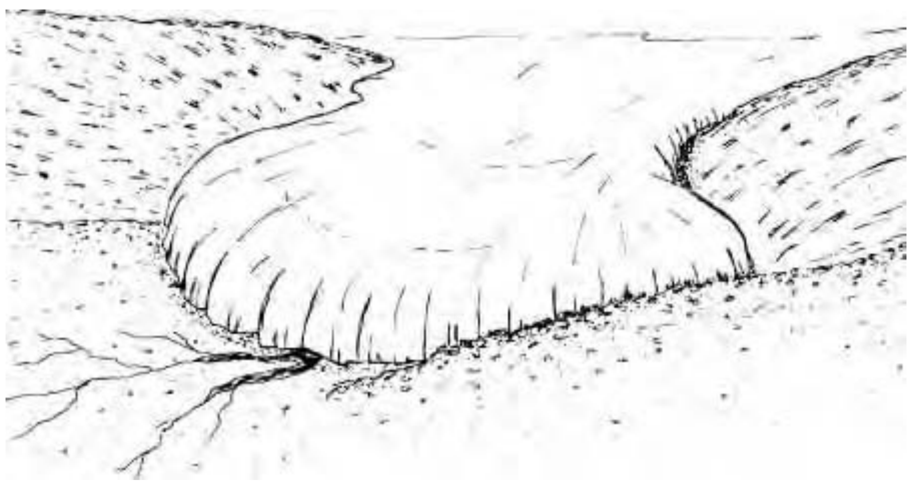
Material for Estuaries

THE PHYSICAL ENVIRONMENT

Formation

Estuaries are formed where rivers meet the ocean. There are no two identical estuaries. Some are small, others cover a very large area.

The actual formation of some estuaries is believed to have occurred during the last ice age, when glaciers carved out river beds along the coast.



Physical Characteristics

Currents

In the estuary, river and tidal currents play very important roles in mixing the lower and upper layers of water. This estuarine circulation, as we will see later, is a crucial factor determining the high productivity of estuaries.

When sea-water enters an estuary in the northern hemisphere, it flows clockwise to the 'right,' and freshwater flowing down-river moves also clockwise, thus flowing to the other side. Due to this coriolis force, one side in the estuary is often saltier than the other side.

Ice

Some of our more northern estuaries have ice cover for up to four months of the year. Ice cover helps provide a constant temperature in the mud, which is beneficial for many marine organisms. Once the ice melts, there is a very sudden increase in freshwater content, contributing to the variability in salinity.

Salt

Salinity constantly changes in estuaries. When freshwater mixes with saltwater it is called brackish water. The water of estuaries and salt marshes can be brackish.

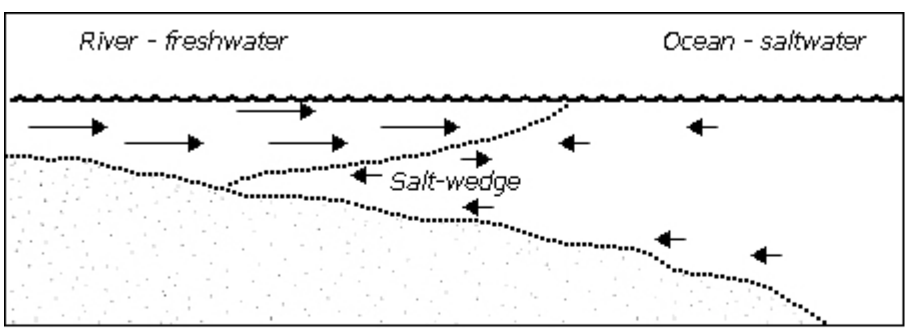
Salinity

Salinity is an important feature of estuaries. Estuary water is a mixture of freshwater and saltwater in proportions that vary according to the location in the estuary. An out-going tide can reduce salinity slightly.

The degree of salinity can also be influenced by factors such as the level and intensity of the tides, the melting of snow in the spring, heavy precipitation, and dry periods during the summer season.

The salinity can be weak upstream in the estuary, about 0.5 ppt, and very high downstream, up to 30 ppt. In the sea, the average salinity is 35 ppt. The zone where freshwater changes to saltwater is called a pycnodine.

