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ABSTRACT

Estuaries are marine systems that serve as nurseries for animals, links in the migratory pathways, and habitat for a complex community of organisms. This curriculum guide intended for use at the high school level seeks to teach what estuaries are; provide opportunities to practice decision-making that affects estuaries; and encourage students to examine their behaviors that affect their estuary. Equally divided into three sections, the first section presents five chapters concerning the geology, local history, ecology, literature and arts, and human use of estuaries that serve as background information for the teacher and students. The second section presents seven activities coordinated with the assignments at the end of the chapters. The activities include taking a field trip to an estuary, conducting a plankton study, monitoring estuary water quality, keeping a marine aquarium, writing activities involving estuaries, thinking globally about estuaries, and exploring what students can do for estuary protection. The third section identifies resource materials for the class. Resources include lists of estuary ecology, protection, and literature resources; a field guide to Padilla Bay organisms; reproducible masters for use during the activities and lessons; answers to chapter questions; a glossary of 59 terms; and a bibliography of 39 references. An evaluation sheet for teachers using the guide is provided. (MDH)

Padilla Bay National
Estuarine Research Reserve
Breazeale Interpretive Center

THE ESTUARY GUIDE

LEVEL 3
HIGH SCHOOL

DRAFT

1043 Bayview-Edison Road
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THE ESTUARY GUIDE

LEVEL 3

DRAFT

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Introduction

Estuaries -- where fresh water meets the salt water of the sea. They are one of our most valuable marine systems, serving as nurseries for many animal species, vital links in migratory pathways, and rich habitat for a complex community of organisms. They filter impurities, absorb flood water, and recycle nutrients. And they are disappearing at an alarming rate.

We need an "educated" public in order to change the current trend of filling, dredging and polluting these important places.

Our belief is that people cannot make responsible, informed decisions regarding resources such as estuaries unless they know what they are dealing with. In the past, estuaries were considered worthless areas, easy to use and improve. Today we know that they are, in fact, critical ecosystems on which many animals -- including humans -- depend.

The goal of this curriculum is to promote responsible decision-making by:

* Teaching *what* estuaries are, what lives there, how they function, and how we depend on them;

* Providing opportunities to practice making *decisions* affecting estuaries; and

* Encouraging students to examine their *daily behaviors* that affect their estuary.

How to Use This Curriculum

Our educational system tends to compartmentalize learning, isolating individual subjects and ignoring the important connections that make learning relevant and useful. The component parts of this curriculum can be taught independently and infused into the traditional disciplines of geology, history, humanities, or biology. Ideally, however, the Padilla Bay estuary will serve as a theme for learning, illustrating how the various subjects interact as a coherent whole. A team of teachers from different disciplines might coordinate to present a tangible theme, bringing the real world into the classroom.

The various relationships humans have with estuaries are numerous and complex. These include economic, legal, emotional, intellectual, and other relationships. The problems that estuaries face today are equally complex. This curriculum is based on the concept that decisions and solutions which address a larger number of perspectives will result in more effective and successful actions.

Please take some time to complete and return the evaluation at the end of this curriculum. We plan to make revisions to this first edition and need your input.

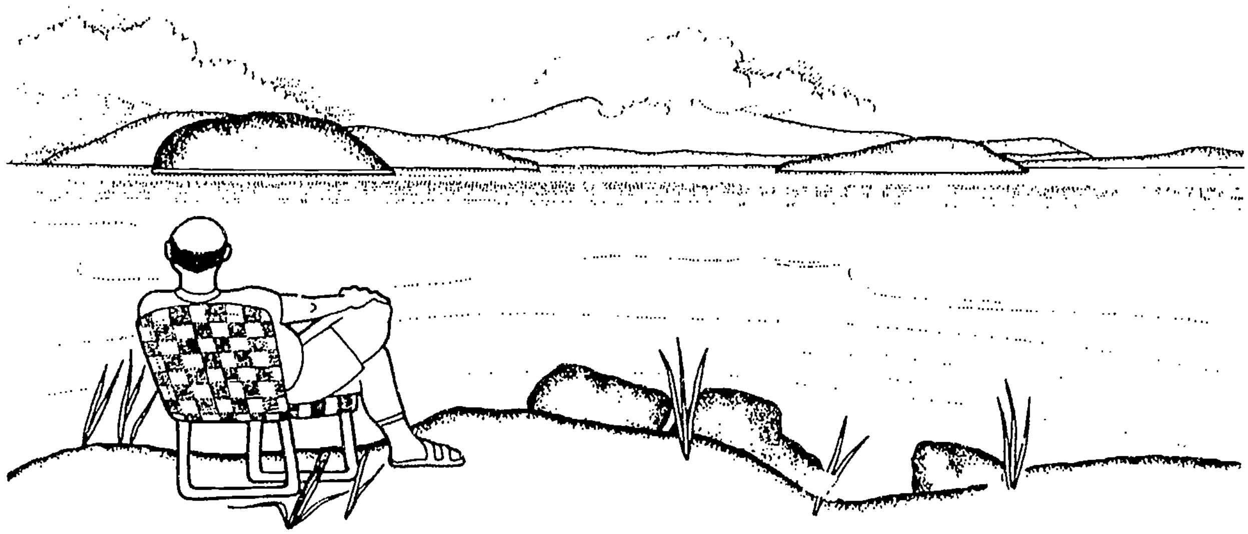
The first five sections of this guide are intended to be used as background information for the teacher or as student reading material. The activities that follow should serve as the curriculum's core, building on the background information and providing relevant, hands-on experience. Key words are italicized and listed in the glossary.

Padilla Bay National Estuarine Research Reserve

Padilla Bay is part of the National Estuarine Research Reserve System. This program was established in 1972 under the Federal Coastal Zone Management Act. The purpose of this program is to set aside estuaries in different biogeographical regions of the United States for research and education. Today, 21 sites throughout the coastal United States and Puerto Rico protect over 300,000 acres of estuarine habitats.

The Breazeale Interpretive Center provides educational and research facilities which include interpretive exhibits, aquaria, curriculum library, and research laboratory. An upland trail, shore access, and shore trail provide public access to the estuary.

For researchers, Padilla Bay Reserve offers one of the largest concentrations of eelgrass on the west coast, along with a distinct collection of invertebrates, fish, birds, and marine mammals. Research topics in Padilla Bay have ranged from primary productivity, seagrass distribution, and Dungeness crab habitat to toxic sediments, pesticide run-off and suspended sediments. The information gained from such research is important to decision makers who must preserve and manage valuable habitats. Educational programs include school programs, adult education, teacher workshops, youth programs, films, guided walks, and family programs.



1 - Estuary Formed - Geology

The vacationing insurance salesman from Indiana unfolds his chair and relaxes on a bluff overlooking Padilla Bay, Washington. He gazes across an expanse of rippling water, watching sea birds in the distance. He feels a sense of permanence with his surroundings; a sense that this bay looks like it always has and as it always will be in the future. His own experience tells him that the earth is reliable and unchanging and he sinks into a peaceful sleep. But he awakens in a new world. What was once an expanse of rippling water is now a field of hissing, fragrant mud. The hoosier rubs his eyes in disbelief. The passing time and *ebbing tide* have introduced this visitor to a place rich with life and marked by dramatic changes -- the estuary.

Estuaries are regions where rivers meet the sea. They occur all over the world and come in many shapes and sizes. The most commonly used definition of an estuary was written by Cameron and Pritchard (1963);

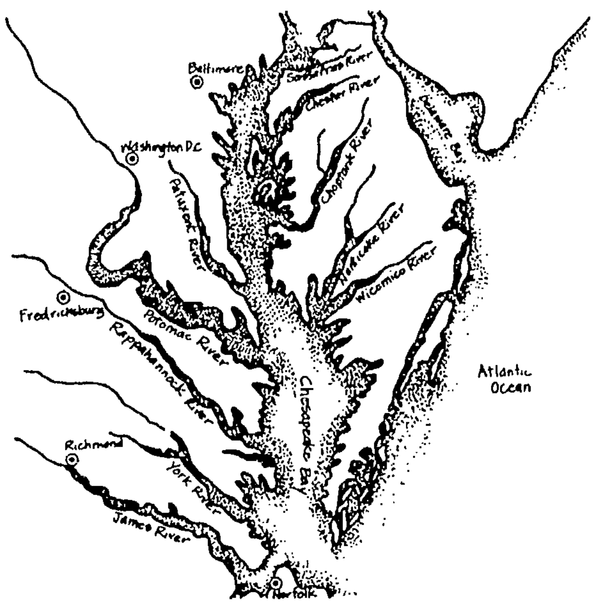
> "An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage."

This definition is useful for describing the physical conditions present in an estuary, but it does not convey the essence of the estuary -- the productive grasses, the sanctuary for juvenile fish, the lush bird habitat, the inspiration for a poet, the natural harbor. Estuaries are these, too.

From the time humans made their appearance, estuaries have been important centers of commerce. They provided wild food, fertile agricultural land, sheltered harbors, and navigational access to the inland areas. Estuaries continue to be places of human activity. Today, most of the world's largest cities are on estuaries, and many have been transformed beyond recognition.

Types of Estuaries

So many different physical factors interact in estuaries that they exhibit incredible variety. This variety makes estuaries difficult to classify. Some scientists have classified them according to their geologic formation. *Coastal plains estuaries* (like Chesapeake Bay) are river valleys which were flooded with sea water when the sea level rose after the last ice age. *Fjords* (like Hood Canal) are estuaries whose deep sides were carved out by glaciers. *Tectonic estuaries* (like parts of San Francisco Bay) were formed by movements of the earth, such as slipping along a fault line. *Bar-built estuaries* are formed at the mouths of large rivers where river sediment is deposited as a sand or mud bar across the mouth. But these are not hard and fast distinctions. For instance, the Columbia River has a protective bar across the mouth, but it is also a flooded river valley.



Chesapeake Bay is an example of a *coastal plains estuary*, a "drowned" river valley.

Other characteristics which are sometimes considered in classifying an estuary include the shape of its basin. (Is it a long, narrow tidal river, a coast that is protected by a barrier island or reef, or an *embayment* with a narrow, restricted outlet to the sea?) How much fresh water enters the estuary? How is it affected by tides? How does the water circulate in the estuary? (Is it *stratified* with distinct layers of salt and fresh water or non-stratified?) What is the chemical make-up of the estuary water? All these things are considered when examining estuaries. Often, one estuary represents several ecosystem types or physical characteristics.

The Indiana salesman didn't realize that he was looking at a shallow bay characterized by mud flats and seagrass meadows, located in the Columbian/Puget Sound biogeographic region of the United States. He knew nothing of the fresh water input or geologic formation. What he did understand, however, was that time had erased his view of rippling water. An estuary is a place marked by change.

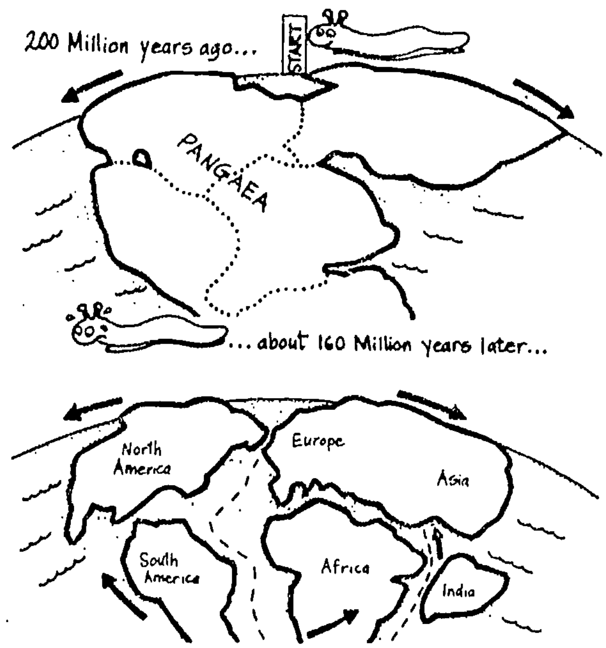
Changes can occur in short periods of time (short, relative to human experience, that is), as the Indiana tourist discovered. Mount St. Helens provides a familiar example of "quick change." The 1980 eruption created a gaping crater in only a few minutes. Earthquakes can also be agents of quick change as California residents can testify. Phenomena such as storms, waves and currents are convincing evidence of the unceasing change that characterizes our planet and our universe; convincing, because they all occur within our time frame.

Long-term change -- change over thousands or millions of years -- is harder to understand. Scientists estimate that the earth completed its formation about 4.6 billion years ago and its permanent crust began to form about 4.1 billion years ago. We humans have been around for only a brief instant of the earth's history; short-timers, so to speak. Working toward a perspective of "long-term change" will aid in understanding Padilla Bay and the entire earth on which we live.

Like the man from Indiana, we must remember that time makes all the difference!

Assembling the Pieces

About 200 million years ago, theory holds, North America, South America, Europe and Africa were all connected, forming a huge supercontinent called Pangaea. But a rising column of hot rock from the earth's interior began to put pressure on the continental crust, causing the land mass to split and move apart. The newly formed Atlantic Ocean filled in the gaps created as these giant jigsaw puzzle pieces separated. When birds and mammals first appeared on the scene and dinosaurs still dominated the earth, the American continents

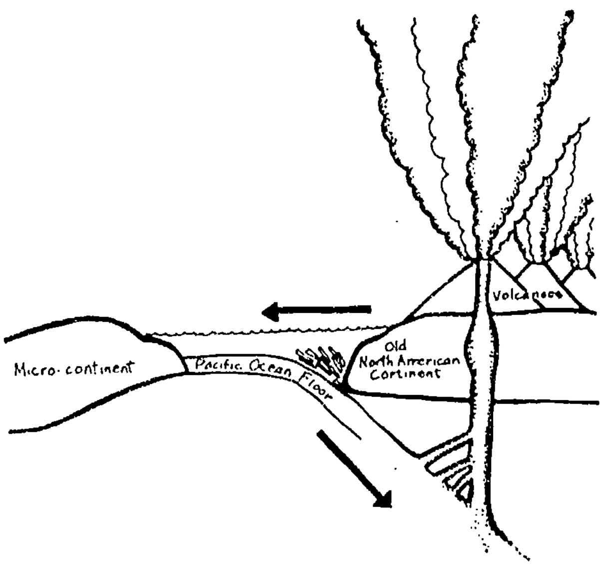


The continents are drifting quickly by geologic standards, but slower than a slug.

were moving away from Europe and Africa at the rate of about 2 to 3 inches per year -- a slow pace when compared to human standards but in geologic time, quite fast. At that rate a continent will cover 32 miles in a million years and in 200 million years, 6400 miles! These processes continue today. As we continue to move westward, the Pacific Ocean shrinks while the Atlantic Ocean expands.

When North America began its westward voyage 200 million years ago, the Pacific Ocean was dotted with small, island micro-continents. Borneo, New Zealand, New

Guinea and Japan are among those remaining. Any that happened to be in the path of the "fast moving" North America collided and were welded on. Several of these "add-ons" now make up areas of Washington, British Columbia, and Alaska.



The westward moving North American continent added on small Pacific islands.

One collision, about 60 million years ago, created a large mountain range in what is now northeastern Washington. As these mountains eroded, rivers washed huge amounts of sand and silt into the adjoining ocean.

These sediments, up to 20,000 feet thick, were compressed into Chuckanut sandstone. The large palm leaf fossils found in Chucknut sandstone indicate that the world climate was warmer then. These fossils are remains of plants that may have grown in estuaries 45 to 55 million years ago.

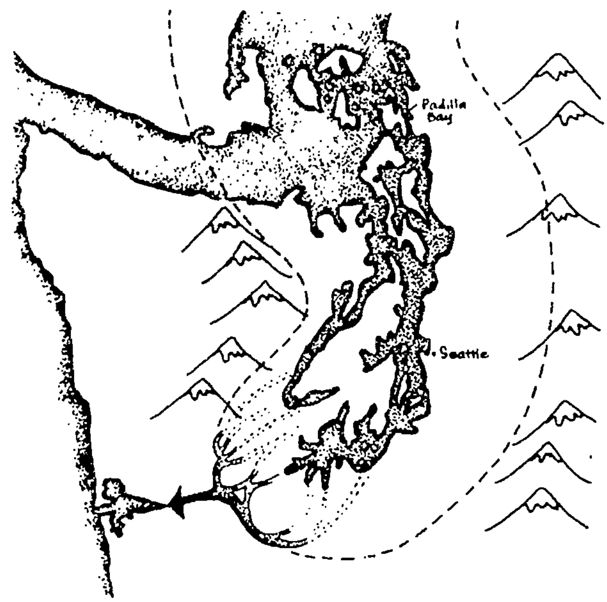
As the North American Continent continued west, riding up over the Pacific Ocean floor and colliding with other micro-continents, massive rocks have been twisted and contorted, forced deep under the earth's surface, crushed and heated, then spewed out in periods of extensive volcanism.

So when the Indiana salesman looked out at the calm bay encircled by peaceful mountains, he was actually riding a great heaving plate of moving earth. At any moment, the next magnitude eight earthquake could rock his chair as North America jumps forward and the mountains push up a little more.

Carving Out the Details

The finishing touches to the Puget Sound area occurred a mere ten to twenty thousand years ago when the world climate was colder than it is today. A massive sheet of ice carved and deposited the details of the landscape.

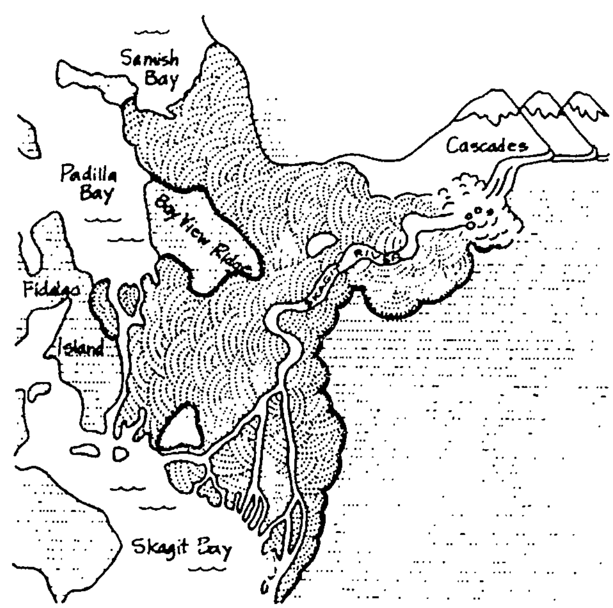
The upper third of Washington state was covered with ice at least twice and perhaps seven times during the *Pleistocene Epoch*. The tongue of ice that pushed south into the Puget Lowland all the way to Olympia is known as the Puget Lobe. It completely covered the area between the Olympic and Cascade Mountains. Padilla Bay, for example, was buried under ice more than a mile thick! At the top of Mount Erie, just west of Padilla Bay, scratches made by the glacier can still be seen in the solid bedrock.



The approximate limits of the Puget Lobe. Willapa Bay was created from the melted glacier water flowing to the southwest.

As the climate changed, the Puget Lobe began to melt, creating a lake in the depression it had occupied. The lake would have drained naturally out to the Pacific Ocean had it not been for a remnant of ice blocking the Strait of Juan de Fuca. The scene must have appeared quite different than it does today. Huge piles of rock, sand, and gravel (glacial till) that had been scraped up in the glacier's path became islands, while the lowlands were covered with water. Eventually the dam gave way to the pressure of the confined lake waters, releasing torrents into the Pacific. The leftover piles of glacial debris are still around, visible today as eroding bluffs around the shores of Puget Sound.

Meanwhile, the Skagit River was flowing hard and fast out of the Cascades, bringing with it mountains of sediment and depositing it in an advancing *delta*. Now, some ten thousand years later, the Skagit River sediments have filled one-hundred thousand acres of what was once part of Puget Sound. Sediments have reached the mound of glacial debris we call Bayview Ridge, once an island far from the shore. One result of this process is Padilla Bay, a shallow bay supplied with fresh water from the Skagit River.



10,000 years of advancing river sediments have made Padilla Bay a flat and shallow estuary.

The Indiana tourist has long since departed in his RV. The tide still comes in and goes out without him. Indeed, to the casual observer, everything seems tranquil. But the Indiana tourist was struck from his carefree, vacation bliss with a bolt of **time**.

Certainly Padilla Bay is not as it always has been. This estuary is in its fragile infancy, only recently born to the earth.

Related Activity:

"Creative Exercises" in Activity 6.

Questions

1. List five factors that might be considered in classifying an estuary.

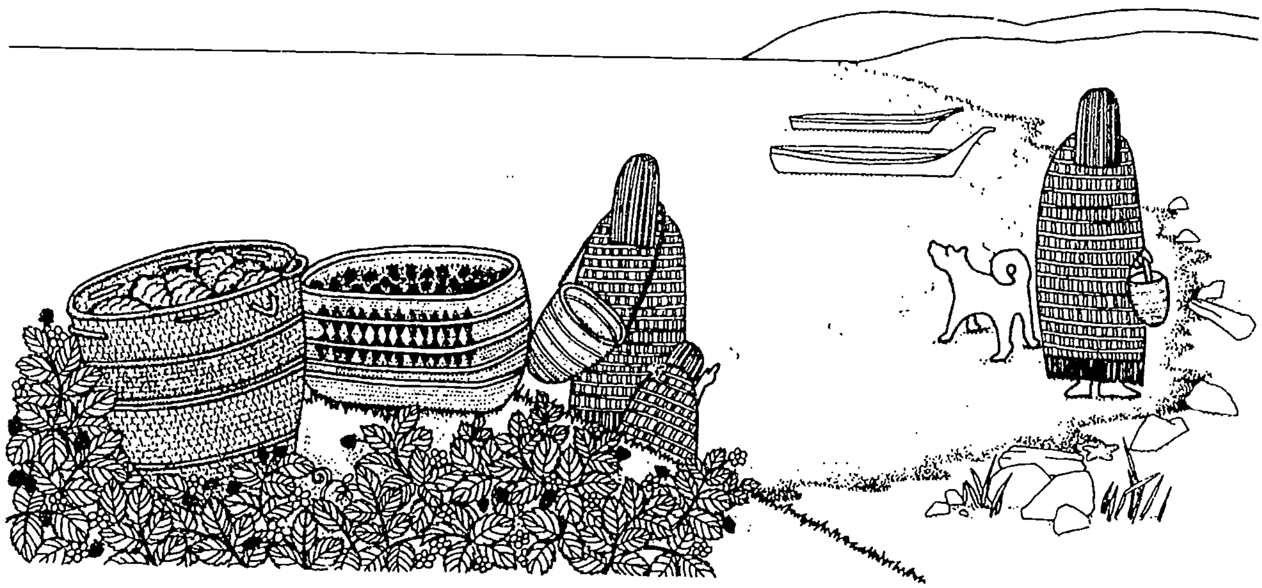
2. Match the estuary with its geologic category.

Hood Canal	tectonic
Chesapeake Bay	bar-built
Columbia River	coastal plains
San Fransico Bay	fjord

3. List three geologic processes involved in forming the shorelines in the Puget Sound region.

4. From what you've read about geologic processes in this chapter, make a list of evidence you have seen that the Puget Sound region is still changing today? (Don't include changes from human activities.)

5. Describe some geologic processes that might change the Puget Sound in the next 10,000 years.



2- Estuary Settled - Local History

History is usually studied as a series of events. We know when famous people were born and died. We know when wars were fought and treaties were signed. What makes history significant is not only the sequence of events, but also how attitudes and behaviors change over time. Unfortunately, attitudes are more difficult to record and understand. We can see what people did, but do not always know what they thought or what motivated them. If we could live the events, read the letters, and see the art, we would have a clearer picture of their attitudes.

This section is a chronicle of events, but as you read of the people and events that have shaped Padilla Bay's past, try to imagine the rest. Look beyond the names and dates to a story of changing attitudes.

The First Inhabitants

In the early 1820s, a fur trader named John Work described some people he visited near Padilla Bay as "fine looking Indians."

> "I passed 12 houses belonging to these people on the east side of our road, not far separated, in the opposite side of the bay I counted at least 12 houses in a village, besides which at a great distance, the smoke of two other villages appeared."

What John Work saw was part of a flourishing culture that, by Work's time, had been subjected to a series of devastating epidemics. It is to the credit of the Indian people of the region that both they and their culture continued and adapted to the tide of human events.

An 1855 map indicates that the Samish and Swinomish lived in the area around Padilla Bay. Modern anthropologists still do not agree where these people came from but their own oral history says that they originated right here in the Pacific Northwest. The name that the Samish have for themselves (pro nounced SEE opsh) is translated "The First People." In any case, they lived for ten thousand years on the calm bays of the Skagit Valley, with abundant food and a temperate climate. Indeed, the spring-fed, forested area around Padilla Bay must have been a tempting place to settle as it provided everything they needed for a comfortable life and safe access to an efficient marine highway.

All the aspects of modern culture which are represented by our modern institutions of church, school, medicine, industry, and politics were integrated into the daily lives of these native people. In the summer they lived in portable dwellings made of cattail mats as they moved from place to place gathering the gifts of the land and water, storing berries, farming and processing bulbs and roots, and collecting seaweed and other sea foods for the cold wet seasons ahead. Before the arrival of European settlers, the lands around Padilla Bay were an immense and productive wetland. They were like a vast public market where various groups came together by consent to harvest the plentiful resources. In the winter native people lived in permanent wooden houses where they shared and gave thanks for their abundance with friends and relatives.

This way of living was passed down from generation to generation via the oral tradition: a chain of knowledge connecting the present with the past and the future. The chain was almost broken in recent history due to pressures brought on by cultures from another part of the world. The first to strike were the European diseases which decimated the population. Next came the Europeans themselves with their concept of ownership of resources. By the end of the nineteenth century, it was made illegal to possess artifacts such as drums, masks, and artwork which were used in the practice of the native way of life. At that time, the oral tradition went underground and many teachings were passed on in secret.

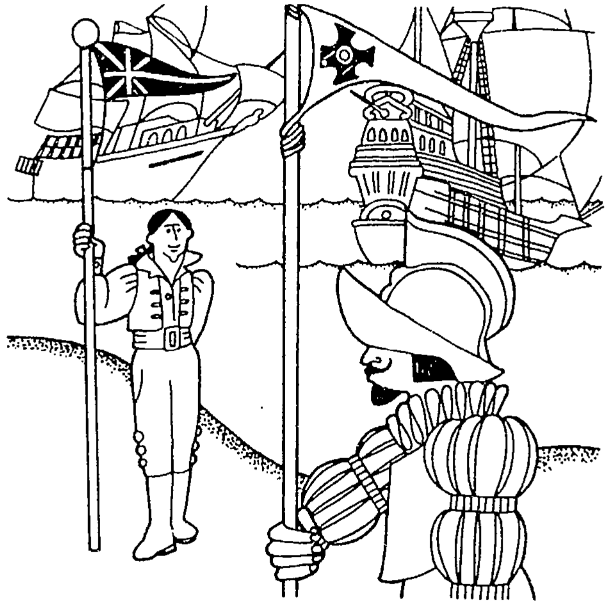
The *Treaty of Point Elliott*, signed in 1855, created the reservation system we see today. In exchange for ceding their land to the white settlers, the Samish and others were promised a reservation with adequate land, education, money payments, and medical help. They had to wait many years for some of the promised compensations. Others have never been fulfilled. Many people believe that though the Point Elliott Treaty ceded land to the United States, the accompanying resources were reserved from the treaty and never negotiated away. Today, many Native Americans are asking for access to resources they feel were set aside for them.

Our society is beginning to realize that there is value in a way of life that does not disrupt natural systems. The Native way of life recognizes a closeness with the plants and animals, air, water, and earth. This philosophy recognizes an equal right to a healthful living, and that it is up to humans to be sure it is maintained. According to the oral tradition of the Samish Tribe, this was the agreement between the First People and the Creator.

Exploration and Expansionism

When Spanish explorer Jose Narvaez sailed through Guemes Channel in the summer of 1791, he described the shallow bay that lay before him as "a great sand flat with one-half fathom of water on it . . . and an extended piece of flat land beyond the horizon. In the sandflat could be seen many Indians after shellfish." Narvaez was sailing under the orders of the governor of Spanish North America, Viceroy Juan Vicente de Guemes Pancheco de Padilla Horcasitas y Aguayo, conde de Revillagigedo. Narvaez named the bay "Seno de Padilla" or "embrace of Padilla."

He was not here sightseeing, nor was he here to learn more about the native way of life. The Spanish were exploring the area as part of a national policy to acquire territory, expand trade, and spread Catholicism. This highly competitive struggle among world leaders of the eighteenth and nineteenth centuries is referred to as *expansionism.* Narvaez sailed here hoping to beat the British and secure these lands as the Imperial possessions of Spain. Shortly after the Spanish visit, English sea captain George Vancouver mapped the Sound completely and then named the southern reaches after his lieutenant, Peter Puget. He assigned new place names to various mountains, rivers, islands and other bays; names which quickly replaced most (but obviously not all) awarded by the Spanish. Vancouver's reports were quickly published in Europe while those of Spanish expeditions were kept secret, since Spain did not want to advertise this area of the new world. Ultimately, Spanish power was broken both on the seas and at home. By 1795, Spain had relinquished its claims on the Northwest to the British.



Both the Spanish and British explored Puget Sound in an effort to claim new territory.

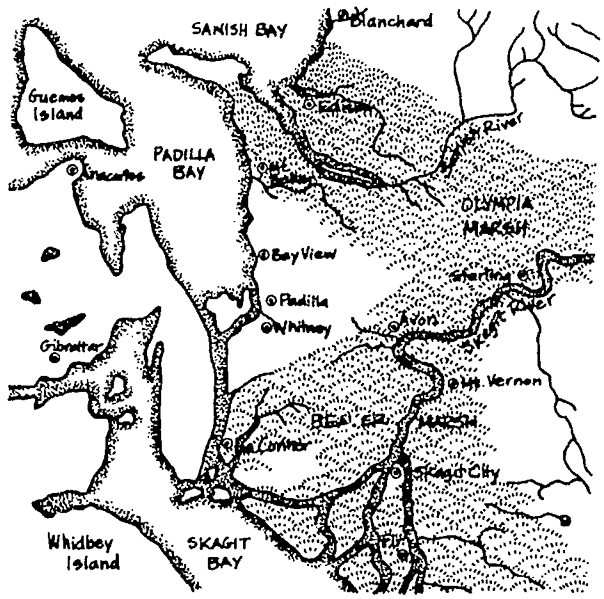
Meanwhile, another hungry giant, equally intent on expansionism, was rising in the east and claiming land in a westerly direction. In 1792, Robert Gray, in the armed ship, Columbia, claimed the Oregon country for the United States, and in 1804-1805 the Lewis and Clark Expedition provided detailed reports of the Pacific Northwest. Finally, the expansionist administration of President James K. Polk proposed that American claims should extend up to the southern boundary of Russian Alaska. The British rejected the idea at first but agreed to compromise after hearing reports of trapped-out fur and over five thousand Americans already living in Oregon. On June 15, 1846, the Oregon Treaty was signed by the United States and Great Britain establishing the boundary between Canada and the U.S. along the 49th parallel and out through the middle of the Straits of Juan de Fuca.

Settlement

Trappers were probably the first European inhabitants of the region. Between 1800 and 1835, almost every well-dressed man in the East and in Europe wore a beaver hat. The trappers were apparently too preoccupied with the accumulation of beaver pelts (almost to the point of the beaver's extinction) to leave written records of their visits. They did, however, leave trade agreements, transportation routes, and tools. Much like the natives, these trappers viewed the land as a common resource rather than as a commodity to be owned.

European settlement began in earnest after the signing of the Oregon Treaty. Immigrants came overland by covered wagon to the Columbia River, then north to the southern part of Puget Sound, finishing the trip by water. Many came by sea around Cape Horn or across the Isthmus of Panama. Still others took the train to Sacramento (completed in 1867) and completed the journey by sailing north out of San Francisco. In all cases the last leg of the journey was by sea. Consequently, islands such as Whidbey, Camano, Fidalgo, Guemes and Samish were the first areas to be settled.

About 1863, Samuel Calhoun, who worked in a lumber mill on Camano Island, hired an Indian to take him to the mainland by canoe. They went up a branch of Sullivan Slough and landed at Pleasant Ridge, east of present day La Conner. He climbed the ridge for a better perspective but could see nothing because of the dense forest of virgin cedar. (Similar stands of huge cedars, some in excess of 48 feet in circumference, covered most of the higher ground, including Bay View Ridge.) Calhoun climbed a tree and was finally able to get a view of his surroundings

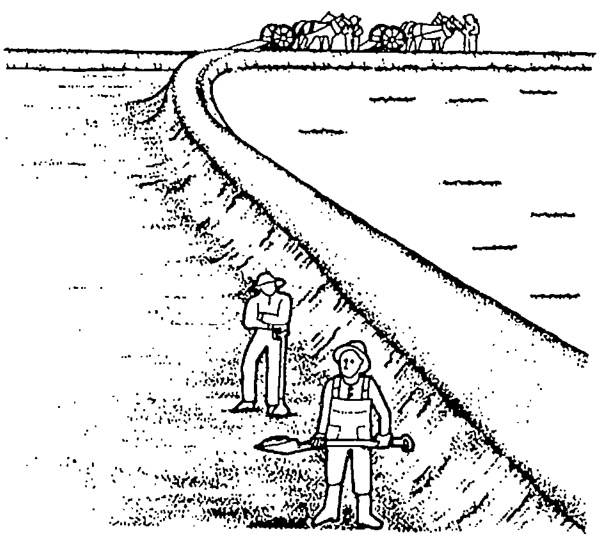


The wetlands surrounding Padilla Bay around 1860.

where deep forests gave way to marshes and sloughs. It was the marshy ground that caught his attention. Calhoun knew of diking techniques that yielded farm land from salt marsh. He decided to return to the area and carve out a farm from the marsh.

So the face of the land began to change -- much more quickly than it had during the thousands of years of glaciation and sedimentation. Early *dikes* were built by men with shovels, wheelbarrows and visions of ownership and profit. The early dikes were about eight feet wide at the base, two feet at the top and about four feet high. They had to extend along the entire salt water margin of the claim and far enough up the major *sloughs* to be beyond the reach of high tides. Many early diking efforts failed but when Calhoun and his partner, Michael Sullivan, finally raised a crop of barley on 40 acres of diked land and sold it on the spot for $1,600, the smell of success gave new energy to others.

Eventually, dike building machines were invented and implemented. Large sloughs were diked and made navigable to farm houses and granaries. Small sloughs were simply filled. Additional protection in more exposed areas was provided by *piles* driven just outside the dikes to stop the washing of waves. (The remnants of these piles are still visible in Padilla Bay.) Much of the salt marsh around Padilla Bay that formerly provided habitat for fish, waterfowl, muskrats, mink and otters was now producing agricultural crops.



Building and maintaining a dike was no easy task.

The dikes did not end the problems for the early "salt farmers". The farms, while relatively safe from intrusion by the sea, were now subject to periodic attacks from the rear when the Skagit River flooded. Because the dikes kept the fresh water from filtering out into the sound, the entire valley would flood. With each flood, the profitable farm land became further damaged. Cattle were drowned and farm houses floated away. Cutting the dike to release the water was an obvious necessity; however, the dikes were privately owned, and each farmer felt that someone else's dike should be sacrificed. Some farmers tried to dike just the areas of the river that overflowed onto their property. Because these efforts were so fragmented, they had limited value. The diking of the river required a higher degree of organization in order to succeed. It wasn't until the 1890s that the settlers began to realize that a cooperative effort would benefit all.

Another resource that drew attention to the Padilla Bay area was the virgin timber that had grown on Bay View Ridge for 10,000 years. Logging began on the ridge around 1876. Initial efforts proved fairly easy. The timber near the water could be felled directly into the bay and easily transported to the mill. The size of the trees being harvested presented about the only problem. Some exceeded eight feet in diameter at the base. The saws were not long enough to cut such widths, so loggers chopped wedges into the trunk, inserted "springboards" on which to stand, and sawed through the trunk eight to ten feet above the base. Since the logs seemed limitless, no one worried about waste. By 1882, there were 11 logging camps in the area producing 38 million board feet of timber annually.

Early loggers came from the Great Lakes where forests had been decimated by the 1880s. Others came from Maine and New Hampshire where forests were also depleted. Still others came from eastern Canada, New Brunswick and Prince Edward Island, rushing to stay ahead of a resource that couldn't possibly keep up with even primitive harvesting methods.

In 1902, the splendid old growth of Bay View Ridge caught the attention of the Ballard Lumber Company. They purchased 1,700 acres, and the town of Bay View became home to one of the largest logging concerns in the state. The "modern" company replaced *skidroads* and oxen with a 4-mile-long railroad from the eastern top of the ridge down to the water near Bay View. Logs were transported from the cutting sites (often with just a single log fitting on a flatcar!), dumped into the bay and floated or boomed to the

A "skid road" and logging camp.

company mill in Ballard. In a short time the Ballard Company was harvesting 65,000 to 75,000 board feet of first-growth cedar, fir and spruce daily.

Fires soon followed. As the old growth timber was removed, the normally wet under story dried from exposure to the sun and fires raged through the areas, unchecked until the rains came. The worst fire on record was the 1909 "Ridge fire." The town of Bay View had to build and rebuild often as a result of fires in the early 1900s.

By 1910, the Ballard Lumber Company had logged off all of its land, or about two-thirds of the timber on Bay View Ridge. Stumps, abandoned skidroads and fire scars awaited the next wave of settlers.

As the saying goes, beauty is in the eyes of the beholder. As the large trees were removed, the area attracted those intent on farming. To a farmer, the forest of stumps seemed much less intimidating than a forest of dense trees. The Great Northern Railroad offered reduced rates to entice farmers to come to Washington State, advertising fertile land that logging companies were eager to sell.

Clearing a stump farm was a huge undertaking. The most efficient method of removal was dynamite but most early pioneers couldn't afford such luxury. Some planted crops between the stumps, some burned them, some cut them up for firewood or sold them to a shingle mill. Still others had "logging bees" to clear the land. These were work/social occasions where human labor was rewarded with good food and stiff drink.

By the early part of the 20th century, the personality of the Padilla Bay region had changed. The raucous, get-rich-quick logging operations gave way to a more stable element: settlers looking for a permanent situation in which to raise a family and make a living from a new land that they could call their own.

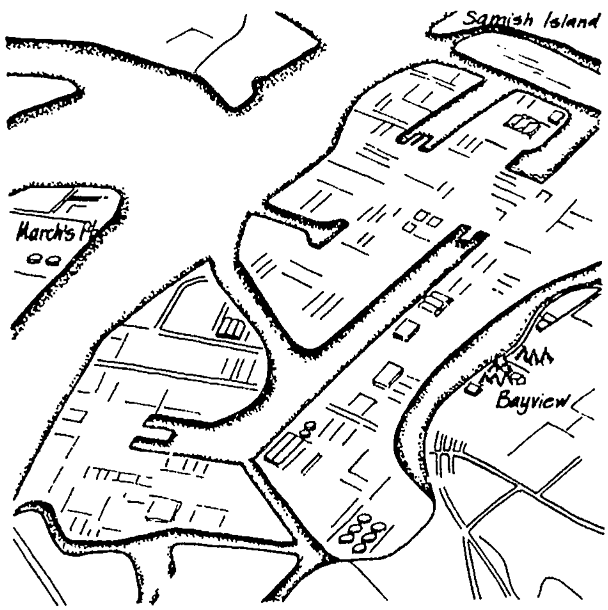
How To "Use" Padilla Bay

As the land became occupied, interest turned to the economic potential of the bay itself. Several enterprising ideas were proposed beginning in the 1920s.

In 1925, commissioners of the newly formed County Diking District accepted bids for the diking and reclamation of 10,000 acres of tideland in Padilla Bay. The proposed dike was to span the outer margin of the tidal lands from Samish spit to Hat Island and from Hat Island to the south end of the bay. Work began in 1929, starting at the mouth of Indian Slough. After only 1.5 miles of dike was completed, the contractor went broke and the project died.

In 1930, 943 one-acre tracts were platted in southern Padilla Bay, creating the "Associated Oyster Tracts." Each parcel was a long , narrow triangle -- only six feet wide and over two miles in length! A management company oversaw the overall project, with the goal of planting and harvesting Japanese oysters.

Initially, the oyster farming seemed promising but after a few years, production and quality began to decline. Pollution, the lack of fresh water and the reproductive success of predators were speculated as causes for failure. The oyster company claimed pollution as the culprit and sued the Scott Pulp Company for destroying the oyster habitat. The judge ruled against the company on the basis that the oysters' failure was due to a lack of nutrients.



A 1961 proposal for a deep water port and industrial park.

In 1961, investors had another idea. Padilla Bay was to be the site of the largest industrial park in the state. The plans included dredging a three-mile-long, 60-foot deep waterway to accommodate ship traffic. The dredged material would then be used for filling 9,400 acres. Some local people, interested in preserving Padilla Bay, began to protest. However, the County Commissioners claimed to be powerless to intervene, since the land was owned and controlled by the promoters of the project. By 1963, after plans failed to secure a 1.4-million dollar Federal industrial loan, the tracts were sold at auction to the Seattle-based Orion Corporation.

The Orion Corporation thought the bay would be perfect for the development of a "Venice-like" housing project with meandering channels, beaches and boat launches, and a marina to complete the scene; home to 30,000 people. The project won unanimous support from the Skagit County Development Association. Again, the locals protested.

Then, in 1965, the Area Development Administration funded a feasibility study to determine the potential of using 600 acres of Padilla Bay for industry. The results indicated that the eventual profits would far outweigh the costs, and it was thumbs up for another industrial venture.

In the meantime, area residents who favored preserving the bay had organized the Citizens Committee for the Preservation of Padilla Bay. Their efforts were successful in stalling both the housing and industrial projects until 1971 when help arrived in the form of the state Shoreline Management Act. Shortly after the Act's passage, the Washington State Department of Ecology began preparing policies and guidelines to assist local governments in their development of rules to protect coastal resources. In 1976 the state-approved Skagit County Shoreline Management Program was adopted, creating a regulatory framework for public input and protection of the county's shorelands. This program, reflecting the opinion of the state legislature, designated Padilla Bay as a "Shoreline of Statewide Significance" to be "managed with the interest of all the people in mind, and whose natural character should be preserved."

Beginning in the mid-1970s, the Washington State Department of Ecology began evaluating potential sites for participation in a federal program called the National Estuarine Research Reserve System. Administered by the National Oceanic and Atmospheric Administration (NOAA), this program protects a variety of estuary resources around the U.S. in order to conduct long-term research and educational programs. After extensive review along with many committee meetings and public hearings, the Padilla Bay National Estuarine Research Reserve was designated in 1980. The purchase of tidelands within the proposed 13,535 acre boundary began immediately, with the state purchasing only from willing sellers based on appraised values.

The policies and regulations found in the county's Shoreline Master Program and the state Shoreline Management Act have made some types of development in Padilla Bay impossible. Residential and agricultural uses are currently prohibited, while other uses such as crab or salmon fisheries and others may be enhanced by habitat protection and wise management practices.

The Orion Corporation, still owning a large portion of the bay, filed suit against the State of Washington and Skagit County. They claimed that the development rights for their tidelands had been removed by state and county governments without a fair offer of compensation. The state argued that fair market value had been offered for the property. The suit will significantly test the legal strength of state and federal laws to protect the environment. The fundamental issue of private ownership versus environmental protection will be influenced by the court's decision.

Edna Breazeale

A description of the events surrounding Padilla Bay since the turn of the century would be incomplete without mention of Edna Breazeale. Miss Breazeale came to Padilla Bay as a small child in 1901. Her father had taken advantage of the inexpensive land being offered in the early 1900s and purchased a parcel one-half mile north of the present interpretive center, overlooking the bay. Her childhood was spent collecting agates on the beach, sitting silently in the uplands observing coveys of quail, and developing an environmental ethic long before it was fashionable. She rode the train from Whitney (across from the present Farmhouse Inn Restaurant) to Burlington Edison High School until her graduation in 1912. The train was the only practical means of transportation at that time. The land between Burlington and Bay View Ridge was an extensive wetland called Olympia Marsh. Edna Breazeale described the boggy area as a place where one could jump up and down and cause twenty acres of land to quake in all directions. After high school, she attended the University of Washington, where she graduated with honors in 1917. She taught school for the next 40 years, inspiring students and fellow teachers alike.

