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Stapp, William B. and Mark K. Mitchell. *Field Manual for Water Quality Monitoring*. Dexter, Michigan: Thompson-Shore Printers, 1991.

Monitoring Equipment

HACH Company
PO Box 608
Loveland, Colorado 80539
1-800 227-4224

VWR Scientific
PO Box 3551
Seattle, WA 98124
1-800 333-6336

La Motte Chemical Products Co.
P.O. Box 329
Chestertown, MD 21620
1-800 344-3100

Millipore
(800) 645-5476
Fecal Coliform Test Equipment

Research Nets Inc.
14207 100th NE
Bothell, WA 98011
(206) 821-7345
Plankton Nets

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Lewis, Barbara A. *The Kid's Guide to Social Action: How to Solve the Social Problems You Choose – and Turn Creative Thinking into Positive Action*. Minneapolis: Free Spirit Publishing, Inc., 1991.

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Council on the Environment, Inc.
51 Chambers St. Room 225
New York, NY 10007.

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Washington State Department of Ecology. *Wetland Regulations Guidebook*, Publication #88-5. Washington State Department of Ecology, 1988. (360)407-6000.

Government Agencies

U.S. Environmental Protection Agency
Region 10
1200 - 6th Ave. OEA, AO-143
Seattle, WA 98101
(206) 553-1107 or (800) 424-4EPA.

U.S. Fish and Wildlife Service
3704 Griffin Lane SE, Suite 102
Olympia, WA 98501
(206) 753-9440

Washington State Department of Ecology
Northwest Regional Office
3190 - 160th Ave, SE
Bellevue, WA 98008
(206) 649-7000

Washington State Department of Natural Resources
919 North Township St.
Sedro-Woolley, WA 98284
(360) 956-0083

Washington State Department of Wildlife
16018 Mill Creek Blvd.
Mill Creek, WA 98012
(425) 774-8812

Organizations

Audubon Society
See phone book for your local chapter.

YMCA Earth Service Corps
909 Fourth Ave.
Seattle, WA 98104
(206) 382-5013
Organizes and supports environmental action clubs in schools.

Environmental Education Association of Washington
EEAW
PO Box 4122
Bellingham, WA 98227
A network of individuals and organizations committed to environmental education. Members include: teachers, Educational Service Districts, students, public agency employees, tribal representatives.

The GREEN Project
Global Rivers Environmental Education Network
University of Michigan
School of Natural Resources
430 E. University Ave. Dana Building
Ann Arbor, MI 48109-1115
International clearing-house, including telecommunications, on water quality issues.

Nisqually River Education Project
Chris Maun
Yelm School District
PO Box 476
Yelm, WA 98597
(206) 458-6137
An inter-district watershed education effort including water quality monitoring, natural and cultural history, and economics.

Northwest Aquatic and Marine Educators
for information, contact:
Padilla Bay NERR
10441 BayView-Edison Rd.
Mt. Vernon, WA 98273
(360) 428-1558
Educators and enthusiasts interested in marine and aquatic education. NAME is the regional chapter of the National Marine Education Association (NMEA).

People for Puget Sound
1326 Fifth Ave. # 450
Seattle, WA 98101
(206) 382-7007
Citizen's group that protects the health of the Sound through education and advocacy.

Puget Sound Alliance
130 Nickerson St. Suite 107
Seattle, WA 98109
(206) 286-1309
Public membership organization concerned with the health of Puget Sound. Workshops, speakers, special programs.

Pure Sound Society
P.O. Box 526
Vashon Island, WA 98070
(206) 463-5607
Curriculum, posters, field trips, teacher training, newsletter, story-telling presentations.

Washington Environmental Council
5200 University Way NE
Seattle, WA 98105
(206) 527-1599
A non-profit group working on statewide issues through legislation and education.

Places

Bellingham Maritime Heritage Center
1600 "C" Street
Bellingham, WA 98225
(360) 676-6806
Salmon hatchery; education programs.

Marine Life Center
1801 Roeder Ave.
Bellingham, WA 98225
(360) 671-2431
Touch tanks, aquaria with NW animals, education programs available

Discovery Park
3801 West Government Way
Seattle, Wa 98199
(206) 386-4236
Extensive urban park with a variety of shoreline habitats.

Marine Education Foundation
P.O. Box 3110
Blaine, WA 98230
(206) 332-8833
New interpretive center. Completion scheduled for Spring 1993.

Point Defiance Zoo and Aquarium
5400 North Pearl Street
Tacoma, WA 98407
(206) 591-5335
An exemplary zoo with aquarium. Education programs available.

Pacific Science Center
200 Second Ave.
Seattle, WA 98101
(206) 443-2001
Vast exhibits, educational programs, and curriculum available, plus a bookstore.

Port Townsend Marine Science Center
Fort Worden State Park
Port Townsend, WA 98368
(360) 385-5582
Touch tanks and education programs available.

Poulsbo Marine Science Center
17771 Fjord Drive NE
Poulsbo, WA 98370
(360) 779-5549
Marine center with comprehensive school programs.

The Seattle Aquarium
Pier 59, Waterfront Park
Seattle, WA 98101
(206) 386-4300
Extensive aquariums and exhibits; school programs.

The Whale Museum
PO Box 945
Friday Harbor, WA 98250
(360) 378-4710
Museum and research dedicated to whales.

Curricula

Aquatic Project Wild
Project Wild Coordinator
Washington State Dept. of Wildlife
600 Capitol Way N.
Olympia, WA 98501-1091
(206) 753-5707
A compilation of diverse, interdisiplinary activities for all ages. Available through teacher workshops only.

Clean Water, Streams, and Fish
Washington State Office of
Environmental Education
17011 Meridian Ave N. Room 16
Seattle, WA 98133-5531
(206) 542-7671
An interdisciplinary secondary curriculum with units on salmonids, watersheds, and the many social issues relating to these subjects.

Coastal Zone Studies
Washington State Office of
Environmental Education
17011 Meridian Ave N. Room 16
Seattle, WA 98133-5531
(206) 542-7671
An in-depth junior and senior high school curriculum for coastal areas, including estuaries.