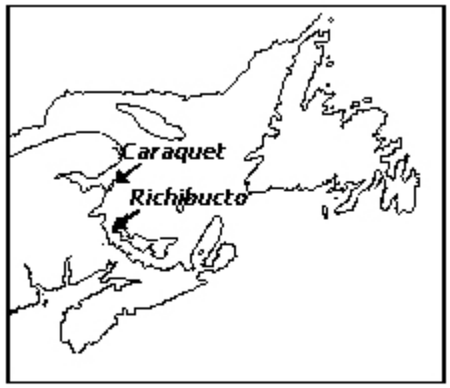
The freshwater from rivers is lighter than saltwater, so it has a tendency to stay on top of the saltwater. If the estuary is deep enough, the saltwater from the sea will travel up the estuary by passing under the freshwater while the freshwater going down the river will stay above the saltwater layer and enter the sea. This is called a salt-wedge estuary. This kind of estuary tends to form in situations with low turbulences; therefore, little mixing occurs. It often happens in certain places that there is virtually no salt content at the water's surface, but the salinity is very high at the bottom. If the estuary is shallow or where water turbulence is great, the salt and freshwater will mix and the salinity change is gradual.



There are a few organisms, such as salmon, that undergo physiological changes so that they can move from saltwater to freshwater environments and vice versa.

By following the saltwater wedge, some marine organisms can advance farther into the estuary. By following the freshwater, some aquatic organisms can move farther down the estuary. Thus some marine species can be found very far upstream in an estuary.

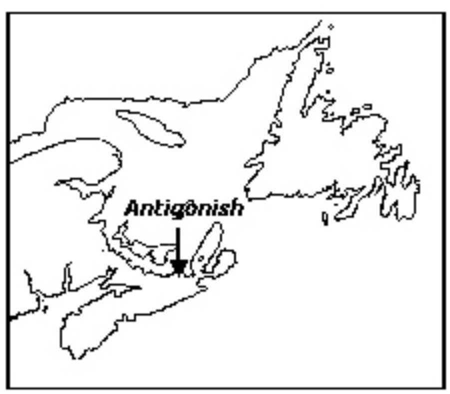
At the mouth of the Caraquet River, New Brunswick, salinity of 4 ppt has been observed at low tide in the spring. Melting snow and ice, spring rains and run-off contribute to the low salinity levels. During the summer the salinity can vary between 20 and 25 ppt at the same place.



In the Richibucto River, it's possible to collect American Oysters as far up as the Nicolas River, located 25 km from the coast.

Sediment

An estuary is constantly changing and tends to accumulate sediments. Sediments come from rivers, streams and brackish marshes located inland, and salt marshes and sand dunes located near the mouth of the estuary. Sediments can be composed of animal and plant matter, as well as inorganic material, such as mud or sand.



Temperature

Temperature is one of the main elements influencing reproduction of invertebrates and fish. Since estuaries are shallow and semi-enclosed, temperatures can be slightly higher than in open areas, providing the levels required for some species to lay their eggs. Cold temperatures can negatively affect fish in their planktonic stages, slowing down the hatching and growth of the young.

Tides

With the rise and fall of tides, nutrients are brought into the estuary. The movement of tides also causes turbulence, resulting in an upwelling of water, which brings nutrients from the bottom of the estuary to the surface.

The further up the estuary you go, the more delayed the tide becomes. Since estuaries are usually funnel-shaped, incoming tides at the mouth tend to increase in amplitude as the channel narrows. The frictional contact from the shore and bottom act against the tide and tend to lower the height of the tide. With these counteracting forces, it can be difficult to predict whether the tidal range will be smaller or greater at the head of the estuary. The rise and fall of tides can be felt far up-river, especially in bigger estuaries.

BIOLOGICAL FEATURES

In the summer there is an abundance of biological activity in the estuary. The tides, currents, and wind bring nutrients to the water's surface (upwelling). Plentiful nutrients combined with warm shallow waters set the stage for a profusion of activities. Some invertebrate animals, birds, and fish are able to take advantage of these factors. Estuaries and other coastal ecosystems tend to be in areas of high productivity and therefore have high-quality habitats for many species of wildlife.

