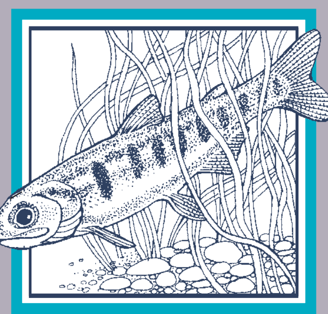
SALMON & TROUT IN ESTUARIES

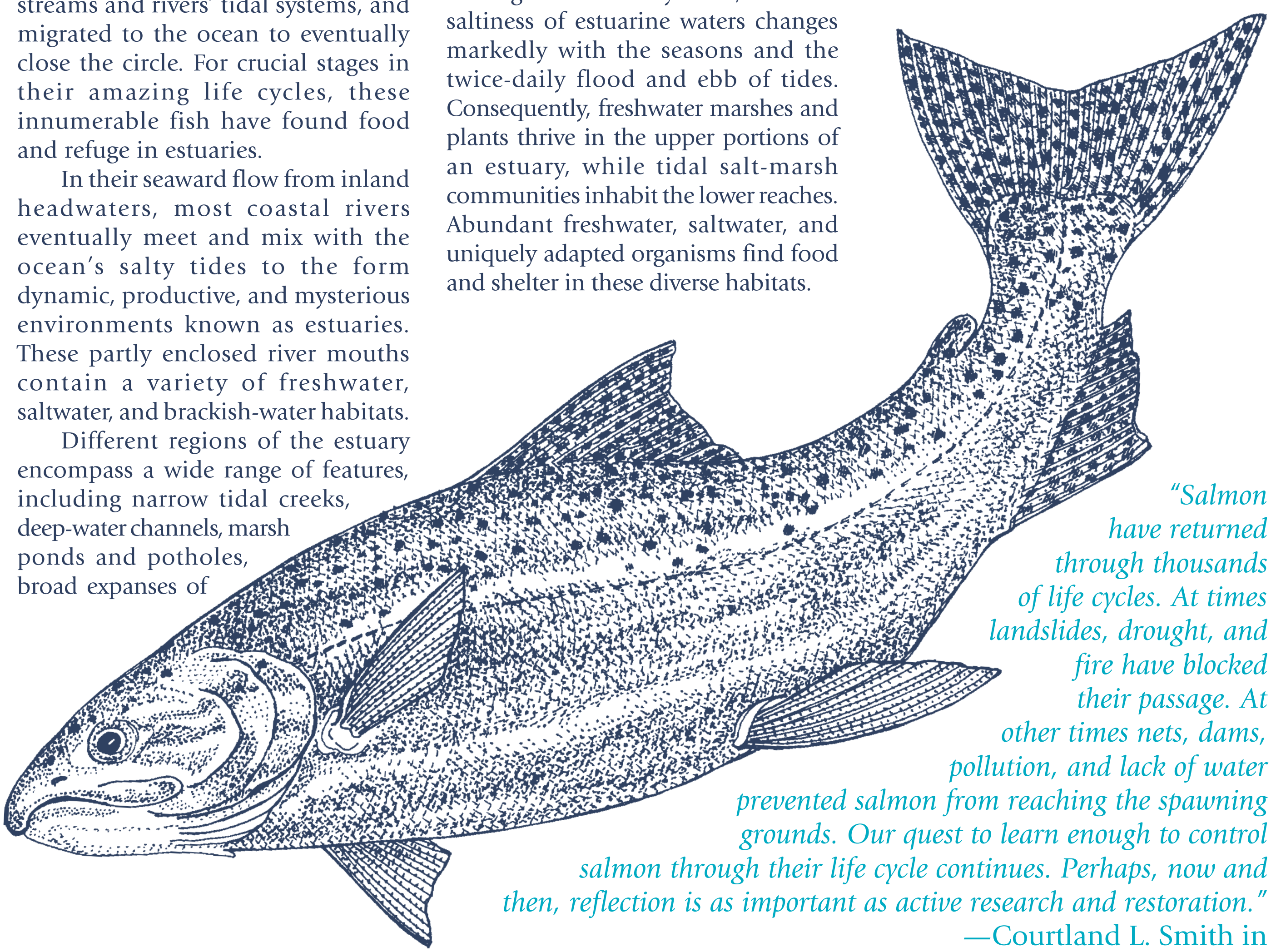


For untold eons, Pacific salmon and close kin have traveled thousands of miles and grown fat but fit in the food-rich waters of the ocean. As hardy adults they have returned to the coastal rivers of their origin and followed the tastes, smells, and secrets of their natal streams beyond. In the thin waters and rocky rubble of moist mountains, they have dug in the gravel, deposited their eggs and sperm, then died. Their countless progeny have emerged from the gravel, grown in the freshwater streams and rivers' tidal systems, and migrated to the ocean to eventually close the circle. For crucial stages in their amazing life cycles, these innumerable fish have found food and refuge in estuaries.

In their seaward flow from inland headwaters, most coastal rivers eventually meet and mix with the ocean's salty tides to the form dynamic, productive, and mysterious environments known as estuaries. These partly enclosed river mouths contain a variety of freshwater, saltwater, and brackish-water habitats.