Edna Breazeale retired from teaching in 1957 and returned to live with her brothers Fred and Marcellus on their farm overlooking the bay. When rumors began to circulate of plans to fill the bay, she initiated a campaign to save the area that she had learned to value as a child. She, and a handful of other committed area residents, carried a petition from "the hills above Concrete to the taverns of Anacortes," Breazeale recounted. She volunteered for the tavern duty herself, thinking no one would dare laugh at an old lady with gray hair. She was right; two thousand citizens signed the petition to save the bay. So, for ten years, a small group of citizens with no financial backing held off powerful business interests. In 1971, government finally caught up with the foresight of Breazeale and others; the State Shoreline Management Act, spawned by the voters' initiative process, was passed.

Edna Breazeale's contribution did not end there. In 1981, on behalf of herself and her two brothers she donated the farm to the Padilla Bay National Estuarine Research Reserve. It is on this site that the Breazeale-Padilla Bay Interpretive Center now stands. Miss Breazeale and her brothers felt that "something should be kept for people who want green, open space . . . so much is 'keep off, keep off.' "

At a ceremony honoring her involvement in the creation of the Padilla Bay National Estuarine Research Reserve in 1980, Edna told the audience, "I believe that what we have worked for will be remembered long after all of us are gone." She died September 16, 1987, at the age of 92. Indeed, Edna Breazeale and her family will be remembered.

Edna Breazeale showed how one person's actions and values can shape history. She was one person, but she was not alone. Similar values were expressed elsewhere. The famous Wisconsin Wildlife Manager, Aldo Leopold wrote:

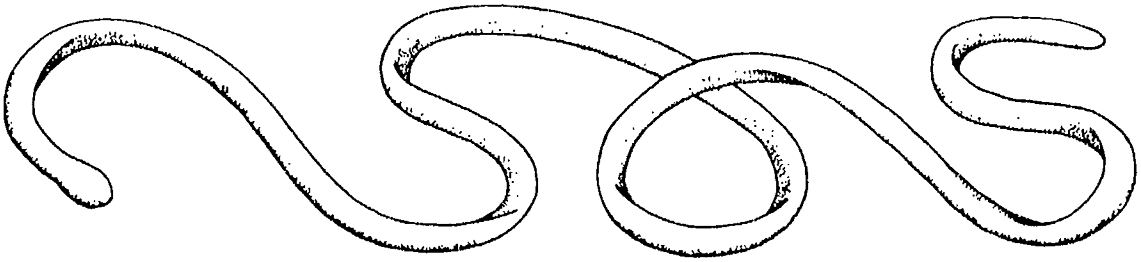
> We abuse the land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect.
>
> -from "*A Sand County Almanac*"

Related Activity:

"Creative Exercises" in Activity 6.

Questions

1. How had local Native American tribes already been changed when John Work saw them in 1820?
2. "Many people believe that though the Point Elliott Treaty ceded land to the United States, the accompanying resources were reserved from the treaty and never negotiated away." (See p. 8.) What does this mean? What repercussions does this belief have today?
3. List four nations that have claimed land in the Puget Sound region.
4. Why did early settlers choose to settle near estuaries rather than sites further inland? (List as many reasons as you can.)
5. List the plans to develop Padilla Bay and why they failed.
6. How have attitudes towards estuaries changed in the past 200 years?
7. Why do you think Edna Breazeale fought against development interests?



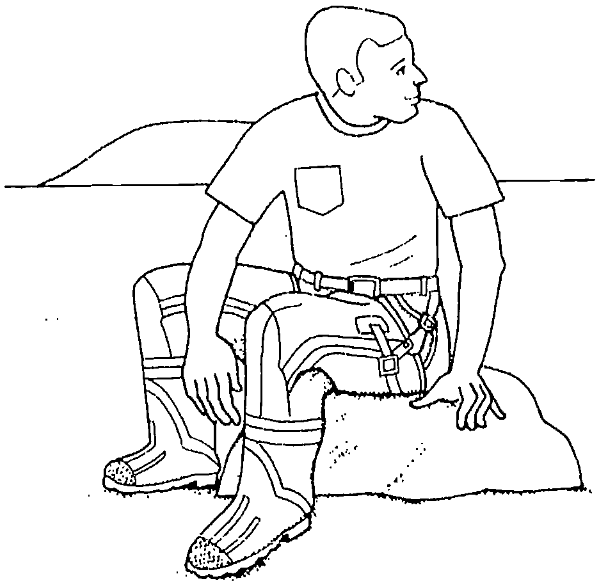
3 - Estuary Alive - Ecology

What you are about to read was told to a high school science teacher by one of her less than academic students. For the entire first semester of biology this student, although pleasant, was not what you'd call a lean, academic machine. Social temptations usually conquered school responsibilities. So, when this student earned a 100% on the final exam, frankly, it was somewhat suspicious. The story is retold here as an example of the mysteries being discovered in estuarine ecology.

It was a dark, clear night with bright stars and a slight shimmering of the Aurora Borealis as I headed to my home near Bay View. In spite of all this beauty I just couldn't keep my mind off of the spectacular sight I had witnessed earlier in the evening on the ferry ride to Anacortes. It must have been a meteor. Maybe it looked so close because of the northern lights in the background. But I'd seen meteors and this just wasn't the same. The movement of the object was too slow and controlled. And all other meteors seem to disappear harmlessly in the night sky while this seemed to fall right out of the sky!

As I turned north toward Padilla Bay I sank into the routine of driving that familiar road. Far away thoughts drifted through my head. Maybe I should have studied for tomorrow's biology exam instead of playing all weekend on the island. Not far from home, I glanced out over the bay for one last look at the shimmering waves of light over Hat Island when, to my amazement, I saw a glowing sphere far out on the mud flat. The music from "Twilight Zone" was twinkling in my head as I turned off the road and pulled into the parking lot near the beach. I rubbed my tired eyes, fully expecting the object to be gone when I reopened them, but it was still there. A bluish, white light pulsed from the object and reflected off the shiny surface of the mud flat.

My first inclination was to drive home and call 911. But after thinking a minute, it occurred to me that if I were the first to make contact with alien beings (and what else could the glowing sphere possibly contain?) I might get some extra credit points from my biology teacher which might help make up for the lost study day. I opened the trunk, pulled on my hip boots, and started sloshing my way toward the space craft.



As I cautiously approached, a door opened. I expected to see a little green man emerge with either one or three eyes (certainly not two) that would talk in a squeaky voice and say something mundane like, "Greetings, earthling," or "take me to your leader." But imagine my surprise when a pale, snake-like, writhing, mucous covered *proboscis* thrashed wildly out of the opening. I fell backward in horror and disgust. My hands became stuck in the mud in a reflex move to break my fall. The slimy proboscis whipped back in my direction and, as I sat there defenseless, wrapped around my neck and across my face. Pulling my right hand free from the mud and then my left, I grabbed the proboscis and peeled it off like a piece of masking tape. I started to slide back in retreat, deciding that I was wrong not to have called 911, when I heard a squeaky, nasal voice, "Greetings, earthling."

I breathed a sigh of relief in the thought that at least something about this experience was predictable and replied, "Greetings yourself. Why did you attack me?"

"Well, it's just my way; these are my sensory organs. Don't take it personally," said the creature. "I have a lot of questions to ask and very little time because when the tide comes in, we're sunk." The creature laughed uncontrollably at his own pun until I interrupted.

"Who are you, where are you from and why are you here?" I asked.

"All fair questions," the creature replied. "I am a Nemartian from the planet Stasis. I have been sent here to interview an average earthling and learn of the environment here. I was specifically directed not to talk to a 'leader' as that information would probably be unreliable. You're not a leader are you?"

"No," I replied, "but . . ." and before I could go on, the Nemartian started questioning me.

"My planet is one huge mud flat," the Nemartian said. "As I circled for my landing, I noticed that it is not so here. There seem to be several strange habitats surrounding this familiar mud flat. Can you explain how you organize all this complexity?"

Suddenly I was faced with the prospect of having to explain my environment to an alien! This Nemartian didn't have a clue and I, of all people, had become the expert. As I glanced around the bay, things that I had been only half listening to in school started to crawl out from their hiding places in the nooks and crannies of my brain and stand out in clear detail. I began to think this might even be fun!

Classification

"You're right," I said to the Nemartian. "This is a complex place and it is difficult to keep track of things sometimes. But we humans have devised systems of classification to simplify our perceptions of the earth. What you noticed, as you circled, was the Padilla Bay *estuary*. It's an important *ecosystem* here." I can't explain it, but I somehow sensed a blank stare from the proboscis. I concluded that I would have to define my terms.

"An ecosystem," I continued, "according to my biology book, is a distinct, self-supporting unit of interacting organisms and their environment. The ecosystem you landed in is an estuary, a place where fresh water flows into the sea."

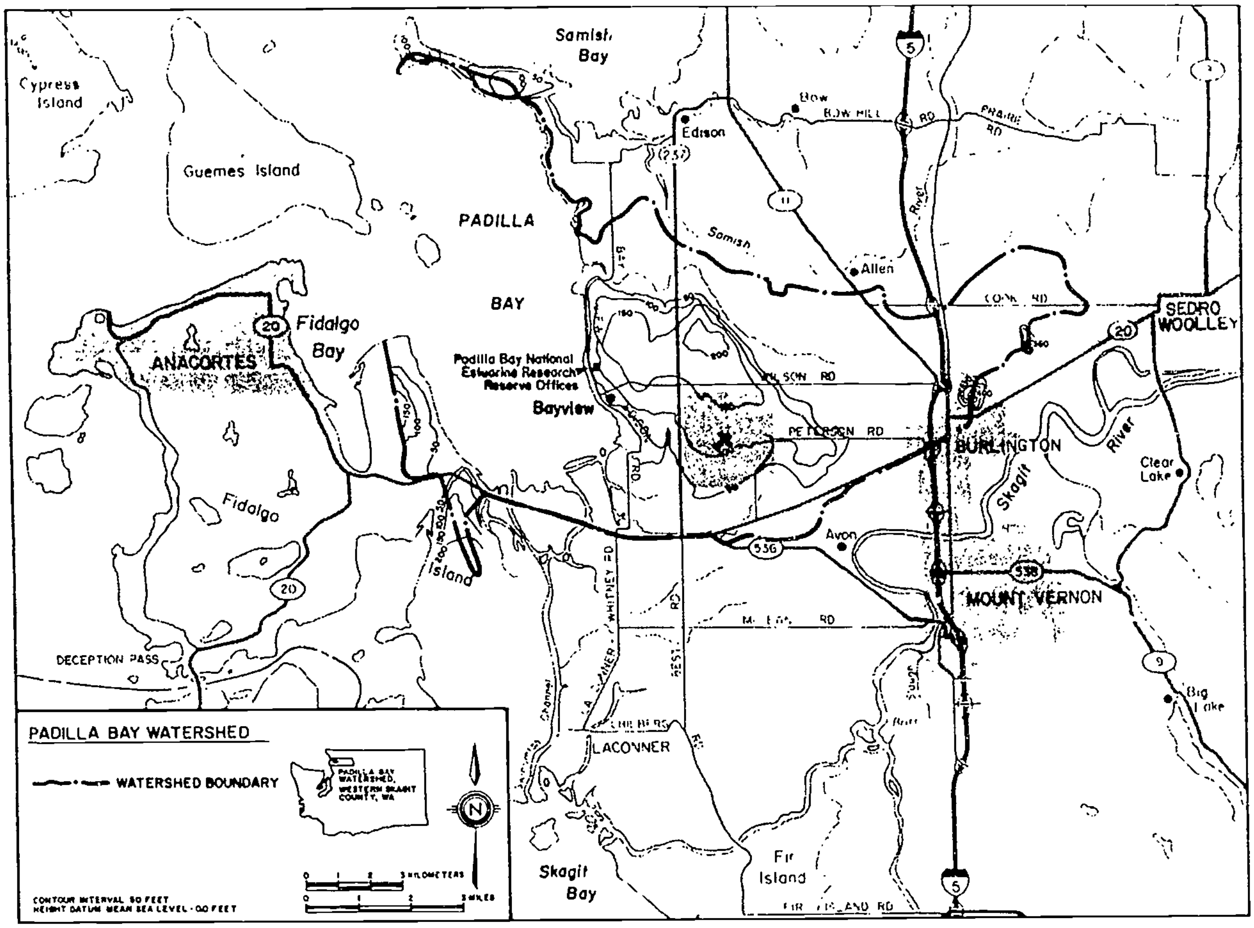
"I think I understand," said the Nemartian. "This ecosystem I observed is somehow walled off from the others, making it 'distinct and self-supporting.' What is the nature of these walls?" I started to realize this wasn't going to be as easy as I had originally thought. I guess it wasn't so much the Nemartian's fault, though, as it was the fault of our classification. We use terms to try to define things for our convenience but, come to think of it, the environment doesn't really make these distinctions.

"No," I explained, "you've got the wrong idea. There are no walls. In fact, all the ecosystems on earth are interconnected." I thought if I explained the water cycle and *watershed*, he might get the picture. "Right now the seat of my jeans is pretty well saturated, but that water hasn't always been here. It may once have been on that farmer's field over there, or on my high school parking lot, or even in the Pharaoh's wine!"

The Nemartian didn't seem to get it, so I elaborated. "Picture a drop of ocean water. It evaporates from the surface of the ocean, enters the atmosphere as a gas, condenses with other water molecules to form a cloud, travels landward with the wind, condenses further until it falls to earth in heavy droplets, obeys the forces of gravity and moves downhill until it drains into a tiny rivulet and, picking up speed, drains into a rushing creek that drains into a torrential stream that drains into the powerful, surging Skagit River that flows ever downward toward the sea. Eventually, the water ends up in the Skagit's estuary. Some of that water may end up here in Padilla Bay.

"A *watershed* is all the land area that drains into a river or body of water. One watershed can include many ecosystems. Padilla Bay's watershed is pretty small, in fact, you can see most of it from here. All the rain that falls on those farms over there and that forest over there drains right into Padilla Bay. Other watersheds, like the Skagit's, are enormous and may include glaciers, timberland, and cities. The point is, this water has been a lot of places and carried a lot of things, some good, some not so good, to this estuary."

"Like what?" asked the Nemartian, looking somewhat drained itself at this point. (I use "it" because it was virtually impossible to determine the sex, if any, of this creature. And . . . it really didn't seem to make any difference.)



"The river picks up and carries *sediments* when moving fast but when it slows down in the flats, the sediments fall out and become trapped in the estuary. This vegetation you see covering the mud here slows the water even more and helps hold the sediments here. The river carries dead plants and animals in various stages of decay and deposits them here. We call that *detritus*. Those things are okay but other things come down the river and end up here. Feces from dairy cows, human sewage, chemicals from industry, oil that is washed off our roads, and fertilizer from our lawns all eventually end up here. So, you see, there are no walls to separate ecosystems. Whatever happens in one will eventually affect others."

And so began a long series of questions about an environment that I knew well. After all, I had lived near Padilla Bay all my life. I had observed many things on my own while exploring the rivers, beaches, mud flats. Also, I had learned things just sitting in class, listening to teachers explain the underlying concepts and principles of science, history and the humanities. What was different, though, was that somehow, standing out on the mudflat at night, in the presence of the Nemartian brought about a synthesis of all this knowledge. I could now see the connections that linked and intertwined all the observations, ideas and information that had ever entered my brain.

The Abiotic Estuary

"If there are no walls then what **does** make this estuary an ecosystem? Why is it any different from the hills and mountains and ocean around it?"

This was a tricky one and I thought hard. "I guess each system is uniquely shaped by the abiotic elements -- in this estuary it's the water, the mud, and the climate that determines what will live here. An estuary is not an easy place for an organism to live because the conditions change so much. The water here is constantly changing due to the flow and ebb of two daily tides (at this point the Nemartian lowered its proboscis toward my watch). Tides, plus the irregular influx of fresh water, results in changes in salinity, temperature, dissolved oxygen, and pH."

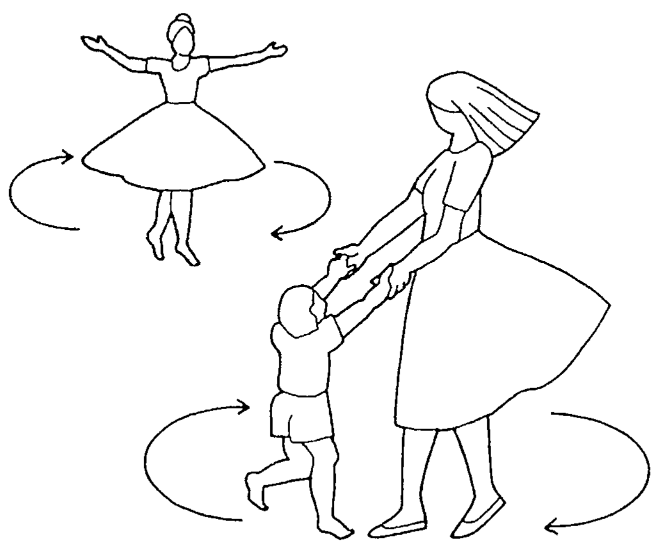
"This is of particular interest to me," replied the Nemartian. "On my planet Stasis, there are no such changes. Everything is always the same. Tell me the details of these changes."

Tides

"Tides are the result of two physical forces: 1) the **gravitational** forces of the sun, the moon and the earth and, 2) the **centrifugal** force caused by the rotating earth and moon system. These forces cause the water in the ocean basins to be pulled into bulges.

Both the sun and moon are exerting gravitational force on the earth. This force pulls the water in the oceans into a bulge on the sides of the earth closest to the sun and moon. Because the moon is so much closer, its tide raising force is more than twice that of the sun.

"While the moon is pulling on one side of the earth, centrifugal force is pulling on the side opposite the moon. If there were no moon, the rotation of the earth would exert centrifugal force equally, in all directions, much as a dancer's skirt twirls when she turns.

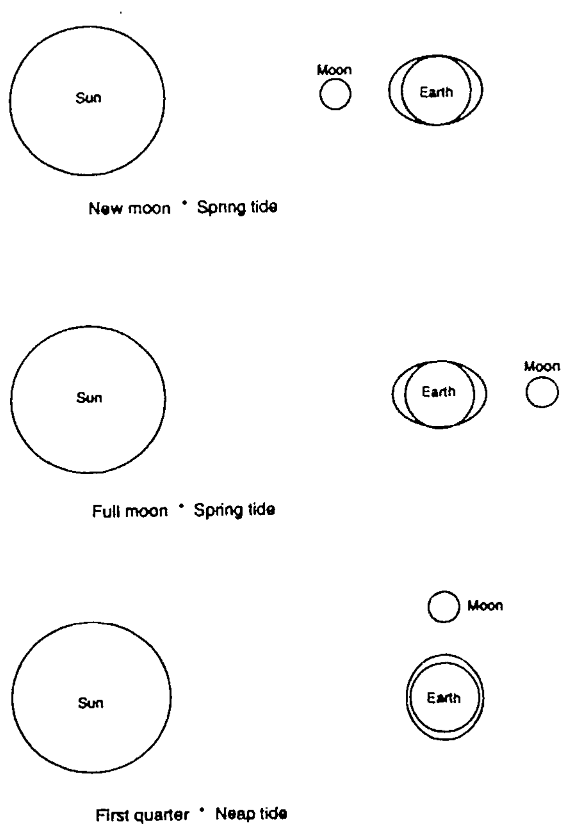


The earth-moon system rotates like a mother and child dancing.

But because the earth and moon are rotating together, the center of rotation is not at the center of the earth, but is closer to the moon. This causes a greater centrifugal force on the side of the earth away from the moon. Picture a mother and child holding hands and spinning in a dance. The mother's skirt will lift higher on the side away from the child."

"What is a dancer and what is a skirt?" asked the confused Nemartian.

"Never mind. It's not that important. What is important is that the gravitational pull of the moon is making the water bulge on one side of the earth (causing high tide) while centrifigal force is making a bulge on the other side (another high tide). In between the bulges there is less water, and therefore, low tide.



Spring and neap tides are affected by the positions of the earth, moon, and sun.

"Tides would be pretty simple and predictable if that was the whole story, but there's a lot more we don't have time to get into. The sun is also exerting gravitational force, and because the earth-moon system is not only rotating, but also revolving around the sun, there is a second centrifugal force. Add to that the fact that these bulges or tidal waves keep bumping into land and bouncing back, and you have a very complex picture.

"You're lucky you came here today. There is a new moon, and that means that the tide is especially low right now. Because the sun and moon are both on the same side of the earth, they pull together, causing an extra large bulge. In two weeks, the moon will be on the side of the earth opposite the sun, and forces will again be lined up, meaning higher (and lower) tides. These extreme tides are called *spring tides*. On the weeks between, the forces of sun and moon will be pulling in different directions, and will tend to cancel each other out. These are *neap tides*, and aren't nearly as high or low.

"Life between the tides is not easy. Organisms have lots of adaptations to deal with the changing water level. Some plants can completely dry out at low tide on a sunny day and survive. Others, like eelgrass can't dry out, and only grow in areas where they stay wet; areas like the very flat mud here in Padilla Bay.

"Some of the larger animals like fish swim out with the tide. Others have various strategies for staying wet. Clams, barnacles, oysters, and mussels can close their shells tightly to keep water in. Snails and limpets clamp tightly to rock. Some animals burrow into the mud and sand. Some hide under rocks. Then there are those animals just waiting for low tide to munch out. If you'd been here earlier this evening, you would have seen hundreds of gulls and herons following the edge of the water as it receded."

Salinity

"Now, as you might predict, when the tide is high, the salt water is driven far up into the estuary. This occurs twice in a 24-hour period here in the Northwest. Low tides, by contrast, allow fresh water to dominate the estuary. Other marine environments are not subject to such exaggerated change.

"So salinity in the estuary is the result of a constant battle between the freshwater from the land trying to dilute the salt water of the sea. High tide gives the advantage to the sea while low tide provides an advantage to the fresh water. But the fresh water recruits help during flood season. With increased fresh water flow, the battle lines (or salinity gradients) are moved downstream. Therefore, at different seasons of the year, different salinities can be expected in different areas of the estuary.

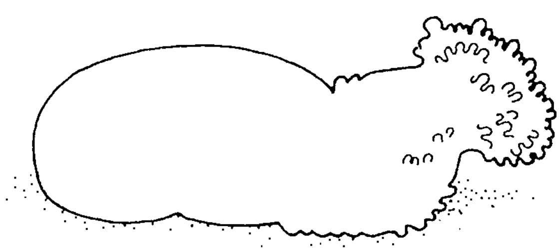
"Salt water is denser than fresh water, you know, so it tends to sink to the bottom. There is often a distinct layer of fresh water floating above the salt water. We call that *stratification*. Wind, waves, and tides can stir up the layers, so estuary animals and plants need to be prepared for quick changes in salinity."

"How could any living thing possibly survive in such an unpredictable place as this?" the Nemartian asked.

"Animals have different strategies for dealing with changing salinities. *Osmosis* is a fancy word for what happens in many animals when the salt content or concentration inside their cells is different from the concentration outside (in the water). The water simply passes through the cell membrane until the concentration is equalized. For example, if a jellyfish or sea cucumber finds itself in water that's saltier than its cell content, water passes out of its cells until its cell fluids become as salty as the water. If the surroundings become fresher, then water enters its cells until they are fresher, too. Of course, too much change could be fatal, and most organisms have a range of salinity in which they can survive.

Sea cucumber in very salty water

Sea cucumber in fresh water



Osmosis at work

"An animal like a clam or snail closes up when the salinity moves beyond its tolerated range. Other animals, like salmon, have an active mechanism that maintains a constant internal fluid medium. When a salmon is in freshwater, it experiences a water **gain** by osmosis. It compensates by not drinking and excreting lots of diluted urine. In salt water, the salmon experiences water **loss** by osmosis, so it drinks lots of sea water, produces a little bit of very salty urine, and secretes excess salt through cells in its gills. I guess you can see that life isn't simple where fresh and salt water mix.

"In the *sediment*, things are different. As you know, the mud we sit on is permeated with water." (I was especially aware of this since my rear end was soaked!) "The water is held in the spaces or *interstices* between the particles of sediment. This interstitial water obviously originates from the overlying water, but it moves slowly due to the density of the mud. Therefore, the salinity of interstitial water is not subject to the changes occurring in the water above, and remains relatively constant. Organisms that live burrowed in the mud are buffered from drastic changes in salinity."

"My kind of people," replied the Nemartian with a homesick expression. "Tell me more about this mud or sediment, as you called it."

Sedimentation

"Most estuaries are dominated by muddy sediments such as these. They are deposited from both the sea and land.

"Strong ocean currents can scour the sea floor. When the currents slow down in the sheltered estuary, the reduced motion lets the mud settle out. I remember reading that the estuary of the River Thames had been *dredged* and the material dumped into the sea. Ocean currents returned the dredged materials to the same estuary a short time later!

"Rivers and streams carry silt in suspension. When these suspended particles mix with the various charged particles (ions) present in the sea water at the estuary, they flocculate or clump together. They become larger and heavier and thus settle to the bottom.

"It is interesting to see how these sediments are deposited in the estuary. Stronger currents can keep larger particles in suspension. As the current slows, the largest particles begin dropping out. Where there are strong currents, like along the channels that flow through the mud flat or near the upper reaches of fresh water drainage, the sediments are coarse (sand or gravel). In areas of the estuary where currents are slower, the sediments are dominated by fine silt, or mud.

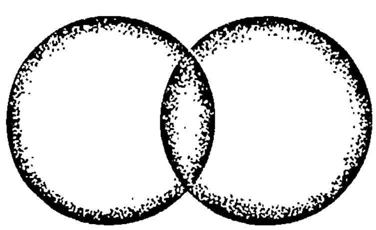
"Many of the particles that settle out in this way are bits of dead plants and animals. A good term for this material is *detritus*. Imagine all of the dead organisms, in various stages of decay, that are carried here from both the sea and the river, then add them to all of the dead organisms in the estuary itself. Why this is a virtual detritus grave yard. This material is very important to organisms that live in the estuary since it is such a good source of energy."

"So they have everything they need right in the mud!" the Nemartian concluded.

"Well, they have plenty of food but they still need something to breathe."

Oxygen

"As you may know, oxygen will dissolve in water just like a spoonful of sugar in iced tea." The Nemartian looked puzzled at this point but I pretended not to notice and



went on. "So, the regular influx of fresh and salt water into the estuary, coupled with the shallowness and surface turbulence, usually provides plenty of oxygen in the water. As the temperature and salinity change, the ability for water to hold oxygen changes. That means the oxygen is not constant in any one place at any one time. But in the substrate, it is a totally different matter. As I mentioned before, the interchange between interstitial water and the water above is slow. Although the mud is rich in nutrients (the result of detritus accumulation), the supply of oxygen (necessary for *aerobic* organisms) is a limited resource. The bacteria in the sediments use up a lot of the oxygen in the interstitial water. Estuarine sediments are anoxic (without oxygen) below the first few centimeters as you can see by the color change."

I took out my pocket knife, cut a cross section from the mud and held it up to the light of the space craft. The Nemartian noted the difference between the light brown mud at the surface and the black-as-tar stuff down below. "There is no oxygen in this black layer. The *anaerobic* bacteria which live here produce hydrogen sulfide as a by-product of respiration, accounting for the strong sulfur smell." I held the cross section of mud out so the Nemartian could lower its proboscis and take a whiff. "So the mud, while being rich in food, has no oxygen making it hard for organisms to survive. Burrowing animals have adapted means to beat the system. Many of them excavate tunnels through which the oxygen rich water can flow. This not only benefits the burrower but also the microorganisms living nearby." Just then the Nemartian interrupted.

"My sensors tell me the temperature is falling. Is there someplace we can go to get out of the cold?"

"Sorry, not around here."

Temperature

"The temperature in the ocean is pretty constant. Marine organisms that never venture into the estuary can count on temperatu. , in a fairly narrow range. But, estuaries experience a wide range of temperatures.

"Fresh water temperatures change with the seasons. Rivers in temperate regions, such as this, are colder in winter and warmer in summer than the ocean. As a result, estuarine waters have the same seasonal variations. There are also daily variations because of the changing tides. Because an estuary is shallow, the water heats and cools easily. It's like a shallow pond that is warmer to swim in on a hot day than a deep lake.

"Temperature variation poses one more survival problem for estuary organisms. A very hard winter, for example, can cause catastrophic mortality."

"So why on Stasis would anyone choose to live in this unreliable place?" the Nemartian asked in a baffled voice. I started to sense some frustration. I think he thought this would be simpler to decipher.

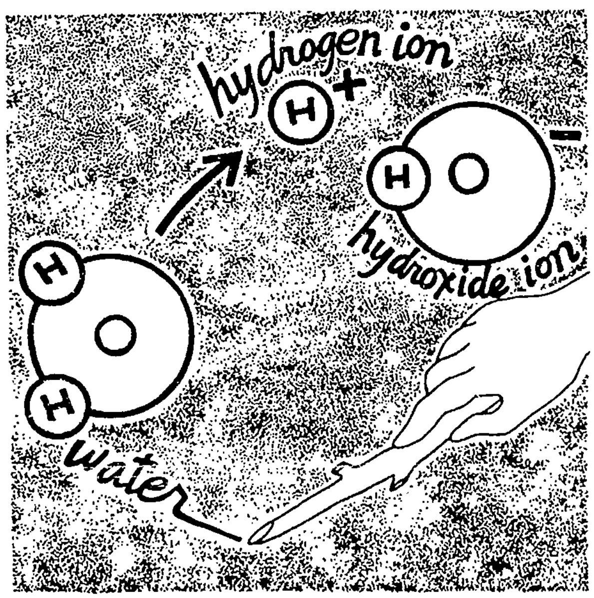
"I don't know," I replied. "Most species have colonized this habitat from the temperature-stable sea. I guess they come for the detritus. Or maybe they're trying to escape some particularly bothersome predators. Whatever the reason, plants and animals seem to love it here."

"I noticed you haven't asked about pH," I said. I had been enjoying this trip through my memory bank so much that I wanted to search all the dark corners. The concept of pH had always been a little confusing to me but now that everything seemed so clear, I thought I'd like to give it a whirl. "O.K., tell me about pH," the Nemartian said, sounding a little perplexed but not wanting to admit to it.

pH

"Well, pH, as I'm sure you know being a space traveler and all, is the scale used to describe the amount of hydrogen ions present in a water solution. We think of the water molecule as H_2O; two hydrogen atoms attached to one oxygen atom. This concept of a permanent structure makes it easy to think about. But in reality, the molecule comes apart a lot, losing one of the hydrogens. The result is one hydrogen yanked away from the oxygen, leaving its electron behind with the remaining oxygen-hydrogen complex. The free hydrogen now has a positive charge (since it left its negatively charged electron behind) and is called a hydrogen ion. The oxygen-hydrogen complex has a negative charge (since it acquired the extra electron) and is called a hydroxide ion."

The Nemartian could no longer contain its confusion. "Say what!?!" I drew the following picture in the mud to help clear things up:



That seemed to help, so I went on. "Some things, when mixed with water, cause lots of hydrogen ions to be floating around free in solution. This is because they attach easily to the oxygen-hydrogen complex, leaving no place for the free hydrogens to attach. Consequently, we say the solution has a high hydrogen ion concentration and is **acidic**. It would be assigned a value of less than 7 on the pH scale. Other things combine readily to the free hydrogen ions and actually reduce the hydrogen ion concentration. This results in a **basic** solution which would have a value greater than 7 on the pH scale. A neutral solution (pH 7 on the scale) has equal amounts of hydrogen ion and hydroxide ion."

"The level of pH, like all the abiotic factors we have been discussing, is significant to organisms living here. Changes in pH can affect the solubility of minerals required by the eelgrass, for example. Enzymes, which mediate all biochemical reactions of living things, require specific ranges of pH to operate efficiently.

"The open ocean contains strong basic ions such as sodium, potassium and calcium. These are examples of particles that attach

ACIDIC **NEUTRAL** **BASIC**

0 2 4 6 8 10 12 14

Approximate pH's

1.0 - stomach acid	6.3 - milk
2.0 - lemon juice	7.0 - distilled water
2.5 - vinegar	7.5 - human blood
<3.5-all fish die->9.5	11 - ammonia
4.0 - oranges	12 - bleach
5.6 - normal rain	13 - lye

pH scale

readily to the free hydrogen ions, leaving a basic solution. This is moderated by the presence of carbon dioxide which acts as a *buffer* to keep sea water within a fairly narrow range. It does this by absorbing hydrogen ions in the water when they are in excess and producing more when they are in short supply. The resulting ocean water is still on the basic side, with a pH range of between 7.5 and 8.4.

"Fresh water entering the estuary typically has a lower pH than the open ocean. The effect on pH in the estuary is the same old story told for temperature and salinity. The mixing of fresh and salt water produces varying levels of pH that organisms have adapted to."

"This is all so incomprehensible," uttered the Nemartian, sounding weary. "Things are so much simpler on Stasis. Is this constant fluctuation typical of your entire planet?"

"Well, maybe not quite so extreme," I replied. "The ocean, about 100 miles behind you, is fairly stable and that's where life got its start. But when things began getting crowded and competition became the mode of existence, organisms started looking for greener pastures. Some of them came to the estuary. This movement away from a previous niche is called *adaptive radiation.*

"The estuary is an example of an ecosystem where an organism can find plenty of food if it can meet the tough demands imposed by the constantly changing conditions. And, the harsh conditions may even prove beneficial if they discourage predators. But the estuary, as a habitat, is not for everybody. Relatively few species have been able to successfully make the transition. While there is lots of life here, the diversity of life is very low. In other words, the number of organisms is high but the number of species is low. This is due not only to the unusual conditions but also to the fact that temperate estuaries are relatively new places. They were formed just after the last glaciation, probably less than 10,000 years ago. So you really have to hand it to the plants and animals living here. They have adapted quickly to harsh environmental conditions in a variety of ways and contribute to a very unique and fascinating ecosystem."

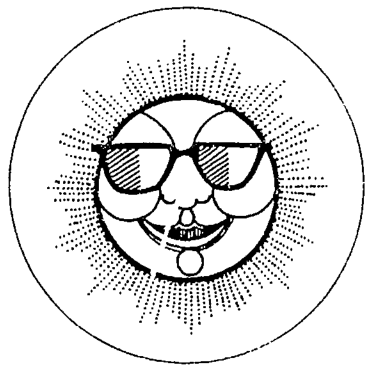
I was anxious at this point to move on and talk more about the organisms that inhabit the estuary. "I'll tell you what," I suggested, "why don't we liven this discussion up with some talk about the *biotic* elements of the estuarine ecosystem?" The Nemartian nodded in agreement.

The Biotic Estuary

For the first time I seemed to be at a loss for words. I knew what I wanted to tell the Nemartian but I just couldn't decide where to start. "Where do I begin?" I thought out loud.

"Well, . . ." the Nemartian suggested, "on my planet, we always start at the beginning!"

"Well, . . ." I countered, "on this planet, things are cyclic. One thing leads to another and then another until you're right back where you started and things don't ever start or stop anywhere." Again the Nemartian looked baffled and I felt sorry for it. All things considered, this must be a trying time for an alien, light years away from home, trying to decipher an ecosystem before the tide comes in. I took a deep breath and picked a starting place at random.



Productivity

"Let's talk about energy. An ecosystem involves a flow of energy that starts with the sun. All organisms need the energy flowing in the system to grow and reproduce, but they get the energy in different ways. We've got autotrophs, heterotrophs, chemotrophs . . ."

The Nemartian's quizzical expression indicated that there was some confusion as to where this discussion was leading. I was learning to read its proboscis like a book.

"*Autotrophs* use the sun's energy, *heterotrophs* use energy from the autotrophs, while the *chemotrophs* use energy from inorganic chemicals. The only chemotrophs I know are certain bacteria that *oxidize* simple inorganic compounds like ammonia, nitrite, and sulfide." The Nemartian looked as if it was beginning to see the point.

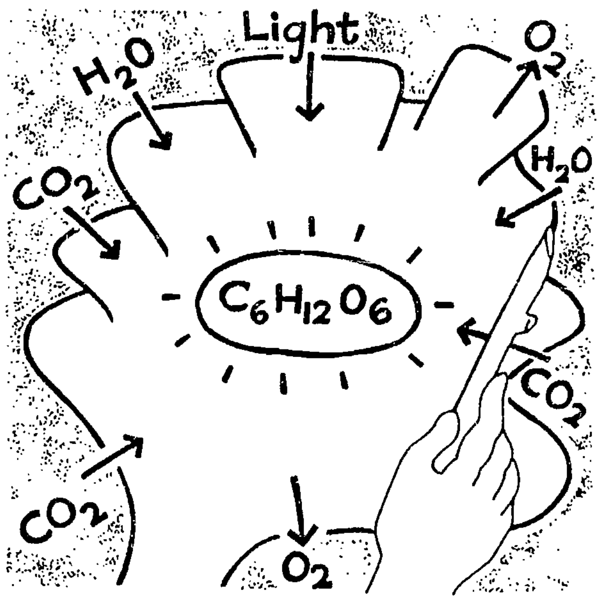
"Autotrophs, or 'producers,' harvest energy from the sun to convert inorganic carbon dioxide and water into the organic compound sugar. The process is known as photosynthesis."

The Nemartian looked amazed. "Do you mean to tell me that some organisms can make molecules with light energy? Are you pulling my appendage?"

"No," I assured him. "Photosynthesis requires a particular pigment molecule called chlorophyll. It has the unique property of capturing photons of sunlight, kind of like a solar collector, and using that energy to set in motion a series of biochemical reactions that result in the production of glucose. The energy stored in the glucose is used by the autotroph or passed on to the heterotrophs if it gets eaten."

"That's incredible!" the Nemartian squealed.

"Yes, with just water, carbon dioxide and the energy provided from the sun, these photosynthesizers provide the starting material required to sustain life on this mud flat and everywhere else on the planet." It was time for another mud drawing:



A photosynthesizing blade of green algae

The Nemartian studied the drawing. "Where did the oxygen come from?" he asked.

"The oxygen is a by-product of photosynthesis. Not only are the producers responsible for creating sugar, they also contribute all of the atmospheric oxygen. Without the producers, you and I would have no oxygen to breathe."

"These producers must be the most revered and protected organisms on earth," commented the Nemartian. "Are these the leaders I was warned about?"

"Well, not exactly," I answered.

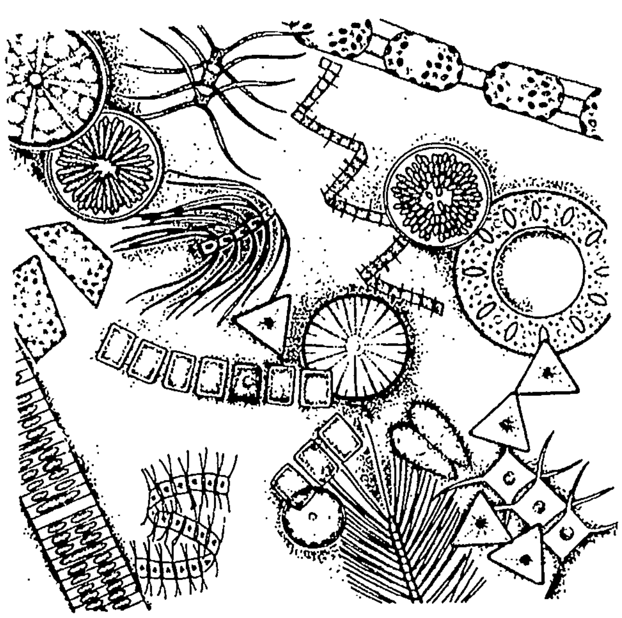
"Then introduce me to the producers here in Padilla Bay," said the Nemartian.

Producers in Padilla Bay

"Some of them are too small to see, but they're hard workers. Primary production (that's the photosynthetic production of sugar) here in Padilla Bay is really incredible. There is twice as much production here as in a farmer's best fields; three times as much as in that healthy forest up on the hill."

"Wait a minute", said the Nemartian. "You're telling me that this barren mud patch produces more sugar and more oxygen than those huge plants over there? Then where is all this growth and reproduction you were telling me about?"

"You can't always see it. Think of a corn field. It starts out in the spring as bare dirt. By the end of the summer 'the corn is as high as an elephant's eye!' That's a lot of growth. The mass of all the living things in the field, or *biomass*, has built up over the summer. But then in the fall, the farmer comes along, cuts it down, hauls it away, and sells it to consumers who live elsewhere. The ground looks bare again but in one year one acre of that field produced a lot of corn.



Diatoms

"Now in a forest you can see production accumulate. There is not as much produced each year but there is less export." In my mind's eye I saw a clear cut but decided not to confuse my new friend with all that. "In a healthy forest bits of dead leaves wash away with the rain and berries and seeds get carried away but the total biomass keeps increasing year after year.

"Here in the eelgrass meadows the productivity is greater than either of those other ecosystems. Even the bare mud surface is covered with microscopic producers called *phytoplankton*. Tiny *diatoms* and *dinoflagellates* photosynthesize so fast that organic products ooze out into the water. Sometimes I see an oily sheen on the water that looks like a gasoline spill, but it's actually just organic matter. Consumers like bacteria turn it into a foamy froth that looks like soap suds washing up on the beach."

My friend still wasn't satisfied. "Where does this incredible amount of production go?"

"The tide washes it away, salmon come in here and gobble up the little consumers, great blue herons and eagles come and carry away huge amounts of biomass. The export rate is so high that the biomass never builds up very much."

"I sure couldn't tell it's that productive just by looking at it," said the Nemartian.

"That's why for so many years people didn't realize estuaries were important. They looked out and saw wastelands, not wetlands. They thought it would be better to turn them into farms, marinas, deep water ports, and industrial parks."

"Aren't there some producers out here that we can see?"

"Sure. Look at the green algae over there. And here are clumps of branching red algae. Look at this eelgrass. Eelgrass is a major producer in this estuary. The *indigenous* eelgrass that is growing out here where you have landed is the *Zostera marina.* Closer to shore is the smaller, non-native, *Zostera japonica. Zostera japonica* was accidentally introduced to the area when Japanese oysters were brought here in the 1800s. Padilla Bay has some of the most extensive beds of eelgrass anywhere on the western coast of North America!"

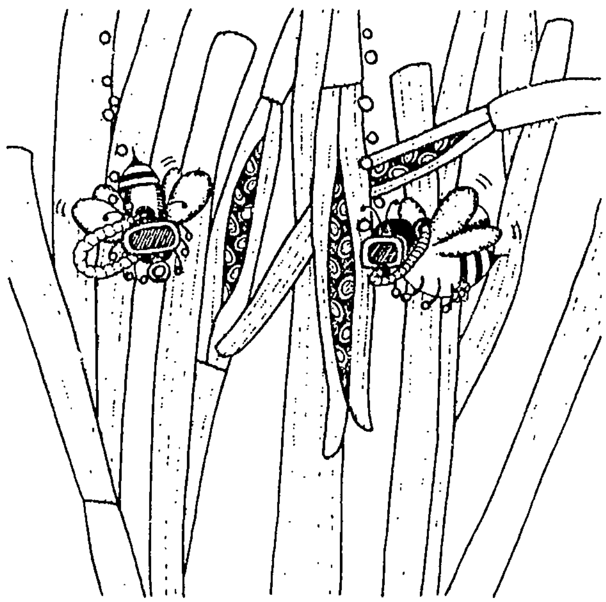
The Nemartian did not look impressed.

"Eelgrass is a flowering plant!" I said.

"Is that unusual?" it asked.

"Well," I continued, "most flowering plants grow on land or at least hold their flowers out of the water. Eelgrass is a rare example of a flowering plant that can tolerate high levels of salinity along with all the other hardships imposed by an estuarine environment. In a way, eelgrass is like a marine mammal. Both evolved on land and subsequently turned to the sea to make a living.

"Eelgrass, like other flowering plants, must bloom and be fertilized." The Nemartian continued its blank stare. "So how do you think it gets fertilized under the water?"



"Scuba bees!" it said with a big grin.

I tried not to react so as not to encourage more bad jokes. "Unlike land plants, which produce very small, roundish pollen grains, eelgrass pollen is stringy and mucous-like. When carried from the parent plant by currents, it will be more likely to wrap around another plant and attach to the stigma. In addition to sexual reproduction involving flowers, eelgrass also reproduces vegetatively from creeping underground stems called rhizomes, like many of its terrestrial relatives."

The Nemartian still looked bored so I tried harder to convince it of the importance of eelgrass.

