by the Washington Natural Heritage Program, and Atlas users are encouraged to contact them for current information concerning reported locations and habitats.

FAMILY	LATIN NAME	COMMON NAME	HABITAT
Campanulaceae	Howellia aquatilis	Howellia	lakes and ponds
	Lobelia kalmii	brook lobelia	bogs, lakes, and ponds
Caryophyllaceae	Arenaria paludicola	swamp sandwort	swamps
Compositae	Lasthenia minor var. maritima	hairy lasthenia	rock islands and cliffs
Crassulaceae	Sedum lanceolatum var. nesioticum	lanceleaved stonecrop	rock islands and cliffs
	Tillaea erecta	pigmy weed	cliffs
Cyperaceae	Carex livida	pale sedge	bogs and swamps
	Carex pauciflora	few-flowered sedge	bogs
	Carex pluriflora	several-flowered sedge	freshwater and brackish marshes, riparian zones
	Carex stylosa	long-styled sedge	freshwater marshes
	Scirpus cyperinus var. brachypodus	wool-grass	freshwater wetlands
Fagaceae	Chrysolepis chrysophylla	golden chinquapin	forested uplands
Graminae	Agrostis aequivalvis	Alaska bentgrass	bogs, lakes, and ponds
	Calamagrostis crassiglumis	thickglume reedgrass	freshwater wetlands, riparian zones
	Poa pachypholis	seacliff bluegrass	cliffs
Hydrophyllaceae	Phacelia bolanderi	Bolander's phacelia	bluffs and cliffs
Juncaceae	Juncus supinus	bulbous rush	lakes and ponds
Leguminosae	Lupinus macrocarpus var. scopulorum	chick lupine	open grasslands
Liliaceae	Erythronium revolutum	coast fawn-lily	forested uplands
	Fritillaria camschatcensis	black lily	freshwater wetlands
Menyanthaceae	Nephrophyllidium crista-galli	deer-cabbage	lakes and ponds
Papaveraceae	Meconella oregana	meconella	grasslands and rock outcroppings
Plantaginaceae	Plantago macrocarpa	Alaska plantain	bogs, lakes, and ponds
Polypodiaceae	Woodwardia fimbriata	chain-fern	bluffs
Ranunculaceae	Anemone felix var. oregana	Oregon anemone	freshwater wetlands
	Coptis asplenifolia	spleenwort-leaved goldenthread	freshwater wetlands
	Delphinium nuttallii	Nuttall's larkspur	open grasslands and cliffs
Rosaceae	Sanguisorba menziesii	Menzie's burnet	bogs

APPENDIX II

Endangered and Threatened Birds and Mammals Known to Occur in Washington Coastal Zone (as listed by the United States Fish and Wildlife Service)

COMMON NAME	LATIN NAME	STATUS
Birds		
Short-tailed Albatross	Diomedea albatrus	Endangered
Bald Eagle	Haliaeetus leucocephalus	Threatened
Peregrine Falcon	Falco peregrinus anatum	Endangered
Aleutian Canada Goose	Branta canadensis leucopareia	Endangered
Brown Pelican	Pelicanus occidentalis	Endangered
Mammals		
Blue Whale	Balaenoptera musculus	Endangered
Fin Whale	B. physalus	Endangered
Sei Whale	B. borealis	Endangered
Gray Whale	Eschrichtius robustus	Endangered
Humpback Whale	Megaptera novaeangliae	Endangered
Right Whale	Balaena glacialis	Endangered
Sperm Whale	Physeter catodon	Endangered

APPENDIX III

Common and Latin names of plants mentioned in the text. Vascular plants, mosses, and freshwater algae are listed together in alphabetical order by common name; marine algae by common name under the appropriate phylum. Many species of fungi and algae lack common names and if referred to by Latin name in the text, they are not included here.

VASCULAR PLANTS and FRESHWATER ALGAE

arrow-grass	*Triglochin maritimum*
arrowhead	*Sagittaria* spp.
Aspidotis	*Aspidotis densa*
baldhip rose	*Rosa gymnocarpa*
Baltic rush	*Juncus balticus*
beach morning-glory	*Convolvulus soldanella*
beach pea	*Lathyrus littoralis*
beach peavine	*Lathyrus japonicus*
beach strawberry	*Fragaria chiloensis*
beakrush	*Rhynchospora alba*
beaked sedge	*Carex rostrata*
bighead sedge	*Carex macrocephala*
big-leaf maple	*Acer macrophyllum*
bishops-cap	*Mitella* spp.
bitter chokecerry	*Prunus emarginata*
blackberry	*Rubus* spp.
black cottonwood	*Populus trichocarpa*
black knotweed	*Polygonum paronychia*
black locust	*Robinia pseudo-acacia*
black twinberry	*Lonicera involucrata*
bleeding heart	*Dicentra formosa*
blister buttercup	*Ranunculus sceleratus*
blue-eyed Mary	*Collinsia parviflora*
blue wildrye	*Elymus glaucus*
bog birch	*Betula glandulosa*
bog cranberry	*Vaccinium oxycoccos*
bog laurel	*Kalmia occidentalis*
bog St. John's-wort	*Hypericum anagalloides*
Bolander's rush	*Juncus bolanderi*
bouncing bett	*Saponaria officinalis*

bracken	Pteridium aquilinum
brittle cactus	Opuntia fragilis
broad-bladed eelgrass	Zostera marina
broadfruited burreed	Sparganium eurycarpum
broadleaved shooting star	Dodecatheon hendersonii
broadleaf stonecap	Sedum spathulifolium
buckbean	Menyanthes trifoliata
California buttercup	Ranunculus californicus
California false hellebore	Veratrum californicum
California poppy	Eschscholzia californica
calypso	Calypso bulbosa
camas	Camassia spp.
Canada thistle	Cirsium arvense
cascara	Rhamnus purshiana
cat-tail	Typha latifolia
cheatgrass	Bromus tectorum
checker lily	Fritillaria lanceolata
chickweed monkey flower	Mimulus alsinoides
coast black gooseberry	Ribes divaricatum
coastline bluegrass	Poa confinis
common bladderwort	Utricularia spp.
common camas	Camassia quamash
common cattail	Typha latifolia
common dandelions	Taraxacum officinale
common forget-me-not	Myosotis scorpioides
common rush	Juncus effusus
common spike-rush	Eleocharis palustris
common velvet-grass	Holcus lanatus
coontail	Ceratophyllum demersum
coralroot	Corallorhiza spp.
cotton grass	Eriophorum chamissonis
cow parsnip	Heracleum lanatum
crabapple	Pyrus fusca
creeping bentgrass	Agrostis alba
creeping buttercup	Ranunculus repens
creeping velvet-grass	Holcus mollis
crowberry	Empetrum nigrum
daffodils	Narcissus sp.
dagger-leaf rush	Juncus ensifolius
dark-throat shooting star	Dodecatheon pulchellum
deadly zigandenus	Zygadenus venenosus