Different regions of the estuary encompass a wide range of features, including narrow tidal creeks, deep-water channels, marsh ponds and potholes, broad expanses of mud flats, sandy beaches, and rocky intertidal areas. Salinity levels are generally low in the upper estuary, highest at the mouth, and variable throughout the bay area, but the saltiness of estuarine waters changes markedly with the seasons and the twice-daily flood and ebb of tides. Consequently, freshwater marshes and plants thrive in the upper portions of an estuary, while tidal salt-marsh communities inhabit the lower reaches. Abundant freshwater, saltwater, and uniquely adapted organisms find food and shelter in these diverse habitats.

Oregon's estuaries developed shortly after the last ice age, about 10,000 to 12,000 years ago. As the glaciers melted into the oceans, sea level rose some 400 feet, inundating the mouths of most coastal rivers and drowning the river valleys. Among Oregon's drowned-river estuaries are the large and economically important Coos, Umpqua, Yaquina, Tillamook, and Columbia tidal systems. All are home and haven to Pacific salmon and anadromous trout at crucial stages of the fishes' life cycles.



"Salmon have returned through thousands of life cycles. At times landslides, drought, and fire have blocked their passage. At other times nets, dams, pollution, and lack of water prevented salmon from reaching the spawning grounds. Our quest to learn enough to control salmon through their life cycle continues. Perhaps, now and then, reflection is as important as active research and restoration."

—Courtland L. Smith in *The Northwest Salmon Crisis: A Documentary History*

CONFLICTS EXIST BETWEEN HATCHERY STOCKS AND WILD FISH

Large-scale hatchery production of salmonids has been controversial for nearly as long as hatcheries have been operating in the Pacific Northwest. Some fish culturalists and others warned at the end of the 19th century that "Artificial propagation should be invoked as an aid and not as a substitute for reproduction under natural conditions..." Nevertheless, it has taken us more than a century to become fully aware of the ramifications that hatchery production can have on these anadromous fish.

By the turn of the 20th century, the once-great runs of Pacific salmon and steelhead in Oregon's rivers were already in sharp decline, primarily because of a booming canning industry that led to overharvest in the estuaries and rivers. Logging and agricultural practices, road construction, dam building, industrial development, and urban sprawl also combined to destroy much of the salmonids' breeding and rearing habitat, impede their migrations, and pollute their waters. To supplement declining populations that couldn't keep up with harvest levels, federal, state, and private hatcheries artificially propagated salmon and steelhead and released many millions of fish annually into coastal streams and estuaries.

While hatchery operations, in some cases, were able to increase numbers of salmon and trout available for harvest, they eventually led to other problems, some of which could have dire consequences for wild stocks. For example, hatchery fish are genetically different from wild fish in various ways.

Hatchery fish are more prone to disease than wild-fish stocks that, over the eons, may have developed natural resistance to certain disease strains. Furthermore, hatchery fish, often the progeny of non-indigenous stocks, can transfer disease to wild-fish populations that may not have developed resistance to certain pathogens. Hatcheries, where occurrence of disease has sometimes exceeded 90 percent, can even introduce diseases to the environment by release of hatchery effluents. These same effluents also often contain high concentrations of disinfectants and nutrients that can pollute downstream waters.

Under natural breeding conditions, the mating process of anadromous salmonids is intense, and sexual selection amounts to the mating of a few of the fittest fish. Hatchery workers, of course, have no way of finding and pairing the best natural breeders. Consequently, the assembly of new genetic combinations becomes random. Thus, hatchery operations may eventually lead to temporary survival of unfit fish.

Studies have shown that because of where and how they are raised, hatchery fry exhibit an impaired ability to recognize ideal habitat and refuge from predators. They have poorly developed territorial behaviors, inferior migration timing instincts, and lower breeding success than wild stocks.

Predator/prey relationships can be detrimental to fish populations in several ways. For example, large numbers of hatchery fry released in waters where wild fry reside can attract predators, which feed indiscriminately on both, thus reducing the number of wild fish available for out-migration. Moreover, hatchery fry are usually larger than their wild counterparts and often prey on wild fry.

Hatchery fish also might not fare so well as wild fish in the ocean. Although hatchery fry are generally larger than wild fry of the same age and may grow faster in streams and estuaries, scale-sample studies indicate that they might grow more slowly in the ocean, and in some cases might temporarily stop growing altogether.