The Estuary Book and others
Western Education Development
Group
University of British Columbia
Vancouver, B.C. CANADA V6T 1W5
This is one of a series of booklets on various water habitats, with information and activities geared for older students.

The Estuary Study Program
South Slough National Estuarine Research Reserve
PO Box 5417
Charleston, OR 97402
(503)888-5558
An imaginative on-site program for upper elementary and junior high school plus classroom activities for senior high school.

Hanging on to Wetlands
Irwin Slesnick
Science Education Department
Western Washington University
Bellingham, WA 98225
(206) 676-3647
Interdisciplinary classroom and field activities for studying wetlands.

ORCA: Ocean Related Curriculum Activities
Discover More Store
Pacific Science Center
200 Second Avenue North
Seattle, WA 98109
(206) 443-2870
Five different books are available for high school level. They are "American Poetry and the Sea," "Marine Biology Activities," "Marine Biology Field Trip Sites," "Marshes, Estuaries and Wetlands," and "Squalls on Nisqually: A Simulation Game."

Puget Sound Project: The Changing Sound
Marine Science Center
17771 Fjord Drive N.E.
Poulsbo, WA 98370
(206) 779-5549
Very thorough program examining Puget Sound water quality and water quality monitoring; content includes background information and student worksheets.

The Seattle Aquarium Curriculum
The Seattle Aquarium
Pier 59, Waterfront Park
Seattle, WA 98101
(206) 386-4300
Curriculum for all grades, pre-K-12, to supplement visits to the Aquarium; teacher information, pre- and post-visit activities included.

Sleuth: Educational Activities on the Disposal of Household Hazardous Waste.
METRO
Exchange Bldg/ MS 81
821 2nd Ave.
Seattle, WA 98104
(206) 684-1233
An activity guide for identifying, modifying, and disposing of household poisons.

***T**he Stream Scene: Watersheds, Wildlife and People*
Oregon Department of Fish and Wildlife
PO Box 59
Portland, OR 97207
(503) 229-5400 ext. 432
A seven unit set of watershed course lessons, teacher backgrounds, data sheets, issues, and stream investigation resources.

Watershed Education Project
Oregon Department of Fish & Wildlife
PO Box 59
Portland, OR 97207
(503) 229-5400
An aquatic education program publication.

WOW!: The Wonders of Wetlands
Environmental Concern Inc.
Education Department
P.O. Box P
St. Michaels, MD 21663
(410) 745-9620
A wetlands guide for teachers, K-12.

Magazines

"Clearing: Nature and Learning in the Pacific Northwest"
Environmental Education Project
PO Box 751
Portland, OR 97207
(503) 656-0155
A valuable network of people and places, information on happenings, ideas, activities, and resources for teaching about the environment.

"Current: the Journal of Marine Education"
National Marine Educators Association
PO Box 51215
Pacific Grove, CA 93950
(408)648-4841
Quarterly magazine of National Marine Educators Association. Each issue focuses on a marine topic. See Vol. 10, No. 1, 1990, for issue on National Estuarine Research Reserve System.

"Coastal Currents"
Washington State Dept. of Ecology
Shorelands & CZM Program
PO Box 47600
Olympia, WA 98504-7600
(206) 459-6766
An excellent reference for information on water quality related events, organizations and issues.

Books

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Adventures from an early naturalist's explorations of the Southeast lowlands.

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Chronicles the thoughts from a solitary year spent on a Cape Cod beach.

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The celebrated marine biologist's view of the dynamic sea coast zone.

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A passionate story of a family's life in the saltwater tidelands of South Carolina.

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Collected stories from the residents of the Black Bay salt marsh area.

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Adventures of a renowned walker.

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Four centuries of stories about the people, oysters, crabs, and ducks of the bay.

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A naturalist's personal guide and tribute to the ecology of the U.S. Atlantic coast.

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A writer's view of the famous scientific expedition through the Gulf of California.

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A look into the living cycles and history of an Atlantic coast marsh.

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Pulitzer Prize winning look at the animals and people of Chesapeake Bay.

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White, John. "Indians Fishing." In *A Sense of Place: The Artist and the American Land*. By A. Gussow. San Francisco: Friends of the Earth, 1972.

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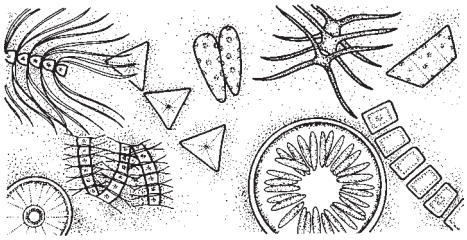
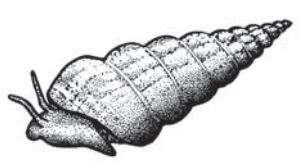
A Field Guide to Padilla Bay Organisms

Following is a description of organisms that are commonly found at Padilla Bay. The organisms have been arranged according to habitat rather than taxonomic classification. Remember that many animals move between several habitats.

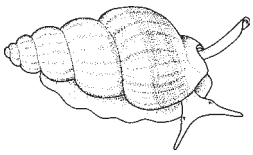
Mudflat Habitat



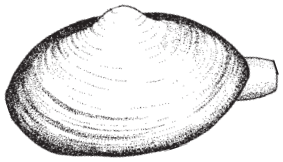
Diatoms - Mud is covered with microscopic, single-celled algae called diatoms. They are beautifully decorated, symmetrical cells enclosed in a silicon "shell." They contribute enormous amounts of organic material and oxygen to the estuarine system. Diatoms can photosynthesize so quickly that they produce organic compounds faster than they can assimilate them. The compounds are exuded into the water where they become available to other microscopic organisms such as bacteria. Look for an oil-like sheen on the mud suface or a brownish foam along the shore and you'll know that diatoms have been busy.