death camas	Zygadenus venenosus
deer fern	Blechnum spicant
Deptford pink	Dianthus armeria
devil's club	Oplopanax horridum
dogwood	Cornus spp.
Douglas' aster	Aster subspicatus
Douglas fir	Pseudotsuga menziesii
Douglas' water-hemlock	Cicuta douglasii
dulichium	Dulichium arundinaceum
dune tansy	Tanacetum douglasii
dune wildrye	Elymus mollis
dwarf owlclover	Orthocarpus pusillus
early blueberry	Vaccinium ovalifium
elderberry	Sambucus spp.
Elodea	Elodea canadensis
enchanter's nightshade	Circaea alpina
Enteromorpha	Enteromorpha spp.
Eriophyllum	Eriophyllum lanatum
European beachgrass	Ammophila arenaria
European eelgrass	Zostera noltii
evergreen huckleberry	Vaccinium ovatum
false lily-of-the-valley	Maianthemum dilatatum
fat-hen	Atriplex patula
felonwort	Solanum dulcamara
fescue	Festuca spp.
field chickweed	Cerastium arvense
filaree	Erodium cicutarium
fireweed	Epilobium angustifolium
foamflower	Tiarella trifoliata
foxglove	Digitalis purpurea
fragrant water lily	Nymphaea odorata
fringecup	Tellima grandiforum
Garry oak	Quercus garryana
giant fawn-lily	Erythronium oregonum
giant vetch	Vicia gigantea
Glehnia	Glehnia leiocarpa
gold-back fern	Pityrogramma triangularis
gorse	Ulex europaeus
graceful arrow-grass	Triglochin concinnum
grand fir	Abies grandis
Greene's bogorchid	Habenaria greenei

green sedge	Carex oederi
grindelia	Grindelia intergrifolia
gumweed	Grindelia intergrifolia
hairgrass	Aira spp.
hairy cats-ears	Hypochaeris radicata
hairy honeysuckle	Lonicera hispidula
hairy manzanita	Arctostaphylos columbiana
hardhack	Spiraea douglasii
hardstem bulrush	Scirpus acutus
hazelnut	Corylus cornuta
hemlock-parsley	Conioselinum pacificum
Himalayan blackberry	Rubus discolor
honeysuckle	Lonicera spp.
Hooker's onion	Allium acuminatum
Hooker's willow	Salix hookeriana
horned pondweed	Zanichellia palustris
huckleberry	Vaccinium spp.
humped bladderwort	Utricularia gibba
Idaho fescue	Festuca idahoensis
Kentucky bluegrass	Poa pratensis
kinnickinnick	Arctostaphylos uva-ursi
kneeling angelica	Angelica genuflexa
Labrador tea	Ledum groenlandicum
lady fern	Athyrium felix-femina
lanceleaved stonecrop	Sedum lanceolatum var. nesioticum
large flowered blue-eyed Mary	Collinsia grandiflora
Leichtlin's camas	Camassia leichtlinii
Lemmon's needlegrass	Stipa lemmonii
licorice fern	Polypodium glycirrhiza
lilaeopsis	Lilaeopsis occidentalis
Lindley's microseris	Microseris lindleyi
little hairgrass	Aira praecox
lodgepole pine	Pinus contorta
low clubrush	Scirpus cernuus
Lyngby's sedge	Carex lyngbyei
madrona	Arbutus menziesii
maidenhair spleenwort	Asplenium trichomanes
manroot	Marah oreganus
mare's tail	Hippuris vulgaris
marram grass	Ammophila arenaria

marsh skull-cap	Scutellaria galericulata
marsh yellowcress	Rorippa islandica
Meconella	Meconella oregana
Menzies' burnet	Sanguisorba menziesii
Menzies' larkspur	Delphinium menziesii
mistletoe	Phoradendron flavescens
morels	Morchella spp.
mother-of-thousands	Tolmiea menziesii
mountain balm	Ceanothus velutinus
myrtle boxwood	Pachistima myrsinites
naked broomrape	Orobanche uniflora
narrow-bladed eelgrass	Zostera noltii
nettles	Urtica dioica
ninebark	Physocarpus capitatus
nitella	Nitella sp.
nodding onion	Allium cernuum
Nootka rose	Rosa nutkana
northern dune tansy	Tanacetum douglasii
northern wormwood	Artemesia campestris
ocean spray	Holodiscus discolor
orange honeysuckle	Lonicera ciliosa
orchard grass	Dactylis glomerata
Oregon ash	Fraxinus latifolia
Oregon grape	Berberis nervosa
Oregon wood sorrel	Oxalis oregona
osoberry	Oemleria cerasiformis
Pacific blackberry	Rubus ursinus
Pacific dogwood	Cornus nuttallii
Pacific silverweed	Potentilla pacifica
Pacific willow	Salix lasiandra
paper birch	Betula papyrifera
parsley fern	Cryptogramma crispa
path finder	Adenocaulon bicolor
peppergrass	Lepidium virginicum var. menziesii
pickleweed	Salicornia virginica
pigmy-weed	Tillaea erecta
pine bluegrass	Poa scabrella
pink sand verbena	Abronia umbellata
poison oak	Rhus diversiloba
Pomo-celery lomatium	Lomatium utriculatum
pondweed	Potamageton spp.

purple cinquefoil	Potentilla palustris
quaking aspen	Populus tremuloides
rattlesnake plantain	Goodyera oblongifolia
red alder	Alnus rubra
red currant	Ribes sanguineum
red elderberry	Sambucus racemosa
red fescue	Festuca rubra
red huckleberry	Vaccinium parvifolium
red osier dogwood	Cornus stolonifera
reed canarygrass	Phalaris arundinacea
rein orchid	Habenaria spp.
rhododendron	Rhododendron macrophyllum
Rocky Mountain juniper	Juniperus scopulorum
rosy plectritis	Plectritis congesta
rush	Juncus spp.
salal	Gaultheria shallon
salmonberry	Rubus spectabilis
salt grass	Distichlis spicata
sand-dune sedge	Carex pansa
sandmat	Cardionema ramosissima
sand verbena	Abronia spp.
sawbeak sedge	Carex stipitata
saxifrage	Saxifraga integrifolia
scalepod	Idahoa scapigera
Scot's broom	Cytisus scoparius
scouler willow	Salix scouleri
seacliff bluegrass	Poa pachypholis
seacoast bulrush	Scirpus maritimus
sea-pink	Armeria maritima
sea purslane	Honkenya peploides
sea rocket	Cakile edentula
seashore bluegrass	Poa macrantha
seashore lupine	Lupinus littoralis
seashore salt grass	Distichlis spicata
seaside amsinckia	Amsinckia spectabilis
seaside arrow-grass	Triglochin maritimum
seaside bulrush	Scirpus maritimus
seaside buttercup	Ranunculus cymbalaria
seaside tansy	Tanacetum douglasii
sea thrift	Armeria maritima
selaginella	Selaginella wallacei

serviceberry	Amelanchier spp.
sheep sorrel	Rumex acetosella
shooting star	Dodecatheon spp.
shore buttercup	Ranunculus cymbalaria
shore pine	Pinus contorta
silver bursage	Ambrosia chamissonis
silver hairgrass	Aira caryophyllea
simplestem burreed	Sparganium emersum
Sitka sedge	Carex sitchensis
Sitka spruce	Picea sitchensis
Sitka valerian	Valeriana scouleri
skunk cabbage	Lysichitum americanum
slender boykinia	Boykinia major
slough sedge	Carex obnupta
small-flowered blue-eyed Mary	Collinsia parviflora
smallflowered fringecup	Lithophragma parviflora
smallflowered prairiestar	Lithophragma parviflora
smallflowered woodrush	Luzula parviflora
small-fruited bulrush	Scirpus microcarpus
small-leaf alumroot	Heuchera micrantha
small spike-rush	Eleocharis parvula
snowberry	Symphoricarpos albus
soft brome	Bromus mollis
soft rush	Juncus effusus
softstem bulrush	Scirpus validus
spatterdock	Nuphar polysepalum
speedwell	Veronica spp.
sphagnum	Sphagnum spp.
spiked water milfoil	Myriophyllum spicatum
spirea	Spirea douglasii
spoonwort	Cochlearia officinalis
spotted coralroot	Corallorhiza maculata
spreading rush	Juncus spiniformis
spring-gold	Crocidium multicaule
starflower	Trientalis latifolia
star-flowered Solomon's Seal	Smilacina stellata
stinging nettle	Urtica dioica
stink currant	Ribes bracteosum
stonecrop	Sedum spp.
stonewort	Chara spp.
sundew	Drosera rotundifolia