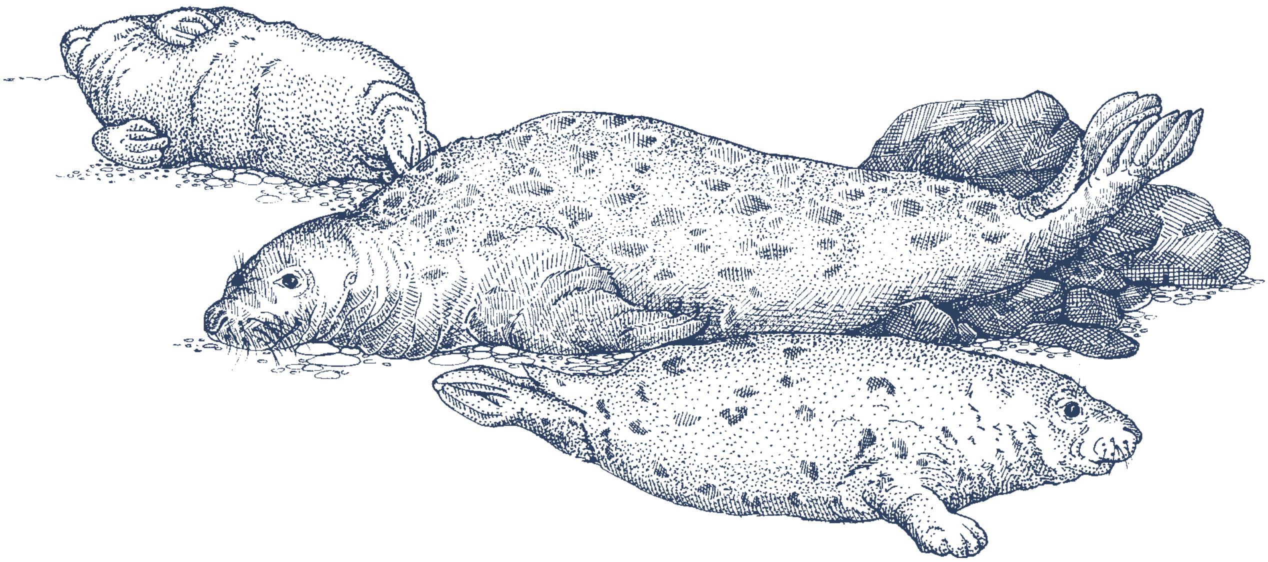
Although long-term monitoring of salmonid hatchery programs has been inadequate, studies show that survival of young fish to adulthood is greater among wild stocks. One study conducted on the Oregon coast revealed that fewer than 0.001 percent of hatchery fish returned to the hatchery as adults. A large release of juvenile chum salmon by a private hatchery on Coos Bay in 1979 yielded a return of only 10 adult fish.

Scientists are also troubled by fishery harvest rates that are based on abundant hatchery fish. In mixed-stock fisheries, where hatchery fish are targeted but both hatchery and wild fish are caught, the wild-fish bycatch can be excessive, thus reducing naturally spawning populations.

Current consensus among scientists is that hatchery practices must change to meet the requirements of wild stocks. Furthermore, hatcheries must play a limited role in the near-term future of anadromous salmonids and perhaps no role at all in the long term. It has become clear that hatcheries alone cannot restore the naturally spawning populations of wild fish.

IF THERE'S A WAY, IS THERE A WILL?

The abuse of salmon populations and the degradation of estuarine habitat in Oregon have been concurrent activities since the middle of the 19th century. We seem to have learned *about* our mistakes, if not *from* them. We might well possess the scientific knowledge to prevent the extinction of Oregon's salmon and anadromous trout. We may even have the technological savvy to restore enough salmon habitat to support spawning populations of wild fish, without hatchery supplementation. We certainly have the ability to stop the loss of estuarine habitat, and perhaps even repair and restore some of our damaged marshes and fringe areas. We probably have the way to do all this, but we need the will.



MARINE MAMMALS IN THE ESTUARY

California sea lions and Pacific harbor seals are the most plentiful and frequently encountered marine mammals in and near Oregon's estuaries. Their populations have increased dramatically in recent years, leading to speculation about the effects of sea lion and seal predation on salmonid stocks. The mammals' high visibility, notoriety associated with particular individuals, widespread media coverage, and a dearth of conclusive scientific information have generated considerable controversy.

Both California sea lions and Pacific harbor seals are opportunistic carnivores that prey on animals that are most readily available and easiest to catch. The diets of sea lions and seals include such seasonally abundant food as squid, northern anchovy, eulachon, shiner perch, English sole, starry flounder, surf smelt, Pacific herring, Pacific whiting, Pacific lamprey, Pacific salmon, and other salmonids.

Until recently, scientists remained unalarmed about the potential impact of marine mammal predation on salmonid stocks in the Pacific Northwest. Most studies of the 1970s and 1980s indicated that salmonids accounted for only a small percentage of the pinnipeds' diets. As long as salmonid populations remained reasonably stable, predation by marine mammals was only a minor and localized problem.

Recent circumstances, however, have led to another look at the potential effects of predation on salmonids and other fish: (1) a more than tenfold increase in the population of California sea lions and Pacific harbor seals since the passing of the Marine Mammal Protection Act in 1972, (2) the decline of most stocks of anadromous salmonids in the Pacific Northwest, and (3) the re-evaluation of earlier studies that may have underestimated the amount of salmonids in pinniped diets.

In 1994, the U.S. Congress called for a scientific investigation to determine whether California sea lions and Pacific harbor seals are significantly interfering with the recovery of depleted salmonid stocks or "are having broader impacts on the coastal ecosystems of Washington, Oregon, and California." Subsequently, the National Marine Fisheries Service established a working group to investigate existing scientific information. Because the one-year deadline imposed by Congress did not allow time to conduct thorough field investigations, the working group relied on information from earlier studies.

Although the findings of the working group were inconclusive and indicated a need for further and better investigations, they pointed to some potential problems. A March 1997 technical memorandum from the National Oceanographic and Atmospheric Administration and the National Marine Fisheries Service concluded, "Predation by California sea lions and Pacific harbor seals may now constitute an additional factor in Salmonid population decline and can affect recovery of depressed Salmonid populations in some situations."

So it appears that scientists on all sides of the issue have their work cut out for them. They seem to agree, though, that we need more and better information, and we need it soon.