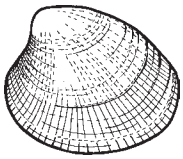
Mud Snail - *Batillaria attramentaria* - This snail covers Padilla Bay's mudflats, though it can be rare in other areas of Washington. Its thin, spiral shell is about 2.5 cm long and is decorated with bands of dark brown spots. It plows along the mud surface scraping up diatoms and detritus. *Batillaria* was accidentally introduced from Japan when the oyster industry began cultivating Japanese oysters.



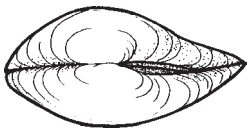
Nassarius - *Nassarius fraterculus* - This snail is smaller than *Batillaria*, with more pronounced ridges running lengthwise across the spirals. Its shell has an obvious notch on the aperture (opening) through which it extends its "inhalent siphon."



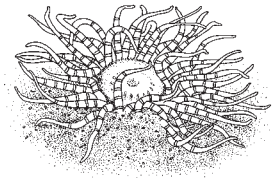
Mud Clam - *Mya arenaria* - Also called the "soft-shelled clam", this clam reaches about 10 cm in length and burrows down in the mud to about 20 cm. Its shell is white or gray, with brown or black shades around the edges. The mud clam is a "gaper", unable to completely close its shell at the neck.



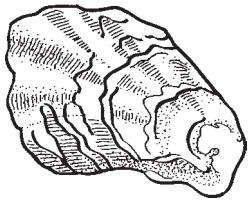
Littleneck Clam - *Protothaca staminea* - This is the common "steamer" found in restaurants and grocery stores. Its heavy, round shell is marked by ridges which run both radially and concentrically. Its siphon is very short (hence the name littleneck) so it is limited to life just under the mud surface



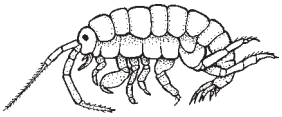
Bent-nosed Clam - *Macoma nasuta* - The bent valves of this clam make it easy to identify. It is about 5 cm long and is white with a brown covering. The periostracum is the covering over the shell which gives it its color. This is often rubbed off, so older clams tend to be whiter than younger ones. *Macomas* have separate orange siphons (inhalent and exhalent).



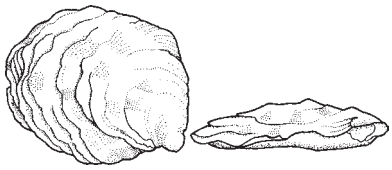
Burrowing Anemone - *Anthopleura artemisia* - This mudflat inhabitant buries its column in the mud and attaches to pebbles or shells. Only the tentacles can be seen at the surface. The burrowing anemone can reach 5 cm in diameter though much smaller specimens can be found in Padilla Bay. The color varies from white to olive.



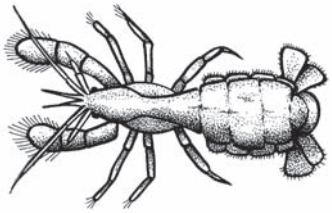
Pacific or Japanese Oyster - *Crassostrea gigas* - This is a large oyster, imported from Japan in the early 1900s. It rarely spawns here in the Pacific Northwest (the water is too cold), so oyster growers must continually bring in spat (microscopic larval stage) from Japan to replenish their beds. Along with this oyster spat came many other organisms - the oyster drill snail, *Ocenebra japonica*, the mud snail, *Batillaria attramentaria*, and Japanese eelgrass, *Zostera japonica*.



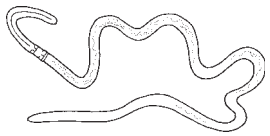
Amphipod - There are about 35 different species of amphipods in Padilla Bay. They are tiny crustaceans resembling a shrimp. The common "sand flea" found in beach wrack is one kind of amphipod. Others are associated with certain algae and are bright green in color. The small, brown amphipod found in tidal pools in the mud eats the detritus that accumulates there. Amphipods range in size from microscopic to 3 cm.



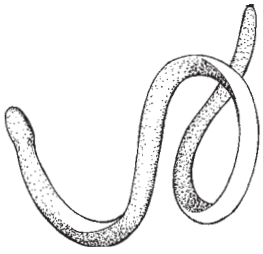
Native Oyster - *Ostrea lurida* - Reaching only about 5 cm, the native oyster is especially sensitive to pollution. It is good to eat, though its small size limits its commercial value. Its shell is rough and gray and often found under rocks. It doesn't have the "fluted" edge found on the Pacific oyster. Oysters, like clams and mussels, filter plankton and detritus from the estuary water.



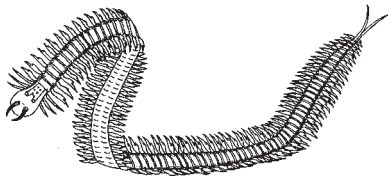
Mud Shrimp - *Upogebia pugettensis* - The "excavator" of the mudflats, this mud shrimp digs extensive burrows in the mud which are then used by many other organisms. The shrimp is about 6-8 cm long with a soft, bluish shell. It uses its feathery pinchers to trap detritus loosened by leaf-like "spinnerettes" under its abdomen. The similar ghost shrimp (*Callianassa californiensis*) is pink in color with one pincher much longer than the other. It tends to live in sandier mud, though both shrimp can be found together. Clams, worms, crabs, copepods and isopods associate with the mud shrimp.



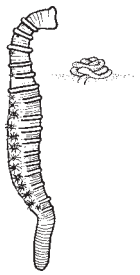
Tongue or acorn worms - *Saccoglossus* sp. - These worms leave fine, almost hair-like fecal castings on the mud surface. The worm itself is 10 to 20 cm long with three distinct body regions. The anterior section is yellow-orange and resembles a tongue. The last section is brownish, long and very fragile. Between the two is a narrow band or collar where the mouth is located. Tongue worms eat mud (and its associated organic matter) with the help of the mucus-covered "tongue".



Mud Nemertean or Ribbon Worm - *Paranemertes peregrina* - This dark brown-purple worm slides along the mud surface on its track of slime. It is carnivorous, feeding on smaller polychaete worms which it subdues with venom before swallowing them whole.