"These eelgrass beds you see before you are not only important because of their marine adaptations. The roots they produce act as traps for sediments that stabilize and build the substrate. Further, the long, ribbon-like leaves slow water currents so that additional particles settle. This stabilization is extremely durable; able to withstand storms as severe as hurricanes. In the 1930s, an unknown disease swept the North Atlantic coast wiping out much of the *Z. marina*. The effects included a dramatic erosion of beaches due to the loss of sediment, no longer held by the *Zostera*, as well as the disappearance of the animals associated with the beds.

"The leaves also provide a protective canopy, shielding other organisms from the effects of strong sunlight. At low tide, the leaves cover the bottom substrate, protecting the inhabitants from drying out."

Now the Nemartian was beginning to move its proboscis in the direction of the extensive eelgrass bed near-by. I sensed a growing respect for the *Zostera marina*. This gave me new energy so I went on.

"See how it's covered with brown fuzz out near the ends of the blades? That's a whole community of small plants and animals that use the blades of the grass for habitat. The organisms growing on a plant are called *epiphytes*. The blades of eelgrass provide a rare solid *substrate* in this soft field of mud. Look closely and you'll see all sorts of inhabitants of this neighborhood -- tiny crustaceans, algae, sponges, bryozoans, worms... Is it any wonder so many hungry fish cruise these parts?"

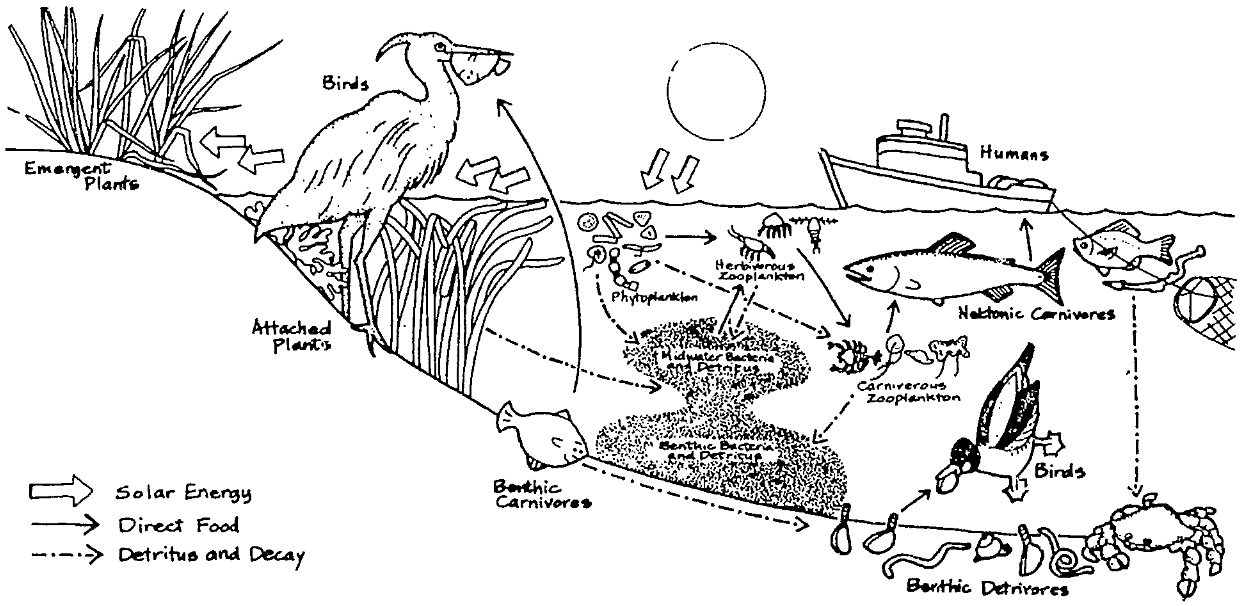
Eelgrass community

"Let me see if I have this straight," said the Nemartian. "Eelgrass provides food, oxygen, sediment stabilization, and valuable habitat. So this must be the most revered organism in the estuary."

"Well, it should be I suppose. When the eelgrass is alive it does all those great things, but that's not all! When it dies, it accumulates with all the other dead plants and animals to become something even greater. Eelgrass is an important source of detritus in the estuary."

The Estuarine Food Web and the Role of Detritus

"As in all ecosystems, some energy flows from the producers to the consumers (organisms that eat other organisms). These consumers living in the estuary depend on energy stored by producers such as eelgrass,



Estuary food web

algae, and phytoplankton. The major source of energy, however, is detritus."

"Excuse me," interrupted the Nemartian "This detritus, as you call it, is dead, right?"

I nodded. "Detritus is decaying organic material, but it is enriched with associated bacteria that are very much alive. Many ecologists believe that the consumers who eat detritus (*detritivores*) derive most of their energy by digesting the bacteria and other microorganisms that live on the particles of organic material.

"But that's not the only way energy is distributed in an estuary. There are primary consumers who eat the producers. There are secondary consumers who eat the primary consumers. *Omnivorous* filter feeders eat anything (detritus included) small enough to be sucked in with the water around them. An estuarine food web is very complex and I don't think anyone completely understands it."

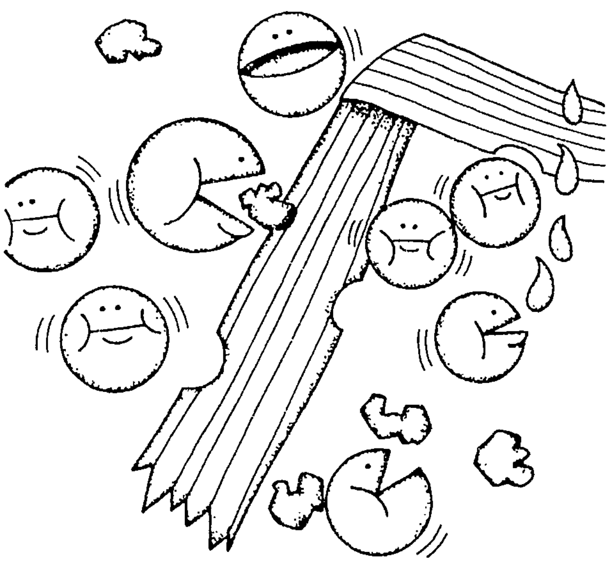
Estuarine Consumers

The Nemartian didn't look as confused as I had looked the first time I heard all this so I assumed I could continue.

Bacteria

"One group of consumers whose importance is often underemphasized, even in the text books, is the group I have already mentioned, the bacteria. Sure, I know they're small, but is that any reason to trivialize their impact on an ecosystem?" The Nemartian withdrew its proboscis a bit and I realized, in my enthusiasm to defend the underdog, I was coming on a little strong. I restrained myself and continued. "Both the water and the mud of estuaries are extremely rich in bacteria. It's a bacterium's dream down here due to the abundance of organic matter to decompose. The water that is beginning to lap around us contains hundreds of times more bacteria than open ocean water, and the upper layers of mud more than a thousand times more bacteria than that! Studies have measured 100-400 million bacteria per gram of estuary mud.

"And, contrary to what many believe, bacteria do much more good than harm. Certainly, the estuary as we know it would not exist without bacteria. The cycling of materials would be impossible without the decomposition of certain molecules by bacteria. In other words, bacteria make the organic material available for all of the inhabitants of the estuary. Even the self-sufficient producers require the action of bacteria to obtain essential nutrients from the substrate.



Munching bacteria

"One role that I haven't mentioned is very remarkable. Bacteria can decompose just about anything. While a dead eelgrass leaf may be considered a tasty morsel to one bacterium, another might like a particle of raw sewage or even a potentially harmful toxic, washed down from an agricultural field. As a result, water passing through an estuary exits cleaner than it entered. A city in Texas has constructed a wastewater treatment facility in which sewage is piped into sixty-foot-high towers and bacteria like those here in the estuary are added. Within six to twelve hours, the organic substances are "eaten" by the bacteria and the purification process is complete. In our case, here at Padilla Bay, the estuary plays an important role in purifying water from the land. Now that so many estuaries have been destroyed, is it any wonder that the waters are polluted?

"However, it would be a tragic mistake to think that anything can be dumped into an estuary and it will be processed and purified. Estuaries, like all ecosystems, have their limits. If those limits are exceeded, then the entire balance is upset."

Estuarine Communities

The Nemartian's proboscis was now moving about across the mud surface, straining to observe some of the bacterial films in the faint light of early dawn. I don't know exactly what sense was involved, but it seemed very efficient at picking up life forms, even the ones that I need a microscope to observe. "I thought you said this place had a low diversity of species," he remarked. "There are all sorts of organisms here."

"You're right, there are many species living in the estuary. But compared to say, a tropical rainforest, the diversity is 'relatively' low. The species that do live here are beautifully adapted to their environment."

The tide was beginning to cover the mud around us, bringing to life a whole world that had been waiting to resume its activity. Clam siphons appeared at the openings of holes. Burrowing anemones spread their tentacles hoping for a little plankton or detritus to come by. Mud snails and bubble shells plowed across the mud surface, searching for food. A mud shrimp emerged from its burrow, dumped its load of excavated mud and quickly disappeared again.

The Nemartian noticed the water lapping up against his landing gear. "I suppose I'll need to take off soon," he sighed, sounding rather drained.

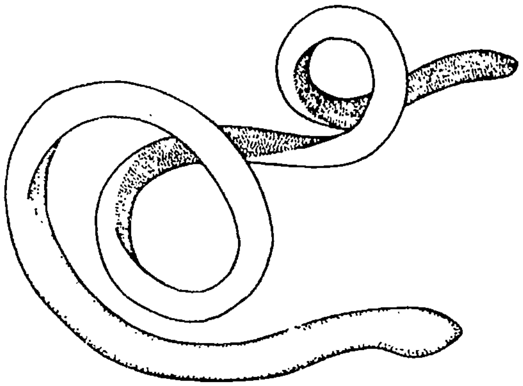
"You can't leave yet! We're just getting to the interesting part." I held out a tiny yellow egg sack, filled with strings of snail eggs. "All this talk -- of tides and salt water, substrate, bacteria, productivity -- it's all just setting the stage for this **community**. This unique assemblage of plants and animals is perfectly adapted to the habitat. Each has a specific role to play, but all are connected and interdependent.

"Just look at this mud shrimp, *Upogebia pugettensis*." I couldn't believe I remembered its scientific name. "That burrow is probably a foot or two deep and is connected to a network of tunnels with turnaround chambers and several openings to the surface. All sorts of animals make use of the mud shrimp's excavation skills. Clams, crabs, worms, even some fish share its burrow. The relationships are complex, and no one knows exactly what goes on in the mud community. It's a fascinating mystery!

"And just ten feet away, right behind you, is a different community, the eelgrass bed, full of organisms that are especially adapted to eelgrass. There's a fish called a pipefish that is skinny and green and swims vertically, aligned with the grass. The eelgrass isopod is shaped like the grass and is perfectly camouflaged. Look, here's a green sea slug that even has stripes that imitate the eelgrass. Its eggs are clear and laid flat against the blade so that even the sharpest eyes can't find them.

"Each community out here has its members: producers, grazers, scavengers and carnivores. No two members occupy exactly the same *niche*. It's truly incredible to see how the whole system fits together. You'll just have to come back to get the rest of the story."

The tide was now well on its way in. I was standing in about six inches of water and remembered that I had that big biology test in just a few hours. "Well, thanks a lot, earthling," the Nemartian squeaked. "It looks as if I'd better be heading back to Stasis." The proboscis began to invert back into the space craft when it seemed to notice something on the mud surface nearby. It suddenly whipped out to full length and focused on a ribbon worm that was just a meter or so from my left foot, crawling along the surface in that characteristic manner. "On second thought, there is time for you to describe this one last animal,



Ribbon worm (*Paranemertes peregrina*)

for it is without a doubt the most beautiful, graceful, intelligent specimen I have yet to see here. Would you mind?" the Nemartian asked.

"I don't know. I'm feeling pretty tired," I said, "but I'll try. That is *Paranemertes peregrina,* commonly called the ribbon worm. It belongs to the animal phylum Nemertea. Nemerteans are typically creeping or burrowing worms with soft bodies covered with cilia. They are highly contractile and some of them resemble rubber bands. They are not rubbery in texture, however. In fact, if you're not careful, they will easily break when handled. They range in size from a few millimeters to 3 meters! Nearly all nemerteans are fierce predators. They eat other worms, molluscs, and crustaceans. Some swallow their prey whole while others suck out their juices.

"The reason such fragile animals can be such fierce predators is that they are armed with a formidable proboscis. It is often larger than the actual body of the worm and is sometimes armed with a sharp barb that operates in conjunction with a venom gland to capture or quiet prey.

"I once placed a nemertean in a dish of seawater with a much larger and seemingly meaner mussel worm (*Nereis*), expecting the worst to befall the ribbon worm. To my surprise, the nemertean's probing proboscis stung the mussel worm, inflicting such pain that the victim writhed for several minutes before escaping to the other side of the dish. Later I learned that some nemerteans prey on these large mussel worms, which are formidable predators in their own right, and swallow them whole after subduing them."

Again, I can't explain just how I sensed this from the expression of a proboscis, but the Nemartian seemed to glow with pride after hearing this story.

"Nemerteans are tough, too," I continued. "As I said before, they have a trait of breaking apart when disturbed. At least some of these pieces will regenerate into complete animals. One study showed that pieces one-hundred-thousandth the volume of the original would continue as miniature worms. In other words, a worm 1/8 inch in diameter could be cut into 1/16 inch slices and all the fragments would regenerate."

"That's disgusting! You humans are sick," said the Nemartian.

"I'm just trying to emphasize how durable these animals are," I countered. I don't know why, but I just couldn't resist pushing the Nemartian's buttons. "They have also tried freezing adult worms and have found that they survive. They have starved some species for more than a year and again, the nemerteans survived. The worm may shrink in that time but it will not die."

"That does it, I'm out of here!" And with that as its parting words, the Nemartian inverted its proboscis into the space craft, slammed the door and, before I could even get to my feet, rose up and vanished in the pale dawn sky.

My next recollection was awakening in my car, parked at the beach. I rubbed my eyes and squinted out at the rippling water that now covered the mudflat. What a wild dream, I thought. I must have been so worried about this biology exam that I dreamed about it. Well it serves me right for not preparing. But still, what a wild dream! I returned home quickly so that I could change clothes and get to school on time. When I opened the trunk to get my things, there were my hip boots, covered with wet, estuary mud.

So, what do you make of that?

Related Activities:

Taking An Estuary Field Trip, Activity 1.

Plankton Study, Activity 2.

Water Quality Monitoring, Activity 3.

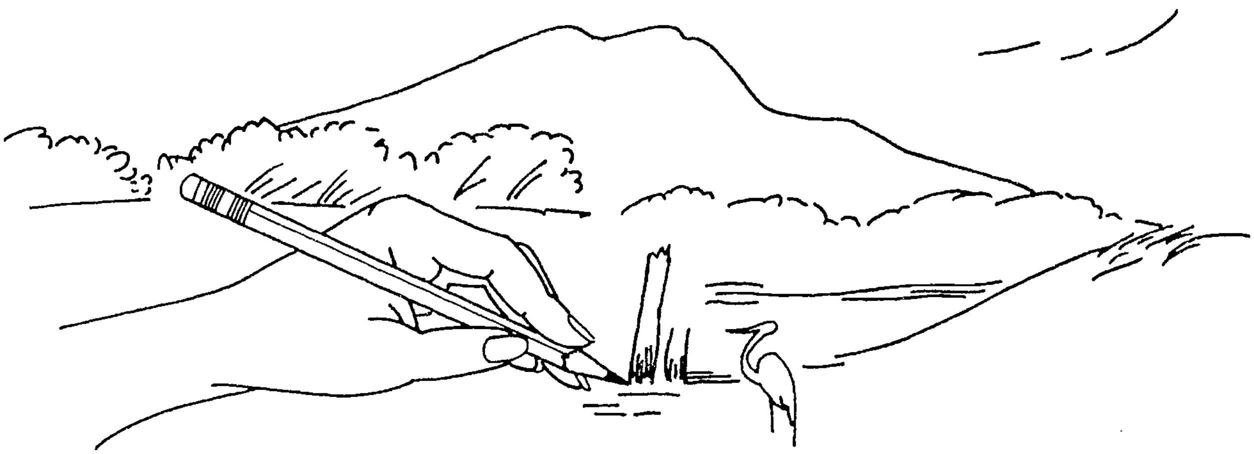
Keeping a Marine Aquarium, Activity 4.

See also:

A Field Guide to Padilla Bay Organisms

Questions

1. What watershed do you live in? What river or body of water does it drain into?
2. Name two ecosystems that are associated with an estuary ecosystem. In what ways are they associated?
3. Explain why it might be difficult for an organism to live in a place that has tides. Explain how it might be advantageous.
4. Why is detritus more nutritious than the dead plants and animals it is made up of?
5. Which produces the most oxygen in one year: an acre of forest, an acre of hay, an acre of eelgrass? Which produces the least?
6. Why did the Nemartian cross the universe?
7. Why do some organisms living in salt water need a strategy to avoid dehydration?
8. How are *Zostera* species examples of adaptive radiation?
9. How did *Zostera japonica* first get into Padilla Bay?
10. List three values of eelgrass.
11. Why are bacteria important in estuaries?
12. Name three ecological communities found in Padilla Bay.



4 - Estuary Inspired - Literature and the Arts

"There are good things to see in the tide pools and there are exciting and interesting thoughts to be generated from the seeing.

"Every new eye applied to the peep hole which looks out at the world may fish in some new beauty and some new pattern, and the world of the human mind must be enriched by such fishing."

- John Steinbeck, from the introduction to ***Between the Pacific Tides*** by Edward Ricketts and Jack Calvin

John Steinbeck, a great American writer, wrote this while on a marine biological expedition in the Sea of Cortez with his scientist friend, Ed Ricketts. He says that inside each of us are the skills of a scientitst or an artist capable of looking through the peep hole at life, and seeing something. What we see, and how we express it is our gift to humanity. He looked into the tidepools and was inspired to write a book about the worlds he saw within them. What do you see? What is your gift?

As people, we have been defined by our landscape. America's human history is the history of our interaction with the land and the water. The oral history of the Native American people tells stories of the land and the water. Our school history books are filled with the European settlers crossing the Atlantic, blazing through the Cumberland Gap, busting sod on prairie homesteads, and fighting for the natural riches of the Pacific Northwest, Alaska, and California. The land is our cultural as well as our physical heritage.

Today we spend days, even weeks indoors. We go from building to car to building as we drive to the mall, the theater, school, and the grocery store. Living in a suburb of Seattle is much the same as living in Akron, Ohio, or Sacramento, California. The stores are the same. The television shows are the same. We're so busy that we sometimes forget to appreciate our home; the land and water in our own backyards.

For many of us, however, the **place** in which we live still makes a difference. It allows us to go backpacking or sailing in our free time. The weather and climate affect our moods and thoughts. The smell of the wet earth, the sight of the mountains or bay leave indelible stamps of places on our minds.

Artists, such as writers, painters, film makers, and musicians remind us of our places. By using nature in their work, they remind us of our connection to the planet, and hold up new images for us to see.

We can still hear the sounds of the primal Pacific Northwest in the myths and stories of the early inhabitants. We can see the world of Walden Pond through the words of Thoreau, the cliffs of Yosemite through the camera of Ansel Adams, the Southwest desert through the paintings of Georgia O'Keeffe. You can't separate the setting from the work, nor can we separate ourselves from what sustains us.

It is natural for people to seek inspiration from nature. Not only for those who produce art, or even science, but for pure sensory and mental gratification. The land is our legacy, and from it our lives are physically and spiritually enriched.

Estuaries, like other natural places, have inspired artists. But more than any other natural environment, estuaries provide deep, instinctual images into our psyche. The roots of both human and ancient cultures are traced to estuaries. The fertile valley of the Tigris and Euphrates rivers is referred to as the cradle of civilization. The Egyptian civilization flourished on the Delta of the Nile. St. Petersburg, Russia's great cultural window on the Baltic, was built on a salt marsh under the cruel leadership of Peter the Great. Rome, London, and New York are just some of the other great cultural cities of the world built on estuaries.

Besides their physical sustenance, estuaries have given us images of peace and solitude, of rhythms and cycles of life, of richness and fertility, and of death and decay.

Death is an often used, and most appropriate, subject for the estuary and the area around it. The estuary is a mud stage where a continuous stream of murders, vicious attacks, and general carnivorous atrocities are enacted. Along with all the carnage comes rebirth as the decaying processes recycle the nutrients back into life.

Dylan Thomas: Estuary Inspired

Dylan Thomas (1914-1953) is one great poet of the twentieth century whose

Dylan Thomas

work was strongly influenced by nature and the life and death struggles within an estuary. He was born and spent most of his life in the gentle countryside of southwestern Wales where the Taf and Towy rivers wind their way to meet the rugged coast of the sea. Some of his later poems were written in a boathouse that overlooked an extensive mudflat of the Taf estuary in Laugharne, Wales.

One central theme in his poetry is the never ending cycle of life. He often emphasized the flow from the miracle of birth and creation, through the fierce struggle to survive, to the inevitable passage of death, then back again to birth. He was enthralled with the biological and spiritual realities of life, and he often used the processes he saw in the estuary as images in his poems.

For instance, death is often symbolized by estuary predators like the heron or the hawk, or by *detritivores* like worms.

The Estuary Under Sir John's hill

Basically, the estuary is not a pretty place to write a poem, so it's no surprise that Dylan Thomas focused on death as he looked across the mudflat and hills of the estuary and wrote his poem *Over Sir John's hill*. (It rains just as much in Wales as it does in the Northwest, so you can imagine how a sunny evening might have inspired him to write a poem.)

Poems have many interpretations, the most important being yours. From the estuarine perspective, *Over Sir John's hill* is a poem mourning the birds and fish preyed upon by predators. It opens with a hawk hovering over a hill at sunset -- above the innocent little birds who don't know what is about to hit them -- until death comes when the "Flash and the Plumes crack." Throughout the poem the poet, as well as the heron, watch all this; the poet thinks of his own death, and the heron simply kills for its next meal.

It is a visual poem in its imagery, but dependent upon sound in its reading. Even if you don't think you understand all of it, read it once aloud. The soft, lyrical melody and light rhyme pattern are a contrast to its dark theme of death. The poet only leaves us clues, the rest is up to us; our vision, our interpretation. Give it a try.

Over Sir John's hill

by Dylan Thomas

Over Sir John's hill,
The hawk on fire hangs still;
In a hoisted cloud, at drop of dusk, he pulls to his claws
And gallows, up the rays of his eyes the small birds of
the bay
And the shrill child's play
Wars
Of the sparrows and such who swansing, dusk, in wrangling
hedges.
And blithely they squawk
To fiery tyburn over the wrestle of elms until
The flash the noosed hawk
Crashes, and slowly the fishing holy stalking heron
In the river Towy below bows his tilted headstone.

Flash, and the plumes crack,
And a black cap of jack-
Daws Sir John's just hill dons, and again the gulled birds
hare
To the hawk on fire, the halter height, over Towy's fins,
In a whack of wind.
There
Where the elegiac fisherbird stabs and paddles
In the pebbly dab-filled
Shallow and sedge, and 'dilly dilly,' calls the loft hawk,
'Come and be killed,'
I open the leaves of the water at a passage
Of psalms and shadows among the pincered sandcrabs
prancing

And read, in a shell
Death clear as a bouy's bell:
All praise of the hawk on fire in hawk-eyed dusk be sung,
When his viperish fuse hangs looped with flames under the
brand

---

swan song: legendary last utterance of a dying swan.
blithe: carefree, cheerful.
-burn: a small stream, in Scottish language.
Towy: a river of southwestern Wales.
jackdaw: Eurasian bird resembling a crow.
halter: a rope used for execution by hanging.
elegiac: A mournful poem, composed to lament one who is dead.
dab: any of a variety of flatfishes. To poke.
psalm: sacred song or hymn.
brand: a mark formerly burned in the flesh of criminals.

Wing, and blest shall
Young
Green Chickens of the bay and bushes cluck, 'dilly dilly,
Come let us die.'
We grieve as the blithe birds, never again, leave shingle
and elm,
The heron and I,
I young Aesop fabling to the near night by the dingle
Of eels, saint heron hymning in the shell-hung distant

Crystal harbour vale
Where the sea cobbles sail,
And wharves of water where the walls dance and the white
cranes stilt.
It is the heron and I, under judging Sir John's elmed
Hill, tell-tale the knelled
Guilt
Of the led-astray birds whom God, for their breast of
whistles,
Have Mercy on,
God in his whirlwind silence save, who marks the sparrows
hail,
For their souls' song.
Now the heron grieves in the weeded verge. Through
windows
Of dusk and water I see the tilting whispering

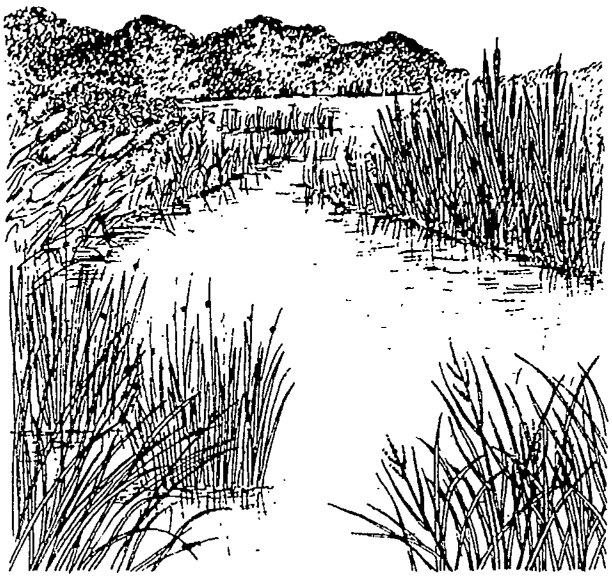
Heron, mirrored, go,
As the snapt feathers snow,
Fishing in the tear of the Towy. Only a hoot owl
Hollows, a grassblade blown in cupped hands, in the looted
elms
And no green cocks or hens
Shout
Now on Sir John's hill. The heron, ankling the scaly
Lowlands of the waves,
Makes all the music; and I who hear the tune of the slow,
Wear-willow river, grave,
Before the lunge of the night, the notes on this time-shaken
Stone for the sake of the souls of the slain birds sailing.

---

dingle: a small, wooded valley.
knell: to ring or sound a bell in sorrow, especially at funerals.

The Short Story

Look now at another form of writing that has used the estuary for inspiration; the short story. *"The Salt Marsh"* illustrates the power an estuary has to tell a story. This story is based on the events of an estuary in Maine.



The Salt Marsh

by Floyd C. Stuart

I rolled down the car window as I sped through the dark, sucking in deeply the aroma of salt marsh, elemental and frank, to drive the odor of perfumes out of my head. Earlier that evening I had strolled through acres of the Maine Mall, in South Portland. Fumes of exotic soaps and powders and colognes filled the department stores, an olfactory summation of a glittery, titillating way of life that I have grown unused to.

I rubbed elbows with customers, handsome and trig, who seemed to accept video games and personal computers as everybody's norm. From a balcony I gazed up at mobiles floating high above the main level; I bowed my head and meditated on the cleavage of a girl selling watches and rings. The colors and lights, the inexhaustible merchandise and milling people, were exciting. Plaster men and women as young and perfect as I should have been gestured to me, suggesting what I needed. At every turn mirrors showed me what I was. On the sides of the escalators they reflected a dozen pairs of suede casuals, gold-strapped sandals, and high-powered racing sneakers. I got dizzy and left.

The road I took back to my motel passes through a salt marsh -- a fragrant, 3,000-acre blackness that winds toward the vaster blackness of the North Atlantic. A marsh smell is nothing you convince anyone about: it is either the stench of putrefying garbage or a tangy whiff of pure existence.

I slowed the car and breathed in a subtly blended essence of spartina grasses; mud rife with bivalves, annelids, and algae; a hint of iodine; decaying vegetation, fish, and crabs; and, because this is an unpolluted marsh, only the normal tinge of the rotten-egg smell of hydrogen sulfide. The headlight of the car cut the dark in half. For the moment I was alone on the highway that strikes across an inland narrowing of the marsh. The honest smell untensed me, and suddenly a dead man flitted through my mind. A few springs ago he had been found here, stuffed in a plastic trash bag. The police had indentified the victim as an older "transient." A bum. They would never know who had killed him, or why.

A salt marsh is a continent's vacant lot, almost a non-place, where we dump garbage from our industries and murders. But left to itself, a marsh is a clean space: flushed out twice a day, chock-full of bacteria fastidiously dicing up what has died into a detritus for larger creatures to dine on too. The tides are a feast, bringing in guests from the ocean deeps, uncovering delicacies for herons, egrets, and gulls. Biologists have esı nated that about two thirds of all marine life is dependent on estuaries and marshes. Acre for acre a salt marsh is one of the most productive habitats there is. The faint odor of death is a reality of a marsh; that perfume clings to all our lives.

On my way back from the mall I drove over a culvert. Below me the swiftest of the marsh's three rivers ran toward the sea. Near here, a year or two before the murdered bum was found, a twenty-two-year-old woman, driving alone late at night, had gone straight where the road curved right. The car neatly missed the guardrail and rocketed into blackness. The woman probably had fallen asleep at the wheel. She slumped for a whole summer and part of an autumn in her overturned Honda on the bottom of a particularly deep tidal channel. The water in a salt marsh is a soup of silt, spartina bits, dead crabs, seaweed fragments, yearling eels, and flecks of mussel shell. You cannot see far in. Search helicopters hovered above the Honda and missed it. Not only was the turbid water deep, it was also the color of the overturned vehicle.

The young woman had been going to visit her boyfriend. For a summer and a fall the hulls of canoes floated above her like dark clouds: children and fathers, solitary bird watchers, lovers preoccupied with each other. One morning in October, after a severe storm that must have ground the Honda onto a shallower bottom, a passing driver spotted the upside-down car in the channel. Later, subtle traces of tire tracks were discovered where the car had crossed a length of marsh before plunging into the water. Hood, tires, grille, head lamps--all were encrusted with barnacles. The dripping car that emerged from the tidal channel looked more like a creature of the marsh than of a mall parking lot.

I kept awake on my drive to the motel. The tide reached its height, hesitated, and then started flowing out, a great, cleansing respiration that must have made my deep-sleeper's breathing in the rented bed seem frenzied and ephemeral.

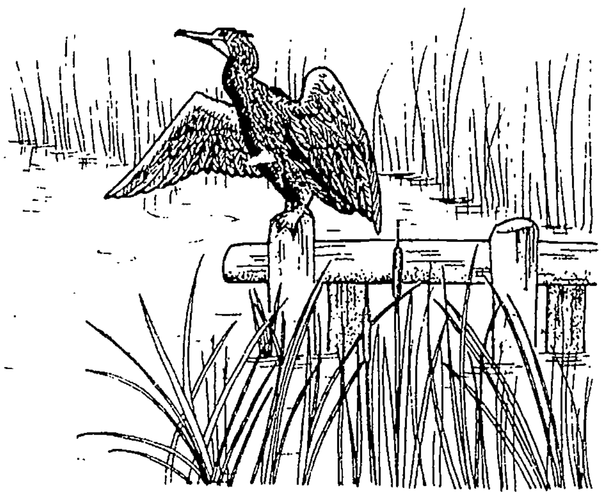
I was back on the sunny marsh by mid-morning, ten-power binoculars slung from my neck, a dime-sized, fourteen-power magnifying lens in my pocket, and two flower books and a bird book in my hand. It was well into September, when an autumn chill should have been upon the marsh. Sweat beaded on my forehead. There was no breeze, and the temperature seemed headed for the nineties.

We do not come to the marsh to hay anymore, driving horses fitted with wooden bog shoes onto the sopping ground. We do not heap teepees of hay on staddles -- clusters of ash pilings pounded into the marsh to make a platform so that the ricks won't float away on the higher tides. One can still find staddles: they are about two feet high, and below ground level the wood is as sound now as the day it was cut, although many staddles are more than a hundred years old. We do not fetch hay off the staddles when the mud has frozen into firm road for teams and wagons. At dusk the white-tailed deer still drift out to graze. We no longer sneak onto the marsh to slaughter by the thousands curlews and golden plover. Our lives have changed. But we do return, and launch our canoes into the sinuous tidal channels, or watch egrets waft upon the marsh like blank pages torn from a notebook. We glide past delicate sprays of sea lavender blooming atop the muddy banks. And during a summer hundreds of us, by ones and twos in our canoes, ghosted above a speechless woman crumpled in a Honda. We paddled toward the North Atlantic and back, and could not see.

The last of the tide was going out when I walked onto the causeway, an abandoned railroad bed that crossed the mile-wide marsh. The waters of the main channel were sucking noisily at the causeway boulders. On the high marsh *Spartina patens* often makes cowlicks -- swirls of flattened grass where the marsh beasts seem to have bedded down for the night. This is the way this spartina does, bending at a curious weak spot near the base of the stem and leaning on its neighbors. In the morning light the cowlicks are brushed-silver medallions among the greener standing stems. The spartina is anchored in mud and its own decayed past, and neither sea nor the fist of man could easily uproot it. Stray hurricanes, the steady battering of winter storms, and the grinding rafts of ice loose upon the tides do not, in the long run, change the marsh very much. The mud and the spartina with its weak spot are too powerful for mere wind and waves. Storm-gored, the marsh heals itself. And we come, transient, not well adapted to the harshness of existence, as though here, in the strange, rustling grasses between sea and land, we might learn to heal ourselves.

I looked at birds and at what was growing along the causeway, refreshing a memory that is sometimes dulled by inland living. I stooped to seaside goldenrod. The bulbous pods of sea rocket, a common mustard, stopped me in my tracks. I sat down in the dust and thumbed my guidebooks, dotting the pages with sweat. Something fragrant, maybe a kind of sage, distracted me, and then two more plants that I could not identify; I am clumsily self-taught. A firehouse siren cranked up and I heard it, but not with any conscious attention. A cormorant beat by, silent as always, his yellow chin patch flashing. We still follow the usage of the early English settlers of this coast and call the bird a shag. He lighted on the top of a utility pole at the footbridge and stretched his scrawny wings to dry. This salt marsh is incomplete without a black shag cross nailed atop that particular post. Shags are swift and lethal swimmers beneath the sea, and because they do not secrete waterproofing grease upon their feathers, as ducks do, water weights them down so that they can dive more readily. But now and then the burdened shags must perch on ledge or buoy or piling and hold out their wings to the wind.

I sat in the dust and dripped on my books, snatching glances at the shag through binoculars, squinting at anthers and filaments



waving into the magnifying lens like the arms of a giant squid. Sometimes I paused, and laid my lenses aside, and saw how circumscribed the world was. The green line of woodland across the marsh arced to distant highway and swept behind the culvert into scrub, which bent to the sandy spit in the brilliant haze where ocean and marsh touched. Twists of land concealed the North Atlantic.

The wallop of sirens, insistent and multiple, broke my trance, and I looked up from my flower book. A car towing a camper was parked on the gravel shoulder by the culvert that I had driven over the night before. A pickup was stopped nose-to-nose with the car, but the two vehicles did not appear to have collided. The road along the rim of the marsh was deserted except for a small yellow pickup parked near the guardrail on the other side of the highway. A bar of blue lights stuttered atop the cab. A policeman leaped the guardrail and disappeared down the farther bank. A few seconds later he shot up, dashed across the road, and scrabbled down the weedy bank to the culvert as if he expected something to flume through. Cars were pulling off the highway -- thirty within a few seconds, it seemed. Some people were gawkers, but others leaped down the bank as if they had business. They peered up the culvert and then focused their attention on the water in front of it. All the while the sirens whooped. The higher-pitched ones belonged to approaching vehicles, but a throatier, incessant honking came from the fire station, a few miles off. Red and blue lights glittered along the highway from both directions.

I watched real life -- whatever it was that was happening -- and yet a restricted life, in a neat binocular ring. The tide was nearly out, and the green-slimed remains of an old wharf or a bridge, which earlier that summer I had canoed over during high tide, jutted out of the mud and the narrowed channel. Beyond the rotten pilings the channel makes a broad loop, parallels the highway until it reaches the culvert, and then swings out of sight behind spartina. At high tide, water had nearly licked the roof of the culvert, which is about eight feet tall. Now a frothy gush a couple of feet deep -- still too emphatic for a man to stand up in -- pulsated out of the shadow. The policeman stood in street shoes on the muddy shore, peering into the deep pool in front of the culvert.

A young fellow in blue jeans and sneakers, and naked to the waist, waited docilely, like a girl letting someone hem her dress, while two other men tied a red lifeline at the small of his back. Then he eased into the pool beneath the culvert waterfall, adjusted his snorkel mask, and floated on his face just under the surface of the water, like a corpse. His companions held onto his red umbilicus for dear life. From somewhere outside the circle of my binoculars men kept spilling down the bank. Suddenly the scene stalled -- silent men lined the shore, the red tip of the snorkel tube was stationary in the pool, spartina blades were quiet in the heat -- and yet one sensed a tremendous urgency. On the bank a man in a T-shirt, slacks, and sneakers waited impatiently while others checked the air tank on his back and fastened a lifeline around his waist. The snorkeler rose out of the pool, stooped and dripping, and spoke briefly with the scuba diver, and then both of them slipped beneath the water.

Crooked lines of cars now littered both shoulders of the highway for hundreds of feet in either direction from the culvert. It looked like a chain-reaction accident on a freeway, and yet amid all the apparent confusion emergency vehicles moved quickly and efficiently. A fire truck roared up, and although several men were in uniform, most of the men clambering on the bank or holding lifelines were in civilian clothes. It was Sunday, and several men standing in the mud wore white shirts and slacks, as if they had rushed out of church. Volunteer firemen, I guessed, remembering the blatting fire-station horn. Down the straight reach of highway an ambulance wove between the parked cars, its flashing lights faded in the sun, its siren sounding louder and louder. The white box shimmered in the heat, as if the pitch of its own siren were melting it. I swung my binoculars back up the road, and from a seaside town came a fire engine towing a lifesaving raft -- a sight not incongruous on our coast.

I could only guess at what was going on. I was sitting in the midst of exciting events and yet was isolated at the edge. A silent hammer of heat beat upon my head and shoulder blades. For protection I put on the drenched T-shirt I had earlier peeled off. Insects leaped from cupped umbels of Queen Anne's lace and from stalks of grasses, criss-crossing my lap, flitting onto my anklebone, or resting a moment in the shelter of my cutoff blue jeans. A diver's arm smacked water and I saw the spatter of silver splinters, but I heard at this distance only the September buzz of insects: nothing ends, ever ends, ends . . .

The men were fighting vicious seconds to rescue someone under water; and they were just tiny figures in the tableau of living and dying, nothing new under the pelting sun.

At night the marsh lures us into accidents; it wraps dark arms around our murders. In the light of day we sometimes discover what has been done. At two o'clock one morning twelve years ago, a forty-year-old businessman was driving through the marsh on his way home. One car was ahead of him. Without warning it swerved off the road, crossed twenty or thirty feet of marsh to a pool, and tipped upside down into it. The tail lights still glowed as the car sank in ink. The businessman skidded to a stop, plunged into the chaos of the night marsh, and struggled toward the disappearing car. "I went up to my shoulders," the good man said later. "It was like quicksand, half water, half mud." The car was completely submerged when he reached it. And yet somehow he saw an arm dangling out the driver's window, and long hair flowing in the water. He seized them and tugged with all his might, yanking a nineteen-year-old girl into new life on the marsh that night.

The rescued girl's mother said that her daughter had fallen asleep at the wheel. "She was thinking of how good bed would feel... She woke up in the marsh. She took a gulp of it and didn't know where the car window was." The businessman staggered out of the marsh with the girl, her head gushing blood. Several motorists had stopped and watched him fight to save the victim, but they did not help. The businessman shouted for someone to call an ambulance. No one would. He slogged onto the highway and civilization again. His arms were full of crying girl, and he asked the bystanders to open his car door. After a while someone did. He drove her to a state-police barracks. Later he apologized to the girl's grateful parents for having had to drag her out by her hair and arm, and said that he hoped he had not hurt her. The marsh had given the businessman tonsilitis.

The firemen were swift. They slid the raft off the trailer, and half a dozen of them lugged it down the bank like a coffin, gripping the yellow rope looped along the black sides. The raft had a rigid bottom, about eighteen or twenty feet long and six feet wide, which was rimmed by an inflated rubber tube that came to a point at the bow. From the open stern the raft looked like two torpedoes with a great white outboard motor slung between. The name of the fire department and MARINE 4 were painted in bold yellow characters along the side. The men moved almost tenderly, launching the raft, guiding it clear of the divers. A puff of blue smoke kicked up from the motor, and wafted off.

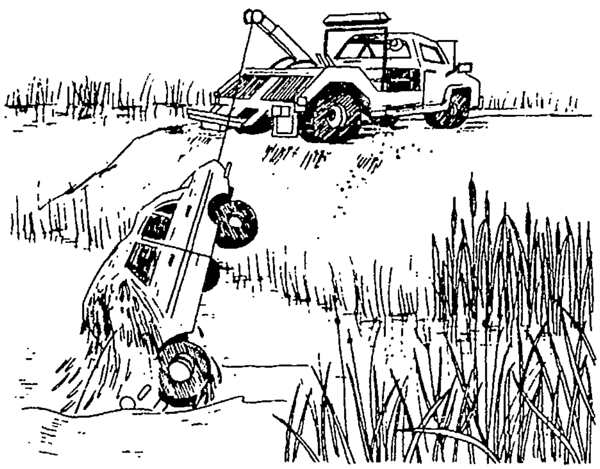
For a long time, it seemed, nothing happened. The divers disappeared at intervals, the scuba diver for longer periods. No one yelled or moved abruptly. The half-dozen men stood on the raft, watching red lifelines slackening and pulling taut upon the pool. Policemen and firemen had raced here to save a life, and now they could not even dredge up a corpse. I let the binoculars dangle against my chest, bored by a hiatus that would have been edited out of telelvision news. Across the channel a line of gray utility poles stood beside the causeway. On each of the first ten a herring gull was perched like a flagstaff ornament. Waiting, for gulls, *is* the grand event. Nothing happened at the culvert for a long, long while -- two or three minutes, at least.

Thudding heat and droning autumn insects correct one's perception of time. Three thousand years -- the lifetime, so far, of this marsh -- is barely a start. This is a sunken coast springing back since the tremendous weight of the last glacier melted off. From Cape Elizabeth north, the State of Maine littoral is abrupt headlands and surfacing island mountaintops; it is drowned river valleys become scraggly inlets and bays. A dozen thousand years is nothing: on our upstart coast post-glacial erosion hasn't really had a chance. The heat, new since the last ice age, beat upon me as I sat in that fledgling marsh. Above, the sky was blue pigment diluted with milk. The haze had bulk; the glare pressed like the ice sheet that a short while ago had been a mile or two thick. The small sound of traffic muttered at the edge of things. Cut off from where human life was taking place, I learned a new kind of time. A mussel secreted a layer of its shell. Granite mountains deep in the interior eroded grain by grain and flowed down coastal currents, silting-in a bay, beginning a marsh. In the stasis of droning insects I thought that all of this was happening too fast.

A perfume-counter smell hit me, ephemeral and as hard as concrete. I suddenly imagined, with the wholeness of a vision, a girl perched on the edge of her bed, intent and serene, resting her chin on her bent knee. She brushed a crucial swath of polish on the nail of her little toe. In the same second, inconsequential in the great grinding-down of the universe, a green wrecker backed as far as it could onto the bank beside the culvert, and stopped. Men unwound a steel cable from the winch and dragged it to the water.

Our comings and goings upon the marsh -- restorative, quotidian, urgent -- and the marsh itself are motes floating in a shaft of geologic time. We can be disposed of in a trash bag or a little car. We contain light years of courage and love. We refuse to help. The mother of the girl that the businessman saved told a reporter: "I can't explain or say what I feel down deep. . . Without him, she'd have drowned. We wanted people to know." We are so vast and small, so much at home in this place where we are lost. Maybe it is not remarkable, then, that we sometimes say what can't be said.