surfgrass	Phyllospadix spp.
swamp gooseberry	Ribes lacustre
swamp sandwort	Arenaria paludicola
sweet gale	Myrica gale
sword fern	Polystichum munitum
tall peppergrass	Lepidium virginicum var. menziesii
tapered rush	Juncus acuminatus
thimbleberry	Rubus parviflorus
thistles	Cirsium spp.
threadleaf phacelia	Phacelia linearis
thrift	Armeria maritima
tiny mousetail	Myosurus minimus
tomcat clover	Trifolium tridentatum
touch-me-not	Impatiens noli-tangere
Townsend's cordgrass	Spartina townsendii
trailing blackberry	Rubus ursinus
trembling aspen	Populus tremuloides
trillium	Trillium ovatum
twinberry	Lonicera involucrata
twinflower	Linnaea borealis
vanilla leaf	Achlys triphylla
velvet-grass	Holcus spp.
vine maple	Acer circinatum
Wallace's selaginella	Selaginella wallacei
watercress	Rorippa nasturtium-aquaticum
water fern	Azolla mexicana
water lentil	Lemna minor
water parsley	Oenanthe sarmentosa
water shield	Brasenia schreberi
water starwort	Callitriche spp.
water weed	Elodaea canadensis
wavy water-nymph	Najas flexilis
waxmyrtle	Myrica spp.
weeping alkaligrass	Puccinellia distans
western blue flag	Iris missouriensis
western dock	Rumex occidentalis
western hemlock	Tsuga heterophylla
western red cedar	Thuja plicata
western springbeauty	Montia sibirica
western white pine	Pinus monticola
Wigeon grass	Ruppia maritima

wildcherry	Prunus sp.
willow	Salix spp.
wood groundsel	Senecio sylvaticus
yarrow	Achillea millefolium
yellow flag	Iris pseudacorus
yellow sand verbena	Abronia latifolia
yerba buena	Satureja douglasii
yew	Taxus brevifolia

MARINE ALGAE

Brown Algae (Phaeophyta)

bull kelp	Nereocystis leutkeana
bladder kelp	Cystoseira geminata
blister wrack	Laminaria bullata
color changer	Desmarestia ligulata
feather boa	Egregia menziesii
giant kelp	Macrocystis integrifolia
honey ware kelp	Alaria marginata
kombu	Laminaria spp.
pompom kelp	Pterygophora californica
Rockweed	Fucus distichus
Sargassum	Sargassum muticum
sea cabbage	Hedophyllum sessile
sea colander	Agarum spp.
sea palm	Postelsia palmaeformis
seersucker	Costaria costata
split whip wrack	Laminaria setchellii
sugar wrack	Laminaria saccharina
tar spot	Ralphsia pacifica
whip tube	Scytosiphon lomentaria

Green Algae (Chlorophyta)

Enteromorpha	Enteromorpha spp.
green rope	Acrosiphonia (Spongomorpha) coalita
sea lettuce	Ulva spp.

Red Algae (Rhodophyta)

black pine	*Rhodomela larix*
iridescent seaweed	*Iridaea cordata*
nori	*Porphyra* spp.
ogo	*Neoagardhiella baileyi*
red laver, purple laver, nori	*Porphyra perforata*
tar spot	*Petrocelis meddendorffii*
tidal pool coral	*Corallina vancouveriensis*
turkish towel	*Gigartina exasperata*

Yellow-Green Algae (Chrysophyta)

diatoms	many species of microscopic algae including: *Asterionella* spp. *Coscinodiscus* spp. *Skeletonema* spp. *Navicula* spp. *Melosira* spp.

APPENDIX IV

Common and Latin names of vertebrates mentioned in the text.

FISH

American shad	Alosa sapidissima
Arrow goby	Clevelandia ios
Bay pipefish	Syngnathus griseolineatus
Black bullhead	Ictalurus melas
Black crappie	Pomoxis nigromaculatus
Blackeye goby	Coryphopterus nicholsi
Black prickleback	Xiphister atropurpureus
Black rockfish	Sebastes melanops
Brook trout	Salvelinus fontinalis
Brown bullhead	Ictalurus nebulosis
Buffalo sculpin	Enophrys bison
Cabezon	Scorpaenichthys marmoratus
Canary rockfish	Sebastes pinniger
Carp	Cyprinus carpio
China rockfish	Sebastes nebulosus
Chinook salmon	Oncorhynchus tshawytscha
Chum salmon	Oncorhynchus keta
C-O sole	Pleuronichthys coenosus
Coastrange sculpin	Cottus aleuticus
Coho salmon	Oncorhynchus kisutch
Copper rockfish	Sebastes caurinus
Crescent gunnel	Pholis laeta
Cutthroat trout	Salmo clarki
Decorated warbonnet	Chirolophis polyactocephalus
Deepsea skate	Raja abyssicola
Dolly varden	Salvelinus malma
English sole	Parophrys vetulus
Eulachon (candlefish)	Thaleichthys pacificus
Goldfish	Carassius auratus
Great sculpin	Myoxocephalus polyacanthocephalus
Grunt sculpin	Rhamphocottus richardsoni
High cockscomb	Anoplarchus purpurescens
Kelp greenling	Hexagrammos decagrammus
Largemouth bass	Micropterus salmoides

Largescale sucker	Catostomus macrocheilus
Lingcod	Ophiodon elongatus
Longfin sculpin	Jordania zonope
Longfish smelt	Spirinchus thaleichthys
Longnose dace	Rhinichthys cataractae
Longnose sucker	Catostomus catostomus
Manacled sculpin	Synchirus gilli
Mosshead warbonnet	Chirolophis nugator
Northern anchovy	Engraulis mordax
Northern clingfish	Gobiesox maeandricus
Northern sculpin	Icelinus borealis
Northern spearnose poacher	Agonopsis emmelane
Northern squawfish	Ptychocheilus oregonensis
Olympic mudminnow	Novumbra hubbsi
Pacific cod	Gadus macrocephalus
Pacific herring	Clupea harengus pallasi
Pacific sanddab	Citharichthys sordidus
Pacific sand lance	Ammodytes hexapterus
Pacific spiny lumpsucker	Eumicrotremus orbis
Pacific staghorn sculpin	Leptocottus armatus
Pacific tomcod	Microgadus proximus
Padded sculpin	Artedius fenestralis
Painted greenling	Oxylebius pictus
Peamouth	Mylocheilus caurinus
Penpoint gunnel	Apodichthys flavidus
Pile perch	Rhacochilus vacca
Pink salmon	Oncorhynchus gorbuscha
Plainfin midshipman	Porichthys notatus
Prickly sculpin	Cottus asper
Puget Sound rockfish	Sebastes emphaeus
Puget Sound sculpin	Artedius meanyi
Pygmy poacher	Odontopyxis trispinosa
Quillback rockfish	Sebastes maliger
Rainbow trout	Salmo gairdneri
Ratfish	Hydrolagus colliei
Red Irish lord	Hemilepidotus hemilepidotus
Redside shiner	Richardsonius balteatus
Redstripe rockfish	Sebastes proriger
Redtail surfperch	Amphistichus rhodorus
Ribbon prickleback	Phytichthys chirus
Ringtail snailfish	Liparis rutleri