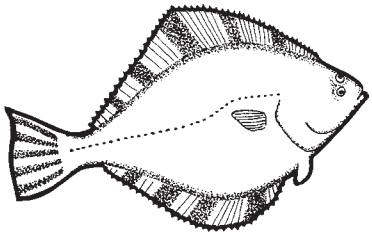


Polychaete Worms - This group of worms is well represented on the mudflats. Polychaetes are made of many segments, each with "parapodia", leg-like structures on each side. Many are microscopic or seldom seen. Others, like those listed below, are conspicuous members of the mudflat community.



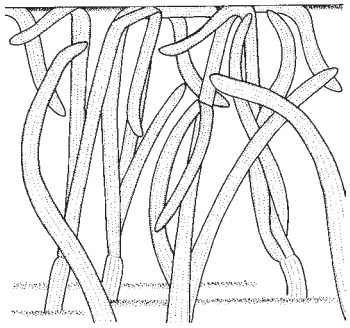
Lug Worm - *Abarenicola pacficum* - Lug worms are the size and same general shape as earthworms, and perform much the same function in the mud. They are detritivores, digesting organic matter found among particles of sand and mud. Their burrows bring oxygen rich water into the often anaerobic mud. They leave spaghetti-like fecal castings on the mud surface which are easily recognized. Two rows of bright red gills give the lug worm a "decorated" appearance.

Ophiodromus - *Ophiodromus pugettensis* - This small, reddish-brown polychaete can be found swimming, serpentine-style, in the mud "puddles" left behind by the tide. It is omnivorous, eating diatoms, small crustaceans and detritus. *Ophiodromus* is often found living commensally on certain sea stars. An adult is about 20 mm long.



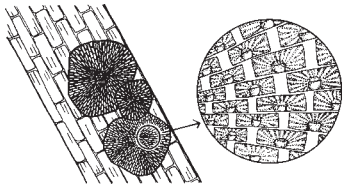
Starry Flounder - *Platichthys stellatus* - This flat fish skims along the mudflat eating crustaceans, worms and small fish. The starry flounder is one of the few flat fish which can have both eyes on either the right side or left side. It is born with an eye on each side. After about 2 weeks, one eye begins to "migrate" to the opposite side and the fish lies down on the eyeless side.

Eelgrass Habitat

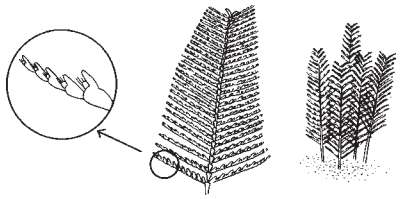


Eelgrass - *Zostera marina* and *Zostera japonica* - Native eelgrass *(Z. marina*) is a bright green grass, about 5-10 mm wide and up to 2 m long. It plays a vital role in the Padilla Bay ecosystem, stabilizing sediments, producing oxygen and organic materials, and providing valuable habitat to many species of invertebrates, fish and birds. It is a true flowering plant, producing small yellow flowers between its blades. *Zostera japonica*, imported accidentally from Japan with the oyster industry, is much smaller and tends to grow higher in the intertidal zone. Together, they cover over 7,000 acres of Padilla Bay's mudflat

Epiphytic algae - Many different species of algae use eelgrass as a substrate. Microscopic diatoms cover the surface of the blade. The red algae, *Smithora naiadum*, grows on the edges of the blades in small, thin sheets that sometimes prevent sunlight from reaching the eelgrass. *Ulva*, or sea lettuce, often attaches to the base of the eelgrass, forming an "understory". These algae attract a host of animals, creating a microcosm within the estuary system.

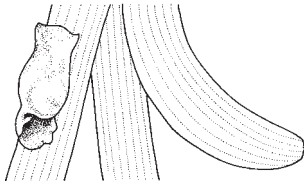


Bryozoans - These colonial animals often grow on eelgrass blades in round, white patches. They build tiny, regularly-shaped boxes called zooids in which individual animals live. Their tentacles catch plankton and detritus passing by, and they can withdraw into their "houses" for protection. They are food for certain species of nudibranchs or "sea slugs".

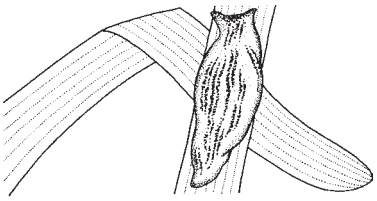


Hydroids - Like bryozoans these, too, are colonial animals though individual hydroids are much more specialized. The hydroid colony looks much like a clump of branching algae but examination with a hand lens or microscope will reveal tentacles for feeding and budding reproductive structures at the tips of the "branches". One common hydroid on eelgrass blades, *Obelia dichotoma*, is usually accompanied by caprellid amphipods (skeleton shrimp) which seem to feed on the tentacles. Several species of nudibranchs are also consumers of hydroids.

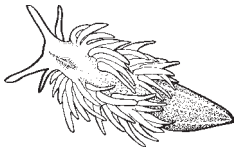
Brooding Anemone - *Epiactus prolifera* - This small anemone is common on eelgrass blades where it feeds on plankton, small crustaceans, and detritus. It is marked by white stripes on its column and "oral disk" and ranges in color from red to brown to green. Its eggs are fertilized in its digestive cavity. The larvae pass through the mouth and down the column where they attach and grow. Hence the name, brooding anemone.



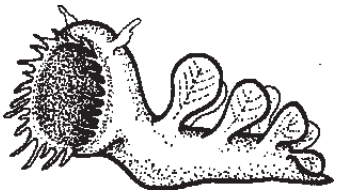
Bubbleshell - *Haminoea vesicula* - This snail relative looks something like a cross between a snail and a sea slug. It has a thin shell which is nearly covered by the mantle, making its appearance much more "sluggish". It forages along eelgrass blades and the mud surface scraping up food with its tongue-like radula. It lays ribbon-shaped masses of yellow eggs attached to eelgrass blades.