Droplets sparked off the cable as it tautened. I put the circle of my binoculars upon the empty pool with the length of rusty cable sticking in it like a spear. The point hit inside a V of steady ripples. Then the surface of the pool was disturbed; the V of ripples wobbled and broke. A silver bumper bulged into the air, water gushing off. The wrecker slowly drew from the channel the trunk of a



Mercedes. The divers treaded water around the car like curious seals. The rear window was gone, and I could see a shallow dent in the rear of the roof. Half the car was now suspended on a thread from the boom of the wrecker. The Mercedes's rear wheels hung from extended shocks like slack jaws. A waterfall tumbled off the roof, and men shoved into the ring of my binoculars, trying to peer into the car windows, which were blurred by saltwater greasiness. The Mercedes was an oxblood color accented by a sexy gold stripe slong the side. I looked for slumped bodies inside, but glimpsed only slabs of daylight through the windows and between men's backs as they huddled around the passenger compartment. The wrecker hauled the car well up onto the bank. Someone opened a door, and water spilled onto his feet. The men gingerly bent in. When they stood back, I could see: nothing. A fireman scraped a handful of ooze off the plush seat and slopped it into the channel. The Mercedes, elegant and slightly dented, leaked and leaked. I wondered where the rear window was. Compression might have popped it out at impact; or maybe the scuba diver had used equipment I had not seen to pry it free. He did not retrieve the window from the pool. The men looked forlorn, at loose ends. They were used to saving lives and seeing death. They were not sure what to do with this. The empty Mercedes spread its doors like wings and squatted on the bank. The shag on the utility pole at the causeway footbridge tilted his beak in the snooty way shags do, and gazed elsewhere. The crowd melted from the guardrail. The rows of awkwardly parked cars were suddenly gone. Someone slammed the ambulance doors shut, and the white box turned around and went back. The red lights stopped flashing. Fire trucks disappeared, even the one towing the trailer. I put the glasses on MARINE 4, and the lifesaving raft put-putted down the channel toward me, the six men standing up and watching the water. The top of a two-way radio and a telescoped antenna stuck out of one man's hip pocket. Even when the light was right, you could see only a foot or two into the sediment-laden channel. I swept the glasses upstream again: the wrecker and the Mercedes were gone, and the guardrail was deserted. All signs of human life, it seemed, had been sucked up the black hole of the culvert.

The men on the lifesaving raft passed me and disappeared around a bend in the tidal channel, seaching for bodies that might have been carried toward the open sea. A car pulled up on the shoulder by the culvert, and two young men took a canoe off the roof. They launched it into the channel, innocent of the excitement they had just missed. They dipped their paddles and scanned the banks. They seemed to think that the world was new, and that they were the first human beings astir in it.

Was it murder, suicide, death by accident, or simply a stolen car? The searchers standing on the lifesaving rafts explored the loops of the tidal channel. Once, their row of severed heads glided along a horizon of spartina like targets in a shooting gallery. Then they were lost for good. I wondered idly if in a hundred years the cement stumps of the mall would be as well preserved as the staddles in the marsh.

Grain by grain the mountains come down: little murders of ourselves and others, misadventures, stolen moments. Out toward the ocean the air was golden and kind of blue, thick with pollen, it seemed, and a powder of steel filings. It trembled a bit as if the world out there were on a shaky footing. A pinhead of light glittered on the spit where cottages and a tarred street ended abruptly at the beach. At first I thought the pinhead was a glint of anything -- car window, waves. But it was red and rhythmic. Out on the last land the dome light of a fire truck flashed -- the pulse of lifesavers doing the humanly possible. The firemen waited for their friends on MARINE 4 and what they might have found. Beyond the shimmering point lay nothing but the rumored Azores.

Related Activities

Taking an Estuary Field Trip, Activity 1

Writing With Estuaries, Activity 5

See Also

Estuary Arts and Literature, Resources Section

Questions

1. Why do you think so much human history is related to these obscure places called estuaries?

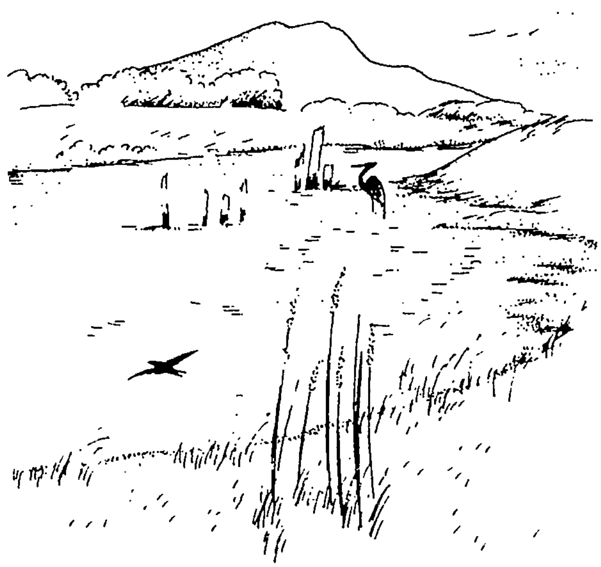
2. How do artists affect the way we see things?

3. Think of your favorite movie. How does the setting affect the characters? How does it affect you, the viewer?

4. Dylan Thomas gives us many estuarine images in his poem, *Over Sir John's hill*, including images of life, death, and renewal. Pick a phrase, word, or line from the poem and describe the image it inspires for you. Try to find this image elsewhere in the poem.

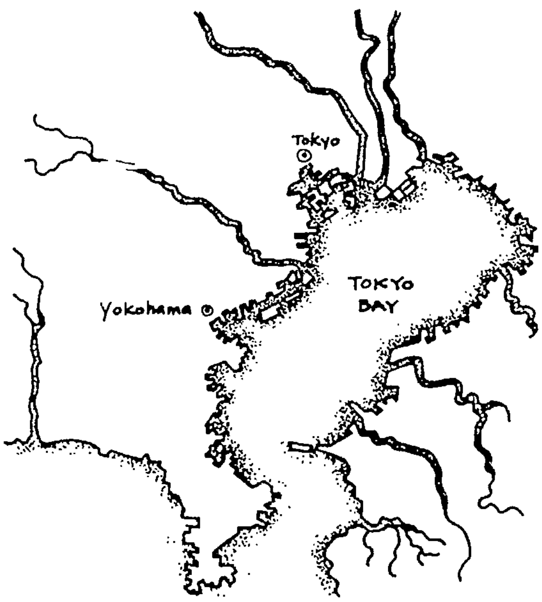
5. Floyd Stuart writes "A marsh smell is nothing you convince anyone about: it is either the stench of putrefying garbage or a tangy whiff of pure existence." Which way do you think Mr. Stuart feels? Provide quotes to justify your answer.

6. Find two references in *The Salt Marsh* to images of death and two images of birth, renewal, or productivity.



5 - Estuary Developed - Human Uses

People around the world have been using estuaries since prehistoric times. They have been attracted to the abundant food resources in estuary waters. They have taken advantage of access to waterways for travel and moving goods. They have farmed the surrounding fertile land, and have learned to love the estuary's quiet bays and flourishing wildlife. They have also left their mark on estuaries. They have dredged, filled, developed and poisoned estuaries so that sometimes the environment that attracted people in the first place no longer exists.



The highly altered shoreline of Tokyo Bay.

Many large cities have grown up around estuaries. Seattle, San Francisco, Los Angeles, New York, Boston, Baltimore, Washington, D.C., and New Orleans are all United States cities on estuaries. In Europe, estuaries are the sites for London, Amsterdam, Lisbon, Stockholm, Helsinki, and St. Petersburg. In Asia, the cities of Calcutta, Bombay, Hong Kong, Shanghai, Tokyo, Bangkok, and Manila are some of the hundreds located on estuaries. In most of these cases, deep channels have been dredged for shipping, marshes and mudflats have been filled for housing and industry or drained for agricultural land, and waters have been polluted with sewage and industrial wastes.

Many of the world's richest estuaries have completely disappeared and others face continuing pressure from development. Because estuaries are important parts of the larger marine system, this development of estuaries has most likely had a global effect. The decision to alter one salt marsh may seem inconsequential, but the effects will reach beyond its edges. Taken together with losses around the world, the effects can be enormous.

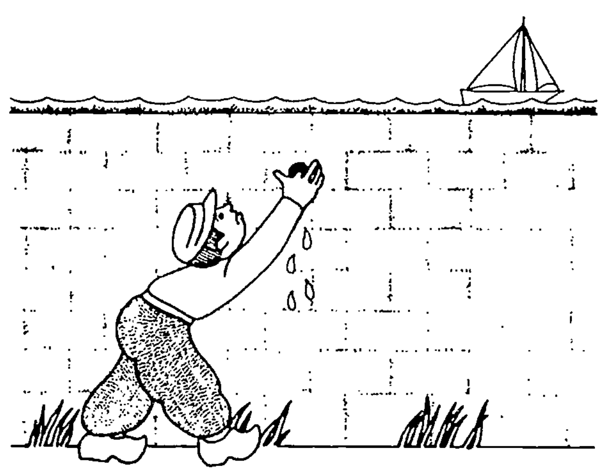
Many different human activities can harm estuaries. The following is a discussion of the activities which have had the most significant effects on the Puget Sound estuary.

Diking

Since European settlement began in the mid-1800s, most of the Pacific Northwest's estuarine wetlands (salt marshes, swamps, and eelgrass beds) have been lost. About 90% of that loss was a result of *diking* for agricultural land between 1880 and 1930. The federal Swamplands Acts of 1849, 1859, and 1860 offered free land to encourage the diking and draining of wetlands, and early settlers found that it was easier to reclaim the tidelands for farming than it was to remove forests and stumps from the rugged upland. During the logging boom in the late 1800s, the demand for oats, hay, and potatoes was high, so farmers could quickly earn enough money to pay for the dike construction.

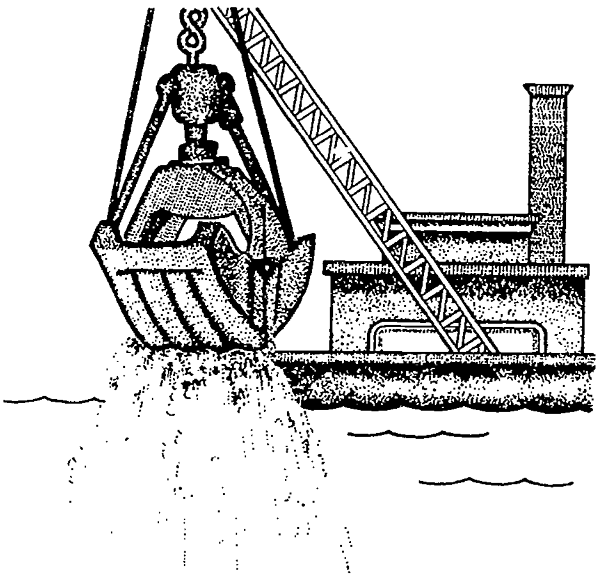
Early dikes were built by hand, with shovels and wheelbarrows. Most were four feet high and eight feet thick at the base, extending along the salt water side of the claim and as far up the sloughs as the tides reached. The earth for the dike was taken from the "inside" of the dike, leaving a deep ditch for drainage. A tide gate or "sluice box" under the dike allowed water to drain out at low tide, but prevented salt water from returning at high tide. The complex network of channels and sloughs within the marsh were either filled or allowed to become drainage ditches.

Although diking is no longer a threat to estuaries in Puget Sound, it did cause the loss of much valuable estuarine habitat. In some areas, such as the Samish delta, over 90% of the estuarine marsh was turned into fertile farmland. All but about 60 acres of the extensive salt marshes bordering Padilla Bay have been converted to agricultural land. It is important to remember that when people talk of habitat loss today the total remaining "pie" we continue to slice up is a mere fraction of the original habitat.



Legendary Peter plugged a hole in the dike and saved his country from flooding by the sea.

In other parts of the world, diking has been even more prevalent. The Netherlands, for example, began reclaiming tideland in the 1300's. Today, over half of the country's land area is diked and drained tideland.

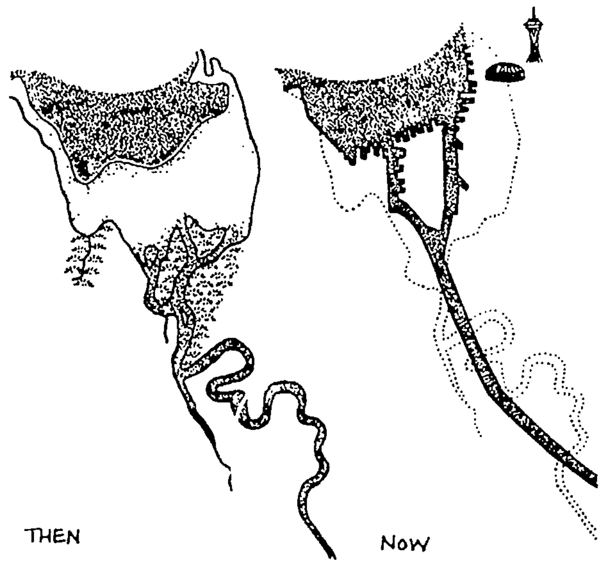


Dredging and Filling

Before the days of *dredges*, people were pretty well stuck (literally) with only naturally occurring waterways. Deep water ports were at a premium and navigation of large vessels was restricted to deep channels and large rivers. Rivers such as the Columbia, whose mouth is blocked by a shifting sand bar, were difficult to navigate, and ships spent weeks outside the bar, waiting for the right conditions to sail through. They often ended up grounded or wrecked.

Dredges -- floating cranes with scoops or "clam-shell" buckets -- changed water transportation dramatically. Channels and harbors could be dug out wherever needed, making them predictable and safe.

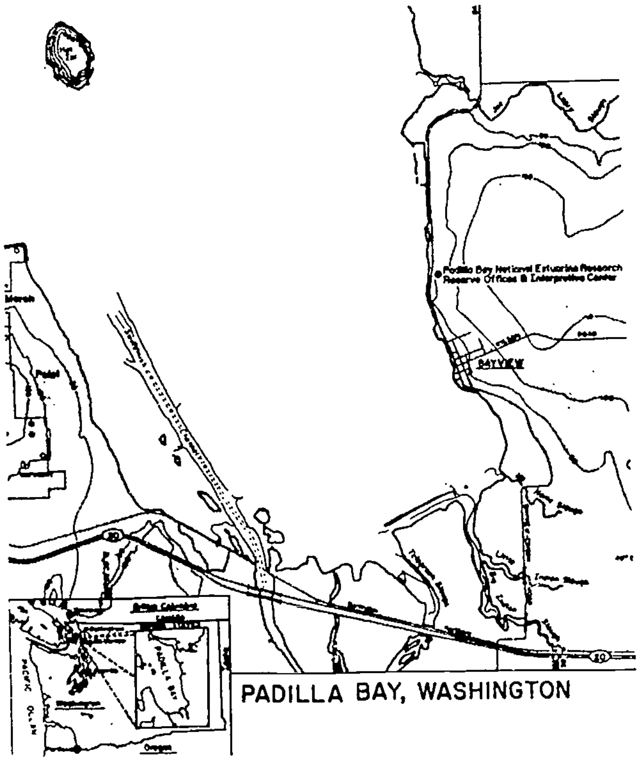
In the past dredging and filling often went hand in hand. Early ports in Puget Sound were often long piers, stretching out across mudflats and marshes to deep water. These intertidal areas, separating the town from the dock, began to be filled with unwanted ballast from ships and sawdust from lumber mills located on the piers. Later, when people began dredging shipping channels, the dredged material was deposited in the intertidal area. It didn't take long before the filled area was seen as valuable commercial and industrial land and the "city" moved out to the end of the dock.



The Seattle shoreline has changed dramatically in the past 100 years.

At Bayview State Park on Padilla Bay the Washington State Parks and Recreation Commission dredged, not to create deeper water, but to build up a picnic area and sandy beach on the edge of the mudflats. In this case, dredging was the "tool" or the means to achieving the end -- an attractive picnic site. Though the dredging destroyed an area of intertidal mudflat habitat, it created a pool where eelgrass flourishes.

The Swinomish Channel which flows into Padilla Bay is dredged every few years to maintain a shipping channel. Between 1930 and 1950, the material was deposited in the bay on dredge spoil islands. The islands, now a favorite haul out spot for harbor seals, are by-products of the dredging. Since the late 1970s, all dredged materials from the Swinomish Channel have been transported to deep water disposal sites.



The Swinomish Channel is dredged every few years.

Today, both the shipping and pleasure boating industries in Puget Sound depend on dredging to maintain 50 miles of channels, 50 miles of port berths and 200 small boat harbors. The channels vary from 12 to 30 feet deep, and all must be periodically dredged. For some, dredging every 10 or 15 years is sufficient, while others are dredged each year. The U.S. Army Corps of Engineers maintains most of the major waterways, and accounts for about one third of the dredging activity. Puget Sound ports, as well as small marina owners, private businesses, the U.S. Navy, and municipalities, also dredge.

Past effects of dredging and dredge material disposal have been the filling and loss of intertidal areas such as mudflats and marshes. Dredging can also stir up fine sediments, clouding the water and harming sensitive areas such as eelgrass beds. Now a new problem, contaminated dredge spoils, has emerged.

As disposal sites near the dredging activity have become scarce or are used for other purposes, dredged materials are discharged directly into the Sound. The Washington State Department of Natural Resources regulates eight "unconfined open-water disposal sites" where much of the material is discharged. Some dredged material, however, cannot be disposed of in these sites. It contains contaminants that most likely entered the Sound from industrial or municipal discharge and storm runoff. These contaminants are discussed in more detail below.

When contaminants enter the estuary, they often find their way to the sediment where they bind with the sediment particles. If this contaminated sediment is then dredged and disposed of in an unconfined open-water site, the pollutants are spread to a different area of the Sound and may be released into the water where they pose a greater threat to marine animals and humans. New state regulations require that all dredged materials be tested for *toxic* contaminants. In contaminated areas (often near large, urban centers), dredge operators must find their own disposal sites, either on land or in a confined site, where the material is capped with a layer of clean sediment.

As land in the Puget Sound area becomes more developed and more pollutants enter the Sound, it is becoming increasingly difficult to find appropriate disposal sites for dredged materials. Testing sediments for contaminants is costly, and some dredging projects have been stopped because of increased costs or the lack of a safe disposal site.

Toxic Contamination

According to some researchers and water quality officials, *toxic* contamination poses the most serious and long-term threat to Puget Sound. Contaminants can enter an estuary in many ways. Industrial discharge, sewage treatment plants, storm drains, septic tanks, and runoff from farm fields and parking lots are some of the more conspicuous sources.

The main toxic chemicals that may find their way into an estuary are heavy metals and *organic* compounds. Heavy metals such as lead, mercury, copper and arsenic may not be harmful to marine organisms in naturally occurring low levels, but in large quantities and certain chemical forms they can accumulate in tissues of plants and animals and cause disease or death.

Organic compounds can be either naturally occurring or created by humans (synthetic organics). The naturally occurring ones are the "fuel" on which the estuary runs. In the proper amounts, they contribute to a healthy system. Petroleum hydrocarbons such as oil occur naturally, and become a problem only when they appear in large quantities. Synthetic organics can accumulate in animal tissues and be toxic. Two well known synthetic organics that persist for years are PCB's (polychlorinated biphenyls) and DDT, a pesticide. These contaminants are still causing problems in marine systems, even though their use has been banned in the United States.

Some of the contaminants that enter an estuary dissolve into the water and are either carried out and diluted with the tide or become a part of the water column food web. Most contaminants, however, bind with sediment particles and settle out as the water slows down and its load is deposited in the estuary. This natural settling makes the estuary especially vulnerable to toxic contamination.

Once in the sediments, the contaminants can cause problems for benthic organisms. Toxic contaminants not only affect the organisms which live in and consume the sediments, but they also affect predators such as bottom fish. Because the contaminants often accumulate in animal tissue, they can be passed on up the food chain to fish like salmon as well as marine birds, marine mammals, and even humans.

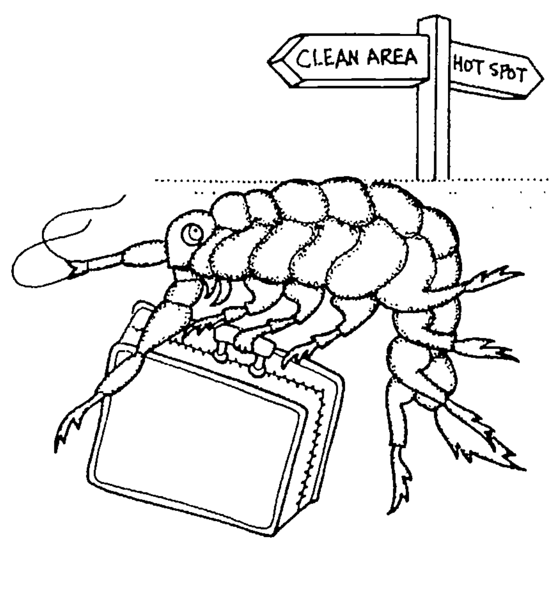
In a healthy estuary, a complex community of detritivores performs the role of decomposing and recycling nutrients. If sediments become contaminated, only a few species of organisms, such as worms and molluscs, survive. Sensitive animals such as amphipods are used by researchers as "indicator" species. Their mortality in sediments helps researchers determine whether toxic contamination is a problem.

In Puget Sound, sediment contamination is patchy, so clean areas can occur right next to contaminated "hot spots." Most contaminants have been found around urban areas, where industry and development is most concentrated, but non-urban bays can also be contaminated. A recent study in Padilla Bay indicated the presence of toxic sediments near an old county dump site. The study involved placing amphipods in sediment samples collected from various sites around the bay. Those samples in which a significant number of amphipods died most likely contained toxic contaminants.

Contaminants other than toxics also affect estuaries. Excess nutrients (from fertilizers, human sewage, or industries), temperature changes, organic materials that lower the oxygen level in the water, and salinity changes can all upset the natural balances of an estuary. Disease causing organisms can enter from boats, septic systems, sewage treatment plants, pets, and livestock, causing danger to humans using the estuary. Many of Washington's productive shellfish beds have been closed because of fecal contamination.

Though in the past 20 years, regulations have come a long way toward reducing the contaminants entering Puget Sound, the problem still exists. Much of the contamination comes from "non-permitted" sources such as storm runoff -- sources that are difficult to regulate. (Examples of "permitted" sources, those which obtain permits to discharge waste into water, include industries and city sewage treatment plants.)

Other estuaries, such as those on the more densely populated east coast and those in developing countries, face much larger contaminant problems. Many developing countries feel they cannot afford to control industrial and municipal wastes. When people are hungry and unemployed, governments are hesitant to impose environmental regulations.



Amphipods are especially sensitive to toxic sediments.

The loss of fishing jobs and edible seafood that accompanies polluted waters often goes unrecognized.

"Outside" Influences

Estuaries are not isolated systems. They are connected to both the river and ocean through the movement of water. What happens upstream or in nearby ocean water can have a big effect on the estuary.

Watershed is a term for the area of land which drains into one stream, river, or bay. A watershed like the Mississippi's can include millions of acres and many states. The Skagit River watershed reaches into British Columbia. The Padilla Bay watershed, on the other hand, is only a small area within one county.

Something that enters the water far upstream can eventually find its way into the estuary. Poor logging practices in the mountains can lead to erosion and too much sediment entering the water. The sediment ultimately ends up in the estuary where it may harm fish and plant life by clogging gills, slowing egg development, and blocking sunlight. One gallon of used motor oil dumped into a ditch can send toxic chemicals to an estuary miles away. Though rivers and streams have the ability to "clean" themselves with time, rivers can be overloaded, and the water entering our estuaries is often contaminated.

Chesapeake Bay is an example of an estuary whose health is endangered by intense human activities in its watershed. Though about 8 million people live along the bay's shores, over 13 million live within its watershed. When people began the challenge of cleaning up the bay in the late 1970s and early 1980s, they looked not only at pollution sources located right on the bay (sources like Baltimore's sewage treatment plant or industrial wastes) but they also targeted farmers upstream in Pennsylvania along the Susquehanna River, the source of one-third of the estuary's fresh water.

The use of river water for hydroelectric power, agricultural irrigation, and drinking water can create serious problems in the estuary. When people divert fresh water for irrigation, industry and household use, it can lead to less fresh water entering the estuary. This is a problem for many estuaries in the arid southwest. Hydroelectric dams interrupt migrations of salmon and hold back the natural supply of sediment that nourishes the estuary marshes. Flood control levies at the mouth of the Mississippi River have stopped the accumulation of sediments in Louisiana's extensive salt marshes. Without the constant supply of sediment, the marshes are sinking, and valuable wildlife habitat is being lost.

An estuary is not only affected by activities within its watershed, but it is also vulnerable to pollutants which enter with the ocean tides. Puget Sound beaches are sometimes the final destination of marine debris from as far away as Japan. Oil spills are a constant threat to estuaries, not only in areas like the Gulf of Mexico, Alaska, and the Persian Gulf, where oil is a major industry, but anywhere there are ships in the water.

Shoreline Development

People are attracted to the coast. The population of coastal areas is growing much faster than inland areas, placing intense development pressure on our estuaries. The Puget Sound region is the most heavily populated area in the Pacific Northwest, home to about 3.2 million people. That number is expected to increase to 4.4 million in the next 20 years. As more people arrive, waterfront property will become more and more valuable for housing and industry.

In our society, a house on the shore is very desirable and valuable. A small house on Samish Island, on the north shore of Padilla Bay is worth more than twice as much as a comparable house a few miles inland. Our aesthetic values tell us that the closer we are to the water, the better. Homes have often been built right at the land's edge, perhaps with a spacious deck suspended over the water.

Improper shoreline development poses problems for the estuary system. Much of the current development in the Puget Sound region is in relatively rural areas without sewage treatment facilities. Private septic systems often fail to function properly, expecially when located near the shore. This can result in bacterial and organic pollution of estuary waters.

Another problem with shoreline development stems from the temporary and changing nature of the coast. Beaches are moving environments, fed by river sediments and the erosion of bluffs. As soon as people build a home or business on the shore, they want to stop this natural change. The most obvious way to do this is to build a wall between the land and the sea. In highly developed King County, over half of the shoreline is hidden behind some type of bulkhead or erosion control structure.

Many bulkheads and sea walls simply don't work. When they do work, they interrupt the natural movement of sediment along a shore. A single bulkhead often causes more erosion to the properties on either side. A bulkhead protecting a house on a bluff can result in the loss of a nearby beach that depended on the bluff's erosion for its sediment.

In an estuary like Puget Sound, where the shore is often steep, erosion control structures can disturb the narrow intertidal area which is vital habitat for many marine plants and animals. The best answer to the erosion problem is to build back from the shore.

State and local governments regulate shoreline development through minimum setback (how far a structure must be from the shore), zoning (what types of structures are allowed and how dense), and septic codes. The pressures of a growing population and the high value of shoreline property cause homeowners and developers to make maximum use of their property. In spite of current regulations, governments often lack the staffing and resources to adequately protect these sensitive areas.

Introduced Species

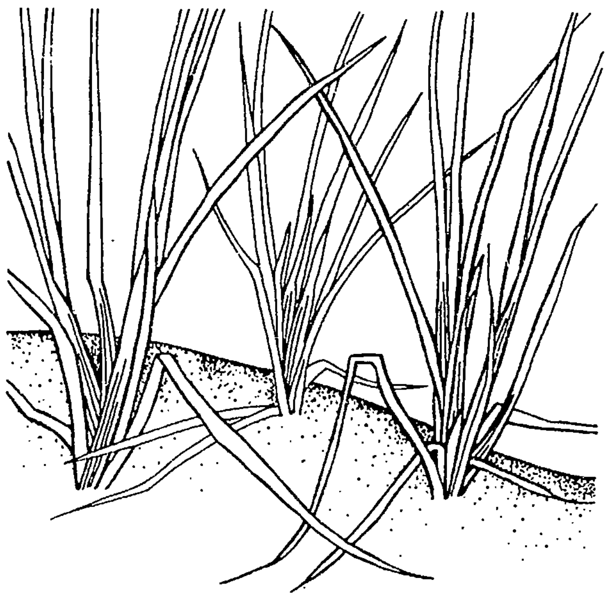
Padilla Bay today is quite different from what it was when the first Europeans arrived. The shape of the bay and the face of the surrounding land have changed dramatically. More subtle changes have occurred in the bay itself with the introduction of new plant and animal species.

An estuary, like all ecosystems, is characterized by an array of organisms -- organisms which have evolved together into complex, balanced, interacting communities. When a new species is introduced into such a community, it can change the balance and affect the entire system. Sometimes an introduced species will fit into its new home causing little more than a slight shift in population balances. Sometimes, however, non-native species can be devastating.

When an organism is introduced into a new environment, it often has no natural predator and can therefore overcome the native species in the competition for food or space. Most of our serious agricultural pests are introduced species, and have become a problem because there is no natural check on their population.

In Padilla Bay, many of the non-native species arrived with the oyster industry. Though native oysters are edible and were highly regarded by the native people and early settlers, they are too small to be commercially attractive. Oyster growers preferred the large Atlantic oyster or the Pacific oyster from Japan. To cultivate the larger oysters, growers imported "spat," larval oysters ready to settle from their *planktonic* stage. Along with the microscopic oyster spat which was scattered in Puget Sound estuaries, there were seeds of the Japanese eelgrass, *Zostera japonica.* Many species of snails were also introduced from Japan, including *Batillaria attramentaria*, the mud snail which covers Padilla Bay's mudflats, and the oyster drill (*Ocenebra japonica*).

A plant which was apparently intentionally introduced in Padilla Bay is cordgrass or *Spartina alterniflora.* On the east coast, *Spartina* is the dominant salt marsh species, and provides important habitat for many animals. In the Pacific Northwest, it can crowd out native species and create a less diverse community. This means that though some organisms may thrive with the *Spartina* there are fewer kinds of organisms. *Spartina* grew in Willapa Bay in small patches for many years until, one year, it started blooming and producing seeds. It is now a serious problem and has covered 2,500 acres of the bay, trapping sediments, eliminating important eelgrass habitat, and threatening valuable oyster and crab habitat.



The introduced marsh grass, *Spartina alterniflora.*

The *Spartina* in Padilla Bay is still limited to several patches, but they are growing larger. Steps to eliminate the *Spartina* in Padilla Bay are being considered now, before it has a chance to flower and become a bigger problem.

What You Can Do

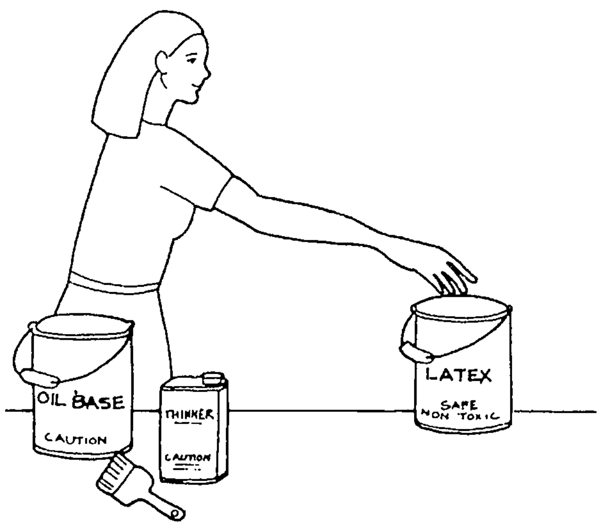
Though the threat to estuaries on a global scale may seem dismal and beyond anyone's control, the picture is not entirely hopeless. While you may not be able to single handedly save the waters of the Persian Gulf, there is a lot you **can** do for your estuary.

In our country, the federal and state governments are responsible for regulations protecting sensitive natural areas like estuaries. These regulations may state exactly how much waste a company can dump into your estuary. They may prevent a port from dredging eelgrass habitat. When making decisions about these regulations, government officials consider public input. They often ask for public comment, though the request may not be extensively publicized. You can find out about public hearings by contacting the relevant government agency or "watchdog" organizations such as local and national environmental groups. (The Audubon Society is one that stays on top of current issues.) Letters from you to the elected officials who determine those regulations **do** make a difference.

Though state and federal agencies regulate our shorelines and water resources, most development projects are actually approved or rejected on a local county or city level -- a level where you, as a high school student and citizen, have the most influence. Often regulations alone are not enough to prevent improper development. When development threatens water resources or wetlands near you, you can contact the government agencies that have information about that area.

It might involve the city or county planning department, Washington State Department of Ecology, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, or the U.S. Environmental Protection Agency. Once you know more, then you will be able to voice your opinion on the development in writing or at a scheduled permit hearing. This requires accurate knowledge of the issue, good research skills, and an understanding of all the different view points. It may help to join together with other people who feel the same way you do.

Citizens definitely have influence over development decisions. Edna Breazeale's efforts to prevent major development of Padilla Bay is an example of one person making a difference. But individuals have even more influence over their own actions which affect their estuary.



You, as a high school student, make daily decisions affecting your estuary. The water that goes down the drains in your house may end up in your estuary. What **you** pour down with that water has an effect. When you change the oil in your car or clean out a paint brush with thinner, what you do with the toxic waste makes a difference in your estuary. Finding safer alternatives to toxic household chemicals is one thing you can do.

Limiting your water use helps insure that your septic system or sewage treatment facility works properly to clean up the water entering streams, rivers, and bays. Cutting down on car travel by walking, biking, carpooling, or using public transit also cuts down on the toxic runoff from roads, reduces the need for parking lots and, at the same time, cleans up the air.

When visiting your estuary or beach, you make decisions which affect the organisms there. Handling creatures carefully, filling in the holes you dig, replacing rocks, and walking gently in areas where walking is allowed, all make a difference, especially in heavily used areas like parks.

We are all tempted to blame environmental problems on "them;" big, intangible entities like industry, development, or society. In reality, it is individual people or groups of people that make the decisions which affect places like estuaries. You, your friends, your neighbors, and your family can make informed decisions. You can choose activities that are compatible with the health of natural systems.

Related Activities:

Water Quality Monitoring, Activity 3.

Thinking Globally, Activity 6.

What We Can Do for Estuaries, Activity 7.

Questions

1. List three ways humans have changed estuaries and the human use that it was changed for.

2. Match the city with the river forming its estuary:

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

3. Name three negative effects of dredging.

4. What watershed do you live in? What body of water does it drain into?

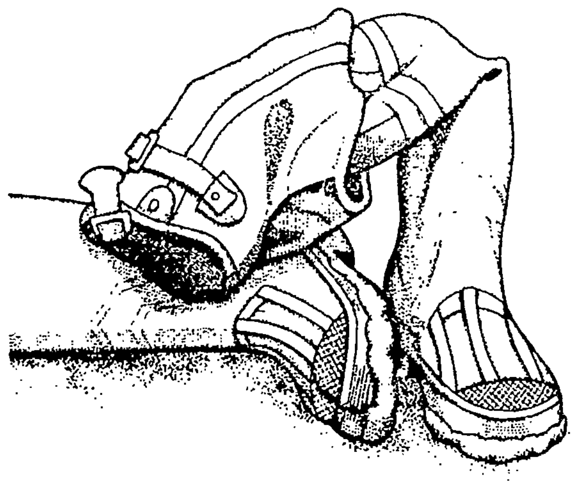
5. Name one human activity in your watershed that could have adverse effects on an estuary.

6. Look at the illustration on p. 60 of the house built on a bluff overlooking the water. Why would this be a desirable location for a home? Why would it be undesirable?

7. What problems might develop from building a structure to control erosion of the bluff illustrated on p. 60?

8. How does the introduction of an east coast cordgrass threaten west coast bays?

9. List five actions you could take to help reduce the stresses on an estuary. Of these actions, identify those that you will do and those you will not do. Explain why.



Taking An Estuary Field Trip - Activity 1

By all means, take your class to an estuary near you. Your possibilities are endless. Here are a few ideas to get you started.

Things to Do on a Field Trip

1. Focus on changes. Look for signs of natural change (eroding bluffs, sedimentation, evidence of wave action). Look for signs of human influence. Take along someone who has seen the changes happen.

2. Focus on estuary life. Observe and identify. Examine the sediment (maybe with a shovel and sieve). Check an ecology textbook for field study techniques that your class could employ. Try a beach seine. Collect and observe plankton. Compare several sites or habitats. Return all organisms to a habitat in which they can survive.

3. Focus on quantifying. You can count a population, study waves, profile a beach, monitor water quality . . .

4. Customize a "Scavenger Hunt" to help focus attention. Ecological concepts, historical perspectives, geological formations, inspirational objects or events could be included. (See the "Copies and Overheads" section for an example.)

5. Make your own site-specific field guide.

6. Observe and create. Do some exploring, then try the writing activities on pp. 97-101. Instead of writing, you could draw, paint, sculpt, or compose.

7. Invite an "expert" to join you: wildlife biologists, fisheries biologists, historians, geologists, marine biologists, poets, artists, and naturalists could be a valuable resource on a trip.

8. Don't hesitate to contact your local marine science center for suggestions.

9. Look through the curricula listed in the Resources section for other field trip ideas.

Pre-trip Checklist

1. **Visit the site**
   When will the tide be high? low?
   Is it a public beach? Do you need permission to use the beach?
   Are there bathrooms?
   Are there hoses or faucets for clean up?
   Is there protection from adverse weather?
   Is there a phone for emergencies?
   Is the access steep or dangerous?

2. **Define trip objectives and activites.**
   Do they match the coursework?
   Do they match the site?
   Will the school support it?

3. **Arrange transportation**
   Are buses available for the whole day?
   If not, can car pooling be arranged?
   Do you need to supply a map?
   Is emergency transportation available?

4. **Class preparation**
   Do they know their responsibilites?
   Do they know what equipment to bring?
   Has acceptable behavior been agreed to?

5. **Arrange assistance**
   Do any parents want to help?
   Are older students available?

Trip Checklist

1. **Enthusiasm**- Yes, field trips can be enjoyable.

2. **Emergency Numbers and First Aid Kit**

3. **Communicate responsibilites**
   -- Introduce goals, expectations, boundaries, equipment.

4. **Communicate Mandatory Behavior**
   -- Tread lightly! Your presence in the estuary will damage the site. Do everything possible to minimize that damage.
   -- Observe, don't collect.
   -- Fill in all holes (a Washington State law).
   -- Return rocks to exact positions.
   -- Return animals to appropritate tide zone.
   -- Collect marine debris.

5. **Equipment needs will vary, but here are some suggestions:**

   - **for observing**
     jars (plastic)
     shovels
     sieves (for benthic organisms--standard size is 0.0197 in.)
     trays

   - **for measuring**
     Field Notebooks, pencils
     Meter stick, measuring tape, thermometer, monitoring equipment

   - **for identification/recording**
     Field guide to habitat. (We recommend Kozloff or Snively- See Resources)
     Binoculars
     Microscopes, magnifying glasses
     Video cameras, cameras
     Clipboards and data sheets

- **for cleaning**
  Water source, hose, and sprayer
  Buckets, brushes
  Plastic bags for storing wet items

Student Checklist (Absolutely required!)

1. Only old shoes, boots that do not easily pull off, or hip boots.
2. Rain and cold weather gear.
3. Extra socks, shoes, and sweatshirt.
4. Bag for wet clothes.
5. Food and beverage.

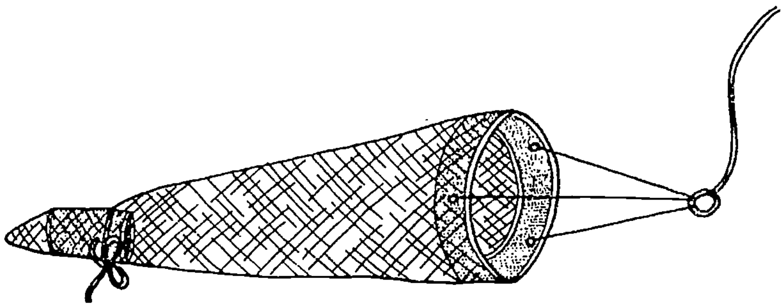
Possible Field Trip Sites

County	County Parks & Rec. Phone Number	Sample of Public Facilities	Habitat
Whatcom	(206) 733-2900	Semiahmoo Co. Park	Sand Beach
		Birch Bay State Park	Sand Beach
		Larrabee State Park	Rock, Gravel
Skagit	(206) 336-9414	Padilla Bay Reserve	Mudflat
		Skagit Habitat Mgt. Area	Mudflat, Wetlands
		Washington Park	Rock, Gravel
		Deception Pass State Park	Rock, Gravel
Island	(206) 679-7373	City Beach	Sand, Mud
		Fort Ebey State Park	Sand, Rock
		Point Partridge Rec. Area	Rock
		Libbey Beach Co. Park	Rock
		S. Whidbey Co. Park	Sand, Rock
Snohomish	(206) 339-1208	Kayak Pt. Co. Park	Gravel
		Mission Beach Park	Gravel
		Howarth Park	Sand, Gravel
		Olympic Beach Park	Sand, Gravel
King	(206) 296-4230	Richmond Beach Park	Sand
		Golden Gardens Park	Sand
		Carkeek Park	Sand, Gravel
		Discovery Park	Sand, Gravel
		Alki Beach Park	Sand
		Lowman Beach Park	Gravel
		Dash Point State Park	Gravel
		Redondo Co. Park	Gravel
		Saltwater State Park	Gravel

For More Information

Washington Parks Department	(206) 753-2027
WA Dept. of Ecology (Public Access)	(206) 459-6781
WA Dept. of Fisheries	(206) 753-6600
WA Dept. of Natural Resources	(206) 753-5324

(1992 phone numbers)



Plankton Study - Activity 2

Plankton are free-floating organisms which play a vital role in the marine world. Though they are small, they are the foundation of the marine food web; the critical "first step" in the flow of energy through the system.

Biologists consider any organism which drifts with the currents and tides a plankter. Most are microscopic, though some (jellyfish, for example) may be large enough to see. *Phytoplankton* are photosynthetic, single-celled algae. Animal plankton are called *zooplankton.*

Nearly all marine animals go through a planktonic stage. These juveniles, "temporary" plankton one might say, are called *meroplankton.* Those animals which remain plankton their whole lives are called *holoplankton.*

Plankton are not evenly distributed around the world. Open oceans are relatively unproductive and lack the nutrients plankton need to flourish. In contrast, coastal areas, including estuaries, support an abundance of plankton and associated marine life. Puget Sound is especially fertile due to an upwelling from the ocean floor. Rivers are also constantly contributing nutrients from the land. The number of plankton in coastal water defies imagination. One study in England estimated 4.5 billion (4,500,000,000) phytoplankton in **one liter** of water! Such tremendous production is important for the entire marine system which depends on plankton, not only for its energy, but also for most of its oxygen.

Plankton Sampling

A net for collecting plankton can be as simple as a nylon stocking held open by a wire ring or tuna can with the bottom cut out. With a film canister or small jar in the toe and three lengths of string for a leader, your net is ready to use. Fine mesh cloth such as silk can be used instead of the stocking for a more effective net.

Commercially made nets come with varying sizes of mesh ranging from 5μ to 1000μ (μ=micrometer, or 1/1000 of a millimeter). A very fine mesh (8μ or 0.008mm) is necessary for catching the smaller phytoplankton, while a larger mesh (100μ or 0.1mm, for example) is useful for zooplankton. Nets are available from Research Nets, listed in the resource section.

Plankton is often collected by dragging the net behind a boat. If the current is strong enough, the net can be held from a bridge or pier. Attach your net to a stick and you can wade at your nearest beach, moving the net back and forth in front of you as you walk. Transfer the plankton to a container with a water tight lid for transport. Keeping your plankton cool (in a refrigerator or on ice) and allowing air exchange will prolong their life, but remember the population will change as they consume each other.

Observation

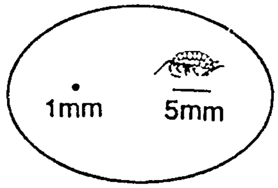
A dissecting scope is excellent for observing live plankton. Place a small amount of your sample in a glass petri dish. You may want to dilute the sample with estuary water if your sample is too crowded.

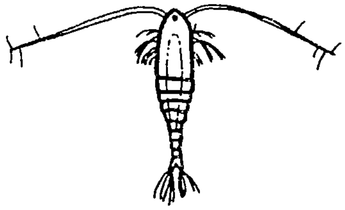
1. Watch for different types of movement. Some animals dart through the water with a jerky motion. Others glide or spin. For some, cilia may be the only body part that moves.
2. Identify the different types of plankton in your sample. The accompanying plankton guide should be useful. To identify something not included in the guide, check the books listed in the References section.
3. Draw what you see. Try to guess what the various body parts are called. Identify which are phytoplankton and which are zooplankton.
4. Estimate the size of different plankton. Compare relative sizes of phytoplankton and zooplankton.
5. For a more detailed look at your plankton, use a compound microscope and glass slide.