ESTUARIES ARE ESSENTIAL TO OREGON'S SALMON AND TROUT

The unique life histories of anadromous salmon and trout require that individuals migrate through the estuary at least twice during their lives. The first migration occurs when these fish are juveniles as they leave their natal streams on their way to the ocean. The second migration occurs when the adult fish leave the ocean and return to the streams to spawn.

Oregon's anadromous salmon and trout, collectively known as salmonids, are members of the trout family *(Salmonidae)*, which comprises Atlantic and Pacific salmon, the trouts, chars, whitefishes, and graylings. Of the five species of Pacific salmon that populate the coastal waters of North America, chinook, coho, and chum salmon spawn in Oregon waters and depend on Oregon's estuaries for food, shelter, and transitional acclimation between freshwater and saltwater environments. All Pacific salmon die after spawning, but even in death they become food for bears and eagles, and their carcasses return nutrients to the water that will nourish their own offspring.

Two anadromous trouts, steelhead and sea-run cutthroat, are common residents of coastal Oregon waters. Both species are important to the state's recreational fishery but their numbers are depleted in many of their native waters. Unlike Pacific salmon, steelhead and sea-run cutthroat may live to spawn repeatedly and again use the estuaries during their migrations.

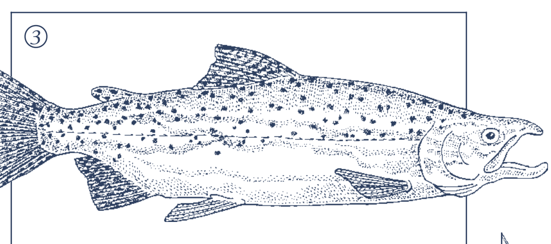
SALMONIDS USE ESTUARIES IN DIFFERENT WAYS

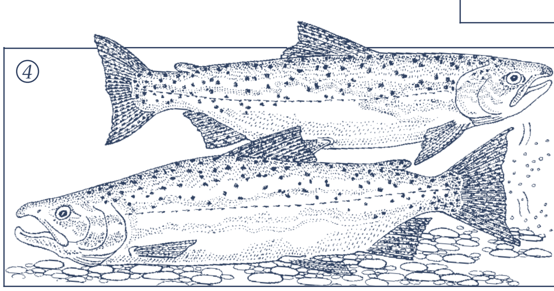
By definition, any anadromous fish must use an estuary as temporary habitat. Some travel quickly through the estuary to reach fresh or salt water, while others linger longer, seeking food and shelter. For most salmonids, the estuary provides an important link, or transition zone, between riverine and marine habitats.

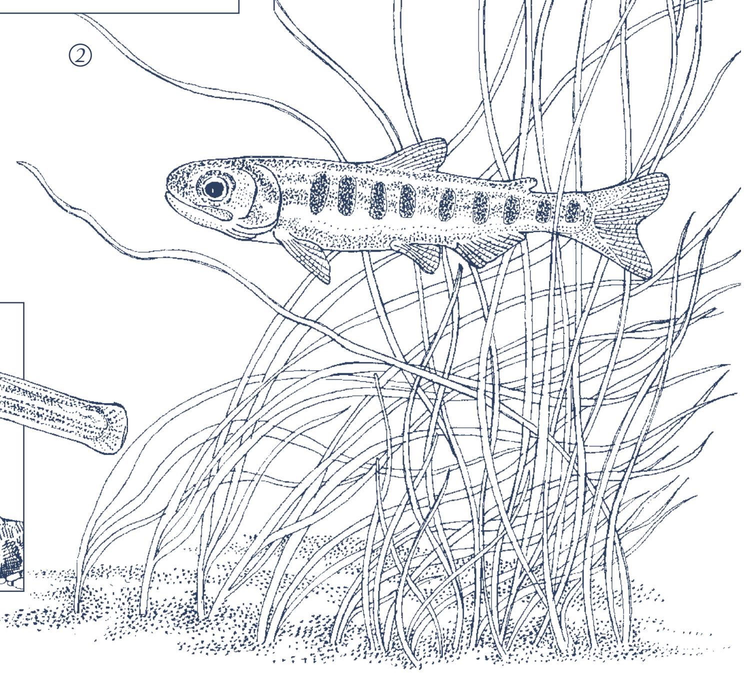
Oregon's estuaries appear to be particularly important for juvenile salmon for three reasons. First, tidal creeks, marshes, eelgrass beds, and channels furnish the young salmon with *productive feeding areas* where they forage and grow before heading out to sea. Second, the shallow estuarine habitats also offer *refuge from predators*, especially those marine mammals, birds, and fish that hunt for juvenile salmon in the deep channels and nearshore areas. Finally, the brackish estuarine waters provide an *acclimation area for salmonid smolts* while they adapt to the marine environment.

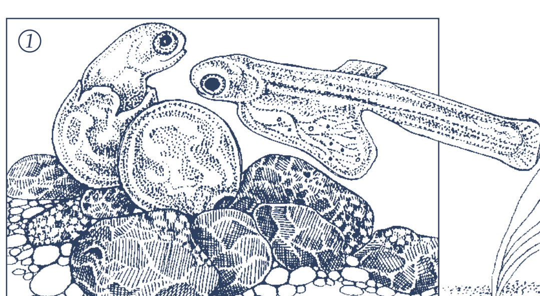
Chinook, the largest-growing but least-abundant Pacific salmon, occur along the West Coast in five races defined according to what season adults migrate from salt to fresh water. Some populations re-enter the coastal rivers and creeks in winter or spring, while others return in summer or fall. With the exception of a summer run in the Columbia River, all chinook that use coastal Oregon streams are spring or fall migrants.