Taylor's Sea Slug - *Phyllaplysia taylori* - This attractive, green sea slug is perfectly camouflaged to hide on eelgrass. It lies flat between the blades when the tide is low, and can be difficult to find in spite of prolific numbers. Its clear eggs are laid in rectangular patches on the eelgrass, making them even harder to spot than *Phyllaplysia*.

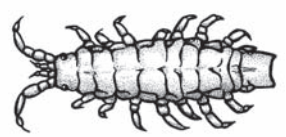


Opalescent Nudibranch - *Hermissenda crassicornis* - This nudibranch is common in eelgrass beds as well as in other habitats. It is covered with orange-tipped plumes called cerrata which may act like gills. *Phidiana* eats a variety of foods including hydroids, other molluscs, eggs, and bits of detritus. It can incorporate the stinging cells from the hydroids it eats into its cerrata, most likely as a defense. Its ruffled, pink egg masses are often found among the eelgrass blades.

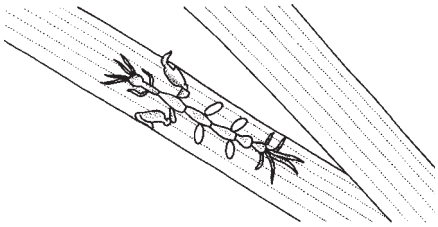


Hooded Nudibranch - *Melibe leonina* - This strange looking, colorless nudibranch moves slowly around the eelgrass beds catching small crustaceans with its fringed "oral hood". It can grow up to 10 cm long and is able to swim (somewhat) using thrashing movements. It can also fill its hood with air and float to a new location.

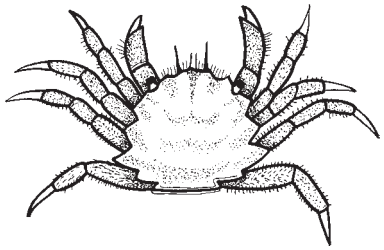
Lacuna variegata - A tiny snail often found on eelgrass blades, this herbivore scrapes diatoms and bacteria from the plant surface with its radula. It can also consume eelgrass tissue, though its small size limits the damage it can do. *Lacuna's* yellow eggs are laid in donut-shaped rings and are often seen on eelgrass washed up on the shore.



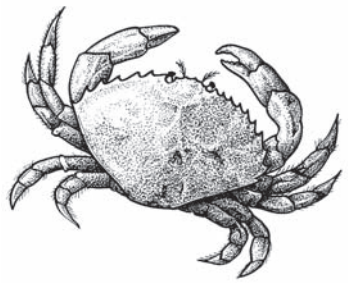
Eelgrass Isopod - *Idotea resecata* - This crustacean is perfectly adapted to life in the eelgrass. Its shape and color blend in perfectly and its diet consists of eelgrass and algae. It swims gracefully from plant to plant, avoiding fish predators. Females carry the eggs and then the young until they are large enough to survive alone.



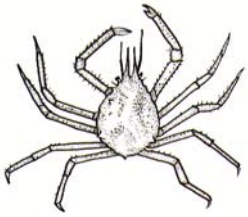
Skeleton Shrimp - This odd-looking crustacean is actually a type of amphipod called a caprellid amphipod. It hooks its hind legs onto eelgrass and with a "bowing" motion, picks up bit of detritus, diatoms, and hydroids with its front claws. Club-like gills protrude from the thoracic segments, and females also have a "thoracic pouch" which is conspicuous when full of eggs. Skeleton shrimp are an important food source for juvenile fish.



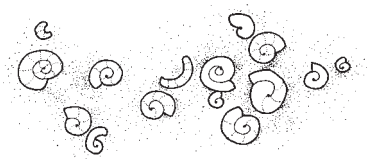
Helmet Crab - *Telmessus cheiragonus* - This hairy, bristly crab rambles around the eelgrass and kelp beds feeding on algae. It can be identified by its yellowish-greenish color when young and by six widely spaced points on each side of its carapace. Adults show a more orange or red color.



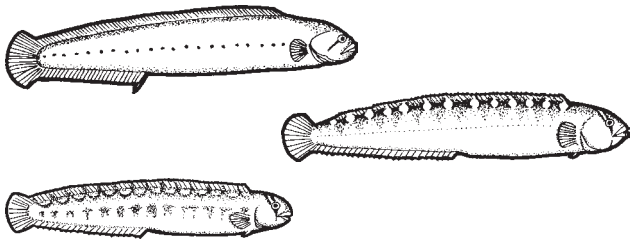
Dungeness Crab - *Cancer magister* - This is the target of crab pots, found in fish markets and restaurants throughout Puget Sound. Though the adults can be found in deep water, juveniles tend to congregate in eelgrass beds. How they get there is still a mystery to researchers, but it seems that the eelgrass habitat is critical to the abundance of this commercial species. This crab feeds on small clams, crustaceans, worms, and even fish. Its carapace is grayish brown, sometimes with a purple tinge.



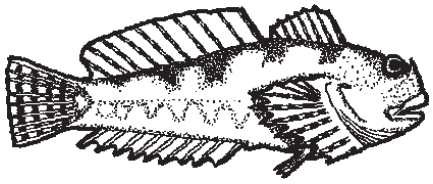
Decorator Crab - *Oregonia gracilis* - This spider crab has a rough, triangular carapace on which such colonists as algae, hydroids and bryozoans easily grow. Its long, thin legs give it a "spidery" look, and its delicate pinchers can skillfully add to the "decorations".



Snail Worm - *Spirorbis* sp. - This tiny polychaete builds a coiled, calcareous tube on the surface of rocks, eelgrass, and algae. Its red tentacles catch plankton and detritus, and are quickly withdrawn when disturbed.

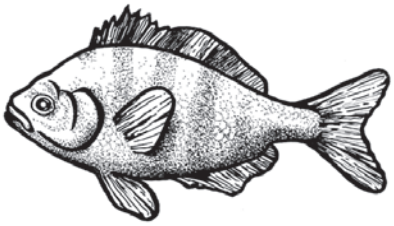


Gunnel - Several different species of gunnels are found in Padilla Bay eelgrass habitat. The long, compressed body resembles that of an eel. Some gunnels reach 18", though 6"-10" is more common. They eat small crustaceans and molluscs.