Questions

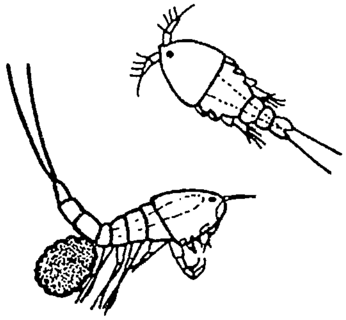
1. Which plankton forms are common in your sample? Which are rare? What do you think might be the reason for this?
2. Why are there more plankton in Puget Sound than in the middle of the Pacific Ocean?
3. One study in England found 4.5 billion phytoplankton in a liter of water. Does your sample have that many? What might affect the number of plankton caught in a single sample?

Plankton Guide

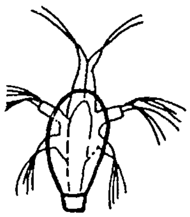




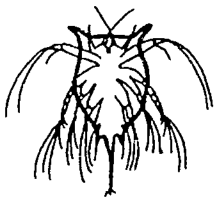
Copepod (calanoid) .5-2mm



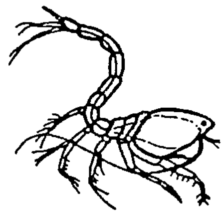
Copepod (harpacticoid) .5-2mm



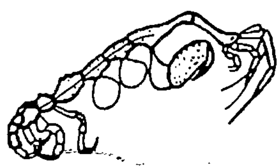
Copepod (nauplius) .2-.5mm



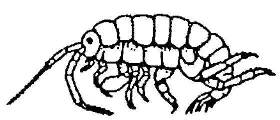
Barnacle nauplius .5-1mm



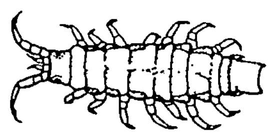
Cumacea 1-2mm



Caprellid amphipod 4mm



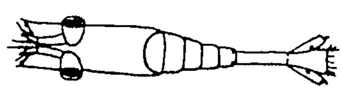
Amphipod (gamarid) 1.5-10mm



Isopod (*Idotea*) 1-20mm

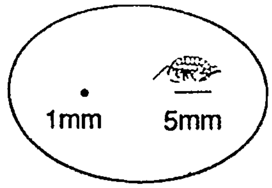
Crab Zoea 2mm

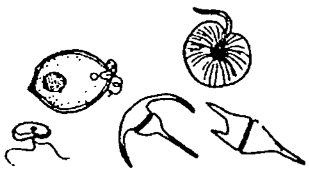
Hermit crab Zoea 2-4mm



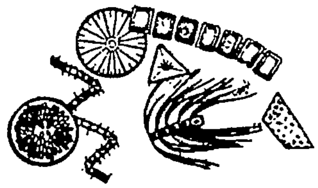
Shrimp Zoea 4mm

Plankton Guide

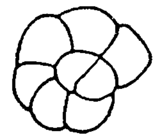




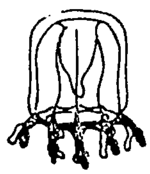
Dinoflagellates .05-.5mm



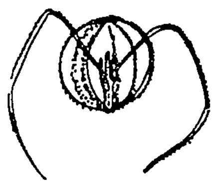
Diatoms .025-.3mm



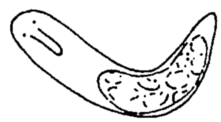
Foram .6mm



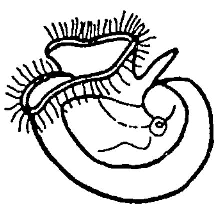
Hydroid medusa 2-10mm



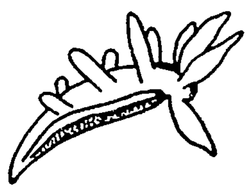
Ctenophore (comb jelly) 4mm



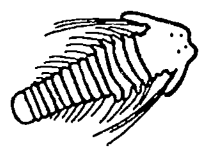
Nemertean larva .5-4mm



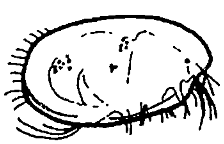
Snail veliger .5mm



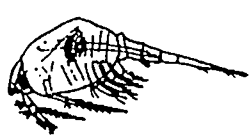
Juvenile nudibranch 2-4mm



Polychaete larva .5-4mm

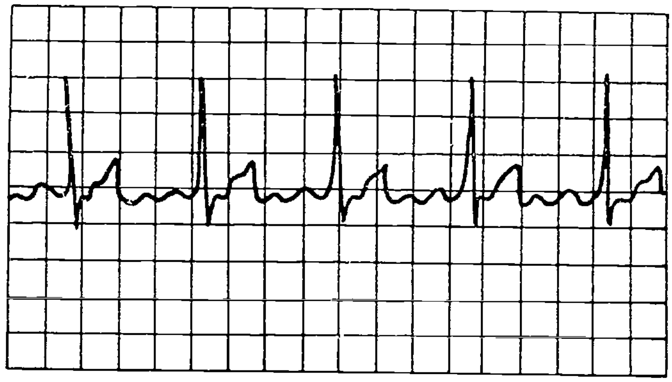


Ostracod .5mm



Leptostracan 3-4mm

Tanaid 1.5mm



Water Quality Monitoring - Activity 3

Introduction

Water monitoring is a systematic measurement of parameters that indicate water quality. This section describes eight tests which give information about the health of a body of water: temperature, salinity, dissolved oxygen, nitrates, phosphates, pH, turbidity, and coliform bacteria.

After following these activities, you should understand the purpose of these tests, know how to run accurate water quality tests, become familiar with sources of water pollution, and see how these parameters relate to human and non-human uses of estuaries. For example, you may find that your estuary water may not be safe for swimming or shellfish harvest.

Monitoring is a fundamental tool of research. When studying a particular system, researchers begin by carrying out a baseline study, a broad assessment of many different variables. They do this for several reasons. The results are important for the comparison of future data. To assess the damage done by an accident such as a toxic spill, it is important to have an idea of what was in the water **before** the spill.

Researchers also use baseline studies to determine which topics they should investigate further. If a baseline study shows an unexpected high level of coliform bacteria, then the researcher may want to design a study to determine why.

These activities are valuable as "one shot" field studies or classroom labs. Taking a set of measurements once from one site gives a small picture of conditions in the estuary. If possible, monitor several sites. This will give a larger picture and demonstrate the great variability within the system. The salinity at the mouth of a stream will not be the same as the salinity upstream or further out in the bay. Understanding what is happening in an estuary at a given moment, however, is not necessarily a complete picture. It is much more accurate (and interesting) to follow an estuary over time -- to take a "moving picture."

Estuaries undergo daily, seasonal and long-term changes that can only be assessed with periodic monitoring. Salinity might change drastically over the course of a single tide. Nutrients such as nitrogen vary seasonally as varying amounts are added to the water and used by organisms. Human activities such as dredging or dumping may permanently alter the characteristics of an estuary.

Though your class may not be able to carry on an extended monitoring program, it is possible to share your results with other schools. Your study area might be an estuary near your school, or it could be Padilla Bay. Your results could be compared to those of other researchers through an organization such as GREEN (Global Rivers Environmental Education Network -- in the Resources section). You may be able to join with other classes who are a part of a coordinated monitoring program in Puget Sound. Check with your local marine science center or the Breazeale Interpretive Center at Padilla Bay for information about such programs.

If you intend to compare or coordinate your results, it is essential that your monitoring be standardized, that is, follow the exact same procedures as other researchers. Different monitoring techniques may yield slightly different results. Be sure to check with the other schools or organizations to be sure your techniques match theirs as closely as possible.

Keep in mind the limitations of water monitoring. The individual activities give a small piece of information about the estuary water. They do not prove very much by themselves. Taken together with the other small pieces, they tell a little more. The estuary is a complex place with hundreds of interacting chemical and biological processes. It is difficult to draw definite conclusions about cause and effect from the results of one test.

The following monitoring activities include a short description of the parameter, how that factor is important in an estuarine system, and a description of monitoring procedures. For more detailed information, see the Resources section. *Puget Sound Project: The Changing Sound*, from the Poulsbo Marine Science Center, offers a complete set of student work sheets and monitoring directions that you may wish to use.

Warning: Many water quality tests involve toxic chemicals that must be handled and disposed of properly. Be sure to use proper lab safety equipment and procedures. All hazardous wastes should be collected and disposed of properly. (Call 1-800-RECYCLE for hazardous material information.)

Questions

1. List four reasons researchers monitor water quality.

2. As a group, create a list of local, state, and federal agencies that might currently be monitoring water quality in a body of water near your home or school. (Soil Conservation Service, County Health Department, Department of Fisheries, etc.) Call each agency and ask: 1) if they are monitoring, 2) what they are measuring, 3) why, and 4) what methods they are using.

WATER MONITORING DATA SHEET

SCHOOL: DATE:

RESEARCHERS:

TIME:

TIDE:

AIR TEMP:

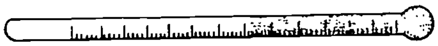
WEATHER:

WATER COLOR:

WIND:

OTHER:

SITE NUMBER DEPTH	1	2	3
DISSOLVED OXYGEN (mg/l) & (% sat.)			
FECAL COLIFORM (colonies/100ml)			
pH units			
TEMPERATURE (^{o}C)			
SALINITY (ppt)			
TOTAL PHOSPHATES (mg/l)			
NITRATES (mg/l)			
B.O.D. (mg/l)			
TURBIDITY (m)			



Temperature

Though temperature is simple to measure, it is important. Many other characteristics of water depend on temperature. Cold water holds more oxygen than warm water. The rates of metabolism and photosynthesis increase as water temperature rises. Organisms are limited to certain temperature ranges and may be more susceptible to disease or poisoning from toxins when the temperature rises.

Human activities can upset the temperature balance in an estuary. Many industries use water for cooling purposes and release large amounts of warmed water. Though they may not add chemical pollutants their thermal pollution may be just as harmful to organisms.

You'll find that many of the other monitoring procedures in this section include measuring temperature. Because cold water is denser than warm water, many bodies of water have distinct layers of water of different temperatures, with the warmer water on top and the colder water on the bottom. The area between the warm and cold water is called the thermocline and you may have noticed it while swimming in a lake or in Puget Sound. Because of the thermocline, it is important to take temperature readings from several depths at any location.

Procedure

1. Obtain a water sample. Commercially produced sampling devices are readily available from biological supply companies (see References) or you can construct your own.

2. Because the sample temperature may change quickly, immediately insert an alcohol-filled Centigrade thermometer into the sample.

3. After about 2 minutes (long enough for the thermometer to stabilize), read the temperature.

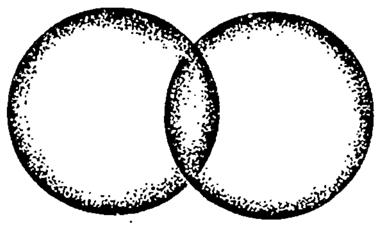
4. Record your location, depth, and temperature reading.

Questions

1. Why is water temperature important to the organisms living in it?

2. Did the water temperature at your site vary with the depth? Why?

3. When might you expect the temperature at your site to be different? Why?



Dissolved Oxygen

For estuary organisms, oxygen (O_2)is one of the most important chemicals dissolved in water. It is necessary for respiration and its abundance (or scarcity) often determines which organisms can live in an area. It can enter the water directly from the air by diffusion, or is supplied by the photosynthesis of plants.

Many things affect the amount of O_2 dissolved in water:

1. Temperature -- Cold water holds more O_2 than warm water,
2. Aeration -- Water stirred by currents and winds picks up extra O_2,
3. Photosynthesis,
4. Plankton growth -- Plankton blooms caused by excess nutrients deplete the O_2 when the microorganisms die and decay,
5. Organic matter -- It takes O_2 to decompose organic matter.

Organic matter can come from many sources: decaying estuary organisms, urban and agricultural runoff, sewage treatment plants, and industrial wastes (dairies, lumber mills, paper plants, food processing plants, etc.).

Once in the estuary, organic matter is decomposed by organisms such as bacteria and fungi which use up a lot of oxygen. Normally, the decomposers deal with organic matter at a reasonable rate and the system can replenish the oxygen supply. When excessive amounts of organic matter are added, however, oxygen levels can be depleted and other organisms can be affected. Fish kills are often the result of the sudden discharge of too much organic matter for the system to handle. A low oxygen level may limit the number of different organisms living in an area and very low levels may eliminate nearly all the organisms there.

Procedure

There are many ways to measure dissolved oxygen (DO). The method you choose may depend on your budget, time allowance, or how much you want to emphasize chemical principles.

Dissolved oxygen meters are available, but are expensive. Many companies offer an inexpensive dissolved oxygen test kit. You can follow the same method (known as the

Winkler technique) without purchasing a kit if you have access to lab equipment and some readily available chemicals. Whichever method you choose, be sure to carefully follow the manufacturer's instructions. Here are a few tips to insure that your results are as accurate as possible.

1. It is best to sample several depths at each site, for example: 0.5 meters below the surface, mid-column, and 0.5 meters above the bottom.

2. When collecting the samples, try to prevent extra oxygen from entering the sample through bubbles. Siphon the water from one container to another rather than pouring, and allow the bottle to overflow to eliminate any atmospheric oxygen. Place the stopper or lid on carefully so that no air bubbles remain in the bottle.

3. Remember to record the water temperature when you collect the sample. Other useful information might be: date and time, location, weather, tide, depth of collection.

Questions

1. Design experiments to test how DO is affected by: a) temperature, b) salinity, and c) organic matter.

2. When measuring DO, you were required to either complete the measurement immediately or fix the oxygen before storage or transportation. What might make the DO levels change if you don't take these precautions?

3. What changes to the watershed could be made to increase the DO at your site?

Follow-up

Biochemical Oxygen Demand (BOD) is a measure of how much oxygen is consumed by microorganisms, and is an indicator of dissolved organic matter. This standard test is used at sewage treatment plants and some industries to make sure they aren't "polluting" the water with too much organic matter. If during your monitoring you discover a site with unusually low DO, you may wish to test the nearest water *source* for organic matter. The source may be a stream, river, or drain pipe which is contributing organic matter to the estuary.

You can perform a BOD test by filling 2 bottles with sampled water. Determine the DO for one bottle. Completely wrap the second bottle with black tape and incubate it in a dark place for 5 days (68°F). After 5 days, determine the DO for the "black" bottle.

$$BOD = DO^1 - DO^2$$

DO^1 = DO of first sample
DO^2 = DO of incubated sample

This measure is the amount of oxygen which was consumed over a five-day period.

Coliform Bacteria

A healthy, balanced estuary is teeming with bacteria, minute organisms that enter into the many biological processes from digestion to nutrient cycling. Bacteria are essential members of a functioning ecosystem. Too many of the wrong kinds of bacteria, however, can mean trouble.

A sudden input of large numbers of bacteria can deplete the oxygen supply affecting sensitive animals such as fish. Certain pathogenic (disease causing) bacteria can accumulate in invertebrates such as shellfish and cause human illnesses.

Coliform bacteria normally grow in the intestinal tracts of mammals, humans included. They are present in large numbers in human sewage and have thus become an indicator of contaminated water. They can enter water systems in several ways: directly from boats, from septic tanks which are not working properly, from sewage treatment plants, and from pets and livestock (cows in a stream or inadequate storage and spreading of manure). Treatment plants which process both household sewage and runoff from storm sewers are often overloaded during periods of heavy rain. Raw sewage and runoff are then combined and released untreated into the water supply.

The presence of coliform bacteria is not a problem in itself. In fact, coliform bacteria generally do not reproduce outside of the digestive tract. They may indicate problems, however, since they indicate the possible presence of harmful bacteria and the contamination of water by sewage. That contamination is often accompanied by a concentration of toxic, heavy metals and an overload of organic matter.

State and Federal agencies have set standards for safe levels of fecal coliform bacteria. Though they vary depending on location, the following guidelines may be useful when comparing your own results.

Intended Use	Maximum No. of Fecal Coliform
Drinking Water	1/100 ml
Water Above Shellfish Beds	70/100 ml
Primary Contact Recreation (such as swimming)	1000/100 ml
General Recreation Surface Water	2000/100 ml

Procedure

The presence of coliform bacteria can be determined by using a Millipore Sterile Filtration Apparatus. (See Resources section.) This technique involves filtering a 0.5 ml water sample using a vacuum pump system and a sterile filter and then incubating the filter in a special bacterial growth medium. The medium contains a dye which turns green when coliform bacteria break down the sugar, lactose, into a compound called aldehyde. Each bacterium cell in the sample grows into a green colony which is easy to recognize and count.

Follow the manufacturer's instructions carefully, being especially aware of using sterile techniques when handling bacteria. Though highly unlikely, there may be pathogenic bacteria present in your sample. Be sure to WASH YOUR HANDS after this activity.

When you have counted the coliform bacteria in your 0.5 ml sample, convert your results to the number of coliform bacteria present in 100 ml. Then you can compare your sample to the guidelines above.

Questions

1. Are coliform bacteria harmful to humans?

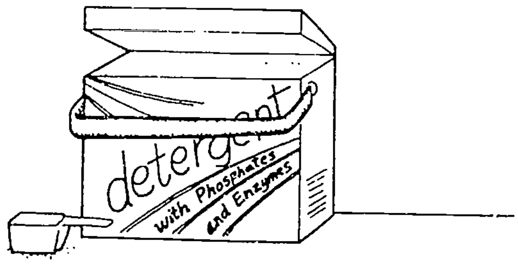
2. Why do researchers measure coliform bacteria levels?

3. Is your house on a septic system or municipal sewage system? How might this sewage get into the surface water (ditch, stream, lake, wetland, river)?

4. What should you do if your test results indicate a high level of coliform bacteria in the water at your site?

Follow-Up

See the activity, Drawing Your Own Water in Activity 7, "What You Can Do for Estuaries."



Nitrates and Phosphates

Nitrates and phosphates are two of the many nutrients that plants need for growth. They are present in varying amounts throughout the year in Puget Sound and their availability is one factor that determines the rate of plant production. Sunlight and temperature also affect plant growth. Any of these factors can limit growth if in short supply. For example, phytoplankton growth is slow in November and December due to short days and cloudy weather even if the plants have plenty of available nutrients from winter rain runoff. In spring, longer days coupled with availability of nutrients that accumulated during the winter cause a huge increase in production. In mid-summer, sunlight is adequate but there is often a shortage of nutrients after the rapid growth of spring.

Though nutrients such as nitrates and phosphates are necessary for a productive system, too much of these can be a problem. Over-fertilization can cause too much growth of certain plants. This bloom clouds the water, and depletes the nutrients needed for a healthy, balanced system. Human activities such as fertilizing lawns, washing clothes, and raising livestock often cause an excess of nitrates and phosphates entering the watershed.

Procedure

Many companies offer test kits for measuring nitrates and phosphorus in water. The following descriptions refer to the Total Phosphate Test Kit and Low-range Nitrate Test Kit from the HACH company. The method you choose may be slightly different.

<u>Measuring Total Phosphorus</u>

1. Be sure to carefully follow the instructions which accompany your test kit. It is important that the glassware for this test be soaked in diluted HCl (hydrochloric acid) and rinsed thoroughly with distilled water. This removes any phosphate detergent film which could disrupt the test.

2. After carefully obtaining your water sample, add potassium sulphate and sulfuric acid and boil for 30 minutes. Add demineralized water to keep it from boiling dry. This procedure makes all the phosphorus in your sample available to the reagent in the next step.

3. When the sample has cooled, add sodium hydroxide and the "PhosVer III" reagent,

mixing thoroughly.

4. Compare your sample with an untreated water sample using the "comparator box." Rotate the color disk until a combined color and density match is obtained. Read mg/L phosphate as total phosphate.

<u>Measuring Nitrate</u>

1. You must use demineralized water during the nitrate test because any other water, including distilled, contains ammonia (NH_3) ions that will disrupt this test. Carefully follow the instructions accompanying your test kit.

2. Fill the color-viewing tube with your collected sample water and add "NitraVer 6" reagent. Stopper and shake for 3 minutes.

3. After 30 seconds you will see particles of cadmium metal settling to the bottom. Pour the sample into the second color-viewing tube, leaving the cadmium particles behind. (Discard the cadmium in a toxic waste container).

4. Add "NitraVer 3" reagent to the sample and shake. Wait 10 minutes for the reaction to be completed. (During the wait, rinse the first tube and fill it with your original water sample).

5. After 10 minutes, place both tubes in the comparator, hold it up to a light source and rotate the disk to obtain a combined color and density match. Read the mg/L through the scale window. To convert this reading to mg/L Nitrate (NO_3^-) multiply the reading on the scale by 4.4.

Questions

1. In the Puget Sound region, in what season would you expect to find the highest level of nutrients in the water? the lowest? Why?

2. How can high levels of nutrients be harmful to aquatic systems?

3. How can "fertilizing lawns, washing clothes, and raising livestock often cause an excess of nitrates and phosphates entering the watershed?" (see p. 81)

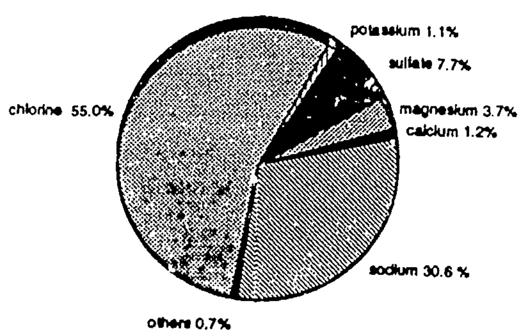
4. Are there any human activities in the watershed above your sampling site that may elevate your readings?

5. Are there any chemicals or reagents used in these tests that could be hazardous? How can they be disposed of properly?

Salinity

Saltiness is the most obvious characteristic of sea water. An estuary is less salty than the ocean, but how diluted is it? And what difference does that make to the plants and animals there?

Sodium chloride is the table salt that we are all familiar with and it is an important element of sea water. It is not the only salt, however. In fact, nearly all the known elements are dissolved in sea water. Animals and plants need these salts for growth and reproduction.



The most common elements in sea water

People get required salts through the food they eat. Organisms living in salt water get these elements directly from the water. In the ocean, most organisms have the same concentration of salts inside their cells as in the outside water. *Osmosis* (molecules moving through a membrane from an area of higher concentration to an area of lower concentration) regulates this balance. In fresh water, organisms rely on physiological adaptations to keep the salt levels inside their cells **higher** than the fresh water outside. Though most organisms can adjust to small changes in salinity, a drastic change can be lethal.

Estuary organisms face a constant fluctuation in salinity as tides and fresh water flow interact. Salt water is denser than fresh water, so the organisms often have to deal with "layers" of different salinities. Because of this *stratification*, it is important to take samples from varying depths when testing for salinity.

Salinity is usually measured in parts per thousand. That means that sea water, with about 35 parts per thousand salt has 35 grams of salt for every 1000 grams of water. The symbol $^0/_{00}$ means parts per thousand. (You know the symbol % which means parts per hundred, or per<u>cent</u>.)

Humans can affect the salinity of bodies of water as they develop and utilize shoreline areas. Farmers' dikes keep salty tides from coming up into sloughs that were once saltmarshes. Pumping large amounts of fresh water from underground aquifers may result in sea water intrusion as salt water moves in to take up the empty space. This has threatened many fresh drinking water supplies. Irrigation upriver reduces the fresh water flow into an estuary, making it saltier.

Procedure

Most researchers use a salinity meter to measure salinity most accurately. Since salt water conducts electricity better than fresh water, a salinity meter can determine the conductivity of a solution, and then convert conductivity to salinity. These meters can be expensive but are reliable and easy to use. If you don't have access to a salinity meter, you can also calculate salinity using a hydrometer, available at aquarium stores.

About The Hydrometer

A hydrometer is a hollow glass tube with a scale printed on the top. It works on the principle that increased salinity results in increased density. Things are more buoyant (they float higher) in saltier water. The hydrometer will float higher in saltier water and the water surface will be lower on the printed scale. Unfortunately, cold water is also denser than warm water, so the temperature affects the buoyancy at the same time.

To determine the salinity of your sample you will need to take the measurement on the hydrometer and correct it for temperature. Since the hydrometer chart is based on water at 15°C, you need to determine what the water density would be at this temperature.

1. Obtain water samples from various depths.

2. Pour about 450 ml of your sample into a container such as a 500 ml graduated cylinder.

3. Measure and record temperature (centigrade).

4. Measure density with the hydrometer. (Look at the point where the water line crosses the scale.)

5. Correct the density using Chart 1, the Density-Water Temperature Chart. (For example: Your sample was 5°C with a density of 1.0100. Find the 5° column. Go down that column to the 1.0100 line. The chart reads -9. Subtract .0009 from 1.0100 to get your corrected density of 1.0091).

6. Use this new, corrected density to determine salinity on Chart 2, Salinity/Corrected Density Chart.

Questions

1. Why does fresh water float on salt water?

2. Why do some organisms living in salt water need a strategy to avoid dehydration?

3. Convert 35 parts per thousand (0/00) to percent (0/0).

4. What human activities can alter the salinity of coastal waters?

5. A salinity meter and a hydrometer can both be used to determine salinity, though they measure different properties of salt water. What are these properties?

Follow up

Check salinity at different places in the estuary you are monitoring. Check right after a heavy rain and after a long dry spell. Check a site at low tide and again at high tide.

When would you expect the salinity to be higher or lower?

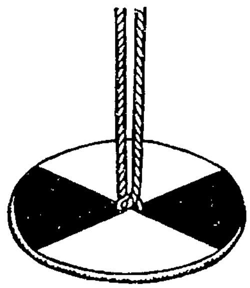
DENSITY - WATER TEMPERATURE CHART

Observed Density	TEMPERATURE OF WATER																			Observed Density
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	Diff.	
1.0000	-3	-4	-5	-5	-6	-6	-6	-5	-6	-5	-5	-4	-3	-2	-1	0	1	3	4	1.0000
1.0010	-4	-5	-6	-6	-6	-6	-6	-6	-6	-5	-5	-4	-3	-2	-1	0	1	3	4	1.0010
1.0020	-4	-5	-6	-6	-7	-7	-6	-6	-6	-6	-5	-4	-3	-2	-1	0	1	3	5	1.0020
1.0030	-5	-6	-6	-7	-7	-7	-7	-6	-6	-6	-5	-4	-3	-2	-1	0	1	3	5	1.0030
1.0040	-5	-6	-7	-7	-7	-7	-7	-7	-6	-6	-5	-4	-3	-2	-1	0	1	3	5	1.0040
1.0050	-6	-7	-7	-7	-8	-7	-7	-7	-7	-6	-5	-5	-4	-2	-1	0	1	3	5	1.0050
1.0060	-6	-7	-8	-8	-8	-8	-8	-7	-7	-6	-6	-5	-4	-3	-1	0	2	3	5	1.0060
1.0070	-7	-7	-8	-8	-8	-8	-8	-7	-7	-6	-6	-5	-4	-3	-1	0	2	3	5	1.0070
1.0080	-7	-8	-8	-8	-9	-8	-8	-8	-7	-7	-6	-5	-4	-3	-1	0	2	3	5	1.0080
1.0090	-8	-8	-9	-9	-9	-9	-8	-8	-7	-7	-6	-5	-4	-3	-1	0	2	3	5	1.0090
1.0100	-8	-9	-9	-9	-9	-9	-9	-8	-8	-7	-6	-5	-4	-3	-1	0	2	3	5	1.0100
1.0110	-9	-9	-10	-10	-10	-9	-9	-8	-8	-7	-6	-5	-4	-3	-1	0	2	3	5	1.0110
1.0120	-9	-10	-10	-10	-10	-10	-9	-9	-8	-7	-6	-5	-4	-3	-1	0	2	3	5	1.0120
1.0130	-10	-10	-10	-10	-10	-10	-9	-9	-8	-7	-6	-5	-4	-3	-2	0	2	3	5	1.0130
1.0140	-10	-11	-11	-11	-11	-10	-10	-9	-8	-7	-7	-6	-4	-3	-2	0	2	3	5	1.0140
1.0150	-11	-11	-11	-11	-11	-10	-10	-9	-8	-8	-7	-6	-4	-3	-2	0	2	3	5	1.0150
1.0160	-11	-11	-12	-11	-11	-11	-10	-10	-9	-8	-7	-6	-4	-3	-2	0	2	4	6	1.0160
1.0170	-12	-12	-12	-12	-12	-11	-11	-10	-9	-8	-7	-6	-5	-3	-2	0	2	4	6	1.0170
1.0180	-12	-12	-12	-12	-12	-11	-11	-10	-9	-8	-7	-6	-5	-3	-2	0	2	4	6	1.0180
1.0190	-13	-13	-13	-13	-12	-12	-11	-10	-9	-8	-7	-6	-5	-3	-2	0	2	4	6	1.0190
1.0200	-13	-13	-13	-13	-13	-12	-11	-11	-10	-9	-7	-6	-5	-3	-2	0	2	4	6	1.0200
1.0210	-14	-14	-14	-13	-13	-12	-12	-11	-10	-9	-8	-6	-5	-3	-2	0	2	4	6	1.0210
1.0220	-14	-14	-14	-14	-13	-13	-12	-11	-10	-9	-8	-6	-5	-3	-2	0	2	4	6	1.0220
1.0230	-15	-15	-14	-14	-14	-13	-12	-11	-10	-9	-8	-6	-5	-3	-2	0	2	4	6	1.0230
1.0240	-15	-15	-15	-14	-14	-13	-12	-12	-10	-9	-8	-7	-5	-3	-2	0	2	4	6	1.0240
1.0250	-16	-15	-15	-15	-14	-13	-13	-12	-11	-9	-8	-7	-5	-4	-2	0	2	4	6	1.0250
1.0260	-16	-16	-16	-15	-15	-14	-13	-12	-11	-10	-8	-7	-5	-4	-2	0	2	4	6	1.0260
1.0270	-17	-16	-16	-15	-15	-14	-13	-12	-11	-10	-8	-7	-5	-4	-2	0	2	4	6	1.0270
1.0280	-17	-17	-16	-16	-15	-14	-13	-12	-11	-10	-9	-7	-5	-4	-2	0	2	4	6	1.0280
1.0290	-18	-17	-17	-16	-16	-15	-14	-13	-12	-10	-9	-7	-5	-4	-2	0	2	4	6	1.0290
1.0300	-18	-18	-17	-17	-16	-15	-14	-13	-12	-10	-9	-7	-6	-4	-2	0	2	4	6	1.0300
1.0310	-19	-18	-18	-17	-16	-15	-14	-13	-12	-10	-9	-7	-6	-4	-2	0	2	4	7	1.0310

<u>SALINITY - CORRECTED DENSITY CHART</u>

(Density at 15°C. · Salinity in parts per 1,000)

Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity	Density	Salinity
0.9991	0.0	1.0048	7.1	1.0101	14.2	1.0158	21.4	1.0211	28.6	1.0266	35.8
.9992	.0	1.0047	7.2	1.0102	14.4	1.0157	21.6	1.0212	28.8	1.0267	35.9
.9993	.1	1.0048	7.3	1.0103	14.5	1.0158	21.7	1.0213	28.9	1.0268	36.0
.9994	.3	1.0049	7.5	1.0104	14.6	1.0159	21.8	1.0214	29.0	1.0269	36.2
.0995	.4	1.0050	7.6	1.0105	14.8	1.0160	22.0	1.0215	29.1	1.0270	36.3
.9996	.5	1.0051	7.7	1.0106	14.9	1.0161	22.1	1.0216	29.3	1.0271	36.4
.9997	.7	1.0052	7.9	1.0107	15.0	1.0162	22.2	1.0217	29.4	1.0272	36.6
.9998	.8	1.0053	8.0	1.0108	15.2	1.0163	22.4	1.0218	29.5	1.0273	36.7
.9999	.9	1.0054	8.1	1.0109	15.3	1.0164	22.5	1.0219	29.7	1.0274	36.8
1.0000	1.1	1.0055	8.2	1.0110	15.4	1.0165	22.6	1.0220	29.8	1.0275	37.0
1.0001	1.2	1.0056	8.4	1.0111	15.6	1.0166	22.7	1.0221	29.9	1.0276	37.1
1.0002	1.3	1.0057	8.5	1.0112	15.7	1.0167	22.9	1.0222	30.0	1.0277	37.2
1.0003	1.4	1.0058	8.6	1.0113	15.8	1.0168	23.0	1.0223	30.2	1.0278	37.3
1.0004	1.6	1.0059	8.8	1.0114	16.0	1.0169	23.1	1.0224	30.3	1.0279	37.5
1.0005	1.7	1.0060	8.9	1.0115	16.1	1.0170	23.3	1.0225	30.4	1.0280	37.6
1.0006	1.8	1.0061	9.0	1.0116	16.2	1.0171	23.4	1.0226	30.6	1.0281	37.7
1.0007	2.0	1.0062	9.2	1.0117	16.3	1.0172	23.5	1.0227	30.7	1.0282	37.9
1.0008	2.1	1.0063	9.3	1.0118	16.5	1.0173	23.7	1.0228	30.8	1.0283	38.0
1.0009	2.2	1.0064	9.4	1.0119	16.6	1.0174	23.8	1.0229	31.0	1.0284	38.1
1.0010	2.4	1.0065	9.6	1.0120	16.7	1.0175	23.9	1.0230	31.1	1.0285	38.2
1.0011	2.5	1.0066	9.7	1.0121	16.9	1.0176	24.0	1.0231	31.2	1.0286	38.4
1.0012	2.6	1.0067	9.8	1.0122	17.0	1.0177	24.2	1.0232	31.4	1.0287	38.5
1.0013	2.8	1.0068	9.9	1.0123	17.1	1.0178	24.3	1.0233	31.5	1.0288	38.6
1.0014	2.9	1.0069	10.1	1.0124	17.3	1.0179	24.4	1.0234	31.6	1.0289	38.8
1.0015	3.0	1.0070	10.2	1.0125	17.4	1.0180	24.6	1.0235	31.8	1.0290	38.9
1.0016	3.2	1.0071	10.3	1.0126	17.5	1.0181	24.7	1.0236	31.9	1.0291	39.0
1.0017	3.3	1.0072	10.5	1.0127	17.6	1.0182	24.8	1.0237	32.0	1.0292	39.2
1.0018	3.4	1.0073	10.6	1.0128	17.8	1.0183	25.0	1.0238	32.1	1.0293	39.3
1.0019	3.5	1.0074	10.7	1.0129	17.9	1.0184	25.1	1.0239	32.3	1.0294	39.4
1.0020	3.7	1.0075	10.8	1.0130	18.0	1.0185	25.2	1.0240	32.4	1.0295	39.6
1.0021	3.8	1.0076	11.0	1.0131	18.2	1.0186	25.4	1.0241	32.5	1.0296	39.7
1.0022	3.9	1.0077	11.1	1.0132	18.3	1.0187	25.5	1.0242	32.7	1.0297	39.8
1.0023	4.1	1.0078	11.2	1.0133	18.4	1.0188	25.6	1.0243	32.8	1.0298	39.9
1.0024	4.2	1.0079	11.4	1.0134	18.6	1.0189	25.8	1.0244	32.9	1.0299	40.1
1.0025	4.3	1.0080	11.5	1.0135	18.7	1.0190	25.9	1.0245	33.0	1.0300	40.2
1.0026	4.5	1.0081	11.6	1.0136	18.8	1.0191	26.0	1.0246	33.2	1.0301	40.3
1.0027	4.6	1.0082	11.8	1.0137	19.0	1.0192	26.1	1.0247	33.3	1.0302	40.4
1.0028	4.7	1.0083	11.9	1.0138	19.1	1.0193	26.3	1.0248	33.4	1.0303	40.6
1.0029	4.8	1.0084	12.0	1.0139	19.2	1.0194	26.4	1.0249	33.6	1.0304	40.7
1.0030	5.0	1.0085	12.2	1.0140	19.4	1.0195	26.5	1.0250	33.7	1.0305	40.8
1.0031	5.1	1.0086	12.3	1.0141	19.5	1.0196	26.7	1.0251	33.8	1.0306	41.0
1.0032	5.2	1.0087	12.4	1.0142	19.6	1.0197	26.8	1.0252	34.0	1.0307	41.1
1.0033	5.4	1.0088	12.6	1.0143	19.7	1.0198	26.9	1.0253	34.1	1.0308	41.2
1.0034	5.5	1.0089	12.7	1.0144	19.9	1.0199	27.1	1.0254	34.2	1.0309	41.4
1.0035	5.6	1.0090	12.8	1.0145	20.0	1.0200	27.2	1.0255	34.4	1.0310	41.5
1.0036	5.8	1.0091	12.9	1.0146	20.1	1.0201	27.3	1.0256	34.5	1.0311	41.6
1.0037	5.9	1.0092	13.1	1.0147	20.3	1.0202	27.4	1.0257	34.6	1.0312	41.8
1.0038	6.0	1.0093	13.2	1.0148	20.4	1.0203	27.6	1.0258	34.7	1.0313	41.9
1.0039	6.2	1.0094	13.3	1.0149	20.5	1.0204	27.7	1.0259	34.9	1.0314	42.0
1.0040	6.3	1.0095	13.5	1.0150	20.6	1.0205	27.8	1.0260	35.0	1.0315	42.1
1.0041	6.4	1.0096	13.6	1.0151	20.8	1.0206	28.0	1.0261	35.1	1.0316	42.3
1.0042	6.6	1.0097	13.7	1.0152	20.9	1.0207	28.1	1.0262	35.3	1.0317	42.4
1.0043	6.7	1.0098	13.9	1.0153	30.0	1.0208	28.2	1.0263	35.4	1.0318	42.5
1.0044	6.8	1.0099	14.0	1.0154	30.2	1.0209	28.4	1.0264	35.5	1.0319	42.7
1.0045	7.0	1.0100	14.1	1.0155	30.3	1.0210	28.5	1.0265	35.6	1.0320	42.8



Turbidity

Turbidity refers to the number of particles suspended in water, or how cloudy the water is. Clear water has low turbidity. Cloudy water has higher turbidity.

Life in estuaries depends on phytoplankton and plant production for much of its energy. Plants, in turn, depend on sunlight for photosynthesis. When the water is too turbid, too much light is diffused, not enough reaches the plants that need it, and production decreases. Too many suspended solids reduce the growth of invertebrates such as clams and oysters. Egg development is slowed or stopped when water contains too much silt. Eelgrass doesn't grow at the mouth of a large river where turbidity is too high.

High turbidity can have several causes. Rivers naturally carry large amounts of silt, clay, and detritus from their watersheds. Moving water carries more suspended solids than still water, so waves and tides can cause turbidity. Human activities such as logging, dredging, farming, and construction result in more particles entering the water. Large numbers of phytoplankton can cause turbidity -- which may be a sign of a healthy, productive environment, or a sign of over fertilization.

Turbidity is often measured with a device called a Secchi disc. It consists of a weighted disc that is lowered into the water until it disappears. This "vanishing point" is the point at which there are so many suspended particles diffusing the light between the disc and the viewer that the disc can no longer be seen. The vanishing point will be deeper in water with fewer particles and shallower in more turbid water.

Procedure

The Secchi disc has two sides -- one white and one with alternate white and black quadrants. The side you choose is a matter of personal preference. Try them both and decide which is easier for you to see. The rope should be marked at 0.25 m intervals and should not stretch.

1. Lower the disc into the water and record the depth at which the disc disappears.
2. Slowly raise the disc and record the depth at which it reappears.
3. Record both observations and calculate the average.

Note: In currents, the disc may hang at an angle, resulting in the line actually being longer than the depth. Make your readings with the line hanging straight down.

Direct sunlight may obscure your view of the disc, so try to lower the disc into a shaded spot.

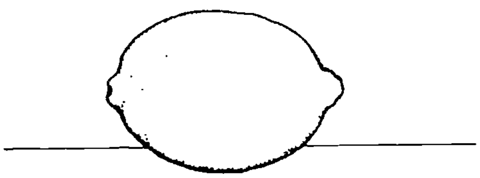
Questions

1. Padilla Bay no longer has a river emptying into it. How do you think the turbidity in Padilla Bay compares with the turbidity in Skagit Bay, the present mouth of the Skagit River? Where would you expect to find more eelgrass?

2. How might an increase in turbidity affect productivity in an estuary?

3. List two human and two natural causes of increased turbidity.

4. What are some factors that can cause inaccurate secchi disc measurements?



pH

The pH scale is a measure of the amount of hydrogen ions in a solution (please read the discussion of pH on pages 26-28 in the "Ecology" section. The pH of water is an important chemical factor determining which organisms can survive in an area. Though sea water is naturally buffered against drastic changes in pH, an estuary is faced with constantly changing fresh and salt water interactions and is often influenced by human activities. The presence of a water treatment plant or industrial effluent may change the pH enough to affect the organisms living nearby.

The "p" in pH stand for "potential." "H" stands for hydrogen. A pH of 1 stands for 10^{-1} grams of hydrogen ion (H^+) per liter. A pH of 7 stands for 10^{-7} grams H^+. The pH scale ranges from 1 to 14, with 1 being very acidic (having the most H^+), 7 being neutral (having equal H^+ and OH^-), and 14 being the most basic. Since the number of the pH scale refers to an exponent of 10, a change in just one number on the scale indicates a change of 10 times the acidity. So a solution of pH 6 has 10 times the number of H^+ as a solution of pH 7. A pH of 5 indicates 100 times the H^+ of pH 7, and pH 4 is 1000 times more acidic than pH 7.

Most organisms have a specific pH tolerance. Some species have a broad tolerance and can survive large pH changes. For others, however, even a slight change of pH can be limiting. Like temperature, oxygen, and salinity, pH is one more way to measure the health of a system.

Procedure

1. Samples are easily contaminated. Clean equipment and hands are important.

2. Approximations of acidity can be easily obtained using pH paper.
   a. Tear off about 5 cm of pH paper.
   b. Place 3-4 drops of your sample onto the paper.
   c. Compare color to the standard chart.

3. A more accurate procedure uses a pH meter or test kit. One type of kit uses a pH indicator solution which changes the color of the sample. The color is then compared to the pure sample with a comparator wheel. Be sure to follow the directions supplied by the manufacturer of your test kit or meter.

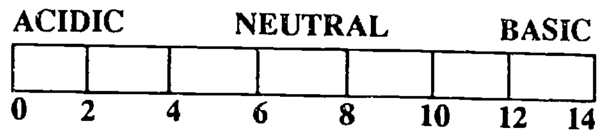
4. **Important**: Measure the pH immediately after sampling, since temperature change can affect pH.

Questions

1. On the pH scale, what readings indicate an acid?

2. A solution with a pH of 9 has how many times more OH^- than a solution with a pH of 7?

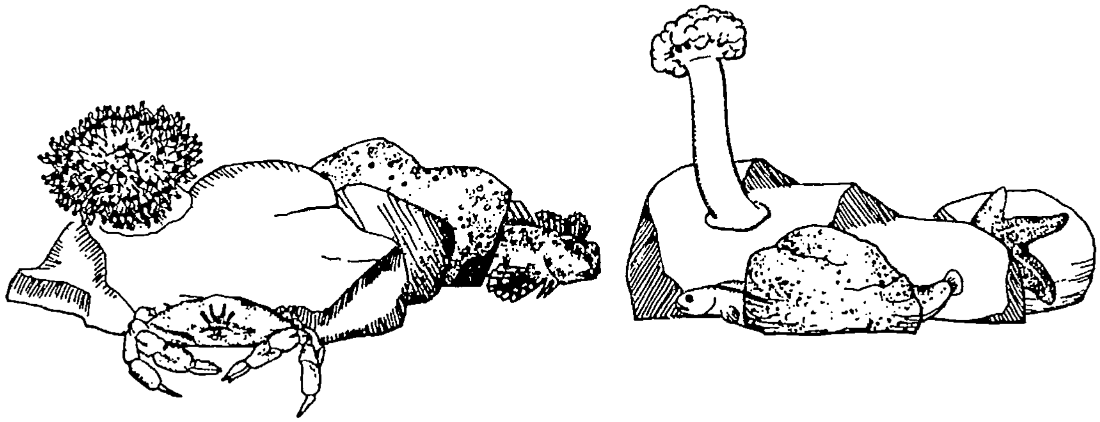
3. True or false? Organisms cannot live in areas where the pH changes? Explain your answer.