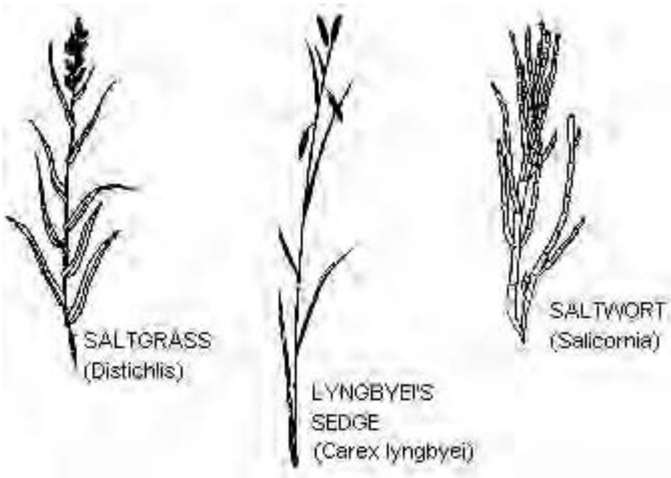
Who Lives Where?

Plankton

Phytoplankton are minute plants such as dinoflagellates. Phytoplankton, along with bacteria and fungi, are the basis of life in the estuary and are carried by the currents. In order to survive, they must remain in a place where the salinity fits their needs. They use the sun and the nutrients from rivers and salt marshes to feed themselves.

Zooplankton are the tiny animal part of plankton. In estuaries, zooplankton benefit from an abundant food supply: phytoplankton, microscopic algae, bacteria, and detritus coming from dead plants and animals.

Plants in estuaries



Plants in estuaries: nature's water garden

Only certain types of plants can flourish in the physical conditions peculiar to estuaries, and each of these plants can grow in only certain parts of the estuary.

One factor influencing the growth and distribution of plants in an estuary is its salinity, or the amount of salt in the water. Certain kinds of plants can tolerate high levels of salt, getting rid of the salt they take up by releasing it through special salt pores on their leaf surfaces. Other plants do not like even a moderate amount of salt and can grow only in areas of the estuary where seawater cannot reach. In between are plants that can tolerate moderate amounts of salt and hence can survive in *brackish* (or slightly salty) areas of the estuary.

A second factor influencing the growth of plants in an estuary is the amount of flooding. The longer and deeper an area is flooded with water, the less oxygen is available in the soil. As plant roots need oxygen to grow and survive, the plants that grow in areas that are usually under water need to be adapted to an oxygen shortage, some of them transporting oxygen from special storage cells in their leaves and stems to their roots.

One marine plant that flourishes in estuaries is eelgrass. This plant can tolerate only brief exposure to air and therefore grows in large submerged beds near and below the lowest tide level. It is especially important as food for American Wigeon and Brant. Plants that grow on land covered by seawater for brief periods each day include salt-tolerant species such as the saltworts and saltgrasses on all three coasts, cordgrasses on the Atlantic coast, and alkali grasses in the Arctic. Plants such as the sedge and bulrush predominate in brackish areas of many estuaries, where they are covered by water for a few minutes to many hours each day. Areas that are covered with fresh water support the cattail in profusion.

In fall and winter, most plants in all parts of the estuary decay and become detritus. Some plants, such as algae, have a much shorter life cycle, lasting only a matter of days or weeks, and these continue to grow and decay even in extremely cold weather.

Plants

Plants modify coastal ecosystems by trapping sediments, slowing down currents, producing food, and giving shelter to organisms.

Eelgrass is a major source of food for a whole community of animals and plants. Small fish such as the Mummichog, Sticklebacks, and the fry of the Striped Bass and Gaspereau shelter and feed in Eelgrass beds. This plant helps to stabilize the bottom with its roots, allowing organisms such as Crabs and Lobsters to move around on it. Accumulations of dead Eelgrass are often found along beaches, enriching other ecosystems.