River lamprey	Lampetra ayresi
Rock sole	Lepidopsetta bilineata
Rockweed gunnel	Xererpes fucorum
Roughback sculpin	Chitonotus pugetensis
Saddleback gunnel	Pholis ornata
Saddleback sculpin	Oligocottus rimensis
Sailfin sculpin	Nautichthys oculofasciatus
Sand sole	Psettichthys melanostictus
Scalyhead sculpin	Artedius harringtoni
Sharpnose sculpin	Clinocottus acuticeps
Shiner perch	Cymatogaster aggregata
Shorthead sculpin	Cottus confusus
Showy snailfish	Liparis pulchellus
Silvergrey rockfish	Sebastes brevispinus
Silverspotted sculpin	Blepsias cirrhosus
Slender sole	Lyopsetta exilis
Slipskin snailfish	Liparis fucensis
Snake prickleback	Lumpenus sagitta
Smooth alligatorfish	Annoplagonus inermis
Sockeye salmon	Oncorhynchus nerka
Soft sculpin	Gilbertidia sigalutes
Speckled dace	Rhinichthys osculus
Speckled sanddab	Citharichthys stigmaeus
Spiny dogfish	Squalus acanthias
Spinynose sculpin	Asemichthys taylori
Starry flounder	Platichthys stellatus
Starry skate	Raja stellulata
Striped bass	Roccus saxatilis
Striped seaperch	Embiotoca lateralis
Sturgeon poacher	Agonus acipenserinus
Surf smelt	Hypomesus pretiosus
Tadpole sculpin	Psychrolutes paradoxus
Threespine stickleback	Gasterosteus aculeatus
Tidepool sculpin	Oligocottus maculosus
Tiger rockfish	Sebastes nigrocinctus
Torrent sculpin	Cottus rhotheus
Tube-snout	Aulorhynchus flavidus
Vermilion rockfish	Sebastes miniatus
Walleye pollock	Theregra chalcogramma
Western brook lamprey	Lampetra richardsoni
White spotted greenling	Hexagrammos stelleri

White sturgeon	Acipenser transmontanus
Wolf-eel	Anarrhichthys ocellatus
Yellow perch	Perca flavescens
Yellow rockfish	Sebastes flavidus

AMPHIBIANS

Northwestern salamander	Ambystoma gracile gracile
Bullfrog	Rana catesbeiana
Cascades frog	Rana cascadae
Dunn's salamander	Pethodon dunni
Green frog	Rana clamitans
Long-toed salamander	Ambystoma macrodactylum
Northern Olympic salamander	Rhyacotriton olympicus olympicus
Northern red-legged frog	Rana aurora aurora
Northern rough skinned newt	Taricha granulosa granulosa
Oregon salamander	Ensatina eschscholtzi oregonensis
Pacific giant salamander	Dicamptodon ensatus
Pacific tree frog	Hyla regilla
Spotted frog	Rana pretiosa
Tailed frog	Ascaphus truei
Van Dyke's salamander	Pethodon vandykei
Western red-backed salamander	Plethodon vehiculum
Western toad	Bufo boreas

REPTILES

Common garter snake	Thamnophis sirtalis
Northern alligator lizard	Gerrhonotus coeruleus principus
Northwestern garter snake	Thamnophis ordinoides
Pacific gopher snake	Pituophis melanoleucus catenifer
Painted turtle	Chrysemys picta
Rubber boa	Charina bottae
Sharp-tailed snake	Contia tenuis
Western fence lizard	Sceloporus occidentalis
Western pond turtle	Clemmys marmorata
Western terrestrial garter snake	Thamnophis elegans
Western yellow-bellied racer	Coluber constrictor mormon

BIRDS

American Bittern	Botaurus lentiginosus
American Coot	Fulica americana
American Golden Plover	Pluvialis dominica
American Goldfinch	Spinus tristis
American Kestrel	Falco sparverius
American Robin	Turdus migratorius
American Wigeon	Anas americana
Ancient Murrelet	Synthliboramphus antiquus
Anna's Hummingbird	Calypte anna
Arctic Loon	Gavia arctica
Arctic Tern	Sterna paradisaea
Baird's Sandpiper	Calidris bairdii
Bald Eagle	Haliaeetus leucocephalus
Band-tailed Pigeon	Columba fasciata
Barn Owl	Tyto alba
Barn Swallow	Hirundo rustica
Barrow's Goldeneye	Bucephala islandica
Belted Kingfisher	Megaceryle alcyon
Bewick's Wren	Thryomanes bewickii
Black-bellied Plover	Pluvialis squatarola
Black-capped Chickadee	Parus atricapillus
Black-headed Grosbeak	Pheucticus melanocephalus
Black-legged Kittiwake	Rissa tridactyla
Black Oystercatcher	Haematopus bachmani
Black Scoter	Melanitta nigra
Black Swift	Cypseloides niger
Black-throated Gray Warbler	Dendroica nigrescens
Black Turnstone	Arenaria melanocephala
Blue Grouse	Dendragapus obscurus
Blue-winged Teal	Anas discors
Bobwhite	Colinus virginianus
Bohemian Waxwing	Bombycilla garrulus
Bonaparte's Gull	Larus philadelphia
Brant	Branta bernicla
Brandt's Cormorant	Phalacrocorax penicillatus
Brewer's Blackbird	Euphagus cyanocephalus
Brown Creeper	Certhia familiaris
Brown-headed Cowbird	Molothrus ater
Brown Pelican	Pelecanus occidentalis

Bufflehead	Bucephala albeola
Burrowing Owl	Speotyto cunicularia
Bushtit	Psaltriparus minimus
California Gull	Larus californicus
California Quail	Lophortyx californicus
Canada Goose	Branta canadensis
Canvasback	Aythya valisineria
Caspian Tern	Hydroprogne caspia
Cassin's Auklet	Ptychoramphus aleuticus
Cassin's Finch	Carpodacus cassinii
Cedar Waxwing	Bombycilla cedrorum
Chestnut-backed Chickadee	Parus rufescens
Chipping Sparrow	Spizella passerina
Chukar	Alectoris chukar
Cinnamon Teal	Anas cyanoptera
Cliff Swallow	Petrochelidon pyrrhonota
Common Crow	Corvus brachyrhynchos
Common Flicker	Colaptes auratus
Common Goldeneye	Bucephala clangula
Common Loon	Gavia immer
Common Merganser	Mergus merganser
Common Murre	Uria aalge
Common Nighthawk	Chordeiles minor
Common Raven	Corvus corax
Common Snipe	Capella gallinago
Common Tern	Sterna hirundo
Common Yellowthroat	Geothlypis trichas
Cooper's Hawk	Accipiter cooperii
Dark-eyed Junco	Junco hyemalis
Dipper	Cinclus mexicanus
Double-crested Cormorant	Phalacrocorax auritus
Downy Woodpecker	Dendrocopos pubescens
Dunlin	Calidris alpina
Dusky Flycatcher	Epidonax oberholseri
Eared Grebe	Podiceps nigricollis
European Wigeon	Anas penelope
Evening Grosbeak	Hesperiaphona vespertina
Ferruginous Hawk	Buteo regalis
Fork-tailed Storm Petrel	Oceanodroma furcata
Fox Sparrow	Passerella iliaca
Gadwall	Anas strepera