Approximate pH's

1.0 - stomach acid
2.0 - lemon juice
2.5 - vinegar
<3.5-all fish die->9.5
4.0 - oranges
5.6 - normal rain
6.3 - milk
7.0 - distilled water
7.5 - human blood
11 - ammonia
12 - bleach
13 - lye

pH scale



Keeping a Marine Aquarium - Activity 4

from: Marine Biology and Oceanography, Marine Science Project: For Sea, Marine Science Center, Poulsbo

From kindergarten to graduate school, the marine aquarium arouses interest and enthusiasm. Traditionally, marine aquaria have been expensive and difficult to operate. Recent technological improvements have reduced the cost and labor involved in maintaining a marine aquarium. Teachers should give every consideration to the establishment of a marine aquarium in the classroom.

Before embarking on a marine aquarium project, some basic questions need to be resolved. The expenditure of time and money will vary greatly depending on your objectives. A simple set-up to keep hermit crabs can be had for a few dollars, and an elaborate temperature-controlled aquarium can cost several thousand dollars.

Regardless of the type of aquarium chosen, some facts pertain to all:

1. Aquarium tank: use only tanks made from all glass, plastic, epoxy-coated wood, or fiberglass. No metal edges. While a 10-gallon aquarium may be used in some cases, 20 gallon size is the preferred minimum.

2. Sub-gravel filter: a good sub-gravel filter should be employed to help control biological wastes.

3. Air pump: you can seldom have too much air. Get a pump with a capacity high enough to effectively run the sub-gravel filtration system.

4. Gravel filtrant: use dolomite, crushed coral rock, or crushed oyster shell. Builders' gravel has iron and similar materials that will harm or kill marine organisms.

5. Thermometer/Hydrometer: tools useful in determining the salinity and temperature of the water.

6. Seawater: synthetic sea salts may be used to make salt water solutions if you are too far from natural seawater.

7. Food: depends upon the type of organism. Use only high quality foods and remove uneaten food from aquarium.

If you buy a marine aquarium kit, instructions for set-up will be included. Otherwise, a few hints are given below:

1. Talk to people who have had marine aquaria (e.g., other teachers, pet shops). Their assistance can be invaluable.

2. Place the aquarium in desired location, away from direct sunlight, but near an electrical outlet.

3. Install sub-gravel filter.

4. Wash gravel in tap water. Spread evenly over the filter.

5. Fill tank with correct amount of water needed to make sea salt solution (follow directions of manufacturer), or fill to 1 or 2 inches from top with natural sea water if available.

6. Run filtration system for 24 hours to mix solution.

7. Shut off filter. Check specific gravity by floating hydrometer and reading it at the water-line: it should read between 1.021 and 1.023 when the water temperature is 68-77°F (20-25°C). If necessary, adjust by adding tap water to lower reading.

8. Run filter for 14 days. Some aquarists recommend placing one or two hardy specimens in the tank for this period. If available, hermit crabs or the like should be added to help condition the water.

9. Add speciments to tank. If you order the animals from a biological supply house, they will come with directions. Otherwise, open each plastic bag of specimens in subdued light and float it on top of the water in the aquarium for 15 to 30 minutes. In this period trickle water from the tank into the bags to slowly equalize temperature and salinity. This is the crucial step. Now add animals to tank, one at a time. (If animals act nervous or contract, stop operation until they have adjusted.)

10. The specimens will live several months without being fed, but to keep them healthy, adopt a simple, regular feeding program. Feed carnivorous invertebrates (sea anemones, crabs, horseshoe crabs, starfish) once a week: they take small minnows, shrimp, earthworms, bits of lean beef. Filter-feeders (barnacles, hydroids, sea cucumbers, clams) eat *Daphnia*, brine shrimp, algae, protozoa, or dried fish foods. Herbivorous species (sea hares, sea urchins, turban snails) may be fed lettuce or spinach. Avoid water pollution -- remove all uneaten food.

Not all plants and animals are suitable for marine aquaria. Sea anemones, chitons, snails, crabs, shrimp, horseshoe crabs, hermit crabs, starfish, and brittle stars make good specimens. Avoid the burrowing forms. Sponges, jellyfish, corals, marine worms, and sand dollars should be avoided, since they may die unseen and foul the water. Cautious observation of fish and plants will determine which species will survive well in your situation. It is important to watch the organisms in your aquarium and remove any deceased members of the community immediately. Further information about suitable organisms can be found in the Resources section.

If you will be collecting your own specimens you need to be aware of state regulations. Species such as sport fishes and shellfish are "classified" with the Washington State Department of Fisheries. When collecting these you must abide by the regulations summarized in the "Salmon, Shellfish, Bottomfish, Sport Fishing Guide". This is available at most sporting goods stores. All other marine animals are regulated by the Washington State Department of Wildlife. To collect or harvest these "non-game species" you must obtain a Scientific Collection Permit. Call the Department of Wildlife at (206)753-2869 for more information.

Once the system is operating, care is easy. Each day, a person familiar with the aquarium should check filters and specimens. Dead animals must be removed at once. Add **fresh water** as often as necessary to keep water at level marked. Do not add salt water, since this will increase the salinity. (Some tap water contains chlorine that is toxic to marine organisms. This water must be dechlorinated with a chemical additive or be allowed to stand for 24 hours, allowing the chlorine to evaporate.)

Though sea-salts don't disintegrate, specimens will stay healthier with partial water changes at regular intervals. Suggestion: once a month, add a few gallons of new seawater solution after siphoning off the same amount from the tank.

For algae control, scrape tank walls every two weeks.

The above suggestions apply to all marine aquaria. If you live in a northern latitude and want to keep local cold water species, you will need a refrigeration unit of some description. Instructions for home-made units can be found in reference books on marine aquaria. Ready-made refrigerated aquaria are available and expensive.

Creating a Mud Tank

What do you get when you take one bucket of mud and an aerator and put them in a 10 gallon aquarium?

Answer: your own mudflat.

This is an easy and inexpensive method to bring the estuary world into your classroom. You won't see a flashy tidepool or the famous aquarium characters like crabs and fish, but you will have a cut-a-way look inside the subtle world of worms, snails, and clams.

1. Start with 3-6 inches of estuary mud in the bottom of a 10 gallon tank.

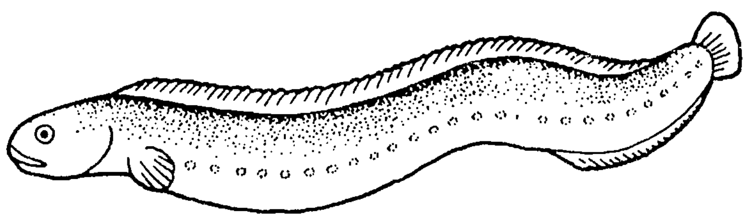
2. Top with estuary water and install an aerator.

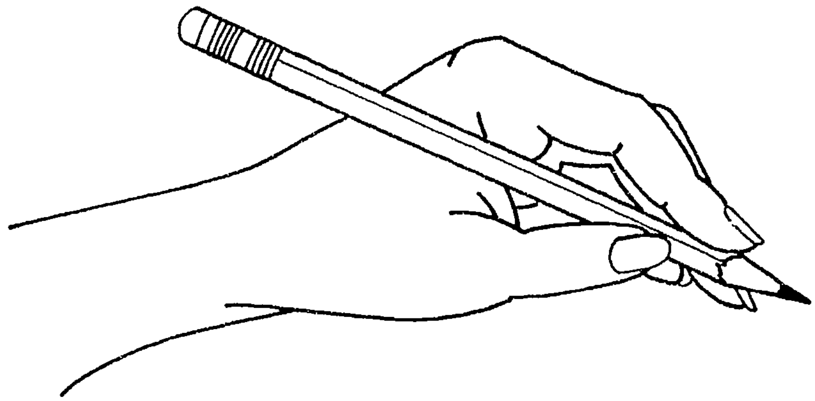
3. Add plankton as often as you can and change the water every few weeks.

4. After you see what's hiding in your mud you can add more. Lugworms, scale worms, snails, burrowing anemones, mud shrimp, and bubble shells (though slimy) are all well behaved visitors. We've had problems with clams (they may need more plankton food than we could provide) and nudibranchs (either they were very picky eaters, or they ate everyone else in the tank). You may want to try these as short-term visitors, releasing them after a week or two.

5. Once your tank is established, you'll notice the landscape changes daily as burrowers and microscopic detritivores poke around in the mud. Examining the mud surface or film on the aquarium sides with a microscope will give you a glimse of these tiny mud creatures.

If, after reading the above, you are discouraged, take heart. Hundreds of teachers are operating successful in-class marine aquaria. The technical problems can be overcome. If you feel that it is unquestionably out of your league and you cannot obtain help from another source, do not completely forsake the idea. A simple aquarium for hermit crabs can be set up for a very few dollars. Solicit donations from students. Go to a pet shop and buy a hermit crab or two and get instructions on how to keep them alive. It can be fun! At the very least, set up a freshwater aquarium with goldfish or tropical fish so that you can use a living example when you talk about aquatic organisms. Here is a real opportunity to use all that creativity that got you into teaching in the first place. Good luck!





Writing With Estuaries - Activity 5

Before You Write

The following writing activities were chosen as a way for you to begin to individually explore and express thoughts about yourself and about the estuary. You can just as easily use the exercises to paint, sculpt, compose, or otherwise create your expression. These activities grew out of the following definition:

> "Self-expression is the source of all abasement (humility), just as . . . it is the basis for all true elevation. The first step is **introspection** - exclusive contemplation of the self. The second step must be genuine **observation** outward - spontaneous, sober observation of the external world."
>
> - Heinrich Novalis (1772-1801)
> German artist and writer

Expressing yourself through introspection and observation is the foundation for the following activities:

> The first step of introspection can be tried in the **journaling activity.**
>
> The second step of observation is the aim of the **object poem activity.**
>
> These two steps are combined into a richer expression through the **I-search exercise.**

Warning: These activities may lead to personal satisfaction. Please perform only with teacher supervision.

Estuary by Journal

"I come to this island every month of the year. I walk around it, stopping and staring, I straddle the sycamore log over the creek, curling my legs out of the water in winter, trying to read. Today I sit on the dry grass at the end of the island by the slower side of the creek. I'm drawn to this spot. I come to it as an oracle; I return to it as a man years later will seek out the battlefield where he lost a leg or an arm."

- Annie Dillard
Pilgrim at Tinker Creek

Writing in a journal is an example of **introspection**. To write in a journal means to write in a purely personal dialogue. This is where many writers do more than record daily activities. They let their feelings as well as their thoughts interact on the paper without restricting their flow. Hopefully, you already have tried, or still keep a journal. Here is our simple suggestion for a journal exercise that focuses on the estuary.

1. Visit an estuary or read a poem or story relating to an estuary. (See Resources)

2. Find a place to write. A spot outside and away from other people is best, though a school desk can work just as well.

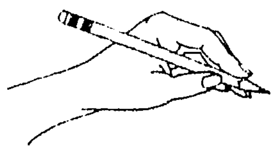
3. Write freely without worrying about punctuation or spelling on these two questions:

   -- How does the place or written piece make you feel? Start with a feeling, then expand on it. Maybe you feel relaxed from sitting in the sun by the water. At the sight of a fishing boat you may feel sorry for the fish or worried about the estuary's future. Maybe you feel disgusted by the images of death and decay. Different people will have different reactions to the same experience. Find your experience and write about it.

   -- Why does it make you feel that way? You can't always justify feelings, but you can explore them. If a boat makes you feel restless, maybe it's because you want to be on it, traveling to a different part of the world. If a small fish getting eaten by a heron makes you sad, maybe you can trace it to a pet that died. Usually it relates back to something going on in your life.

4. Keep writing until the writing takes over; it will come alive if given the time.

5. After you've searched your feelings, read back and find similarities between them and the images around you. (How is my feeling of optimism or pain like the waves? . . .)



Estuary by Object Poem

"When a man becomes proud to be not just the site where ideas and feelings are produced, but also the crossroad where they divide and mingle, he will be ready to be saved. Hope therefore lies in a poetry through which the world so invades the spirit of man that he becomes almost speechless, and later reinvents a language. . . . True poetry is what does not pretend to be poetry. It is in the dogged drafts of a few maniacs seeking the new encounter."

- Frances Ponge, French poet

The second step of self-expression is observation. The object poem, or as poetically labeled, the "thing" poem, is a great way to practice your observation skills at the estuary.

1. Pick an object (ideally an estuary object).
2. Observe it closely.
3. Write a poem about the object.

This appears easy enough, but the catch is to observe the object with such intensity that you actually see through the eyes of that object. If you observe a rock, "become" that rock. What does the rock do, think, feel? What is it like to be a million years old? How do you like being rolled by the waves?

"The boat rolled upon its tether, shifts its body from one foot to the other, restless and stubborn as a colt . . ."

- from "The Boat" by Francis Ponge

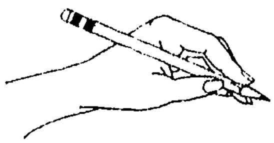
An object poem should not become overwhelmed by your thoughts and feelings. When you write a true object poem, you no longer exist and cannot write from your human perspective.

A Mount Vernon High School student sitting by Padilla Bay wrote this object poem about some footprints:

Footprints nestled in the mud;
    softened by the tides.
Each one its own pool
    after being tucked in by a wave.
The new footprint starts with a sole
    that's pushed down any soul before it.
After the currents have carried it away
    new creatures give it a newer, natural print.
The millions of footprints have mulched up
    the soft folds of life.

- Andrea Holloman

She wrote this in a 30 minute exercise, and already it's published. We observe things everyday, but we have so many stimuli pounding us that our senses become numb. Try reopening them.



Estuary by "I-Search" Paper

"The road I took back to my motel passes through a salt marsh - a fragrant, 3,000 acre blackness that winds towards the vaster blackness of the North Atlantic. A marsh smell is nothing you convince anyone about: it is either the stench of putrifying garbage or a tangy whiff of pure existence."

- Floyd C. Stuart
"The Salt Marsh"

In an "I-Search" paper, the writer uses not only the traditional information sources such as libraries and schools, but also includes personal experiences, thoughts, and feelings to explore a theme.

1. Think of a way that you've experienced the estuary: eating oysters, visiting the beach, going fishing.

2. Research the estuary through the angle of your choice. Study the techniques of catching salmon, the proper preparation of an oyster, or the music of estuarine inhabitants. Photograph birds of the Pacific flyway. Collect the names of estuaries or types of boats. Talk to commercial fishermen, marsh artists -- whatever -- as long as it relates to the place where rivers meet the ocean.

2. Write about your topic using all of what you've discovered and experienced.

3. Tie the information together using your own thoughts, feelings, and memories.

The Sound Of My Life by Carol Goncalves is an example of an estuary "I-search" paper about growing up on Long Island Sound. It begins:

" I remember as a child spending many summer days swimming in the salt water at Fairfield Beach. At night, as I lay in bed, I could hear the sounds of foghorns even though we lived three miles away...I sensed there was something special about the seacoast.

"I wondered what it was like to live on a New England beach year round. What was it like in the crisp air of autumn and the bleakness of winter, after the summer people headed for home? What were the pleasures as well as the dangers of living near the sea.

"I borrowed a few books from the Fairfield Public Library which I thought would provide me some answers . . ."

You can read more in Ken Macrorie's book, *The I-Search Paper*, listed in the Resources section.

Creative Exercises

<u>Choose one of the following situations:</u>

1. You are a Native American living near the Cascade Mountains 10,000 years ago. The great glacier has been gone for many generations, but oral tradition still tells of the colder times. Small glaciers still cover parts of the Cascades and send torrents of water down the many rivers. A remnant of the great glacier can still be seen blocking what is now the Strait of Juan de Fuca. You live on the shore of the huge, fresh water lake that the glacier created. Retell a story about the old times. (See Chapter 1, Estuary Formed.)

2. It is 1860. You are Samuel Calhoun, a lumber mill worker from Camano Island. One Sunday, you borrow a canoe and decide to go exploring in the vast Olympia Marsh. (Camano Island, Bay View Ridge, Fidalgo Island, Samish Island, and the hills around La Conner are all forested "islands" in the wild swamp created by the Skagit River's delta.) You soon realize that you should have hired a guide. Record your adventure in your diary. (See Chapter 2, Estuary Settled.)

3. Describe a walk along the dike between Padilla Bay and fertile farmland that was once a marsh. (Some possibilities: a stormy winter day with an unusually high tide, a hot summer day at low tide, a description of the weather, the view, or the animals you observe)

4. You are an animal in Padilla Bay, and the tide just went out. Write about your community and your role there. (See Chapter 3, Estuary Alive, or the Field Guide to Padilla Bay Organisms, Resources section.)

5. You are a 79-year-old woman living next to the bay in the farmhouse that you grew up in. The land is now worth hundreds of thousands of dollars as it could be subdivided and developed. Write down what is going through your mind as you both reminisce and look to the future.

6. Look through any of the text you have read in this curriculum and choose your own situation to write about. Choose something that is especially interesting to you. It could be from the past, present, or even future. You may want to discuss a problem from a particular point of view (human or non-human). You might look at a topic from many points of view. You might describe a personal experience.

Thinking Globally About Estuaries - Activity 6

Using an atlas or world map:

1. You live in a watershed that drains into an estuary. Locate and identify that estuary. Is there a city there?

2. Make a list of Washington rivers that have cities on their estuaries.

3. List several large rivers in North America. Find their estuaries. Which have a city at their mouth?

4. Find 10 large cities in the United States. Which are located on estuaries?

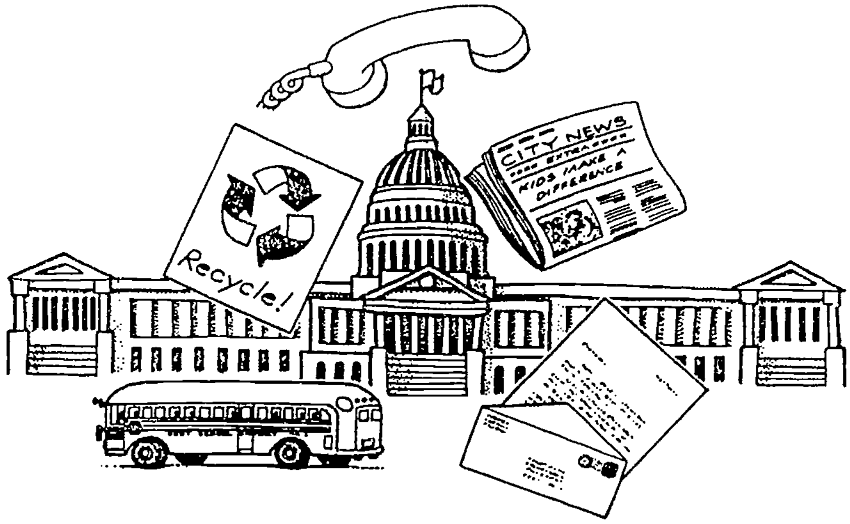
5. Find the world's largest cities. How many are on estuaries?

6. Find these famous rivers: Nile, Amazon, Congo, Mississippi, Columbia, Rio Grande, Hudson, Danube, Rhine, Volga, Euphrates, Tigris, Ganges, Yellow, Yangtze. Which have cities on their estuaries?

7. List some "upriver" activities that might affect water quality in an estuary.

8. Of the rivers listed in question 6, which have watersheds in more than one country? Describe some difficulties this might pose for regulation and management.

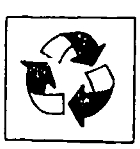
9. Many of Padilla Bay's waterfowl migrate. Research the migration route of one of the following: black brant, western sandpiper, peregrine falcon, bald eagle. Does that bird migrate to another estuary? If so, is it as "protected" as Padilla Bay?



What We Can Do for Estuaries - Activity 7

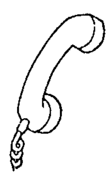
We are constantly making decisions which affect estuaries. Some of the decisions are big, like whether to allow destruction of critical habitat or deciding how much pollution from an industry is acceptable. Other decisions are smaller -- like whether to bike or drive somewhere or what to do with your old motor oil. These activities will 1) help you examine your personal actions that affect estuaries and 2) demonstrate ways that you can take part in the larger decisions being made around you.

In this section, you will find the following activities:



Surveying Your Behavior
Step 1: Drawing Your Own Water
Step 2: Water Quantity Monitoring
Step 3: Perusing Through Poisons
Step 4: Cars and the Estuary

Know the Issues
Become the expert on estuary issues.



Working Together
Take a look at how other high school students have accomplished great things.

Write, Write, Write!
Letters from students make a big difference!

Speaking Your Mind
All about public hearings.

Step 1: Drawing Your Own Water

You remember the water cycle. Water evaporates from the ocean. Clouds form. Rain falls..... But did you ever think of yourself as a part of that cycle?

Think about the water that goes through your house. Draw a picture of your water cycle (this will require some research). Use as many labels from this list as you can:

condensation	septic tank
evaporation	drain field
stream (name?)	ground water
river (name?)	well
estuary	lake
ocean (name?)	sewer pipe
water tower	your home
drain pipe	wetland
tree	cloud
evapotranspiration	
water treatment plant	
sewage treatment plant	
wastewater outfall	

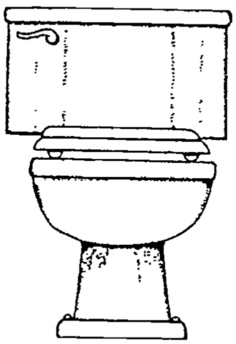
1) What goes down the drain with the water at your house?

2) Are there things in your wastewater that the sewage treatment plant can't clean up?

3) What difference would it make if you used less water?

4) Is there a safe place to dump toxic products in your house or yard?

Step 2: Water Quantity Monitoring



"Mix one part excreta with one hundred parts clean water. Send the mixture through pipes to a central station where billions are spent in futile attempts to separate the two. Then dump the effluent, now poisoned with chemicals, but still rich in nutrients into the nearest body of water . . ."

from *The Toilet Papers*
by Sim Van Der Ryn

In a world where so many people have to walk miles for water, we are very lucky to have seemingly abundant water resources. So abundant that we can let gallons of clean, drinkable water trickle down the storm sewer while we polish the chrome on our car. Are we using this resource wisely? What effect does our extravagant water consumption have on the water system we are part of? In this activity, you will examine the amount of water you, personally, use in a week and then consider whether you can (or want to) use less.

Individually:

1) Estimate the amount of water your household uses in a week. Then divide that amount by the number of people in the household.

--Start by listing all the different uses you can think of (don't forget outdoor uses).
--For infrequent uses (like hosing down the driveway once a month), you'll need to "prorate." For example, you change your 4-gallon fish bowl every month. Write down 1 gallon/week.

As a class:

1) Find out how much water your school uses in a week. Divide by the number of people at your school.
2) What is the biggest water "user" in most homes? List ways you could conserve water in your home. List ways your school could conserve water.
3) Does water conservation affect the way a septic tank works? Does it make a difference in the sewage treatment process? (Call your sewage treatment plant to find out.) Would it make a difference to water quality in your estuary?
4) Why do you think some of us don't try to conserve water? (Think about "values" and what is important to people.) Why would someone voluntarily conserve water to help the environment? Would you (Be truthful)? Why or why not?

Step 3: Perusing the Poisons

Many useful products around our homes are hazardous to people, animals and the environment. If we pour these products down the drain, in a ditch, or in the backyard, there is no doubt they will contact living organisms. Eventually they will drain into a wetland, the groundwater, or an estuary where they can wreak havoc.

This activity is an inventory. Hunt around your house, basement, and garage to find out which of these products you have. Ask your parents to assist you with this activity.

Caution: Please be very careful handling these products. While not all household products are hazardous, many could be harmful. Wash your hands carefully after you handle these containers.

Do you have?	How much?	Where is it stored?	Warnings	Safer Alternative
PAINTS __Enamel or oil based paints				
__Latex or water based paints				
__Rust paint				
__Thinners and turpentine				
__Furniture stripper				
__Stain or finish				

Household products inventory

Do you have?	How much?	Where is it stored?	Warnings	Safer Alternative
HOUSE __Oven cleaner				
__Drain cleaner				
__ Toilet cleaner				
__Disinfectants				
__Upholstery or rug cleaners				
__Furniture or floor cleaners				
__Cleaners with bleach				
__Photographic chemicals				
__Silver polish				
__Pool chemicals				
__Cleaners with ammonia				
__Spot removers				
__Abrasive cleaners				

Adapted from *Away With Waste*, Washington State Department of Ecology Publication #90-12, 1990.

Household products inventory

Do you have?	How much?	Where is it stored?	Warnings	Safer Alternative
AUTO __Antifreeze				
__Used oil				
__Brake fluid				
__Transmission fluid				
__Batteries				
__Gasoline				
PESTICIDES __Herbicides				
__Mouse and rat killer				
__Roach and ant killer				
__Flea collars and sprays				
__Insecticides				
__Fungicides				
__Slug bait				
__Mothballs				
OTHER __ __				

Potentially Hazardous Household Products - Some Safer Subs

For this product	Try this safer substitute
Air freshener	Cinnamon & cloves (simmered)
Bathtub and tile cleaner	Baking soda & vinegar & water
Burn mark remover	Grated onion
Coffee cup stain cleaner	Salt (moist)
Decal remover	Vinegar (soak in white vinegar)
Drain cleaner	Plunger; baking soda or vinegar & hot water
Furniture polish	Olive oil; lemon juice & mineral oil
General household cleaner	Baking soda
Hand cleaner for paint/grease	Baby oil
Ink spot remover	Cream of tartar & lemon juice & cold water
Insects on plants	Soap & water
Moth repellent	Proper storage & laundering of clothing
Oil based paint	Water based paint
Oil stain remover	White chalk (rubbed in before laundering)
Paint brush softener	Vinegar (hot)
Refrigerator deoderizer	Baking soda
Roach repellent	Roach trap or "hotel"
Rug cleaner	Club soda
Rust remover	Lemon juice & salt & sunlight
Shoe polish	Banana peel
Slug repellent	Diatomaceous earth
Spot remover	Club soda; lemon juice; salt
Water mark remover	Toothpaste
Window cleaner	Vinegar (in warm water)
Wine stain remover	Salt

Adapted from *Away with Waste*, Washington State Department of Ecology Publication #90-12, 1990.

Step 4: Cars and the Estuary

Cars! What could be more important to us? They represent our status and freedom. They fuel the economy, give us independence, and take us to wild and exotic places (or to school and work). But at what cost?

You may have heard that automobiles are the largest source of air pollution in Washington, but have you ever thought of cars as water polluters, too? We won't even consider the environmental costs of manufacturing a car. Let's just consider using one.

What goes up usually comes down, so all that smog you've seen hovering around Puget Sound doesn't stay in the air, and it doesn't disappear. Invisibly, air pollution clings to water in the clouds and comes down as polluted rain. Nasty stuff if you are a plant, a lake, a granite statue, or (ironically) a car!

Even more damaging to our waters are the things cars leave behind on the roads. A car's tires wear on the road and leave cadmium and zinc to be picked up by the next rain. A parked car drips oil and grease. Chromium and zinc wear off the body. Copper and lead come from the engine. Once on the driveway or road, this ends up in ditches, storm sewers, and eventually the estuary.

As much as we might hate to admit it, driving less is good for an estuary (and good for lots of other parts of our environment, too). Driving less may seem impossible -- especially to high school students -- but if we want water that's clean, air that we can breathe, and some land that's not paved over, this society is going to have to change its ways.

Here are four short surveys which look at how we use cars. You may want to divide into four small groups and do one survey each.

1. The Student Parking Lot

-- Count the number of cars in the student parking lot. What percentage of students drive a car to school?

-- After school, stake out a spot near the exit and record the number of cars and occupants per vehicle. Calculate the average occupants per vehicle.

-- Total the number of SOVs. (That's short for Single Occupancy Vehicle.)

-- Interview 10 student drivers. Find out why they don't take the bus. Ask if they car pool. Find the average occupants per vehicle. Compare this to your observations above. Ask how many miles per day they drive to and from school. What is their gas mileage? How much gas is used on one trip to school? Calculate the amount of gas used per day per student driving to school.

2. The Faculty Parking Lot

-- Repeat the above survey for teachers.

-- In your interview, find out if public transportation is available. If available, why don't the teachers take the bus? Ask if they ever car pool and why. Find out how many miles they commute daily. What is their gas mileage? How much gas is used per teacher per day driving to school?

3. The Buses

-- Interview five bus drivers. Ask them the number of miles they drive each day for the high school run. Find out their gas mileage and the average number of students per trip.

-- Calculate the amount of gas used per person per day.

4. The Pavement

-- Estimate the percentage of your school property that is paved for vehicles.

-- Go outside and find a storm drain or ditch that catches runoff from the parking lot. (This is easy if it's raining.) Make a note of any visible pollutants on the pavement or in the water. Where does the water go from there? If you need to ask your local public works department, designate one person to call.

Sharing your results with the rest of the class, work together to answer these questions.

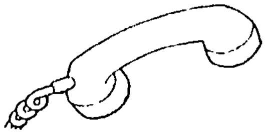
1. Why do some teachers and students choose not to use the bus? What difference would it make if they did?

2. How much space in your community is set aside for the care and use of cars? (Consider driveways, garages, streets, gas stations, freeways, malls. Look in the yellow pages in the automobile section for more ideas.) How does this compare to the amount of space set aside for people to live, play? . . .

3. Does the runoff from your school parking lot go directly to a body of water, or is it treated first? If it goes to a sewage treatment plant, are toxins removed from the water there?

4. List 10 advantages and 10 disadvantages for driving a car. Rank them. When do you choose **not** to use a car?

5. How do you think the use of cars differs for male and female high school students? For high school students and other adults?



Working Together

So you've got your own house in order. You conserve water, electricity, gasoline, and paper products. You recycle, pick up litter, and buy only non-toxic products. You always fill in your holes after clam digging. Now what about those big decisions that are being made by our society? What can high school students do to take part in those big decisions? Try group action!

It is not often that students are advised to take action instead of waiting to be told to do something. But when they do take action, high school students have accomplished things that no one else could.

In Lynden, Washington, Lynden Christian High School students started a salmon enhancement project that raises and releases over 150,000 salmon each year. They've also worked with the Department of Fisheries to restore streams.

The biology students at Seaside High in Seaside Oregon worked for a year to get the city to designate part of the Necanicum estuary as a park. They then raised $7,000, designed the park with the help of an architect, made interpretive signs and brochures, then, to top it all off, constructed the park facilites.

These students took action instead of feeling powerless. They became involved.

Students at Madison High in Portland started their own environmental club. These are the steps they followed. You may want to do the same in your school.

1. **Care**
   After learning about local environmental problems, nine students decided to get involved.

2. **Contact other groups**
   They quickly joined community clean-ups, nature trips, Audubon bird rehabilitations, EPA streamwalks, tree plantings, drama projects, and YMCA Earth Service Corps. Other environmental groups generously donated time and materials. (See References section.)

3. **Find more information**
   They read newspapers and magazines from the library and checked with a local nature center to find out more about issues and events. They basically became experts.

4. **Get training**
   They paid their own way, or sought funding for a variety of conferences, camps, and leadership workshops.

5. **Broaden membership**
   They continually brought people aboard and within six months, expanded to 55 members.

6 **Start a project**
They sponsored a local town Earth Summit meeting, began a cafeteria recycling project, and adopted their own wetland.

7. **Record Involvement**
They made slides, pictures, journals, and portfolios of their activities that they used in presentions for more funding. They also filmed and produced their own video.

Tips from "The Monday Group"

"The Monday Group," an environmental education class seminar in Florida is another example of a group of students working together to solve environmental problems in their community. This class meets for a full day, every other Monday. Each year the group selects a project to focus their efforts on. In past years they have facilitated the purchase and protection of a cypress swamp, helped solve a conflict between the EPA and the local power company over the effects of their canal discharge system on the local manatee population, and assisted the county in drawing up new development regulations protecting the southern bald eagle population.

This group has been effective, in part, because of some fundamental operating rules that maximize the power of their group:

- Be for something. Being against something is not allowable; only positive viewpoints are accepted. Extreme or radical views are also not acceptable.
- Know the issue. You can become the most knowledgeable person in your community on any topic, but remember to look at all the sides.
- Be persistent. Environmental problems are slow and painful to solve. Don't expect a complete victory; small victories are what count.
- Know your allies and enemies. Use positive energy from those who support you, and try to neutralize the energy of those who don't.
- Treat people as individuals. Stereotyping prevents solutions.
- If you fail, recycle. Re-use all the knowledge you gained, pinpoint why it didn't work, then re-do it (without blaming or scapegoating something else).

Know the Issues

Estuaries are affected by many human activities. Many of those activities are a result of ordinary people (not "bad guys") -- people trying to operate an industry, maintain highways, grow food, make a living. Below is a list of issues facing estuaries. Some are "hot" items. Some may only be "warm." All of them are showing up in newspapers around Puget Sound. Look over the list and discuss it in class. What does your class know about these issues as they relate to estuaries? Are any of the issues of concern in your community? Is there a problem in **your** estuary? Choose a topic that interests you. The issues can serve as topics for small group or individual research projects, or the whole class may investigate one topic together.

Salmon
Water Rights
Water Conservation
Property Rights
Oil Transportation
Forest Practices
Commercial Fishing
Non-native Species
Growth Management
Wetland Mitigation
Native American Rights
Shellfish Contamination
Household Hazardous Waste
Shoreline Development
Non-point Pollution
Agricultural Runoff

Before you tackle an issue or let decision makers know how you feel, you need to be well informed. Find out all you can about your issue first. Become an expert. The following steps will help you in your research.

1) Find out why estuaries are important to people and wildlife. Start by reading this book if you haven't already done so.

2) Go to the library and look through newspapers and magazines. Try to find the history of the issue. What is the problem? Does it involve a conflict between different interests?

3) Find out what the existing regulations are concerning your issue (not an easy task!). There is no single law that governs estuaries, nor any single agency that regulates all estuary matters. Rather, there are a number of laws which pertain, at least in part, to estuary issues. These laws are administered by several different agencies, each with specific responsibilities and jurisdiction. To make things even more complicated, these agencies represent all three levels of government -- federal, state, and local. The following overview of major regulations pertaining to wetlands may send you in the right direction (see page 118). Remember, wetlands regulations are changing frequently these days.

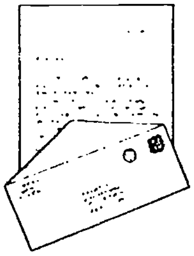
4) What government agencies are involved? Call an agency and ask. (See the "Resources" section or the blue pages of your phone book for a listing of agencies.) When you call or write, be specific about the information you need. "I'm a high school student researching ______. Is your agency involved in ______? Can you direct me to any regulations concerning _______? Who else might have information?"

5) Utilities, industries, and private interests like developers may have important information. Even if they seem to be on the "other side" of the issue, be open to their point of view.

6) Call environmental organizations such as the National Audubon Society or People for Puget Sound who might be following your issue. They are usually up-to-date on current legislation affecting estuaries. (See Resources section.)

7) Organize your information and give a class presentation. Remember to present all the different views. You've now done your homework and are ready to make some changes.

Regulation	Description	Agency
Federal Clean Water Act Section 404	Requires a permit for placement of all dredge and fill materials, and covers all the waters of the United States, including most wetlands.	U.S. Army Corps of Engineers/EPA
Federal Clean Water Act Section 401	Requires certification from the state that any materials discharged into a wetland under a federal permit meet state water quality standards.	Department of Ecology
Federal River and Harbor Act Section 10	Requires a permit for all construction activities in navigable waters, including wetlands within those waters.	U.S. Army Corps of Engineers
State Shoreline Management Act	Requires a permit to ensure that proposed activity complies with local shoreline master plan; includes all land within 200 feet of ordinary high water mark of a state shoreline, and may be extended to include an entire associated watershed.	Local jurisdiction/ Department of Ecology
State Hydraulic Code	Requires a permit for all work that occurs below the ordinary high water mark of state waters, including portions of wetlands.	State Depts. of of Fisheries and Wildlife
State Environmental Policy Act (SEPA)	Requires full disclosure of the potential adverse environmental effects of any proposed actions; applies to all federal, state, and local actions and all wetlands.	Usually a local agency
National Environmental permit Policy Act (NEPA)	Requires full disclosure of the potential effects of proposed federal action; applies to all wetlands	Usually federal agency issuing
Federal Coastal Zone Management Act	Requires a notice of consistency with the state coastal zone management plan as a condition of federal support of local activities; covers Washington's 15 coastal counties and the wetlands within them.	Department of Ecology
Floodplain Management Program	Regulates construction and other activities that might increase flood flow; covers wetlands incidentally.	Local jurisdictions and Department of Ecology
Local Regulations	May require permits for various activities. May identify specific wetlands or performance standards.	Local jurisdiction



Write, Write, Write!

Now that you've researched your issue, you can begin making things happen. People who make changes happen need to hear from YOU! Your parents, teachers, or a librarian can help you to identify your representative in Congress or the state legislature. Depending on your issue, you may also want to write to someone on your county council, the mayor of your city or town, your state's governor or other government officials. Keep up with the news about legislation. If a bill has been proposed that deals with your issue, write and let your legislator know about it before the bill comes up for a vote.

No matter what the issue or who you write to, you'll be more successful if you follow these simple rules:

1. Do your homework. Be certain that you understand the issue and can discuss it clearly.

2. Make a list of what you want to say before you start to write.

3. Use language that shows that you are courteous and respectful of the person to whom you are writing. Thank him or her for taking the time to read your letter.

4. Explain the problem and your feelings about it, but keep the letter short (one page). Be specific. For example: "I am concerned that the shopping mall planned in my community will destroy valuable wetlands nearby." Or, "I am writing to show my support for bill no. _______ which states . . ." and then say why you support it.

5. If you have a reasonable solution in mind, state it. Ask what the person feels can be done about the problem, and ask for a response. Be sure that your address appears on the letter, in case the envelope is lost.

6. Ask someone to check your grammar and spelling. Type or write the final letter on clean paper without errors.

7. If you do not get a response in a few weeks, write a second letter, briefly re-stating what your first letter said. If this doesn't work, don't give up! Try another representative.

Adapted with permission from *WOW!: The Wonders of Wetlands*, Britt Eckhardt Slattery, Environmental Concern, Inc., 1991.

If you have carefully researched a problem and feel that something should be done about it, there are many ways to make sure your voice is heard. You can bring up an issue before a government body such as your city council, county board, or even state legislature. Another very effective place to "speak your mind" is a public hearing.

A public hearing is a meeting scheduled by an agency or organization in order to gather information from the public as well as to provide information to the public. Meetings have different formats, but the most common structure is to schedule part of the meeting for public input. At that time, speakers will be asked to come forward and present their views. This could be you! Decision makers are often required to consider public input when dealing with an issue. One good presentation (especially from a young person) can have a great deal of influence. In fact, one well prepared and informed high school student will attract attention that the decision makers can't ignore.

Before you go to a meeting

1. Know why the meeting was called. Is it a regularly scheduled meeting dealing with more than one topic? Was it called to give information and answer questions? Is it a panel presentation with time for questions and answers? Is it being held to solicit public input (your input)? Not all meetings include a time for you to share your views. If this is the case, the meeting may still be a good place for you to gather information and see other people's perspectives. Who and how many are expected to attend?

2. Know exactly what the topic is and be sure to address that topic.

3. Research the issue. (See p. 116-118.)

4. Prepare your presentation. Outline the points you want to make before you speak. A section on "Power Speeches" in *The Kid's Guide to Social Action* by Barbara A. Lewis has some great tips for preparing an effective presentation. You don't need to limit yourself to "talk." Handouts, visual aids like slides or posters, and petitions can make your presentation more effective.

5. Know your time limit: Lots of people come with too much to say, and run out of time before they get to the main point. Remember the Gettysburg Address? That three-minute speech changed the course of American history. *Short* can be better. Make clear, succinct points and back them up with stories or instances. You may also want to allow time for questions.

6. If you think it would help your cause to have media coverage, you can inform local newspapers, radio and TV stations that you will be presenting.

At the Meeting

1. Arrive on time and get your name on the list of speakers.

2. Be polite. Pay close attention to what others say, especially if their views differ from yours. You may want to take notes. Use this time to gather more information.

3. When it is your turn to speak, identify yourself clearly so that you can be reached in the future. (Include your name and address on any handouts.) Speak up. Your views are important and should be heard.

4. Stay until the end of the meeting. This will demonstrate your desire to listen as well as to be heard.

5. Keep your cool. Things may get hot when emotions misconstrue issues into polarized sides. The resulting outbursts are usually counter-productive. If you look at the issue as a problem to be solved together rather than a fight to be won, you will make a greater contribution to the decision making process.

Resources

Field Guides

Angell, Tony and Kenneth C. Balcomb III. Marine Birds and Mammals of Puget Sound. Seattle: Puget Sound Books, 1982.

Coulombe, Deborah. The Seaside Naturalist. New Jersey: Prentice-Hall, Inc., 1984.

Flora, Charles and Eugene Fairbanks, M.D. The Sound and the Sea. Bellingham, Wahsington: Western Washington Press, 1982.

Kozloff, Eugene. Seashore Life of the Northern Pacific Coast, Seattle, Washington: University of Washington Press, 1983.

Newell, G.E. and R.C. Newell. Marine Plankton: A Practical Guide. London: Hutchinson and Company, Ltd., 1979.

Smith, Deboyd. A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae. Dubuque, Iowa: Kendall/Hunt Publishing Company, 1977.

Snively, Gloria. Exploring the Seashore of British Columbia, Washington and Oregon. Vancouver, B.C.: Gordon Soules Book Publishers Ltd., 1978.

Yates, Steve. Marine Wildlife of Puget Sound, the San Juans, and the Strait of Georgia. Connecticut: The Globe Pequot Press, 1988.

Water Monitoring Equipment

Monitoring Manuals

Fisher, Nina, ed. The Monitor's Handbook. Chesterfield, Maryland: LaMotte Company, 1992.

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

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

D.O. Test Kit -- Model OX-2P
Cat. No. 1469-00

Total Phosphate Test Kit -- Model PO-24, Cat. No. 2250-01

Low-range Nitrate Test Kit -- Model NI-14, Cat. No. 14161-00

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

Salinity Meter - Model 33 S-C-T

D.O. Meter -- Model 57

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

Secchi Disk -- Cat. No. 0171

Turbidity Test Kit -- Cat. No. 7519 TTM

Water Sampler -- Model JT-1
Cat. No. 1077

pH Pocket Tester -- Cat. No. 1755

Millipore
(phone orders only)
(415) 952-1740

Fecal Coliform Test Equipment

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

Plankton Nets

Marine Aquarium Guides

James, Daniel E. Carolina Marine Aquaria. Carolina Biological Supply Co., 2700 York Road, Burlington, North Carolina 27215, 1974. 24 pp.

King, John M. and Stephen Spotte. Marine Aquariums in the Research Laboratory. Aquarium Systems, Inc., 33208 Lakeland Blvd., Eastlake, Ohio 44094, 1974. 39 pp.

Straughan, Robert P.L. The Salt-Water Aquarium in the Home, 2nd edition. New York: A.S. Barnes and Company, 1970.

Resources for Environmental Action

Adler, Allan Robert. A Step-by-Step Guide to Using the Freedom of Information Act. Washington, D.C.: American Civil Liberties Union, 1992. (202) 544-1681

Hansen, Nancy, et. al. Controlling Non-Point Source Water Quality Pollution: A Citizen's Handbook. Washington, D.C.: World Wildlife Fund, 1988.*

King, Jonathan. Northwest Greenbook: A Regional Guide to Protecting and Preserving our Environment. Seattle: Sasquatch Books, 1991. (206) 441-6202.

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.*

Paulson, Gerald A. Wetlands and Water Quality: A Citizen's Handbook for Protecting Wetlands. Washington, D.C.: EPA. 1-800-832-7828.

Training Student Organizers (TSO)
Council on the Environment, Inc.
51 Chambers St. Room 225
New York, NY 10007.

Yates, Steve. Adopting a Stream: A Northwest Handbook. Everett: Adopt a Stream, 1988. (206)388-3313.

Yates, Steve. Adopting a Wetland: A Northwest Guide. Everett: Adopt a Stream, 1989. (206)388-3313.

Washington State Department of Ecology. Wetland Regulations Guidebook, Publication #88-5. Washington State Department of Ecology, 1988. (206)438-7472.

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
(206) 956-0083

Washington State Department of Wildlife
16018 Mill Creek Blvd.
Mill Creek, WA 98012
(206) 774-8812

* available at your bookstore.