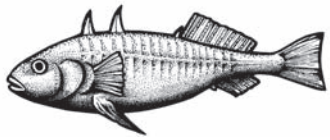


Sculpin - Many members of the sculpin family live in Padilla Bay, including the staghorn, silver-spotted, and grunt sculpin. Sculpins are recognized by their "fat", blunt heads and large pectoral fins. They tend to be slow and lethargic, "sitting" on the muddy bottom and waiting for food rather than pursuing it.

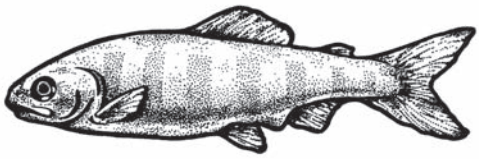
Bay Pipefish - *Syngnathus griseolineatus* - A relative of the sea horse, the pipefish has a stiff, narrow body with an elongated "snout". It can change its color from green to brown to match its eelgrass surroundings, and swims vertically, mimicking the swaying motion of the grass. The male incubates the eggs and broods the young in his brood pouch. Pipefish eat small crustaceans by sucking them into their mouths like a vacuum.



Perch - Two part-time residents of Padilla Bay are the striped and shiner perch -- oval and silvery fish -- that eat skeleton shrimp and other small crustaceans living on the eelgrass. They vary in size from 6" to 15" and often move out to deeper water in the winter.

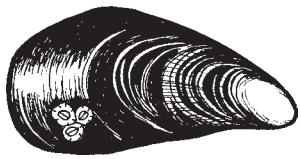


Threespine stickleback - *Gasterosteus aculeatus* - This adaptable fish is found in both fresh and salt water and is a common inhabitant of eelgrass meadows. Under 4" long, this small, sturdy-looking fish eats a wide range of foods from smaller fish to tiny crustaceans and planktonic larvae of crabs and barnacles. They, in turn, are food for seals, larger fishes, and birds. Notice the prominent dorsal "spines".



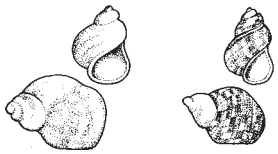
Salmon - *Onchorhyncus* sp. - The bay is used by migrating juvenile chinook, coho, pink, and chum salmon from the Skagit and Samish Rivers and nearby creeks. They feed mostly on copepods and amphipods living on or near the bottom. Adult salmon frequent the bay in late summer, waiting for fall rains to improve access to the rivers.

Pacific Herring - *Clupea harengus* - Padilla Bay is a major holding area for herring. Adults span in late winter, laying great masses of sticky eggs on eelgrass, kelp, and rocks in the bay. The young feed on copepods, various larvae and young fish, all abundant in Padilla Bay. (Reproduced with the permission of the Minister of Supply and Services Canada, 1992. See credits at the end of this section.)

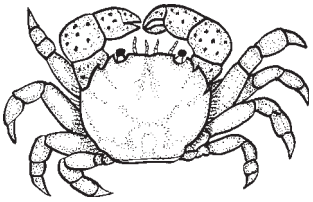


Bay Mussel - *Mytilus edulis* - This edible bivalve attaches to rocks and eelgrass with strong, elastic "byssus threads". It feeds on plankton by "inhaling" water through the slightly open shells and filtering out the microscopic food with ciliated gills. Its color ranges from brown to blue-black.

Rocky Habitat

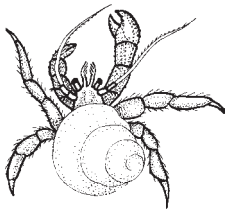


Periwinkle - *Littorina* sp. - Look for this small, dark snail on rocks high in the intertidal zone. A close examination may reveal a checkered pattern on the shell, indicating the checkered periwinkle, *L. scutulata*. The similar but slightly rounder Sitka periwinkle lacks the checkered markings. Periwinkles can survive long periods out of water. They feed on microscopic algae as well as larger forms such as sea lettuce.



Shore Crab - *Hemigrapsus* sp. - This small, tough-looking crab is found under rocks, high in the intertidal zone. Two species, one red and one green, are found in Padilla Bay. Both have a square carapace and proportionately large pinchers. Shore crabs are scavengers.

Limpets - Many different species of limpets graze on the rocks near the Padilla Bay shore. These snail relatives scrape algae from the rock and mud surface with a rough tongue-like radula. Their shell fits exactly to one site on "their rock" enabling them to seal water inside their shell during low tides. Limpets return to the same spot after foraging.



Hermit Crab - *Pagurus* sp. - This well-known inhabitant of rocky tidepools also frequents the eelgrass meadows and estuary shores. A hermit crab has a soft, unprotected abdomen which it keeps in an empty snail shell. As the crab grows, it must also change shells to accomodate its larger size. Its two pinchers are different sizes, and are used in obtaining food and for defense.

Answers to Questions

Chapter 1 – Estuary Formed

1. These factors might be considered: geologic formation, physical shape, salinity, tidal action, circulation, chemical make-up of the water

2. Hood Canal - fjord
   Chesapeake Bay - coastal plains
   Columbia River - bar built, coastal plains
   San Francisco - tectonic

3. Answers may include: plate tectonics or continental plate colliding with micro-continents, continental glaciation, sedimentation from erosion in surrounding mountains, changes in sea level

4. Active volcanoes and earthquakes, erosion of shorelines composed of glacial debris, sedimentation from rivers and other evidence not discussed in this curriculum such as rebound from glaciation. All are evidence of geologic processes seen today.

5. Answers will vary but could include change in sea level, another period of glaciation, further sedimentation, volcanic and earthquake activity, erosion.

Chapter 2 – Estuary Settled

1. The population was devastated by European diseases.

2. Though the land itself was given away, the right to use rocks, trees, berries, animals, water, fish, etc., was not given away. As these resources are now "owned" by others or are damaged or destroyed, the Natives have limited access (or even no access) to these resources.