Gray Partridge	Perdix perdix
Great Blue Heron	Ardea herodias
Great Egret	Casmerodius albus
Great Horned Owl	Bubo virginianus
Greater Scaup	Aythya marila
Greater Yellowlegs	Tringa melanoleuca
Green Heron	Butorides virescens
Green-winged Teal	Anas crecca
Golden-crowned Kinglet	Regulus satrapa
Golden-crowned Sparrow	Zonotrichia atricapilla
Golden Eagle	Aquila chrysaetos
Goshawk	Accipiter gentilis
Glaucous Gull	Larus hyperboreus
Glaucous-winged Gull	Larus glaucescens
Hairy Woodpecker	Dendrocopos villosus
Hammond's Flycatcher	Empidonax hammondii
Harlequin Duck	Histrionicus histrionicus
Heermann's Gull	Larus heermanni
Hermit Thrush	Catharus guttatus
Hermit Warbler	Dendroica occidentalis
Herring Gull	Larus argentatus
Hooded Merganser	Lophodytes cucullatus
Horned Grebe	Podiceps auritus
Horned Lark	Eremophila alpestris
Horned Puffin	Fratercula corniculata
House Finch	Carpodacus mexicanus
House Sparrow	Passer domesticus
House Wren	Troglodytes aedon
Hutton's Vireo	Vireo huttoni
Killdeer	Charadrius vociferus
Least Sandpiper	Calidris minutilla
Lesser Scaup	Aythya affinis
Lesser Yellowlegs	Tringa flavipes
Lewis' Woodpecker	Asyndesmus lewis
Lincoln's Sparrow	Melospiza lincolnii
Loggerhead Shrike	Lanius ludovicianus
Long-billed Dowitcher	Limnodromus scolopaceus
Long-billed Marsh Wren	Telmatodytes palustris
MacGillivray's Warbler	Oporornis tolmiei
Mallard	Anas platyrhynchos
Marbled Godwit	Limosa fedoa

Marbled Murrelet	Brachyramphus marmoratus
Marsh Hawk	Circus cyaneus
Merlin	Falco columbarius
Mew Gull	Larus canus
Mountain Quail	Oreortyx pictus
Mourning Dove	Zenaida macroura
Nashville Warbler	Vermivora ruficapilla
Northern Fulmar	Fulmarus glacialis
Northern Oriole	Icterus galbula
Northern Phalarope	Lobipes lobatus
Northern Shoveler	Anas clypeata
Northern Skrike	Lanius excubitor
Oldsquaw	Clangula hyemalis
Olive-sided Flycatcher	Nuttallornis borealis
Orange-crowned Warbler	Vermivora celata
Osprey	Pandion haliaetus
Parasitic Jaeger	Stercorarius parasiticus
Pied-billed Grebe	Podilymbus podiceps
Pigeon Guillemot	Cepphus columba
Pileated Woodpecker	Dryocopus pileatus
Pine Grosbeak	Pinicola enucleator
Pine Siskin	Spinus pinus
Pintail	Anas acuta
Pectoral Sandpiper	Calidris melanotos
Pelagic Cormorant	Phalacrocorax pelagicus
Peregrine Falcon	Falco peregrinus
Pomarine Jaeger	Stercorarius pomarinus
Prairie Falcon	Falco mexicanus
Purple Finch	Carpodacus purpureus
Purple Martin	Progne subis
Pygmy Owl	Glaucidium gnoma
Red-breasted Merganser	Mergus serrator
Red-breasted Nuthatch	Sitta canadensis
Red-breasted Sapsucker	Sphyrapicus ruber
Red Crossbill	Loxia curvirostra
Red-eyed Vireo	Vireo olivaceus
Redhead	Aythya americana
Red Knot	Calidris canutus
Red-legged Kittiwake	Rissa brevirostris
Red-necked Grebe	Podiceps grisegena
Red Phalarope	Phalaropus fulicarius

Red-tailed Hawk	Buteo jamaicensis
Red-throated Loon	Gavia stellata
Red-winged Blackbird	Agelaius phoeniceus
Rhinoceros Auklet	Cerorhinca monocerata
Ring-billed Gull	Larus delawarensis
Ring-necked Duck	Aythya collaris
Ring-necked Pheasant	Phasianus colchicus
Rock Dove	Columba livia
Rock Sandpiper	Calidris ptilocnemis
Rock Wren	Salpinctes obsoletus
Rough-legged Hawk	Buteo lagopus
Rough-winged Swallow	Stelgidopteryx ruficollis
Ruby-crowned Kinglet	Regulus calendula
Ruddy Duck	Oxyura jamaicensis
Ruddy Turnstone	Arenaria interpres
Ruff	Philomachus pugnax
Ruffed Grouse	Bonasa umbellus
Rufous Hummingbird	Selasphorus rufus
Rufous-sided Towhee	Pipilo erythrophthalmus
Sabine's Gull	Xema sabini
Sage Thrasher	Oreoscoptes montanus
Sanderling	Calidris alba
Sandhill Crane	Grus canadensis
Savannah Sparrow	Passerculus sandwichensis
Saw-whet Owl	Aegolius acadicus
Screech Owl	Otus asio
Semipalmated Plover	Charadrius semipalmatus
Semipalmated Sandpiper	Calidris pusilla
Sharp-shinned Hawk	Accipiter striatus
Short-billed Dowitcher	Limnodromus griseus
Short-eared Owl	Asio flammeus
Short-tailed Albatross	Diomedea albatrus
Skua	Catharacta skua
Skylark	Alauda arvensis
Snow Bunting	Plectrophenax nivalis
Snow Goose	Chen caerulescens
Snowy Owl	Nyctea scandiaca
Snowy Plover	Charadrius alexandrinus
Solitary Vireo	Vireo solitarius
Song Sparrow	Melospiza melodia
Sooty Shearwater	Puffinus griseus

Sora	Porzana carolina
Spotted Owl	Strix occidentalis
Spotted Sandpiper	Actitis macularia
Surfbird	Aphriza virgata
Surf Scoter	Melanitta perspicillata
Starling	Sturnus vulgaris
Steller's Jay	Cyanocitta stelleri
Swainson's Hawk	Buteo swainsoni
Swainson's Thrush	Catharus ustulatus
Thayer's Gull	Larus thayeri
Townsend's Solitaire	Myadestes townsendi
Townsend's Warbler	Dendroica townsendi
Tree Swallow	Iridoprocne bicolor
Trumpeter Swan	Olor buccinator
Tufted Puffin	Lunda cirrhata
Turkey	Meleagris gallopavo
Turkey Vulture	Cathartes aura
Varied Thrush	Ixoreus naevius
Vaux's Swift	Chaetura vauxi
Vesper Sparrow	Pooecetes gramineus
Violet-green Swallow	Tachycineta thalassina
Virginia Rail	Rallus limicola
Wandering Tattler	Heteroscelus incanus
Warbling Vireo	Vireo gilvus
Water Pipit	Anthus spinoletta
Western Bluebird	Sialia mexicana
Western Flycatcher	Empidonax difficilis
Western Grebe	Aechmophorus occidentalis
Western Gull	Larus occidentalis
Western Meadowlark	Sturnella neglecta
Western Sandpiper	Calidris mauri
Western Tanager	Piranga ludoviciana
Western Wood Pewee	Contopus sordidulus
Whimbrel	Numenius phaeopus
Whistling Swan	Olor columbianus
White-breasted Nuthatch	Sitta carolinensis
White-crowned Sparrow	Zonotrichia leucophrys
White-fronted Goose	Anser albifrons
White-throated Sparrow	Zonotrichia albicollis
White-winged Scoter	Melanitta fusca
Willet	Catoptrophorus semipalmatus