Washington State Office of Environmental Education
17011 Meridian Avenue North, Room 16
Seattle, WA 98133-5531
(206) 542-7671

Puget Sound Water Quality Authority
MS PV-15
Olympia, WA 98504-0900
(206) 493-9156 or (800) 54-SOUND

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
1043 BayView-Edison Rd.
Mt. Vernon, WA 98273
(206) 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
(206) 676-6806
Salmon hatchery; 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.

Nisqually Reach Nature Center
4949 D'Milluhr Road NW
Olympia, WA 98506
(206) 459-0387
New building under construction. Completion scheduled for Summer 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
(206) 385-5582
Touch tanks and education programs available.

Poulsbo Marine Science Center
17771 Fjord Drive NE
Poulsbo, WA 98370
(206) 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
(206) 378-4710
Museum and research dedicated to whales; curriculum for elementary grades.

Washington State Office of Environmental Education
17011 Meridian Avenue North, Room 16
Seattle, WA 98133-5531
(206) 542-7671
A resource center for environmental educators; offers curriculum materials, films, videos and teacher workshops.

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.

The 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.

Publications

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.

Estuary Arts and Literature Resources

Books

Bartram, John. Travels through North and South Carolina, Georgia. . . . Philadelphia: James & Johnson, 1791.
Adventures from an early naturalist's explorations of the Southeast lowlands.

Beston, Henry. The Outermost House. New York: Henry Holt, 1956.
Chronicles the thoughts from a solitary year spent on a Cape Cod beach.

Carson, Rachel. The Edge of the Sea. Boston: Houghton Mifflin, 1956.
The celebrated marine biologist's view of the dynamic sea coast zone.

Conroy, Patrick. The Prince of Tides. Boston: Houghton Mifflin, 1986.
A passionate story of a family's life in the saltwater tidelands of South Carolina.

Couffer, Jack and Mike. Salt Marsh Summer. New York: Putnam, 1978.
Collected stories from the residents of the Black Bay salt marsh area.

Dean, Jana. Wetland Tales. Olympia: Washington State Department of Ecology, 1992.
A compiliation of wetland stories.

Gates, David Allan. Seasons of the Salt Marsh. Greenwich: Chatham, 1975.
Explores the dynamics of the estuary.

Hedgpeth, Joel. The Outer Shores. Eureka: Mad River, 1978.
Journal entries and stories from the Ricketts /Steinbeck voyages of the Pacific coast.

Lindbergh, Anne Morrow. Gift From the Sea. New York: Pantheon, 1955.
Personal meditations from the seashore.

Manning, Harvey Williams. Walking the Beach to Bellingham. Seattle: Madrona, 1986.
Adventures of a renowned walker.

Michener, James. Chesapeake. New York: Random House, 1978.
Four centuries of stories about the people, oysters, crabs, and ducks of the bay.

Reiger, George. Wanderer on my Native Shore. New York: Simon and Schuster, 1983.
A naturalist's personal guide and tribute to the ecology of the U.S. Atlantic coast.

Steinbeck, John. The Log from the Sea of Cortez. New York: Viking, 1951.
A writer's view of the famous scientific expedition through the Gulf of California.

Teal, John and Mildred. Life and Death of the Salt Marsh. Boston: Little, Brown, 1971.
A look into the living cycles and history of an Atlantic coast marsh.

Warner, William. Beautiful Swimmers. Boston: Little, Brown, 1976
Pulitzer Prize winning look at the animals and people of Chesapeake Bay.

Short Stories/Excerpts

Cousteau, Jacques. "A Sea of Legends." In Jacques Cousteau: The Ocean World. New York: H.N. Abrams, 1979.

Davis, Norah Deakin. "The Birdfoot Delta." In The Father of Waters - A Mississippi Chronicle. San Fransisco: Sierra Club, 1982.

Eiseley, Loren C. "The Star Thrower." In The Star Thrower. New York: Time Books, 1978.

Frost, Robert. "Sand Dunes." In West Running Brook. New York: Henry Holt, 1928.

Frost, Robert. "West Running Brook." In West Running Brook. New York: Henry Holt, 1928.

Hay, John. "The Common Night." In The Run. New York: Norton, 1979.

Hay, John. "In Front of the Sea." In In Defense of Nature. Boston: Little, Brown, 1969.

Leighton, Clare. "The Magic of the Flats." In "Where the Land Meets Sea." In Sisters of the Earth, New York: Vintage, 1991.

Matthiessen, Peter. "The Restlessness of Shorebirds." In The Wind Birds. New York: Viking, 1973.

Simon, Ann. "Wetlands." In The Thin Edge, New York: Harper and Row, 1978.

Stuart, Floyd. "The Salt Marsh." The Atlantic, October, 1987.

Poems

Bogan. Louise. "Night." In The Blue Estuaries. City: Farrar, Straus, & Giroux, 1968.

Daley, Michael. "Evening" and "Unquiet: A Notebook for the Submarine." In The Straits. Port Townsend: Empty Bowl, 1983.

Hugo, Richard. "Duwamish Head," "At the Stlli's Mouth," and "La Push." In Selected Poems. New York: Norton, 1979.

Lanier, Sidney. "The Marshes of Glynn." In Poems. Baltimore: Johns Hopkins, 1945.

Martin, Connie. "Mud Bay." In The Shelter of the Roar. Cambridge: Yellow Moon Press, 1979.

Mc Closkey, David. Mountains, Rivers, Sea and Sky: Nature Poetry from Cascadia. Seattle: Cascadia Institute (Unpublished as of 8/92).

Roethke, Theodore. "The Meditation at Oyster River," "The Rose," and "The Long Waters." In The Far Field, New York: Doubleday, 1964.

Stafford William. "At the Salt Marsh" and "Sauvies Island." In Stories That Could Be True. New York: Harper and Row, 1977.

Snyder, Gary. "What Happened Here Before" and "Night Herons." In Turtle Island. New York: New Directions, 1974.

Whitman, Walt. "Seashore Fancies." In Specimen Days and Collect. Philadelphia: R Welsh, 1882.

Thomas, Dylan. "Author's Prologue", "Poem In October" and "Over Sir John's hill." In The Collected Poems of Dylan Thomas 1934-1956. New York: New Directions, 1957.

Wagoner, David. "An Offering from Dungeness Bay," "Return to the Swamp" and "Driftwood." In In Broken Country. Boston: Little, Brown, 1979.

Whitman, Walt. "On the Beach at Night Alone" and "As I Ebb'd with The Ocean of Life." In Leaves of Grass. Boston: Thayer & Eldridge, 1860.

Williamson, W.M. The Eternal Sea: An Anthology of Sea Poetry. City: Books For Libraries, 1946.

Paintings

Bartlett, William Henry. "View of the Bay and Harbor . . ." In The Hudson Rivers and its Painters. By John K. Howatt. New York: Viking, 1972.

Cropsey, Jasper Francis. "Shad Fishing on the Hudson." In Jasper F. Crospey 1823-1900. By William S. Talbot. Washington, D.C.: Smithsonian Institution Press, 1970.

Gifford, Sanford Robinson. "Sunset Over New York Bay." In The Hudson River and its Painters. By John K. Howatt. New York: Viking, 1972.

Gussow, Alan. "Rock Weed at Neap Tide." In A Sense of Place: The Artist and The American Land. San Francisco: Friends of the Earth, 1970.

Heade, Martin Johnson. "The Coming Storm." In Heade, Martin Johnson 1819-1904., New York: Pantheon, 1948.

Homer, Winslow. "Watching the Harbor," "Fishergirls on the Beach," and "Hudson River Logging." In Winslow Homer Watercolors. New Haven: Yale, 1986.

Hunt, William Morris. "Sand Bank with Willows; Magnolia." In Art Life of William Morris Hunt. Boston: Little, Brown, 1900.

Jamison, Phillip. "Anthony's Fish House: Maine Marshland" and "Low Tide." In Capturing Nature in Water Color. New York: Watson-Guptill, 1980.

Kensett, John Frederick. "Twilight on the Sound, Darien, Connecticut." In John Frederick Kensett Exhibition. New York: Eastern, 1968.

Pellew, John C. "A Salt Marsh," "Ipswich Marsh," and "Saugatuck Marsh." In Painting Maritime Landscapes. New York: Watson-Guptill, 1973.

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.

Music

Debussy, Claude (1862-1918). "La mer." EMI, 1989.

Smetana, Bedrich (1824-1884). "The Moldau." Mercury, 1961.

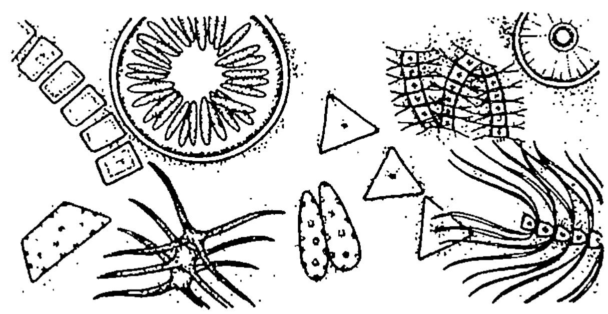
Writing

Macrorie, Ken. The I-Search Paper. Revised Edition of Searching Writing. Portsmouth: Boynton/Cook, 1988.

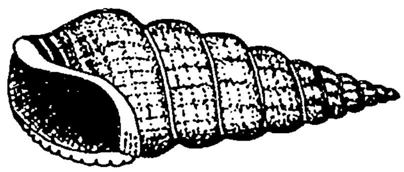
A Field Guide to Padilla Bay Organisms

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, so someone listed with the eelgrass community may also be found on bare mud flats.

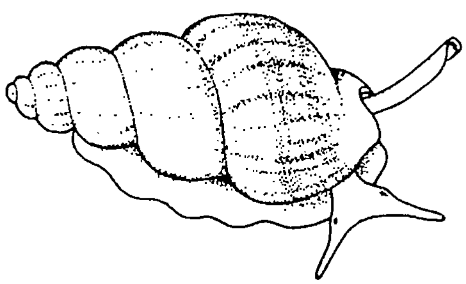
Mudflat Habitat



Diatoms - Though the mud may look barren, it is actually 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.

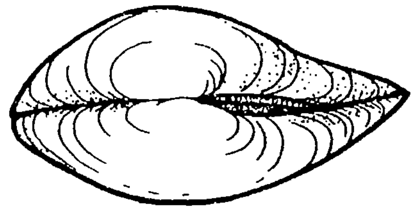


Mud Snail - *Batillaria attramentaria* - This snail covers Padilla Bay's mudflats, though it can be rare in other areas of Washington. Its thin, spiral shell is about 2.5 cm long and is decorated with bands of dark brown spots. It plows along the mud surface scraping up diatoms and detritus. *Batillaria*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

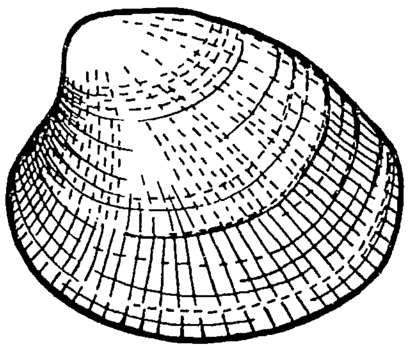


Nassarius - *Nassarius fraterculus* - This snail is smaller than *Batillaria*, with more pronounced ridges running lengthwise across the spirals. Its shell has an obvious notch on the aperture (opening) through which it extends its "inhalent siphon."

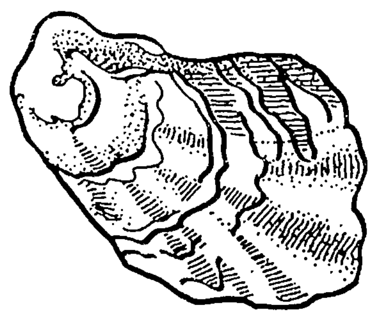
Mud Clam - *Mya arenaria* - Also called the "soft-shelled clam", this clam reaches about 10 cm in length and burrows down in the mud to about 20 cm. Its shell is white or gray, with brown or black shades around the edges. The mud clam is a "gaper", unable to completely close its shell at the neck.



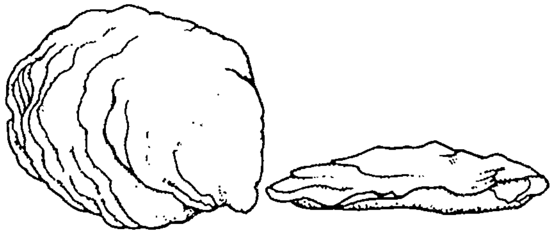
Bent-nosed Clam - *Macoma nasuta* - The bent valves of this clam make it easy to identify. It is about 5 cm long and is white with a brown covering. The periostracum is the covering over the shell which gives it its color. This is often rubbed off, so older clams tend to be whiter than younger ones.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



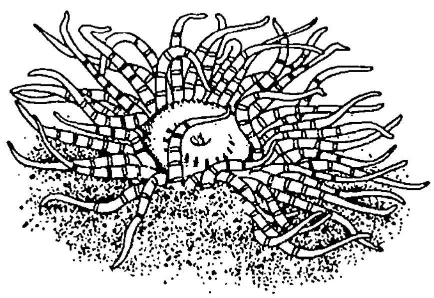
Littleneck Clam - *Protothaca staminea* - This is the common "steamer" found in restaurants and grocery stores. Its heavy, round shell is marked by ridges which run both radially and concentrically. Its siphon is very short (hence the name littleneck) so it is limited to life just under the mud surface.



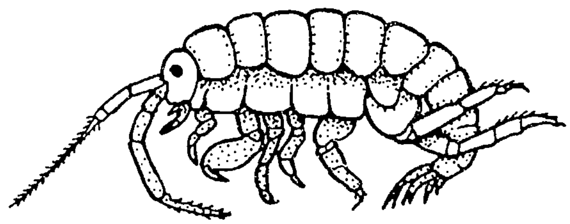
Pacific or Japanese Oyster - *Crassostrea gigas* - This is a large oyster, imported from Japan in the early 1900s. It rarely spawns here in the Pacific Northwest (the water is too cold), so oyster growers must continually bring in spat (microscopic larval stage) from Japan to replenish their beds. Along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



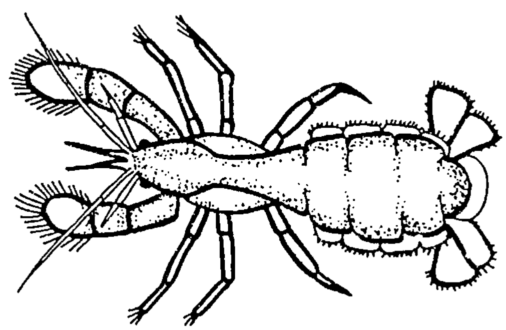
Native Oyster - *Ostrea lurida* - Reaching only about 5 cm, the native oyster is especially sensitive to pollution. It is good to eat, though its small size limits its commercial value. Its shell is rough and gray and often found under rocks. It doesn't have the "fluted" edge found on the Pacific oyster.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



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.

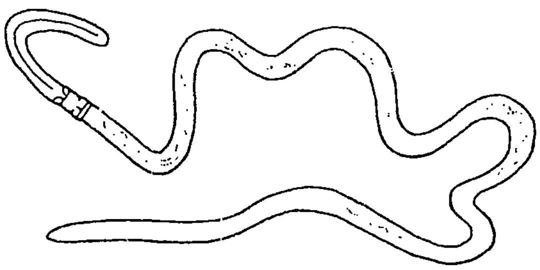


Amphipod - There are about 35 different species of amphipods in Padilla Bay. They are tiny crustaceans resembling a shrimp. The common "sand flea" found in beach wrack is one kind of amphipod. Others are associated with certain algae and are bright green in color. The small, brown amphipod found in tidal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

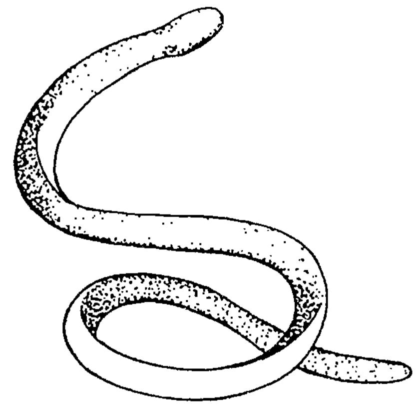


Mud Shrimp - *Upogebia pugettensis* - The "excavator" of the mudflats, this mud shrimp digs extensive burrows in the mud which are then used by many other organisms. The shrimp is about 6-8 cm long with a soft, bluish shell. It uses its feathery pinchers to trap detritus loosened by leaf-like "spinnerettes"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

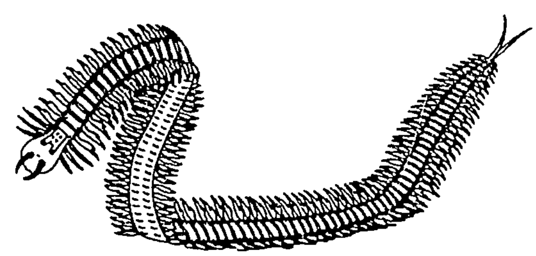
It tends to live in sandier mud, though both shrimp can be found together. Clams, worms, crabs, copepods and isopods associate with the mud shrimp.



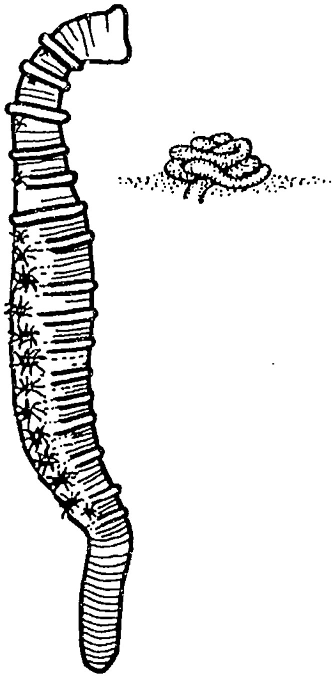
Tongue or acorn worms - *Saccoglossus* sp. - These worms leave fine, almost hair-like fecal castings on the mud surface. The worm itself is 10 to 20 cm long with three distinct body regions. The anterior section is yellow-orange and resembles a tongue. The last section is brownish, long and very fragile. 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".

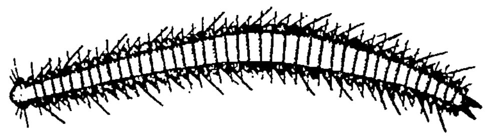


Mud Nemertean or Ribbon Worm - *Paranemertes peregrina* - This dark brown-purple worm slides along the mud surface on its track of slime. It is carnivorous, feeding on smaller polychaete worms which it subdues with venom before swallowing them whole.



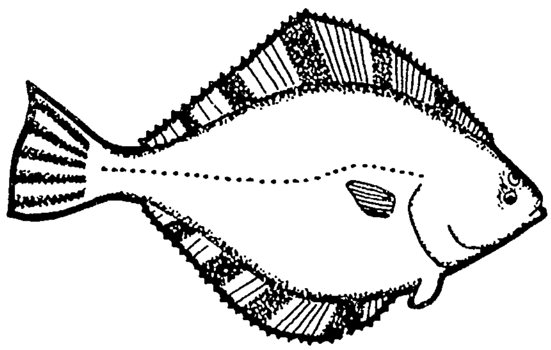
Polychaete Worms - This group of worms is well represented on the mudflats. Polychaetes are made of many segments, each with "parapodia", leg-like structures on each side. Many are microscopic or seldom seen. Others, like those listed below, are conspicuous members of the mudflat community.





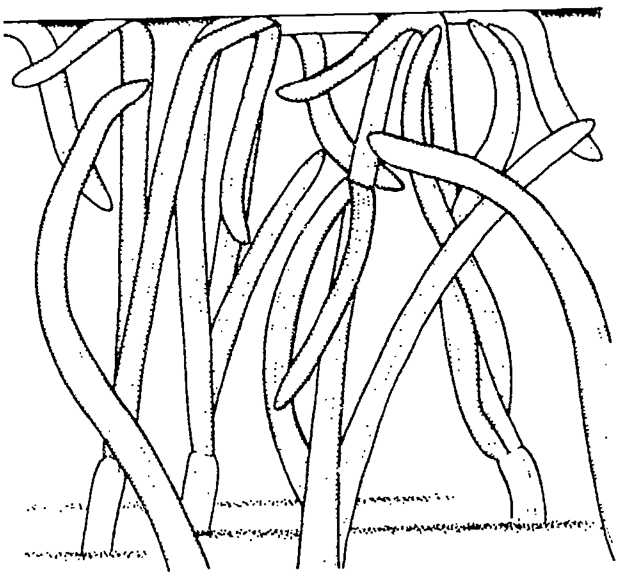
Ophiodromus - *Ophiodromus pugettensis* - This small, reddish-brown polychaete can be found swimming, serpentine-style, in the mud "puddles" left behind by the tide. It is omnivorous, eating diatoms, small crustaceans and detritus. *Ophiodromus* is often found living commensally on certain sea stars.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

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.

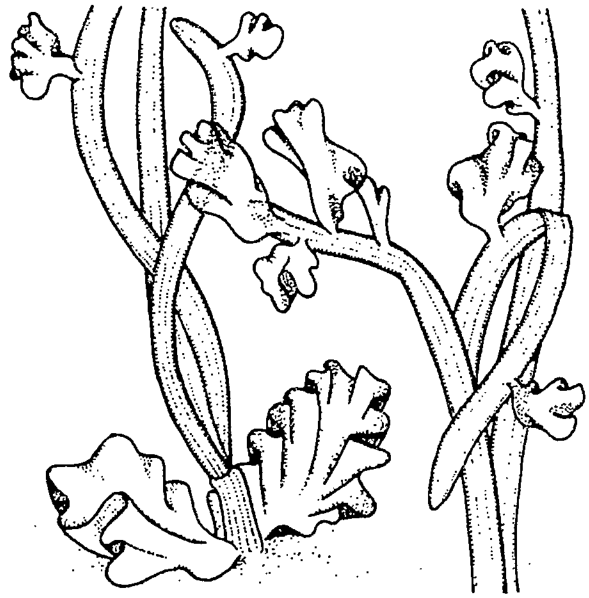


Starry Flounder - *Platichthys stellatus* - This flat fish skims along the mudflat eating crustaceans, worms and small fish. The starry flounder is one of the few flat fish which can have both eyes on either the right side or left side. It is born with an eye on each side. After about 2 weeks, one eye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

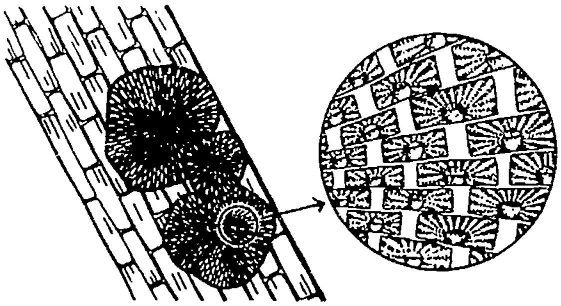
Eelgrass Habitat



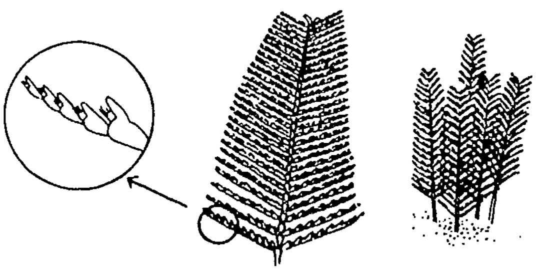
Eelgrass - *Zostera marina* and *Zostera japonica* - Native eelgrass *(Z. marina)* is a bright green grass, about 5-10 mm wide and up to 2 m long. It plays a vital role in the Padilla Bay ecosystem, stabilizing sediments, producing oxygen and organic materials, and providing valuable habitat to many 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.

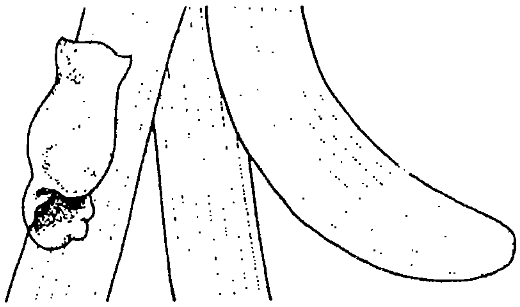


Bryozoans - These colonial animals often grow on eelgrass blades in round, white patches. They build tiny, regularly-shaped boxes called zooids in which individual animals live. Their tentacles catch plankton and detritus passing by, and they can withdraw into their "houses" for protection. They are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

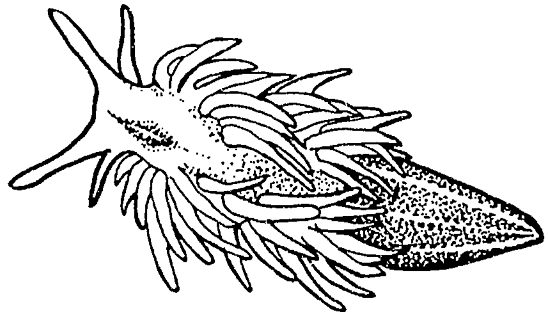


Hydroids - Like bryozoans these, too, are colonial animals though individual hydroids are much more specialized. The hydroid colony looks much like a clump of branching algae but examination with a hand lens or microscope will reveal tentacles for feeding and budding reproductive structures at the tips 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.

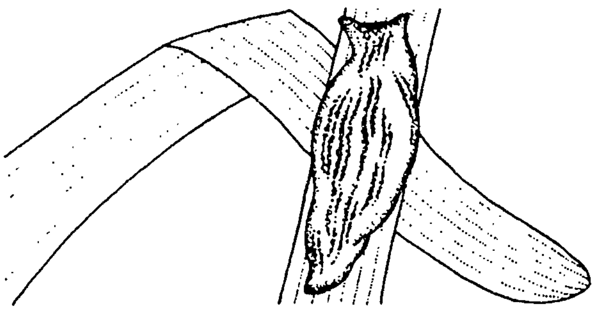
Brooding Anemone - *Epiactus prolifera* - This small anemone is common on eelgrass blades where it feeds on plankton, small crustaceans, and detritus. It is marked by white stripes on its column and "oral disk" and ranges in color from red to brown to green. Its eggs are fertilized in its digestive cavity.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



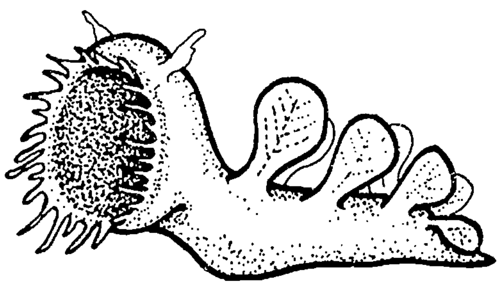
Bubbleshell - *Haminoea vesicula* - This snail relative looks something like a cross between a snail and a sea slug. It has a thin shell which is nearly covered by the mantle, making its appearance much more "sluggish". It forages along eelgrass blades and the mud surface scraping up food with its tongue-like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



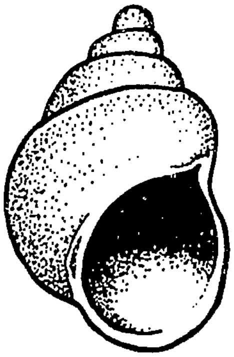
Opalescent Nudibranch - *Phidiana crassicornis* - This nudibranch is common in eelgrass beds as well as in other habitats. It is covered with orange-tipped plumes called cerrata which may act like gills. *Phidiana* eats a variety of foods including hydroids, other molluscs, eggs, and bits of detritus. 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.



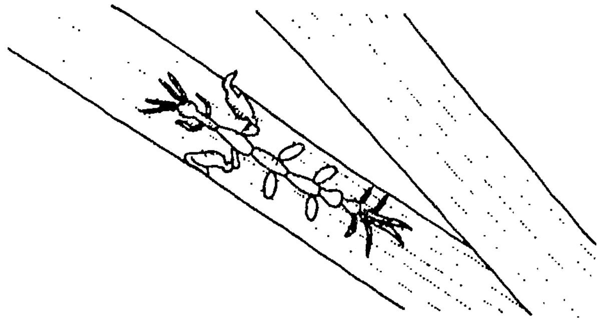
Taylor's Sea Slug - *Phyllaplysia taylori* - This attractive, green sea slug is perfectly camouflaged to hide on eelgrass. It lies flat between the blades when the tide is low, and can be difficult to find in spite of prolific numbers. Its clear eggs are laid in rectangular patches on the eelgrass, making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



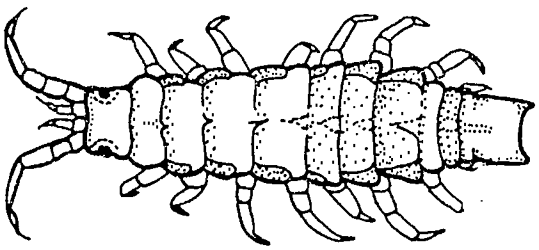
Hooded Nudibranch - *Melibe leonina* - This strange looking, colorless nudibranch moves slowly around the eelgrass beds catching small crustaceans with its fringed "oral hood". It can grow up to 10 cm long and is able to swim (somewhat) using thrashing movements. It can also fill its hood with air and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



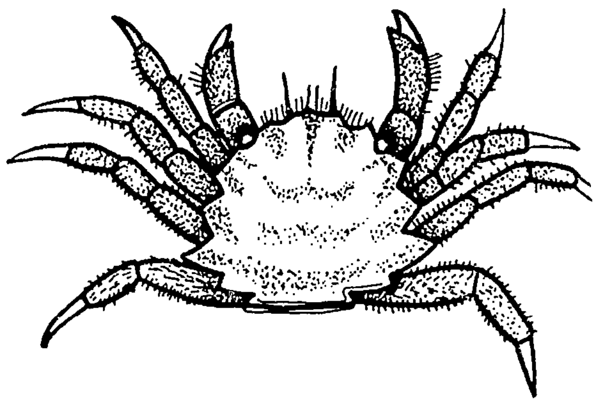
Lacuna variegata - A tiny snail often found on eelgrass blades, this herbivore scrapes diatoms and bacteria from the plant surface with its radula. It can also consume eelgrass tissue, though its small size limits the damage can do. *Lacuna's* yellow eggs are laid in donut-shaped rings and are often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



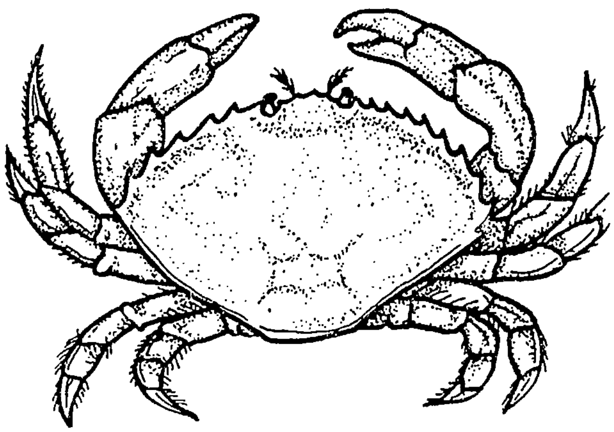
Skeleton Shrimp - This odd-looking crustacean is actually a type of amphipod called a caprellid amphipod. It hooks its hind legs onto eelgrass and with a "bowing" motion, picks up bits of detritus, diatoms, and hydroids with its front claws. Club-like gills protrude from the thoracic segments, and females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



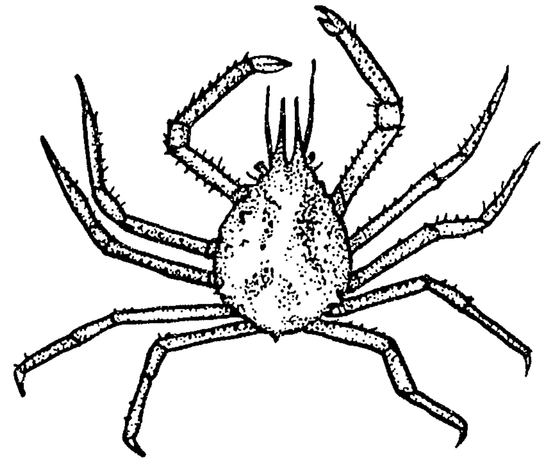
Eelgrass Isopod - *Idotea resecata* - This crustacean is perfectly adapted to life in the eelgrass. Its shape and color blend in perfectly and its diet consists of eelgrass and algae. It swims gracefully from plant to plant, avoiding fish predators. Females carry the eggs and then the young until they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



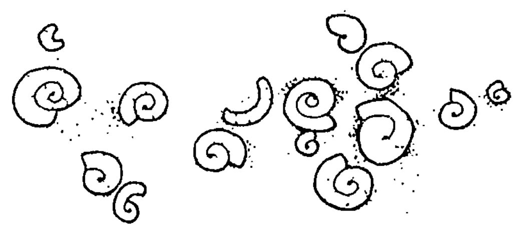
Helmet Crab - *Telmessus cheiragonus* - This hairy, bristly crab rambles around the eelgrass and kelp beds feeding on algae. It can be identified by its yellowish-greenish color when young and by six widely spaced points on each side of its carapace. Adults show a more orange or red color.



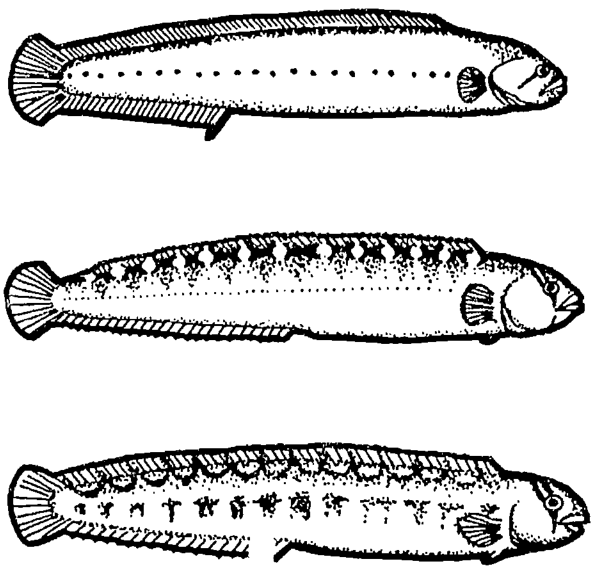
Dungeness Crab - *Cancer magister* - This is the target of crab pots, found in fish markets and restaurants throughout Puget Sound. Though the adults can be found in deep water, juveniles tend to congregate in eelgrass beds. How they get there is still a mystery to researchers, but it seems that the 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.



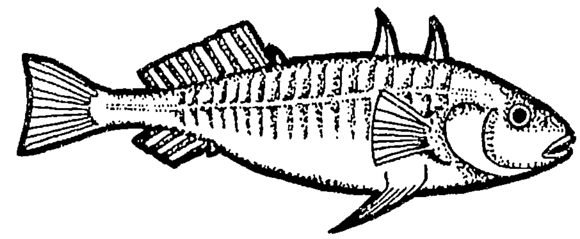
Decorator Crab - *Oregonia gracilis* - This spider crab has a rough, triangular carapace on which such colonists as algae, hydroids and bryozoans easily grow. Its long, thin legs give it a "spidery" look, and its delicate pinchers can skillfully add to the "decorations".



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.

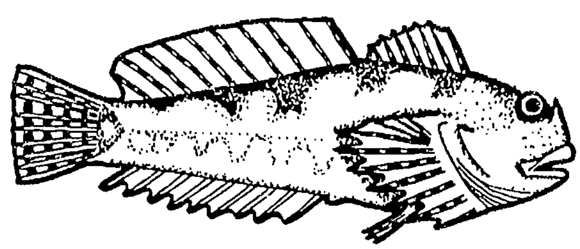


Gunnel - Several different species of gunnels are found in Padilla Bay eelgrass habitat. The long, compressed body resembles that of an eel. Some gunnels reach 18", though 6"-10" is more common. They eat small crustaceans and molluscs.

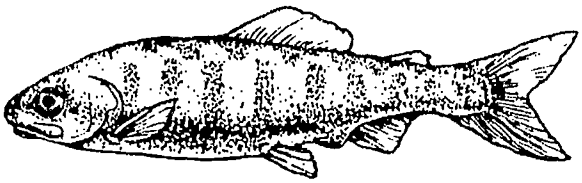


Threespine stickleback - *Gasterosteus aculeatus* - This adaptable fish is found in both fresh and salt water and is a common inhabitant of eelgrass meadows. Under 4" long, this small, sturdy-looking fish eats a wide range of foods from smaller fish to tiny crustaceans and planktonic larvae of crabs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

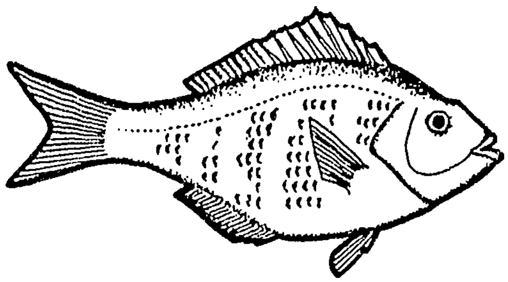
Bay Pipefish - *Syngnathus griseolineatus* - A relative of the sea horse, the pipefish has a stiff, narrow body with an elongated "snout". It can change its color from green to brown to match its eelgrass surroundings, and swims vertically, mimicking the swaying motion of the grass. The male incubates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



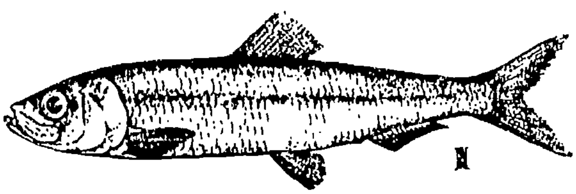
Sculpin - Many members of the sculpin family live in Padilla Bay, including the staghorn, silver-spotted, and grunt sculpin. Sculpins are recognized by their "fat", blunt heads and large pectoral fins. They tend to be slow and lethargic, "sitting" on the muddy bottom and waiting for food rather than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



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.

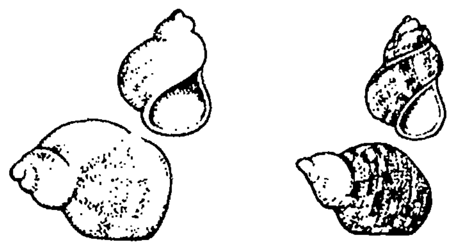


Perch - Two part-time residents of Padilla Bay are the striped and shiner perch -- oval and silvery fish -- that eat skeleton shrimp and other small crustaceans living on the eelgrass. They vary in size from 6" to 15" and often move out to deeper water in the winter.

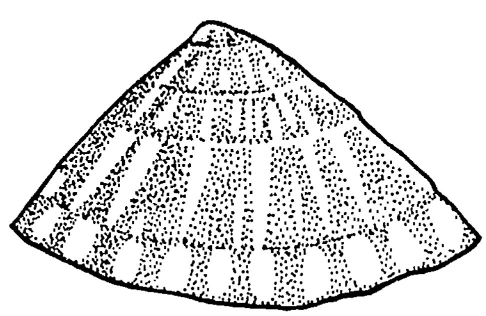


Pacific Herring - *Clupea harengus* - Padilla Bay is a major holding area for herring. Adults span in late winter, laying great masses of sticky eggs on eelgrass, kelp, and rocks in the bay. The young feed on copepods, various larvae and young fish, all abundant in Padilla Bay. (Reproduced with the permission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

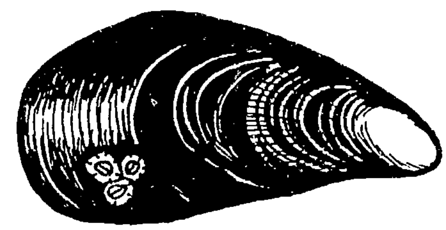
Rocky Habitat



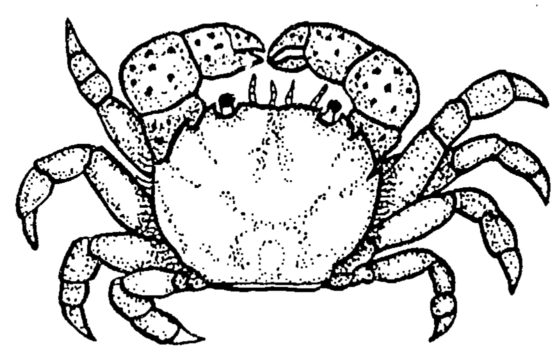
Periwinkle - *Littorina* sp. - Look for this small, dark snail on rocks high in the intertidal zone. A close examination may reveal a checkered pattern on the shell, indicating the checkered periwinkle, *L. scutulata*. The similar but slightly rounder Sitka periwinkle lacks the checkered markings. Periwinkles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



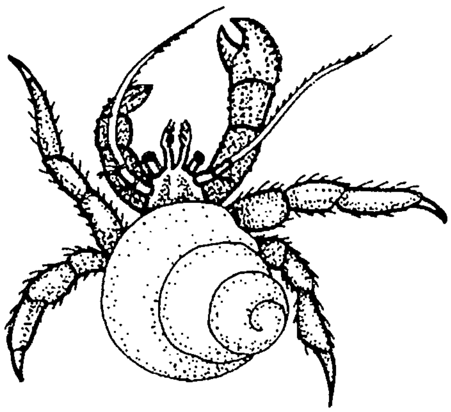
Limpets - Many different species of limpets graze on the rocks near the Padilla Bay shore. These snail relatives scrape algae from the rock and mud surface with a rough tongue-like radula. Their shell fits exactly to one site on "their rock" enabling them to seal water inside their shell during low tides.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



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.



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.



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.

Credits for Illustrations for this Section

Rebecca Hyland: artist
diatoms
Nassarius
mud clam
native oyster
burrowing anemone
tongue worm
polychaete
Ophiodromus
eelgrass
epiphytic algae
bryozoans
hydroids
bubbleshell
Taylor's sea slug
skeleton shrimp
snail worm
periwinkle

Amy Han: artist
mud snail
littleneck clam
bent-nosed clam
Pacific or Japanese oyster
amphipod
mud shrimp
mud nemertean
lug worm
starry flounder
brooding anemone
opalescent nudibranch
hooded nudibranch
Lacuna variegata
eelgrass isopod
helmet crab
Dungeness crab
decorator crab
gunnel
bay pipefish
threespine stickleback
sculpin
perch
limpet
bay mussel
shore crab
hermit crab

Salmon credit:

Thanks to the Washington State Department of Fisheries.

Herring credit:

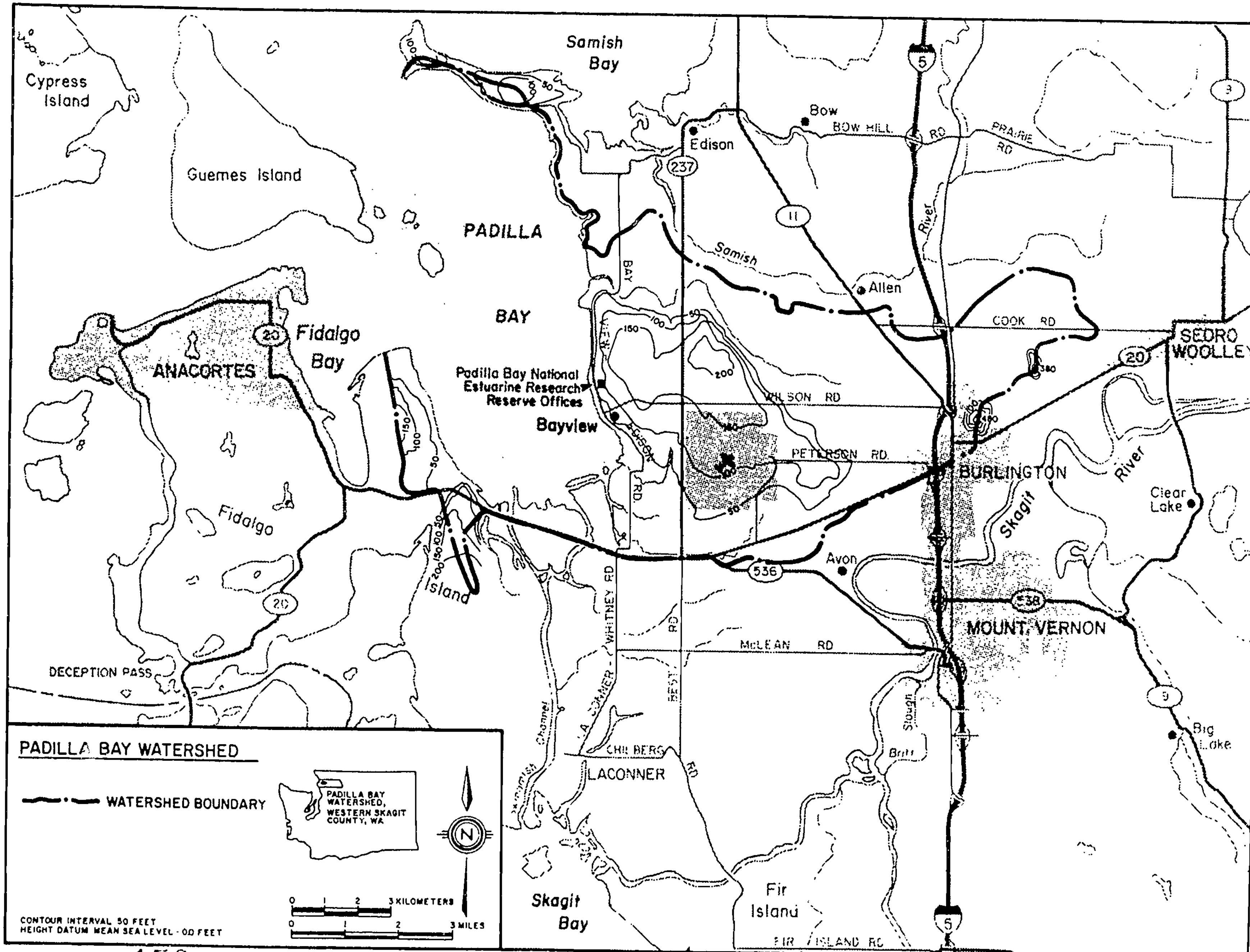
Thanks to Fisheries and Oceans Canada. From the book, Pacific Fishes of Canada, by J.L. Hart, Ottawa: Fisheries Research Board of Canada, 1973. Reproduced with the permission of the Minister of Supply and Services Canada, 1992.