Salmon life history stages:
① Emergence in freshwater streams
② Smoltification in estuarine tide channels
③ Maturation to adulthood in the ocean
④ Spawning in freshwater streams









Chinook fry and smolts often descend rapidly from their natal streams to the ocean, but some individuals might spend up to 18 months in fresh water. So-called subyearling estuarine smolts migrate to the estuaries soon after hatching, where they feed and grow for several months before entering the ocean. Subyearling riverine smolts spend less than a year in fresh water and move quickly through the estuary on their way to the sea. Yearling riverine smolts remain a year in the river, migrating seaward through the estuaries in the spring after they hatch.

Like adults, juvenile chinook are carnivorous and opportunistic feeders. In the estuary, they frequent an assortment of habitats, from mud flats to eelgrass beds, and consume a large variety of invertebrate and fish larvae, crustaceans, insects, and other fish.

Coho salmon range along the Pacific coast from central California to northwestern Alaska and use all of Oregon's estuaries. Although coho rank only fourth in the commercial salmon catch, they are particularly valuable to the recreational fishery and the coastal communities that serve anglers. Estimates in 1986, for example, showed the sport catch originating from the Columbia River alone to be worth over $30 million.

Juvenile coho spend a year or more in fresh water before migrating to the ocean. Depending on location, smolts might spend no more than a couple of days or a month or more in estuaries before heading to sea. Like chinook salmon, juvenile coho are opportunistic carnivores, feeding on large zooplankton and small crustaceans, insects, invertebrate and fish larvae, and juvenile fishes, including other salmonids.

Chum salmon occur throughout the Pacific coast, from California to Alaska, but are most abundant in the northern part of their range. Soon after they absorb their yolk sacs, chum salmon fry head for the estuary, where they might spend up to several months preparing for life at sea. Juvenile chum move throughout the estuary with tidal flows, frequenting tidal creeks, sloughs, and marshes. As opportunistic and carnivorous feeders, young chum salmon forage in shallow estuary waters on small crustaceans and terrestrial insects. Older chum move to deeper waters where they prey on crustacean and fish larvae, copepods, amphipods, and other crustaceans.

Oregon's two anadromous trouts are a study in contrasts. Mature steelhead are 18 to 28 inches long and weigh from about $4^{1}/_{2}$ to 11 pounds. The largest steelhead on record was over four feet long and weighed 42 pounds. Mature sea-run cutthroat, on the other hand, range from about 6 to 18 inches in length and seldom exceed four pounds.

Steelhead smolts and adults spend little time in the estuaries, rarely more than it takes to pass through on their way to the ocean or rivers. Cutthroat juveniles migrate from Oregon's coastal streams into the estuaries from February through May, where they feed on insects, crustaceans, and fish. As they grow, young cutthroat show a marked preference for fish. Adult sea-run cutthroat often inhabit small tidal streams, sloughs, backwaters, and tidal freshwater regions of estuaries prior to the fall rains that initiate their spawning migrations. Some cutthroat reside permanently in estuaries.

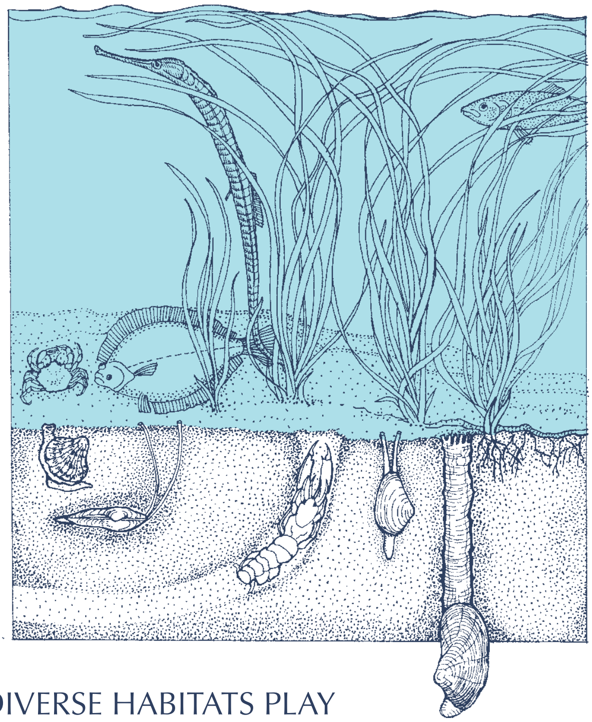
It's not uncommon for adult salmonids occupying nearshore coastal waters to move into the lower estuaries for brief periods to feed on abundant forage species, then return to the ocean. So estuaries serve as important feeding areas for both adult and juvenile salmonids. Additionally, just as ocean-bound juvenile salmonids might use the estuary to gradually acclimate to salt water, some returning adults, bound for their natal streams, similarly use the estuary to re-accustom themselves to fresh water.