Willow Flycatcher	*Empidonax traillii*
Wilson's Phalarope	*Steganopus tricolor*
Wilson's Warbler	*Wilsonia pusilla*
Winter Wren	*Troglodytes troglodytes*
Wood Duck	*Aix sponsa*
Yellow-billed Loon	*Gavia adamsii*
Yellow-rumped Warbler	*Dendroica coronata*
Yellow Warbler	*Dendroica petechia*

MAMMALS

Beaver	*Castor canadensis*
Big brown bat	*Eptesicus fuscus*
Black bear	*Ursus americanus*
Black rat	*Rattus rattus*
Black-tailed deer	*Odocoileus hemionus*
Blue whale	*Balaenoptera musculus*
Bobcat	*Felis rufus*
Bushy-tailed woodrat	*Neotoma cinerea*
California myotis	*Myotis californicus*
California sea lion	*Zalophus californianus*
Coast mole	*Scapanus orarius*
Cougar	*Felis concolor*
Coyote	*Canis latrans*
Creeping vole	*Microtus oregoni*
Dall's porpoise	*Phocoenoides dallii*
Deer mouse	*Peromyscus maniculatus*
Douglas squirrel	*Tamiasciurus douglasii*
Dusky shrew	*Sorex obscurus*
Eastern cottontail	*Sylvilagus floridanus*
Elk	*Cervus elaphus*
Ermine	*Mustela erminea*
European rabbit	*Oryctolagus cuniculus*
False killer whale	*Pseudorea crassidens*
Fin whale	*Balaenoptera physalus*
Fisher	*Martes pennanti*
Fox squirrel	*Sciurus niger*
Gapper red-backed mouse	*Clethrionomys gapperi*
Goosebeak whale	*Ziphius cavirostris*
Gray squirrel	*Sciurus carolinensis*

Gray whale	Eschrichtius robustus
Gray wolf	Canis lupus
Harbor porpoise	Phocoena phocoena
Harbor seal	Phoca vitulina
Hoary bat	Lasiurus cinereus
House mouse	Mus musculus
Humpback whale	Megaptera novaeangliae
Killer whale	Orcinus orca
Little brown myotis	Myotis lucifugus
Long-eared myotis	Myotis evotis
Long-legged myotis	Myotis volans
Long-tailed weasel	Mustela frenata
Marten	Martes americana
Masked shrew	Sorex cinereus
Mink	Mustela vison
Minke whale	Balaenoptera acutorostrata
Moore's beaked whale	Mesoplodon carlhubbsii
Mountain beaver	Aplodontia rufa
Muskrat	Ondatra zibethica
Northern elephant seal	Mirounga angustirostris
Northern flying squirrel	Glaucomys sabrinus
Northern fur seal	Callorhinus ursinus
Northern right-whale dolphin	Lissodelphis borealis
Northern sea lion	Eumetopias jubata
North Pacific beaked whale	Mesoplodon stejnegeri
North Pacific giant bottlenose whale	Berardias bairdi
Norway rat	Rattus norvegicus
Pacific jumping mouse	Zapus trinotatus
Pacific water shrew	Sorex bendirii
Pacific white-side dolphin	Lagenorhynchus obliquidens
Pallid bat	Antrozous pallidus
Porcupine	Erethizon dorsatum
Pygmy sperm whale	Kogia breviceps
Raccoon	Procyon lotor
Red fox	Vulpes vulpes
Red squirrel	Tamiasciurus hudsonicus
Right whale	Eubalaena glacialis
River otter	Lutra canadensis
Saddleback dolphin	Delphinus delphis
Sea otter	Enhydra lutris
Sei whale	Balaenoptera borealis

Shortfin pilot whale	*Globicephala macrorhynchus*
Short-tailed weasel	*Mustela erminea*
Shrew-mole	*Neurotrichus gibbsii*
Silver-haired bat	*Lasionycteris noctivagans*
Snowshoe hare	*Lepus americanus*
Sperm whale	*Physeter catodon*
Striped porpoise	*Stenella coeruleoalba*
Striped skunk	*Mephitis mephitis*
Townsend's big-eared bat	*Plecotus townsendii*
Townsend's chipmunk	*Eutamias townsendii*
Townsend's mole	*Scapanus townsendii*
Townsend's vole	*Microtus townsendii*
Trowbridge's shrew	*Sorex trowbridgii*
Vagrant shrew	*Sorex vagrans*
Western gray squirrel	*Sciurus griseus*
Western red-backed vole	*Clethrionomys occidentalis*
Western spotted skunk	*Spilogale gracilis*
Whitehead grampus	*Grampus griseus*
Yuma myotis	*Myotis yumanensis*

- GLOSSARY -

accipiter • A hawk in the family Accipitridae (e.g., sharp-shinned and Cooper's Hawks, and Goshawks).

accretion • The process of matter building up along the shoreline or river banks.

abyssal zone • Refers to the deepest areas of the ocean extending from 3,000 to 4,000 meters below the water's surfce to the ocean bottom.

aerobic • Organisms thriving only in the presence of free oxygen.

amphibian • Organisms adapted for life either on land or in water, e.g., frogs, salamanders, newts.

anadromous • Oceanic or estuarine species that spawn in fresh water.

anaerobic • Organisms capable of living in absence of free oxygen.

annual • Plant that lives for only one year.

anoxic • Lacking or containing extremely low amounts of oxygen.

aphotic zone • Ocean waters which are so deep they receive no light at all.

aquaculture • The growth of aquatic organisms (freshwater or marine) under controlled conditions.

assimilation • Conversion into protoplasm of ingested and digested nutrient material.

autotrophic • Plants which make their own food by photosynthesis; they form carbohydrates and proteins from carbon dioxide and inorganic compounds.

bathypelagic zone • Deep ocean waters in the aphotic zone, from around 1,000 meters to 3,000 or 4,000 meters below the water's surface.

benthic • Organisms living on the bottom of lakes or marine waters.

benthos • The aquatic community of bottom-dwelling life.

berm • A ledge of mud, sand, or gravel deposited just above normal high water by wave action.

biocide • Collective term for herbicides and pesticides; used to identify those substances introduced into the environment which are harmful to many organisms in addition to those which they are meant to control or destroy.

biogeography • The part of biology dealing with the geographical distribution of plants and animals.

biomass • The living matter in a given space.

brackish • Fresh water mixed with salt water.

broadleaf trees • A general term used to distinguish large-leaved from needle-leaved trees; e.g., red alder, bigleaf maple, black cottonwood, madrona.

bulkhead • An embankment for holding back water.

canopy • Topmost layer of leaves, twigs, and branches of forest trees, or of other woody plants.

carnivore • Organisms which eat flesh of animals; secondary consumers.

carrion • The decaying flesh of a dead body.

carrying capacity • The limit to the amount of life, in numbers or mass, that can be supported by any given habitat. (In another context, used to express reasonable limits of human use of a resource.)

channelization • To direct streamflow in man-made channels.

clay • A firm, but moldable, fine-grained earth.

climax • The mature or stabilized stage in a successional series of communities, when dominant species are completely adapted to environmental conditions.

clonal • Asexual reproduction of plants by root sprouting.

colonization • Establishment of species on a given area.