3. Spain, England, U.S., Samish . . .

4. Settlers were attracted by easy access to resources such as home sites, food, transportation routes, lumber, etc..

5. 1925– Dike and reclaim for farmland. Contractor went broke.
   1930– Oyster farming. Declined due to poor water quality and increased oyster predation. Lack of nutrients, claimed by the judge in 1941, is a questionable verdict but a reasonable answer to this question.
   1961– Industrial park. Faced public opposition, failed to obtain federal funding.
   1960s -- Housing development. New county regulations prevented development of this kind.
   1965– Second industrial complex. Faced public opposition, and finally county regulations preventing this development.

6. Answers will vary but could include: common use of resources (Native American and trappers), territory can be claimed and resources used by another country (expansionism), a good place to settle and own (settlers), a place containing resources that can be harvested for capital gain, a place that can be changed for another use, a habitat to be protected.

7. Edna Breazeale recognized a value in Padilla Bay that would be lost if plans for development were realized.

Chapter 3 – Estuary Alive

1. Answers will vary.

2. Answers could include:
   River ecosystem – influences estuarine water quality and quantity, connected by migratory species.
   Adjacent wetlands – connected by water flow, fauna, affects water quality through filtering, slowing water movement, reducing flooding.
   Pelagic ocean ecosystem – receives nutrients and sediments, affects circulation, tidal action, climate, connected by movements of water and migratory animals.

3. Tides cause extreme ranges of temperature, salinity, oxygen, sunlight, dehydration, etc. Severe conditions mean less competition and predation from those organisms which can't survive the changes.

4. Nutrients may be bound up chemically or in plant or animal tissue. Few organisms have access to the nutrients locked up in plant tissue. Bacteria make the nutrients and energy available by breaking down plant and animal cells and compounds into simpler materials.

5. Most – eelgrass. least – hay

6. To get to the other side, but answers may vary.

7. When the salt content inside an organism's cells is lower than in the surrounding salt water, osmosis causes dehydration.

8. It evolved on land like other flowering plants, then adapted to the marine subtidal zone.

9. It was introduced with oyster spat from Japan.

10. Eelgrass is a source of food, oxygen, detritus, habitat, solid substrate, and sediment stabilization.

11. Bacteria make nutrients available by decomposing organic material in the water and sediment. They also break down toxins.

12. Answers may include: eelgrass, mudflat, under the mud, in the water column, salt marsh, rocky shore, gravel shore.

Chapter 4 – Estuary Inspired

These answers will vary.

Chapter 5 – Estuary Developed

1. Estuaries have been diked for agriculture, dredged for navigation, filled for industry, housing, recreation, polluted by waste disposal, either incidental, accidental, or intentional (pollution includes toxics, pathogens, organic matter, nutrients).

2. London – Thames
   St. Petersburg – Neva
   Seattle – Duwamish
   San Fransisco – Sacramento & San Joaquin
   Washington D.C. – Potomac
   New York – Hudson

3. Dredging may cause loss of habitat, increased turbidity, exposure to toxic sediments.

4. Answers will vary.

5. Answers may include: construction, logging, urban development, irrigation, hydroelectric plants, industrial outfall, improper disposal of household hazardous wastes, . . .

6. *desirable*: water view, cool breeze, beach access, solitude, high market value.
undesirable: erosion, expensive, may be difficult to maintain a properly functioning septic system, exposure to storms.

7. Many erosion control structures cause damage to neighboring properties, interrupt natural flow of sediment, disturb intertidal habitats, or simply don't work.

8. It can replace native plants, destroy valuable shellfish habitat, and disrupt the existing sediment balance.

9. Answers will vary.

Activity 2 – Plankton Activity

1. Net size affects what kinds of plankton are caught. Also, the plankton population varies with the season and location in Puget Sound.

2. Upwelling of ocean currents at the continental shelf and input of large volumes of water from rivers bring nutrients into the Puget Sound region that are scarce in open ocean. The higher temperatures in shallow bays also attribute to growth.

3. Most of the phytoplankton are so small they pass through all but the finest mesh nets. They may also be too small to observe with a dissecting microscope. Time of year and location of sampling also affects numbers of plankton caught.

Activity 3 – Water Quality Monitoring

1. Monitoring is used to get information about the "health" of a body of water, to compare with future data to assess changes, to assess the damage of an event like a toxic spill, to identify areas for further study, and to understand how estuaries work.

2. Answers will vary, but this information is vital to decisions about where, what, how, and why to establish a monitoring program with your class.

Temperature

1. Organisms depend on specific temperatures for their survival. Temperature affects metabolism, photosynthetic rate, ability to fight off parasites and diseases, and dissolved oxygen levels.

2. Usually warmer water floats because it is less dense, though cool fresh water could float on warm salt water.

3. Water temperature fluctuates with the time of day, current, tide, season, and weather conditions.

Dissolved Oxygen

1. Experiments must include a DO measurement before and after the manipulation of each of the three variables. A control is also necessary.

2. DO levels will change due to: a. diffusion between the sample and the air, b. changes in temperature, c. biological action.

3. Answers will vary but could include reducing human sources of nutrients and organic matter, reduce water temperature (shade or change in industrial outflow), removal of obstructions such as dams which increase solar exposure and reduce currents that aerate the water.

Fecal Coliform

1. No

2.The presence of coliform bacteria indicates the possibility of the presence of other disease causing organisms.

3. Septic systems malfunction due to old age, inadequate maintenence, or improper design for the site. All sewage treatment release some sewage into the water. Ideally,

the body of water is able to handle the waste without hazard. Problems occur when circulation is disrupted or the volume of discharge is increased. This occurs if the system is old or too small for the population and, in some cases, during periods of heavy rainfall. Many toxins are not removed by sewage treatment procedures.

4. First, repeat the test. Results have wide variability, even at certified laboratories. Contact your health department and ask for a certified test. See Activity 7, What We Can Do for Estuaries.