Reproducible Masters

This section includes illustrations, maps, and other graphics which can be used to make student handouts or overhead transparencies.

The following are included:

1. Padilla Bay watershed map
2. Padilla Bay habitat map
3. Padilla Bay land use map
4. Pacific Northwest coast
5. Chesapeake Bay
6. North America colliding with micro-continent.
7. Puget Lobe of glacier
8. Former marshland (before diking)
9. Seattle, before and after
10. Spring tide/neap tide diagram
11. Common Padilla Bay organisms, p. 1
12. Common Padilla Bay organisms, p. 2

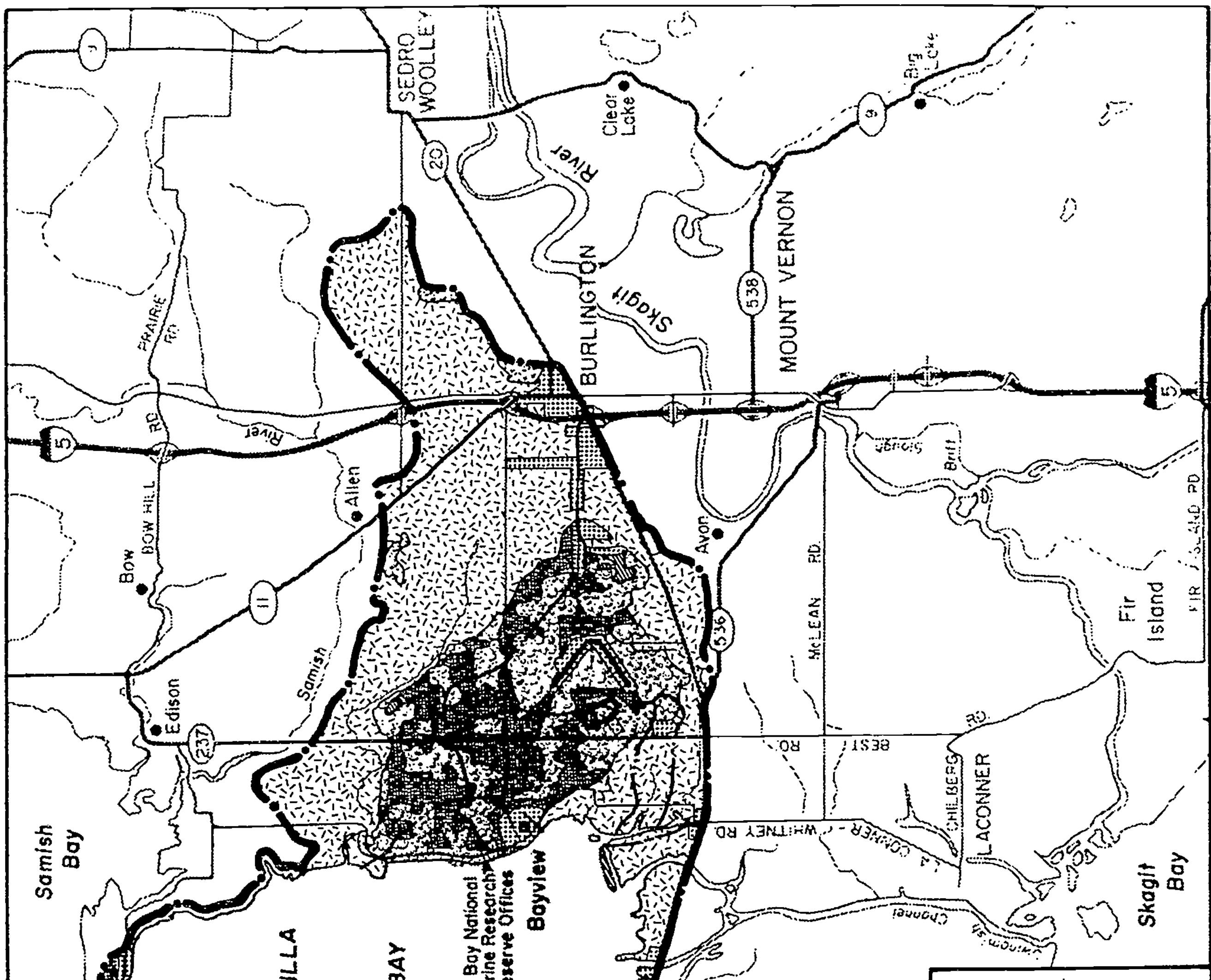


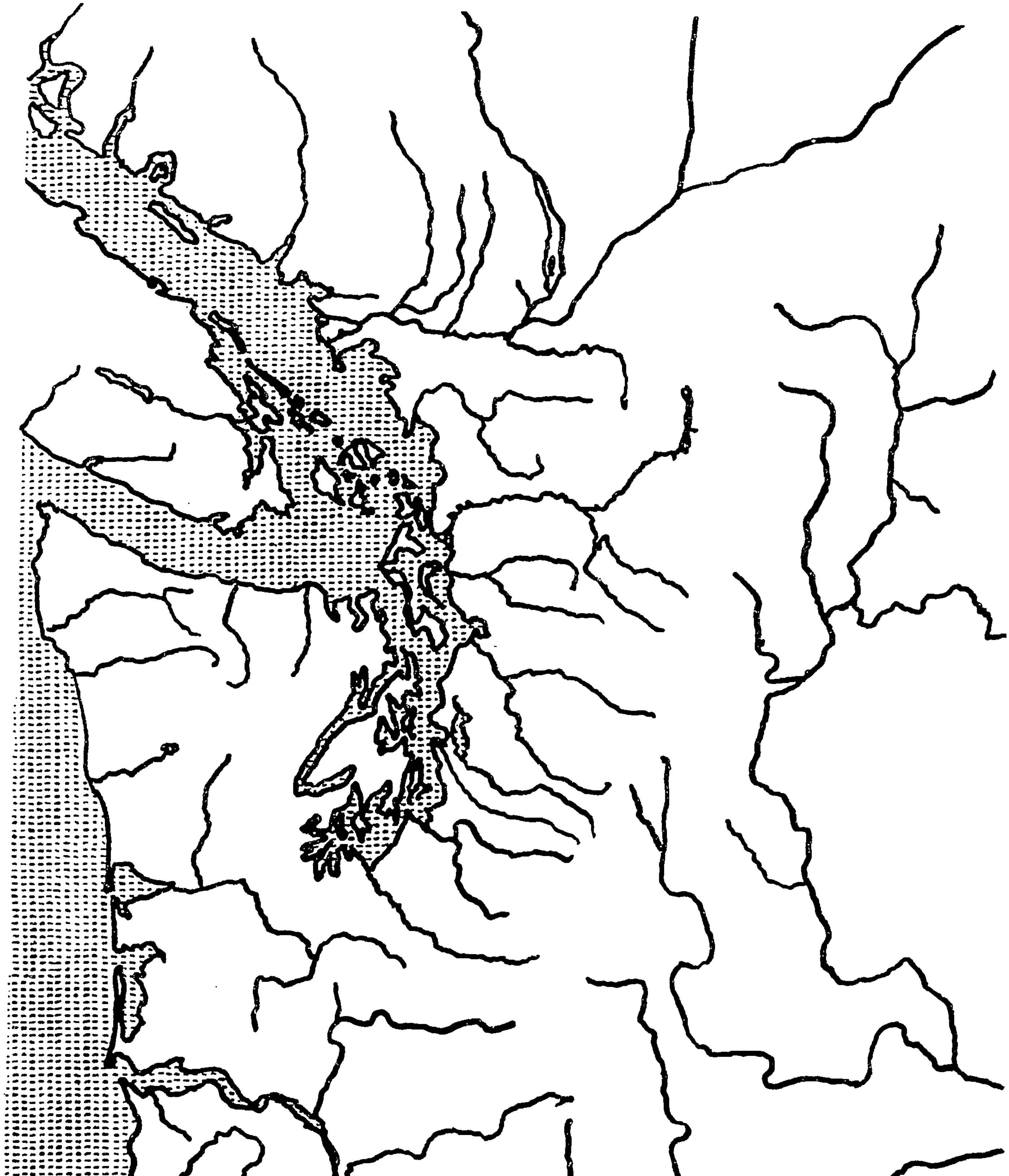
150

BEST COPY AVAILABLE

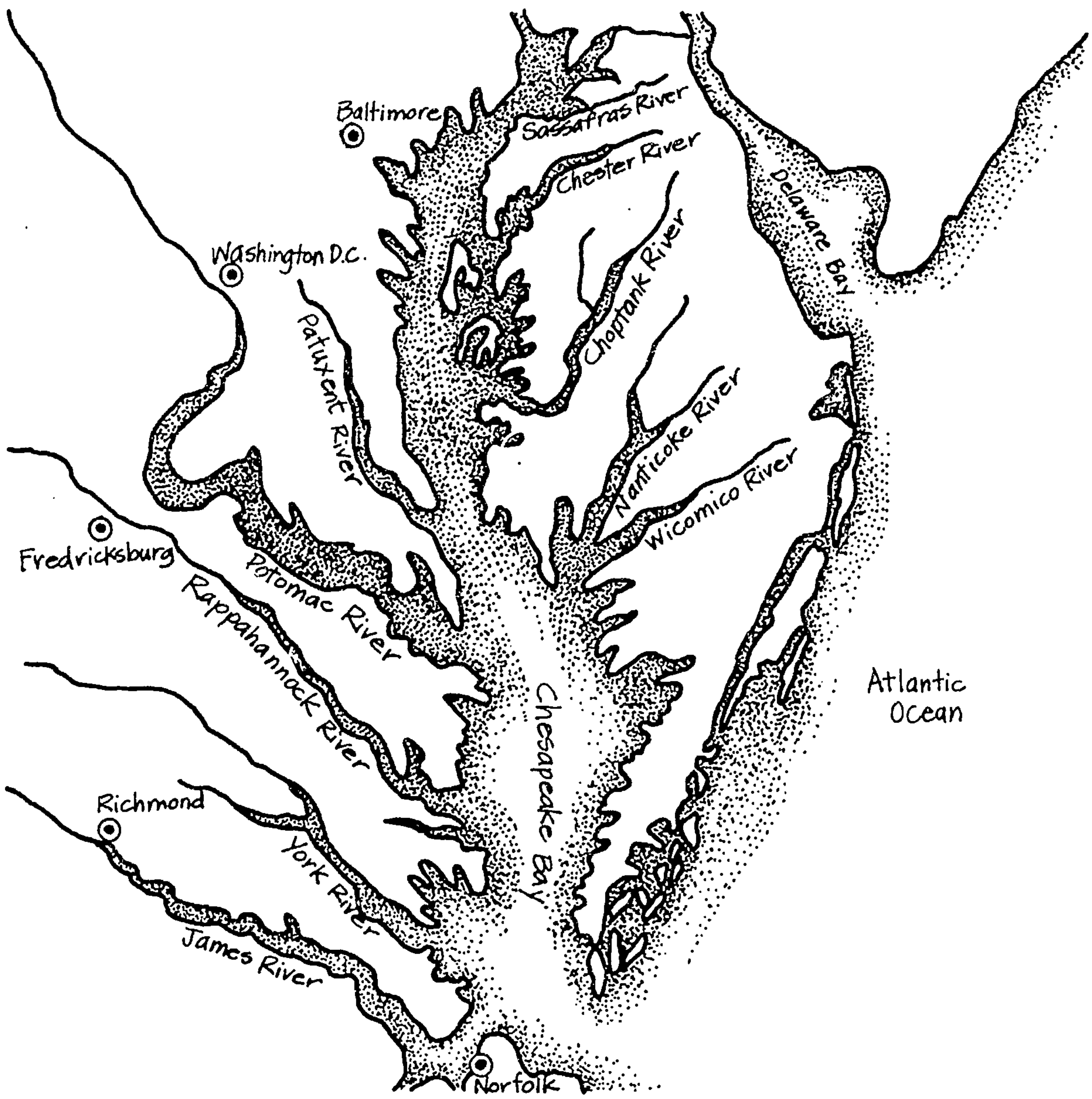
SAMISH BAY
Samish Island
Huckleberry Isl
Saddlebag Isl
Dot Isl
Hat Isl
March Point
OIL REFINERY
Padilla Bay National Estuarine Research Reserve Offices & Interpretive Center
BAYVIEW
Samish River
Joe Leary Slough
No Name Slough
Little Indian Slough
Big Indian Slough
Telegraph Slough
Swinomish Channel
British Columbia
CANADA
UNITED STATES
PACIFIC OCEAN
Washington
Oregon
PADILLA BAY
Soundings in fathoms below Mean Lower Low Water
Height in feet above Mean Sea Level
Contour interval 50 Feet
PADILLA BAY HABITATS
Eelgrass - Zostera marina
Eelgrass - Zostera japonica
Macroalgae
Intertidal Sand and Mud
Saltmarsh

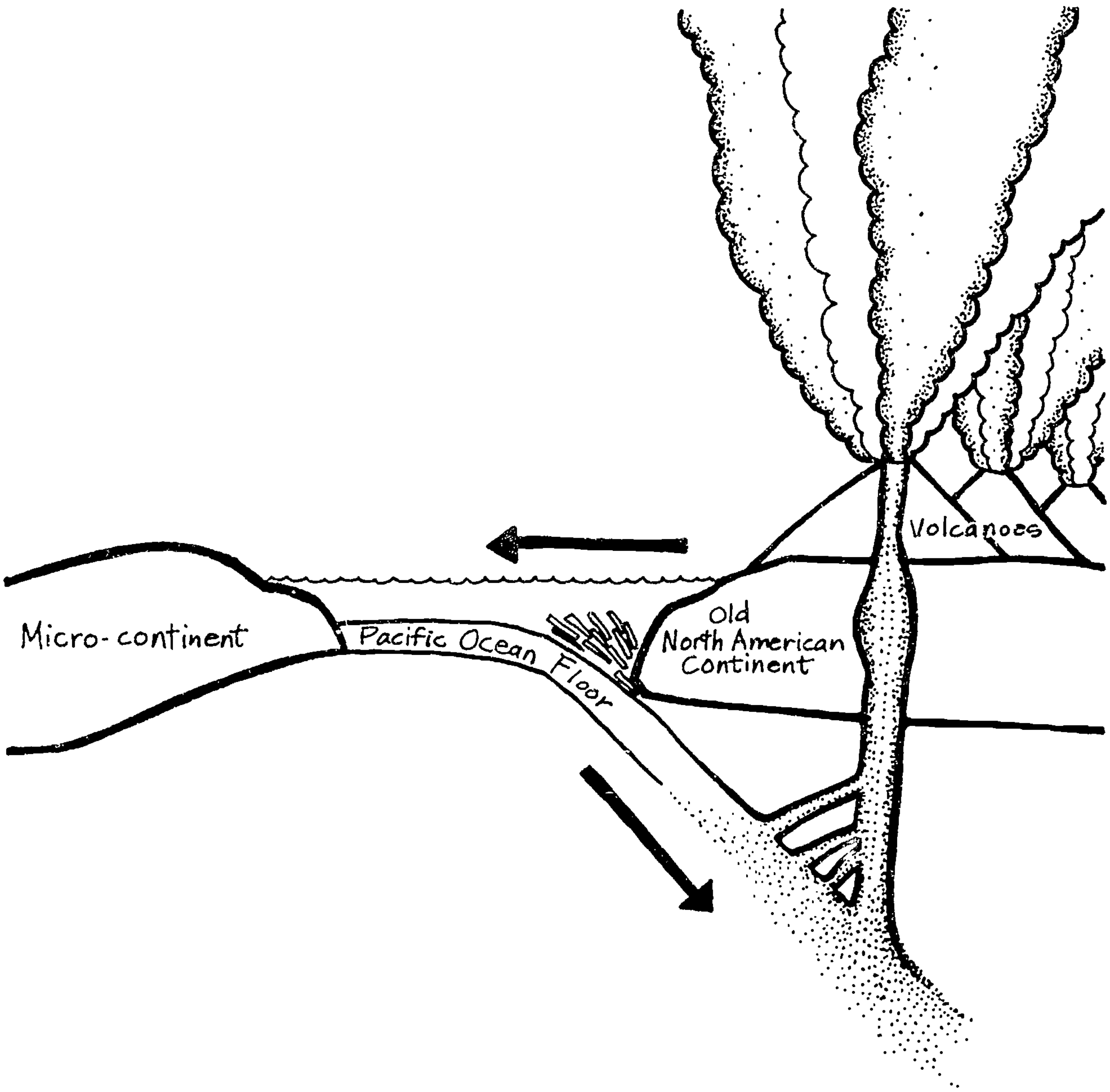
Padilla Bay

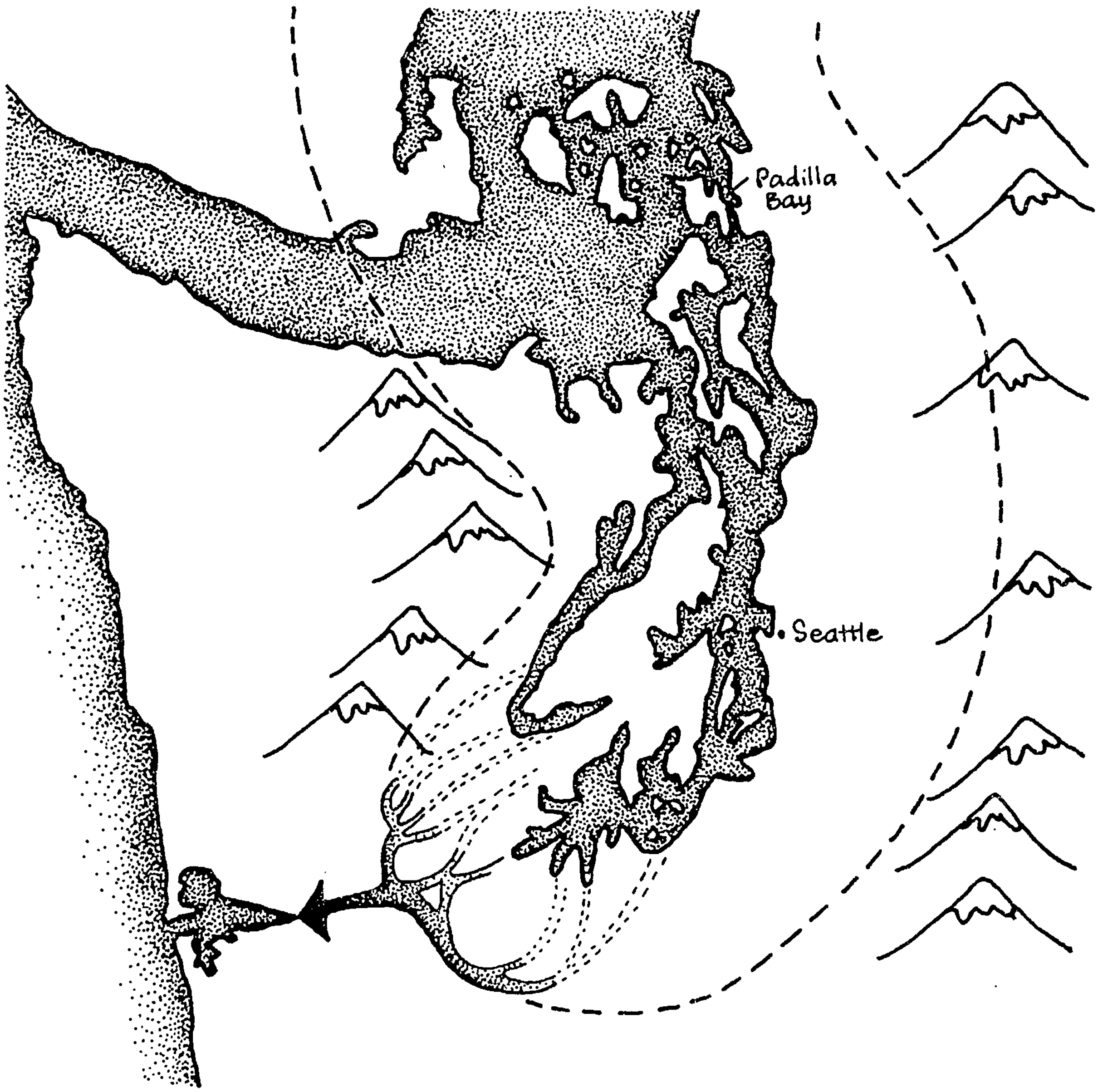

PADILLA BAY WATERSHED
LAND USE
Forest
Pasture/Hayland
Cropland
Other
Developed Commercial/Residential
Industrial (Refineries, Test Track & Airport)
WATERSHED BOUNDARY
SUB-BASIN BOUNDARY
3 MILES
3 KILOMETERS
PADILLA BAY
Padilla Bay National Estuarine Research Reserve Offices
Bayview
Samish Bay
Skagit Bay
Fidalgo Bay
Guemes Island
ANACORTES
Fidalgo
Island
Cypress Island
DECEPTION PASS
SEDRO WOOLLEY
Clear Lake
Big Lake
MOUNT VERNON
BURLINGTON
Skagit
River
Samish
Bow
BOW HILL RD
PRAIRIE RD
Allen
Edison
Avon
LACONNER
Fir Island
McLEAN RD.
BEST RD.
WHITNEY RD.
CHILBERG
Swinomish Channel

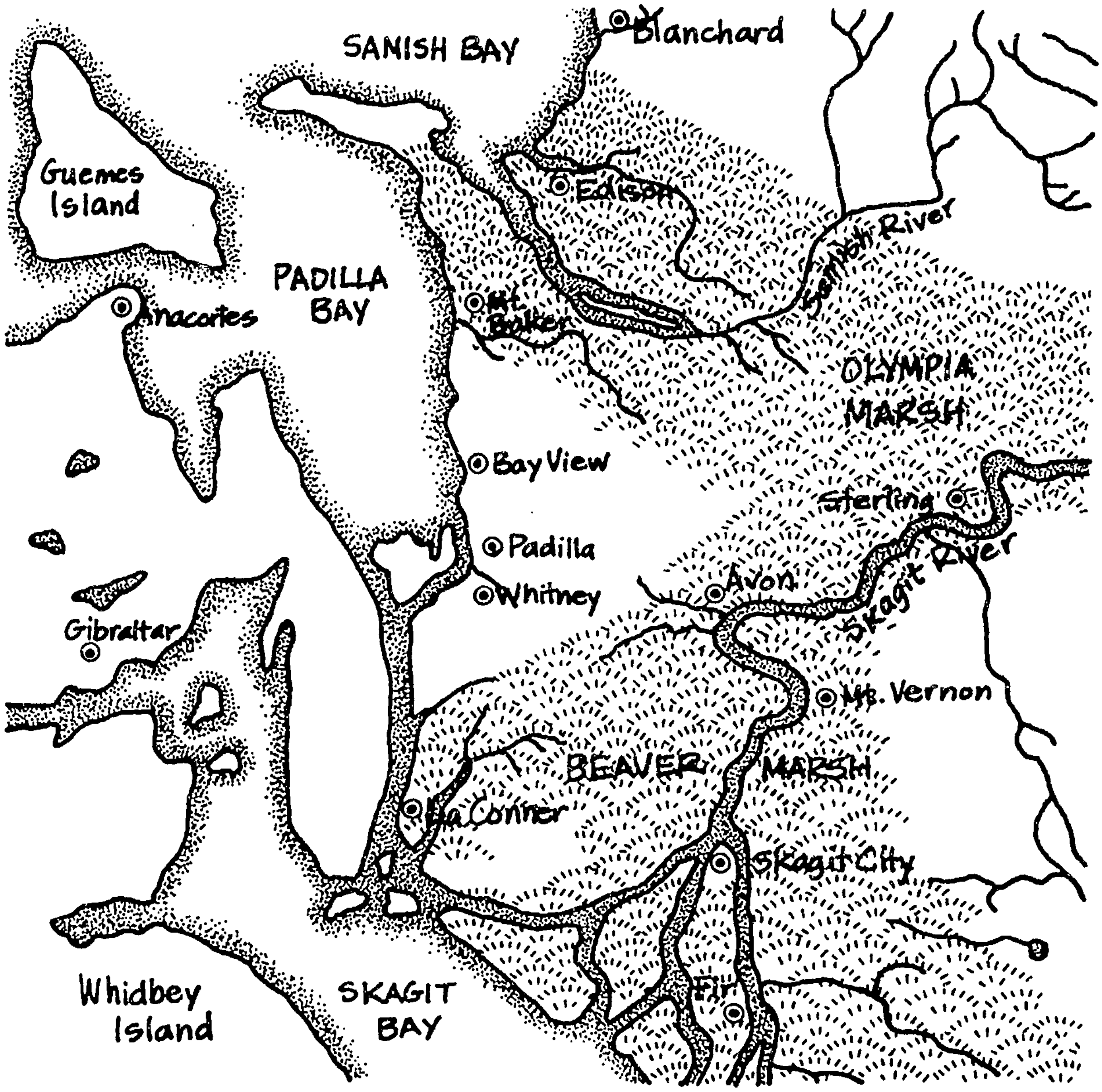


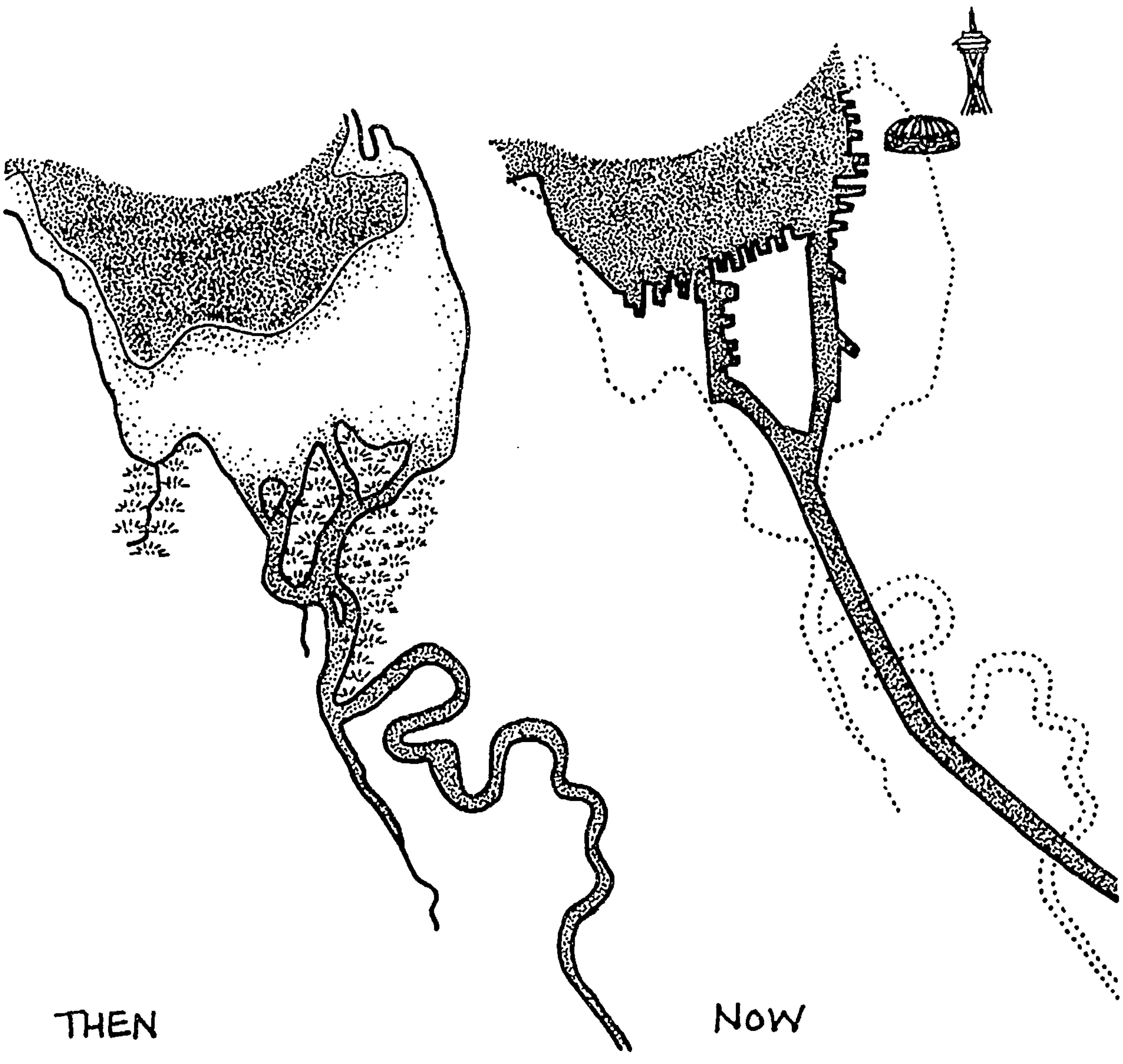
Padilla Bay

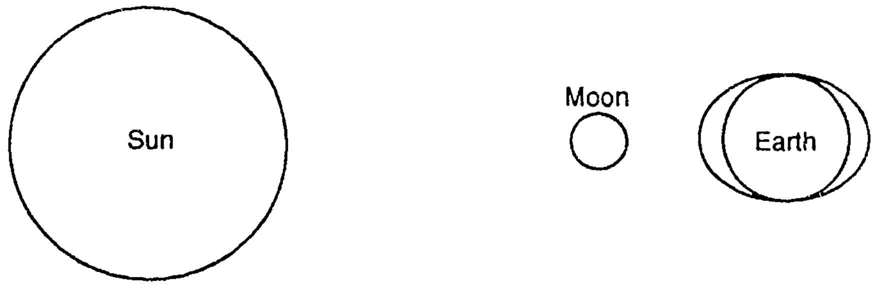

Baltimore
Sassafras River
Chester River
Washington D.C.
Patuxent River
Choptank River
Delaware Bay
Nanticoke River
Wicomico River
Fredricksburg
Potomac River
Rappahannock River
Chesapeake Bay
Atlantic Ocean
Richmond
York River
James River
Norfolk


Volcanoes
Old
North American
Continent
Micro-continent
Pacific Ocean Floor


Padilla Bay
Seattle

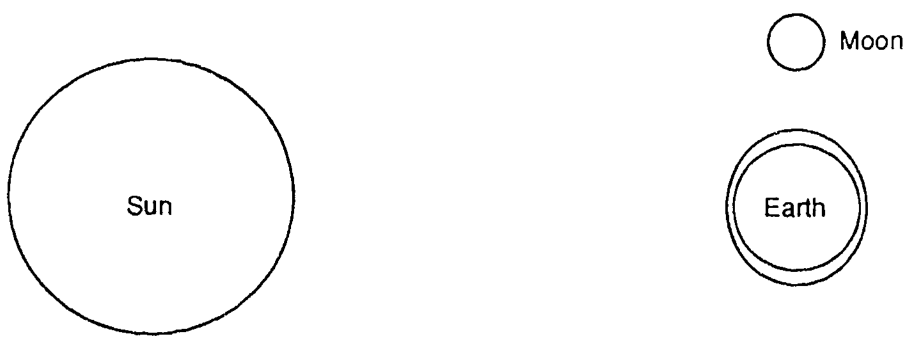

SAMISH BAY
Blanchard
Guemes Island
Edison
Samish River
PADILLA BAY
Anacortes
Mt. Baker
OLYMPIA MARSH
Bay View
Sterling
Padilla
Whitney
Avon
Skagit River
Gibraltar
Mt. Vernon
BEAVER MARSH
La Conner
Skagit City
Whidbey Island
SKAGIT BAY
Fir


THEN
NOW



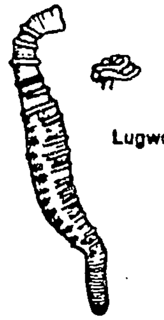
New moon * Spring tide

Full moon * Spring tide



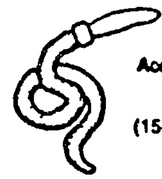
First quarter * Neap tide

Common Padilla Bay Organisms



Lugworm, *Abarenicola pacifica*
(8-10cm)

Polychaete worms
(many species, segmented)



Acorn or Tongue worm,
Saccoglossus sp.
(15-20cm, 3 body parts)

Bubble shell, *Haminoea vesicula*
(2-3.5cm, on mud or eelgrass)

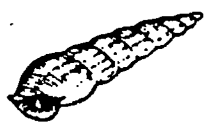
Red worm, *Ophiodromus pugettensis*
(small, 2cm, dark reddish brown)

Opalescent nudibranch,
Phidiana crassicornis
(3-4cm, orange-tipped plumes)

Taylor's sea slug,
Phyllaplysia taylori
(to 4cm, green, on eelgrass)

Nassarius fraterculus

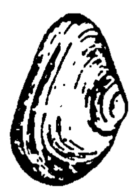
Lacuna variegata
(tiny, <7mm, lives on eelgrass)



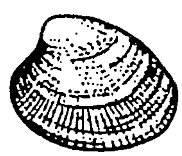
Mud snail or Auger shell,
Batillaria attramantaria

Pacific oyster, *Crassostrea gigas*

Bay mussel, *Mytilus edulus*
(6cm)



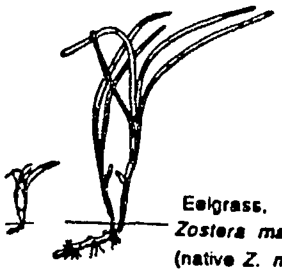
Soft-shell or Mud clam,
Mya arenaria (up to 10cm long)



Littleneck, *Protothaca staminea*
(6cm long)

Bent nose, *Macoma nasuta*
(5cm long)

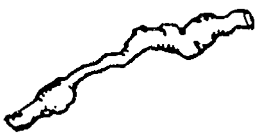
Common Padilla Bay Organisms



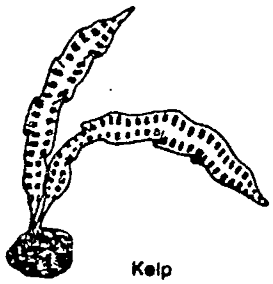
Eelgrass, *Zostera marina* and *Zostera japonica* (native *Z. marina* grows to 2m, imported *Z. japonica* to 15cm tall and 2mm wide.)

Rockweed, *Fucus distichus*
(dark, olive green)

Ceramium pacificum
(red, branching clumps)

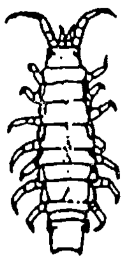


Confetti, *Enteromorpha intestinalis*
(lumpy, hollow, green tubes)

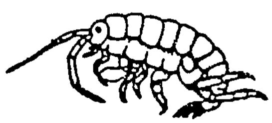


Kelp
(very large, brown sheets)

Sea lettuce, *Ulva fenestrata*
(bright green, transparent sheets)

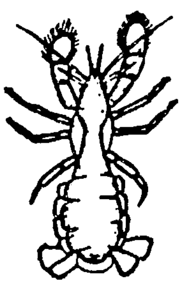


Eelgrass isopod, *Idotea resecata*
(4cm, green)

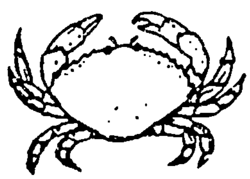


Amphipod
(many species, microscopic to 3cm)

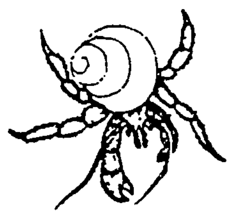
Brooding anemone, *Epiactus prolifera*
(on eelgrass, carries young on column)



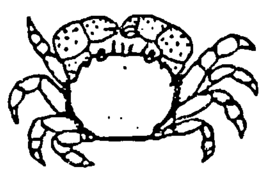
Mud shrimp, *Upogebia pugettensis*
(to 10cm)



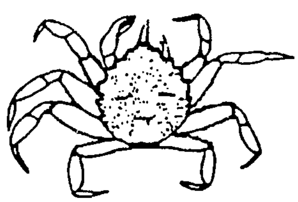
Dungeness crab, *Cancer magister*
(to 20cm)



Hermit crab, *Pagurus* sp.



Shore crab, *Hemigrapsus* sp.
(small, to 4cm)



Bristle or Helmut crab, *Telmessus cheiragonus*
(long legs but smaller carapace to 6cm)

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. <u>desirable</u>: water view, cool breeze, beach access, solitude, high market value. <u>undesirable</u>: 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. Answe·s will vary, but this information is vital to decisions about w ere, 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.

Bibliography

Alt, David D., and Donald W. Hyndman. Roadside Geology of Washington. Missoula: Mountain Press, 1984.

Brown, Mike. "Cooperative Learning in Seaside Brings Results." Clearing, Nov-Dec., 1989, pp. 24-25.

Campbell, Neil A. Biology. Reading, Massachusetts: Addison Wesley/Benjamin Cummings and Longman Publishing Co., 1987.

Carson, Rob. "Uncertain Sanctuary on Padilla Bay." Pacific Northwest Magazine, June 1983, pp. 24-27.

Curtis, Helena, and N. Sue Barnes. Invitation to Biology. New York: Worth Publishers, 1981.

Darrow, Edward E. The Science Workbook of Student Research Projects in Food-Agriculture-Natural Resources. Columbus: College of Agriculture, Ohio State University and Ohio Academy of Science, 1985.

Dillard, Annie. Pilgrim at Tinker Creek. New York: Harper & Row Publishers Inc., 1974.

Dinnel, Paul A., et al. Padilla Bay Dungeness Crab, Cancer magister, Habitat Study. Report to NOAA/OCRM/MEMD. Seattle: Fisheries Research Institute, University of Washington, 1986.

Downing, John. The Coast of Puget Sound: Its Processes and Development. Seattle: Washington Sea Grant Program, 1983.

Dyer, Keith R. Estuaries: A Physical Introduction. New York: John Wiley and Sons, 1973.

Environmental Protection Agency. "Protecting Our Estuaries." EPA Journal, Vol. 13 (6), July/August, 1987.

Hammond, B. "The Monday Group: From Awareness to Action." Project Wild: Secondary Activity Guide. City: Western Regional Environmental Education Council, 1983.

Hedgepeth, Joel. The Outer Shores. Eureka, California: Mad River Press Inc., 1978.

Kennett, James P. Marine Geology. Englewood Cliffs: Prentice-Hall, 1982.

Kolb, James. For Sea: Marine Biology and Oceanography, Grades 9-12. Poulsbo: Poulsbo Marine Science Center, 1980-81.

Kolb, James A. Puget Sound Project: The Changing Sound. Poulsbo: Poulsbo Marine Science Center, 1990.

Kozloff, Eugene N. Seashore Life of the Northern Pacific Coast. Seattle: University of Washington Press, 1983.

Lerman, Mathew. Marine Biology. Reading, Massachusetts: Addison Wesley/Benjamin Cummings and Longman Publishing Co., 1986.

Macrorie, Ken. The I-Search Paper. Revised Edition of Searching Writing. Portsmouth: Boynton/Cook, 1988.

Mann, Kenneth H. Ecology of Coastal Waters: A Systems Approach. Berkeley: University of California Press, 1982.

McKee, Bates. Cascadia: The Geologic Evolution of the Pacific Northwest. New York: McGraw-Hill Publishers, 1972.

McLusky, Donald S. The Estuarine Ecosystem. New York: John Wiley and Sons, 1981.

Michaud, Joy P. At Home with Wetlands: A Landowner's Guide. Pub. No. 90-31. Olympia: Washington State Department of Ecology, 1990.

Newell, G.E. and R.C. Newell. Marine Plankton: A Practical Guide. London: Hutchinson & Company Publishers, 1979.

Nybakken, James W. Marine Biology. New York: Harper and Row Publishers, 1982.

Ponge, Francis. The Voice of Things. Ed. and Trans. Beth Archer. New York: McGraw-Hill, 1972.

Puget Sound Water Quality Authority. Handbook on Puget Sound Sediments. Seattle: Puget Sound Water Quality Authority, June 9, 1989.

Puget Sound Water Quality Authority. Puget Sound Update: First Annual Report of the Puget Sound Ambient Monitoring Program. Seattle: Puget Sound Water Quality Authority, May, 1990.

Puget Sound Water Quality Authority. 1991 Puget Sound Water Quality Management Plan. Seattle: Puget Sound Water Quality Authority, Nov. 21, 1990.

Ricketts, Edward F., and Jack Calvin. Between Pacific Tides. Stanford: Stanford University Press, 1967.

Scott, James. Washington Public Shore Guide. Seattle: University of Washington Press, 1986.

Slattery, Britt Eckhardt. WOW!: The Wonders of Wetlands. St. Michaels, Maryland: Environmental Concern Inc., 1991.

Smith, Deboyd L. A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae. Dubuque, Iowa: Kendall/Hunt Publishing Company, 1977.

Steinbeck, John. The Log From the Sea of Cortez. New York: Viking Penguin, 1951.

Stuart, Floyd C. "The Salt Marsh." First published in The Atlantic, October, 1987, pp. 71-77.

Sumich, James L. An Introduction to the Biology of Marine Life. Dubuque, Iowa: Wm. C. Brown Company, 1980.

Terich, Thomas A. "Structural Erosion Portection of Beaches Along Puget Sound: An Assessment of Alternatives and Research Needs." From Engineering Geology in Washington, Vol. II. Washington Division of Geology and Earth Resources, Bulletin 78 (1989), 1131-1136.

Thomas, Dylan. The Collected Poems of Dylan Thomas, 1934-1952. New York: New Directions Publishing Corporation, 1957.

Western Regional Environmental Education Council. Project Wild: Secondary Activity Guide. Boulder: Western Regional Environmental Education Council, 1988.

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Evaluation - The Estuary Guide, Level 3

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1043 Bayview-Edison Road
Mt. Vernon WA 98273
(206)428-1558

Teacher:______________________________ High School:________________________
Grade/Subject:________________________

1. Check the components of this curriculum that you use. (Circle those sections you photocopy for students.

Text	Activities	Resources
__Geology	__Field Trip	__Field Guides
__History	__Plankton	__Water Monitoring Equipment
__Ecology	__Water Monitoring	__Marine Aquarium Gudies
__Human Use	__Writing	__Res. for Environ. Action
__Literature/Arts	__Thinking Globally	__Gov't. Agencies
__What We Can Do		__Organizations
		__Places
		__Curricula
		__Publications
		__Estuary Arts & Literature

2. What do you think of the sections that you use?

3. What should be changed, added, or omitted to improve this curriculum?

4. How well does this curriculum match your other course work?

5. Did any other teachers at your school use the curriculum? What subject?

6. Please rate this curriculum on the scale below.

INEFFECTIVE				OK				BEST EVER	
1	2	3	4	5	6	7	8	9	10

7. Further comments?

8. Do you use other activities or resources you could share with us?

Thank you for taking the time to fill out an evaluation.
All comments are appreciated and all will be considered.

-fold-

-fold-

stamp

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