community • Any group of populations of plants and animals living in a given area or physical habitat.

competition • This occurs when a number of organisms of the same or of different species use common resources that are in short supply.

coniferous • Any cone-bearing trees or shrubs which are mostly evergreens, e.g., Douglas fir, cedar, spruce.

consumer • Organisms which ingest other organisms or particulate organic matter.

consumptive use • In reference to wildlife, consumptive uses are those in which fish, waterfowl, or other animals are harvested. A broader definition includes harvest of mushrooms, blackberries, and other wild plants.

cover (type) • Land cover in a particular area, generally defined by the plant community, e.g., shrub cover.

deciduous • Trees which lose their leaves at the end of the growing season, e.g., red alder, maple, birch.

demersal • Organisms living on or near the bottom of a body of water.

deposit feeder • An animal (usually a polychaete worm or clam) which feeds by ingesting sediment. Organic matter contained in the sediment is absorbed, while inorganic matter is passed through the digestive system and excreted.

detrital pathway • Foodchain which goes from dead organic matter into microorganisms and then to detritus-feeding organisms and their predators.

detritivore • Organisms which subsist on organic detritus.

detritus • Particles of plant matter in varying stages of decomposition.

dredge spoils • Waste matter removed in making excavations.

dominant species • Species prevalent in a particular community, or at a given period, which also may determine conditions of that area.

duff • Decaying plant matter on the ground in a forest.

dysphotic zone • Ocean waters below the euphotic zone which extend from about 100-200 meters below the surface to about 1,000 meters in depth. This zone receives too little light for photosynthesis.

ecology • The relationship between organisms and their surroundings.

ecosystem • Any unit containing a community and physical environment functioning together to direct a flow of energy within the system.

ecotone • A transition between two or more diverse communities. This community often contains many organisms of each of the overlapping communities and also has species characteristic of the ecotone. Ecotones often have greater numbers of species and individuals than the communities surrounding it, i.e., the edge effect.

edge effect • The tendency for increased variety and density of species at community junctions.

eelgrass • Marine vascular plant also referred to as crabgrass. Unlike algae, eelgrass is rooted in the beach substrate and is a flowering plant. Refer to the Seagrass Narrative (No. 627) for information concerning this marine plant which supports a wide variety of commercially and recreationally valuable organisms.

endemic • Native species restricted to a certain region or part of a region.

epifauna • Organisms living on the bottom surface of aquatic systems, either attached or moving freely on the surface.

epilimnion • The upper, warm circulating water above the thermocline (a steep temperature gradient) in lakes, ponds, and reservoirs.

epiphyte • Plant which lives on surface of other plants.

euphotic zone • The total area of water illuminated by sunlight in lakes, ponds, reservoirs, or oceans in which photosynthesis occurs.

euryhaline • Marine organisms adaptable to a wide range of salinity.

eutrophic • An aquatic system which provides (more than) adequate nutrition for most of the organisms living there.

eutrophication • Nutrient enrichment, leading to excessive growth of aquatic plants.

extreme high water (EHW) • Highest elevation the tide reaches in a typical year.

evergreen • Plants having green leaves throughout the year, e.g., Douglas fir, Sitka spruce, junipers, rhododendron: opposed to deciduous.

exotic • An introduced species not native to an area or region.

exposed beach • A beach which is subjected to contant heavy surf and/or strong currents.

exudation • Any discharge through an incision or pore.

feral • An organisms that is wild or has escaped from cultivation or domestication and reverted to a wild state.

filling • Artificial elevation of land by deposit of soil or sediment.

filter feeder • An animal which uses feather-like structures to filter microscopic organisms and detritus from the water. Also called suspension feeding.

fingerling • A young fish about the length of a finger.

fledge • To grow the feathers necessary for flying.

floodplain • The area of shorelands extending inland from the normal yearly maximum storm water level to the highest expected storm water level in a given period of time (i.e., 5, 50, 100 years).

flora • Plants.

food chain • The step-by-step transfer of food energy and materials, by consumption, from the primary source in plants through increasingly higher forms of fauna (animals).

food web • The network of feeding relationships in a biological community.

fry • A very young fish generally still retaining its egg sac.

game species • Animals classified by the Washington Department of Game that can be legally hunted or fished within predetermined seasons. Examples include deer, elk, waterfowl, and steelhead.

granivorous • Feeding on grain and seeds.

grazing pathway • Food chain which starts from a green plant base, goes to grazing herbivores and on to carnivores.

groin • A small jetty extending from shore to prevent beach erosion.

groundwater • Water found underground in porous rock strata and soils, contributes largely to streamflow.

habitat • The place where an organism lives. This definition includes organisms as well as the abiotic environment.

habitat partitioning • The division of a resource or habitat continuum by physical, behavioral or temporal differences of species which otherwise might use the very same resources.

halophyte • Plant capable of thriving on salt-impregnated soils.

hectare • A metric measure of surface, equal to 1,000 square meters (2.471 acres).

herbaceous • Any seed plant whose stem withers away to the ground after each season's growth, as distinguished from a tree or shrub whose woody stem lives from year to year.

herbivore • An animal subsisting on plant matter, a primary consumer.

heterotrophic • Organisms or systems which are dependent on other organisms or systems for food and energy.

holoplankton • Organisms that remain for their entire life cycle in the plankton population of aquatic systems.

humus • A dark material formed by decomposition of vegetable or animal matter and constituting the organic part of soils.

hydrophyte • An aquatic plant.

hypertrophic conditions • Conditions extremely amenable to growth of organism(s).

hypolimnion • The deep, noncirculating water in lakes, ponds, and reservoirs.

indicator species • A species chosen to represent some particular environmental condition.

infauna • Organisms that dig into the bottom substrate of aquatic systems or construct tubes or burrows.

insectivore • Any animal or plant that feeds on insects.

insular • Detached, isolated, as on an island.

interstitial • Of, forming, or occurring in small or narrow spaces between things, e.g., particles of sand or gravel.

intertidal • The zone between high and low tides.

invertebrates • Animals not having backbones, e.g., crabs, crayfish, worms, clams.

ion • An electrically charged atom or group of atoms which can often combine with other atoms to form new compounds, e.g., the sodium ion and chloride cations can join together to form table salt.

light compensation level • The depth at which photosynthesis (production) just balances respiration (consumption) in aquatic systems.

limnetic • The open-water zone which extends to the depth of effective light penetration in lakes, large ponds, and reservoirs.

litter • The surface layer of the ground in which the leaves are slightly decomposed, usually pertaining to forests.

littoral • The shallow-water region of lakes, ponds, and reservoirs where light can penetrate to the bottom.

macrophytes • Large plants.

mariculture • The husbandry of marine plants and animals.

mean high water (MHW) • Yearly average of all high tides.

mean higher high water (MHHW) • Yearly average of all higher high tides.

mean low water (MLW) • Yearly average of all low tides.

mean lower low water (MLLW) • Yearly average of all lower low tides. The mean lower low water mark is designated as the 0.0 level in tide tables and most tidal elevations are discussed in terms of feet above or below MLLW.

median zone • That area of the coastal zone with intermediate moisture relations, including the eastern half of the Strait of Juan de Fuca and the Puget Sound Basin.

meroplankton • Organisms which spend only part of their life cycle in the plankton population of aquatic systems.

mesic • Conditioned by temperate moist climate, neither xeric (dry) or hydric (wet).

mesopelagic zone • The ocean water zone below the euphotic zone which receives too little light for photosynthesis. It extends from about 100-200 meters below the surface to about 1,000 meters below the surface.