Nitrates and Phosphates

1. Winter should have the highest nutrient level because heavy rainfall increases runoff of nutrients from the land while productivity (which removes nutrients from the water) is limited by low levels of sunlight and cool temperatures. In summer, nutrient levels are reduced when runoff from rain decreases and primary productivity increases with increased sunlight and temperatures.

2. Excessive nutrients can cause a bloom of algal growth. This may increase turbidity and increase BOD.

3. Fertilizer applied too heavily or during heavy rains can run directly into surface water. Many laundry detergents contain phosphates and not all phosphates are removed by current sewage treatment methods. Nitrogen-rich manure pollutes surface water when stored improperly or if animals have direct access to streams, ponds, wetlands, or rivers.

4. Look for urban sewage treatment, septic tanks, agriculture and some industries.

5. Each test kit will list the hazardous chemicals it contains. All hazardous wastes should be collected, then disposed of according the procedures of your city or county. Call 1-800-RECYCLE for specific information.

Salinity

1. Salt water is more dense than fresh water.

2. If the salt content inside the cells is less than that of the surrounding water, then osmosis will cause dehydration.

3. 3.5%

4. Diking prevents tidal waters from entering coastal lowlands. Wells remove fresh ground water causing salt water intrusion. Diversion for irrigation or other uses can reduce fresh water flow.

5. A meter measures conductivity while a hydrometer measures specific gravity or density.

Turbidity

1. Turbidity is much higher in Skagit Bay and more eelgrass is found in Padilla Bay.

2. Increased turbidity reduces the amount of light reaching plants, causing a decrease in photosynthesis. It also slows animal development and growth.

3. Dredging, logging, agricultural, construction runoff, large numbers of phytoplankton, floods, heavy rains, strong currents, and wave action all cause increased turbidity.

4. Direct sunlight, strong current, observer error or inconsistencies.

pH

1. Any reading less than 7

2. 100 times

3. False. Organisms tolerate changes in pH, but have limits to their range of tolerance.

Glossary

abiotic: non-living.

adaptive radiation: the evolution of a species into several related species with different specializations for different environments.

aerobic: pertaining to oxygen.

anaerobic: lacking oxygen; able to live in the absence of oxygen.

autotroph: an organism capable of manufacturing its own food by synthesis of inorganic materials; a "producer."

bar-built estuary: an estuary protected from the ocean and formed by a bar of sediment stretching across a river mouth.

biomass: total weight of plants or organisms per unit area.

biotic: pertaining to life or specific life conditions.

carapace: a chitonous or bony shield covering the backs of some animals such as crabs.

chemotroph: an organism that obtains energy through chemical reactions involving inorganic compounds instead of light.

coastal plains estuary: a former river valley which was "drowned" by the sea; usually wide and shallow.

crustacean: class of arthropods having a segmented body, chitonous exoskeleton, and paired, jointed limbs. Includes lobsters, crabs, shrimps and barnacles.

delta: land form at the mouth of a river or inlet made of sediment either brought downstream with the river or brought in with the tides.

detritivore: an organism that feeds on detritus.

detritus: fragments of decomposing plants and animals.

diatom: single-celled alga consisting of two overlapping, symmetrical, silicon plates.

dike: an embankment of earth and rock built to enclose lands from the tide, rivers, or floods.

diking: the process of building a dike.

dinoflagellate: a group of planktonic producers having two flagella and an outer envelope made of cellulose.

dredge: a type of machine used in deepening harbors and waterways, and in underwater mining; to clean, deepen, or widen with a dredge.

dredge spoils: refuse material removed from a dredging excavation.

ebbing tide: an out-going tide.

ecosystem: a distinct, self-supporting unit of interacting organisms and their environment.

embayment: a bay or bay-like shape; the formation of a bay.

epiphyte: an organism that grows on another plant (for mechanical support but not for a source of nutrients).

expansionism: the practice or policy of territorial or economic expansion, for example, by a nation.

fjord: a long, narrow, often deep inlet from the sea bordered by cliffs or mountain slopes.

heterotroph: an organism that obtains energy by ingesting organic substances.

holoplankton: organisms that remain plankton for their whole lives.

indigenous: occurring or living naturally in an area; not introduced; native.

interstice: a narrow or small space between parts (such as soil or sediment particles).

mantle: the outer membrane next to the shell of molluscs.

meroplankton: organisms that are plankton for only part of their life cycles.

mollusc: phylum of invertebrates, usually unsegmented, with a head, foot, and visceral mass covered by a mantle (includes snails, clams, chitons, octopus).

neap tide: a tide of lowest range; occurs at first and third quarter moons.

niche: the area of a habitat occupied by an organism.

omnivorous: eating both animals and plants.

organic: derived from living organisms.

osmosis: the diffusion of a fluid through a semi-permeable membrane until it is of equal concentration on both sides.

oxidize: to combine with oxygen.

phytoplankton: microscopic, floating producers.

pile: a heavy beam of timber driven into the earth as a foundation or support for a structure.

planktonic: floating; part of the microscopic organisms floating in great numbers in fresh or salt water.

Pleistocene epoch: recent geologic era characterized by the appearance and recession of the northern glaciers and the appearance of early humans.

proboscis: a slender, tubular feeding and sucking structure of some insects and worms.

radula: a flexible, tongue-like organ with rows of horny teeth for scraping food.

sediment: material suspended in, or settled out of, a liquid.

skidroad: a track made of logs used to haul logs to a loading platform or mill.

slough: a stagnant swamp, marsh, bog, or pond, especially as part of a bayou, inlet or backwater.

spring tide: a tide having the greatest rise and fall, occurring at full and new moons.

stratification: arrangement in layers.

substrate: a surface on which a plant or animal grows or is attached.

tectonic: resulting from structural deformation in the earth's crust.

thoracic: in or near the thorax.

tideland: coastal land submerged during high tide.

toxic: harmful, destructive, or deadly poisonous.

Treaty of Point Elliott: One of several treaties signed in Washington State in 1855 between the United States and various Indian Nations intended to secure peace and settle issues of land and resource use.

watershed: the region draining into a river, river system, or body of water.

zooplankton: floating, aquatic animals, usually microscopic.

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