ESTUARIES ARE IMPORTANT FOR OTHER FISH AND SHELLFISH

Some 75 percent of America's commercial food fishes and shellfishes, most inshore and nearshore saltwater sport species, and many important forage fishes are linked to estuaries in some important way. Many species spawn in or near estuaries, which are ideal nursery areas. Others regularly move into estuaries to feed, while some remain in or near these tidal systems for most or all of their lives.

In addition to anadromous salmonids, Oregon's estuaries support a tremendous variety of marine and estuarine species. For example, the Oregon Department of Fish & Wildlife listed 80 species of fish known to occur in the Coos River Basin in 1987, more than 70 of which inhabit the watershed because of the estuary. A similar list identified 63 species in Tillamook Bay.

This great assortment of aquatic wildlife uses the estuaries in various ways. Other anadromous species, for example, are temporary residents of Oregon's estuaries, where they find food and refuge during their migrations to and from the rivers of their origin. These include white sturgeon, American shad, striped bass, and Pacific lamprey. Several species of surfperch visit the estuaries to bear live young in the spring and to feed in the summer. Shiner perch are year-round residents and prey for many fish, birds, and marine mammals. Other forage fishes that spawn and feed in the estuaries include Pacific herring, northern anchovy, and several species of smelt. Juveniles of many important marine species forage and grow in Oregon's estuaries, among them the English sole, sand sole, starry flounder, lingcod, cabezon, and more than a half-dozen species of rockfish. The estuary also serves as home, hideout, nursery, and supermarket for great assortment of shrimps, clams, and oysters. Some, such as the Dungeness crab and Pacific oyster are valuable commercial species.



DIVERSE HABITATS PLAY MAJOR ROLES IN ESTUARIES

Estuaries attract such a great variety of marine and anadromous fishes, marine mammals, and birds because the productive and protective habitats provide food, shelter, and sanctuary for so many different types of organisms. Something so seemingly simple as an eelgrass bed, for example, is actually a complex habitat that performs processes essential to the health of an estuary and its many inhabitants. Eelgrass is a relatively tenacious and highly productive flowering plant, common in the sheltered waters of bays and sloughs. Beds of eelgrass, however, are vulnerable to natural and human-caused disturbances, particularly those activities that cause excessive sediment deposition, erosion, and increased water turbidity.

With the aid of salt glands on its leaves, eelgrass tolerates a wide range of salinities. Its underground stems, or rhizomes, sprout roots and aerial stems every few inches, anchoring the plants and spreading them into dense mats that are among the most highly productive habitats on earth. Under the right conditions, eelgrass can spread over great expanses of estuarine shallows that are exposed only during the lowest of tides.

Submerged eelgrass meadows provide cover and food for great numbers and varieties of organisms. Nearly 200 species of burrowing, bottom-dwelling, and other invertebrates reside among the blades, roots, and rhizomes. More than three dozen species of diatoms and other algae flourish on leaf surfaces, as do organisms that feed on the algae. Herring deposit their adhesive egg clusters on the eelgrass. Snails, worms, starfish, and sea urchins glide and graze in the luxuriant growth. Tiny crustaceans and fish hide and feed among the wispy eelgrass blades, while larger fish, crabs, wading birds, and other predators forage in the meadows on appropriate tides.

In the fall and winter, as much as 75 percent of the eelgrass blades die back and decompose, eventually supplying the estuarine food web with essential nutrient-bearing detritus and food for countless organisms. In spring and summer, the perennial eelgrass beds sprout and grow, renewing the annual cycle of production.

Many animals important to humans use the eelgrass beds extensively, including several species of clams and shrimps, Dungeness crab, English sole, chinook and chum salmon, and sea-run cutthroat trout. In Tillamook Bay, for example, 28 species of adult fish prefer the eelgrass beds to other types of estuarine habitat.

Along the Oregon coast, eelgrass beds typically occur in the subtidal and intertidal areas of the lower estuary, where bottom sediments are a mixture of sand and mud. While they can withstand normal tidal and estuarine currents, seasonal storms that increase wave action and currents can damage leaf blades and uproot plants. Although eelgrass is shade tolerant, it requires a certain amount of water clarity and sunlight penetration to thrive and survive. Consequently, channel dredging and other human activities that lead to excessive turbidity are potentially harmful to the eelgrass beds, as is the construction of docks and marinas above or adjacent to eelgrass.

Salt marshes provide another important estuarine habitat. Salt marsh communities are among the most fertile assemblages on earth, capable of producing six times as much organic matter as commercial farmland. Although salt marshes function in many of the same ways as eelgrass beds by providing food and refuge to countless organisms, they are also ecologically different.

Salt marsh communities serve as transition zones between aquatic and terrestrial ecosystems. Plants in the low marsh—such as salt grass, pickleweed, and arrowgrass—are inundated twice daily by the tides and are highly salt tolerant. Farther upland, where tides intrude only infrequently, the plant community changes and is often dominated by tufted hairgrass and common spike rush.

Animals in the marsh are many and varied, ranging from terrestrial insects and spiders to small and large mammals and a variety of birds. Fish move into and out of the lower marsh areas with the tides to feed and hide, much as they do in the eelgrass beds.

The tremendous productivity of the marsh is related to the decomposition of vegetation. Tidal action carries this material out of the marsh and into the estuary, where it becomes food for the many organisms that consume dead organic matter, which in turn are eaten by other organisms in the estuarine food chain.