microalgae • Extremely small algae.

microbe • A bacterium, a mico-organism.

microphytes • Any small plant.

molt • To cast or shed periodically the outer covering, whether of feathers, hair, skin, or horns.

morel • Any of a group of small edible mushrooms.

mucilage • Any of various thick, sticky substances produced by some invertebrates and plants.

mycorrhiza • Association of the vegetative structure of fungi with the roots of a higher plant.

neritic zone • The ocean's shallow water (near shore) zone above the continental shelf; coastal waters.

net primary productivity • The rate of storage of organic matter in plant tissues in excess of the respiratory utilization by plants during the period of measurement.

neuston • Organisms floating or swimming in surface water, or inhabiting surface film.

niche • The place or role of an organism in its biotic environment. This includes the physical space occupied by an organism, its functional role in the community and its position in environmental gradients, such as temperature and moisture.

nitrogen-fixation • The process by which some plants, e.g., legumes, such as peas and beans move atmospheric Nitrogen into the productivity cycle. This enriches the soil without the use of heavy nitrate fertilizers.

nonconsumptive use • In reference to wildlife, nonconsumptive uses include photography, watching wildlife, and other forms of nonharvest enjoyment of animals and their habitat.

nursery area • A place where young stages of aquatic life concentrate for feeding or refuge.

oligotrophic • An aquatic system which provides few foods and supports few species. Applied to geologically young lakes which typically receive few nutrients from their surrounding watersheds.

omnivore • An animal which eats both animal and plant tissues.

opportunistic • Species capable of rapid colonization of disturbed areas and/or that can take advantage of temporary changes in a given resource(s).

organochloride • Organic compounds such as the insecticide DDT which contain chlorine and hydrocarbons.

osmosis • The tendency of a fluid to pass through a semipermeable membrane, as the wall of a living cell, into a solution of higher concentration, so as to equalize concentrations on both sides of the membrane.

oxbow • The crescent-shaped bend in a river which may be cut off from the river by sedimentation, forming an oxbow lake.

parasite • An organism living with or within another to its own advantage in food or shelter.

passerines • More than half of all birds belong to this group of small or medium-sized, perching songbirds. They have grasping feed with the first toe directed backward.

pelagic • All of the free-swimming and floating life inhabiting open water.

periphyton • The plants adhering to parts of rooted aquatic plants.

perennial • Plants which persist throughout the year, or for a number of years.

photic zone • The water zone where sunlight can penetrate and photosynthesis can occur. In the Northwest, from 10 to 50 feet. In the tropics light can penetrate as much as several hundred feet and allow algae to grow.

phytoplankton • The marine or freshwater plants drifting with the surrounding water; plant plankton.

pioneer species • The first species to attempt colonization of an area.

plankton • The marine or freshwater plants and animals drifting with the surrounding water, including animals with weak locomotory power.

plumage • A bird's feathers.

poikilotherm • A "cold blooded" animal; its temperature varies with that of the surrounding medium of air, water, mud, etc., e.g., fish, reptiles, amphibians.

point bar • A bar in a river or stream channel formed by deposition of sand, gravel, or other material on the inside portion of channel curves.

polygon • Individual mapping unit which defines cover type.

pool • Areas of rivers and streams which generally have slower currents and soft substrate, as opposed to riffles.

population • A group of individuals of any one kind of organism.

prey • An animal hunted or killed by other animal.

primary consumer • Organisms which feed directly on living plants or plant remains.

primary productivity • The rate at which sunlight is stored by photosynthesis of producers (e.g., green plants) in the form which can be used as food materials.

primary succession • The development of a community beginning on an area that has not previously been occupied by a community, e.g., a newly exposed rock or sand surface.

productivity • The rate of storage of organic matter.

profundal zone • The bottom and deep-water area of lakes, reservoirs, and ponds which is beyond the depth of effective light penetration.

protected beach • Beaches which rarely, if ever, are affected by waves greater than two feet in height or scoured by strong tidal currents.

raptor • A general term applied to a bird of prey, e.g., eagle, hawk, owl, vulture are all raptors.

reptile • E.g., snakes, lizards, turtles.

redd • Scrapings in gravel in which salmon, trout, and other fish lay their eggs.

relict • A plant or animal living on or in a particular area as a survivor from an earlier period.

rhizome • A thick horizontal stem partly along and partly under ground, sending out shoots above and roots below.

riffle • Areas of rivers or streams having fast currents and rocky or other hard substrates, as opposed to pools of rivers and streams.

riparian • Frequenting, growing on, or living on the banks of streams or rivers.

riverine • On or near the banks or a river; riparian.

rubble • Rough, irregularly broken pieces of stone, brick, etc.

runoff • Rain in excess of the amount absorbed by the ground.

salmonid • Salmon and trout.

salt pans • Pools of highly saline water.

sapling • A young tree.

scavenger • Any animals that eat refuse and decaying organic matter.

secondary consumer • Carnivorous (flesh-eating) organims which feed on primary consumers or on other secondary consumers.

secondary succession • Community development proceeding in an area from which a community was removed, e.g., a clearcut and burned forest.

sedge • Any of several coarse, grasslike plants usually growing in tufts or clumps in wet ground. The leaves have three sharp edges.

sediment • Any matter or mass deposited by water or wind.

seedling • A very young tree.

seral stage (or step) • The relatively transitory communities occurring throughout succession toward a climax community.

shoal • A sand bar or piece of rising ground forming a shallow place, especially one visible at low water.

snag • Dead trees often partially broken or decayed; these are required by many wildlife.

species richness • Number of species present.

standing crop • The total weight of living matter in a given place at a given time.

stenohaline • Organisms adaptable to a narrow range of salinity.

strand • Land at the edge of a body of water especially ocean shore.

subcanopy • The forest stratum located above the shrub layer and beneath the canopy.

succession • Ecosystem development; an orderly process of community development that involves changes in species and community processes with time.

symbiosis • The living together of two dissimilar organisms in close association or union, especially where this is advantageous to both.

talus • Piles of rock fragments which drop off cliffs and accumulate in uniform masses at the base of cliffs.

taxonomic names • Names established by the scientific classification system for plants and animals.

thermocline • The zone of water in lakes, ponds, or reservoirs which has a steep temperature gradient, preventing complete circulation of surface waters (the epilimnion) and bottom waters (the hypolimnion).

tidegate • A structure which allows drainage of freshwater through a one-way valve into marine waters at low tide. High tide conditions force the valve to close, thus preventing intrusion of salt water into the freshwater area.

turbidity • The relative degree to which sediment in a given aquatic system is stirred up.

understory • The vegetation beneath the canopy layer; i.e., herbs, shrubs, saplings.

upland • Terrestrial areas above tidal or freshwater influence. A broad transition zone such as a marsh often creates an indistinct boundary between "wetland" and "upland".

vascular • Plants having ducts which convey sap, e.g., eelgrass, Douglas fir, alder, and wildrose.

vegetative reproduction • Reproduction by bud-formation or other asexual method in plants and animals.

warren • Rabbit den.

water quality • Water quality values are relative measures dependent on the given species or ecosystem involved (e.g., eutrophic lakes having many nutrients support fish which do not require great amounts of oxygen; algae may be abundant. This same lake probably does not support trout, and the water may not be suitable for human consumption.)

zooplankton • The marine or freshwater animals, including those with weak locomotory power, which drift with the surrounding water.

zoospore • A motile, flagellated asexual spore, as of certain algae and fungi.

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