Salt marshes are beneficial in other ways as well. The emergent stems and leaves of marsh plants filter pollutants from the water, trap sediments, prevent shoreline erosion, and dampen the effects of tidal flooding.

Since the middle of the 19th century, the marshes along the edges of Oregon's estuaries have been ditched, diked, drained, or otherwise modified for agricultural purposes as well as industrial and urban development. Where marshes have given way to residential and municipal construction, they're gone forever. In some rural areas, however, efforts are underway to reclaim some degraded marshes and restore lost estuarine habitat.

WOODY DEBRIS PROVIDES FOOD, SHELTER, AND HABITAT

From headwater streams to the ocean, water carries driftwood and deposits it along the shores where it performs many important ecological functions. During the preceding century, people did their best to remove as much of this woody debris as possible from streams and estuarine channels. They cleared channels, broke up log jams, and removed fallen trees for the sake of navigation, safety, and flood control, as well as to make it easier to float logs downstream. Following seasonal and major floods, state and federal agencies have spent millions of dollars to "clean" streams of logs and rootwads to protect bridges and culverts. People even removed fallen trees and downed branches from streams to protect resident and migratory populations of fish, because biologists thought such woody debris was an impediment to fish passage.

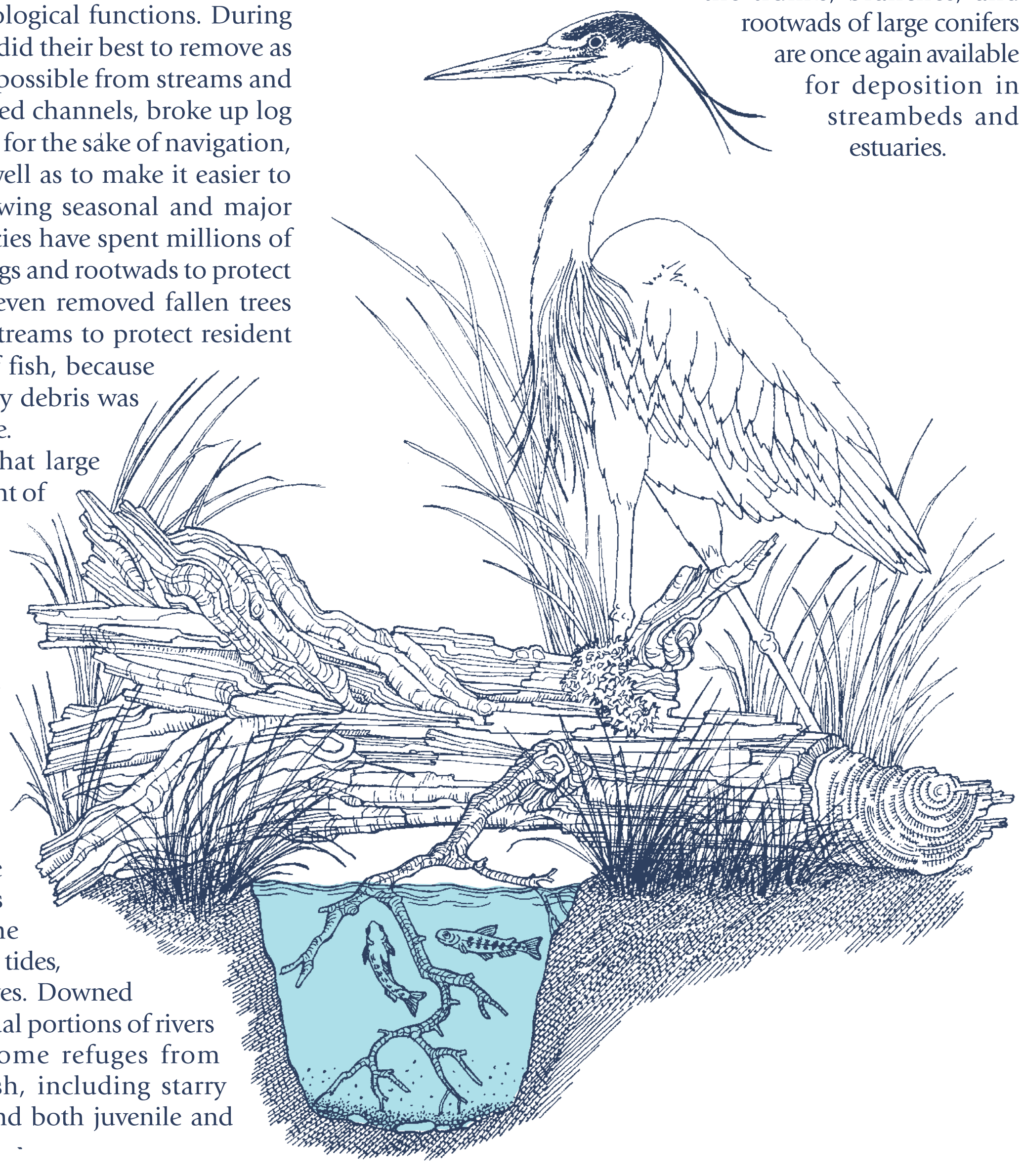
We know now, though, that large wood is an essential component of Oregon's waterways. It provides essential structure in stream beds, helps stabilize stream banks, creates waterfalls and scour pools, moderates stream flow, and protects spawning areas. Woody debris also offers refuge to some organisms and provides food for others.

Most driftwood arrives in estuaries by way of riverine currents. Large woody debris is deposited on the edges of the upper estuary by extremely high tides, storm surges, and seismic waves. Downed trees sometimes settle in the tidal portions of rivers and creeks where they become refuges from predators for a variety of fish, including starry flounder, juvenile sturgeon, and both juvenile and adult salmonids.

Driftwood is usually abundant in upper salt marshes. Scattered throughout the marsh, large wood remains in place until it's refloated by floods, storms, or exceptionally high tides. Refloated driftwood leaves shallow depressions in the marsh, creating potholes that hold water at low tide and harbor juvenile fish and other organisms.

Large woody debris is valuable throughout the watershed, but it's in critically short supply in Oregon, a situation not likely to change in the near future. An Oregon Department of Fish and Wildlife survey of the Tillamook Basin showed that most streams lacked suitable amounts of large woody debris. Evaluating their potential for recruitment of large woody debris, the survey gave a poor rating to 98.7 percent of the streams, a fair rating to 1.3 percent, and a good rating to none.

Large conifers, which are the best sources of large woody debris, are in extremely short supply in the riparian corridors of coastal Oregon. So it could take well over a century before the trunks, branches, and rootwads of large conifers are once again available for deposition in streambeds and estuaries.



GLOSSARY

amphipod *n.* any of small, numerous crustaceans of the group *Amphipoda.*

anadromous *adj.* (of fish) hatching in fresh water, migrating to salt water, and returning as adults to fresh water to spawn.

brackish *adj.* slightly salt, as some estuarine water, with salt content usually ranging from 0.5 to 1.7 percent.

carnivore *n.* an animal that consumes flesh or other animals.

cephalopod *n.* any of the most highly evolved mollusks of the class *Cephalopoda*, including the cuttlefishes, octopuses, and squids.

copepod *n.* any of numerous, tiny crustaceans of the order *Copepoda*, often abundant in plankton.

detritus *n.* loose, finely divided rock or remains of organic tissues.

diatom *n.* any of numerous, mostly marine, unicellular forms of algae.

fry *n.* the young of fish.

indigenous *adj.* native of or originating in a particular region or country.

pathogen *n.* any bacterium, virus, or other microorganism that produces disease.

pinniped *n.* any mammal of the suborder *Pinnipedia*, with flippers or limbs adapted to aquatic life, including seals, sea lions, and walruses.

riparian *adj.* of or pertaining to the bank of a river or shoreline of a body of water.

salmonid *n.* any fish belonging to the family *Salmonidae*, including the chars, graylings, salmons, trouts, and whitefishes.

smolt *n.* a young anadromous salmonid in the seaward-migration stage of its life.

turbidity *n.* the state of being unclear or cloudy because of stirred-up sediments, algal blooms, and the like.

watershed *n.* the drainage area of a river or other stream.

zooplankton *n.* the aggregate of tiny animals and animal-like organisms that drift in the plankton.

RECOMMENDED READING

Childerhose, R. J. and Marj Trim. *Pacific Salmon.* Seattle: University of Washington Press, 1979.

Cone, Joseph and Sandy Ridlington, eds. *The Northwest Salmon Crisis: A Documentary History.* Corvallis, Oregon: Oregon State University Press, 1996.

Maser, Chris and James R. Sedell. *From the Forest to the Sea: The Ecology of Wood in Streams, Rivers, Estuaries, and Oceans.* Delray Beach, Florida: St. Lucie Press, 1994.

Maser, Chris, *et al. Natural History of Oregon Coast Mammals.* U.S. Department of Agriculture, Forest Service, General Technical Report PNW-133, 1981.

Netboy, Anthony. *The Columbia River Salmon and Steelhead Trout, Their Fight for Survival.* Seattle: University of Washington Press, 1980.

Ricketts, Edward, *et al. Between Pacific Tides.* Stanford, California: Stanford University Press, 1985.

WEB SITES

National Estuarine Research Reserves:
http://wave.nos.noaa.gov/ocrm/nerr/welcome.html

South Slough National Estuarine Research Reserve:
http://www.southsloughestuary.com

Tillamook Bay National Estuary Project:
http://osu.orst.edu/dept/tbaynep/nephome.html

The Oregon Estuary Plan Book:
http://www.inforain.org/epb/intro.htm

Oregon Department of Fish & Wildlife Home Page:
http://www.dfw.state.or.us

Oregon Department of Fish & Wildlife Research:
http://www.ors.edu/Dept/ODF/index.html

NOAA Web Sites: http://www.websites.noaa.gov

U.S. Fish & Wildlife Service Fisheries Office:
http://www.fws.gov/r9af

U.S. Environmental Protection Agency:
http://www.epa.gov

The National Marine Mammal Laboratory:
http://nmml0l.afsc.noaa.gov

Pacific Salmon Hatcheries Report:
http://jcomm.uoregon.edu/~josh/salmon

Salmon Topics in the News:
http://www. tidepool.org/ID.salmon.html

Salmon and Related Web Sites:
http://www.cqs.washington.edu/crisp/rel/salmon.html

Bioregional Information on North American Rainforest Coast: http://www.inforain.org

Coastnet Links to Other Sites:
http://secchi.hmsc.orst.edu/coastnet/links.html

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Tillamook Bay National Estuary Project

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