In the early 1930s an epidemic destroyed close to 90 per cent of Eelgrass beds along the Atlantic coast, seriously affecting the organisms that were associated with them. Brant (a type of goose) rely on Eelgrass as food during migration, and were greatly reduced in numbers. Brant and Eelgrass are still recovering to this day.

The formation of an Eelgrass bed can actually be an early successional step in the development of a salt marsh.

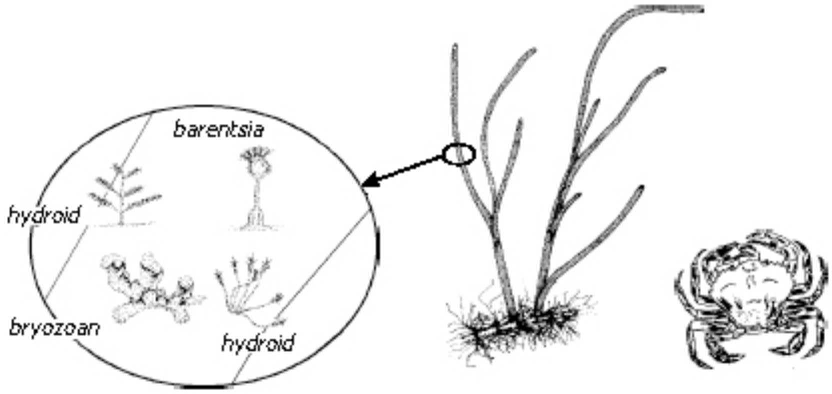
Eelgrass facts

Eelgrass is one of the few plants that flower in the water. It's found in practically all shallow expanses of water, with a sedimentary bottom in Atlantic Canada. In estuaries, it's found just below the low tide line to where the salinity is lower than 14 ppt. It grows best in water temperatures from 10°C to 20°C, reproduces best between 15°C and 20°C, but can tolerate temperatures between -1.5°C and 30°C. Like other sea grasses, it has salt glands on its leaves to remove sodium and chlorine ions from its cells.

When conditions are suitable for growth, Eelgrass beds can be one of the most productive systems in the world. They grow as fast as cultivated wheat or corn and the biomass of plants living on Eelgrass can sometimes be as great as the biomass of Eelgrass itself.

The roots of Eelgrass may become so thick that they tightly bind sediments to the extent that they can withstand severe storms with little erosion. The leaves of Eelgrass slow down currents, allowing the water to deposit their sediment loads.

Apart from Black Ducks, Canada Geese, and Brant, few animals actually feed on Eelgrass. Snails feed on epiphyte vegetation on the surface of the leaves, amphipods and small shrimp on detritus, encrusting bryozoans on suspended food particles, and hydroids on small organisms in the water.



Eelgrass has long blades that can be seen floating in the water or washed ashore in large heaps.

Graceful Red Weed

The Graceful Red Weed is a red seaweed that grows in association with Eelgrass.

Ditch-grass/Widgeon-grass

Ditch-grass is another one of the few flowering plants that grows here. It is a favourite of ducks. More delicate than Eelgrass, it is easily crowded out by it.

Tubed Weed

The Tubed Weed is an epiphyte on Eelgrass that can build up a substantial biomass.

Sea Lettuce

Sea Lettuce is a green seaweed with thin leaves that does look like lettuce.

Bladder Wrack

Bladder Wrack is a brown seaweed that grows in Eelgrass beds where it finds a hold in the substrate.

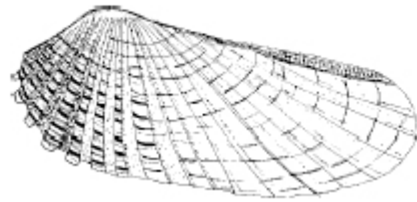
hollow greenweed

Hollow green weed is a very common green seaweed and is a major primary producer in the estuary.

Molluscs

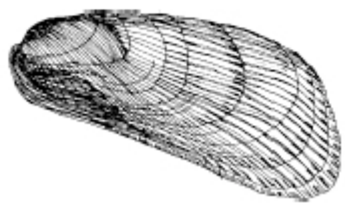
Molluscs are plentiful in estuaries. Some hide in the sediment while others live on sediments or plants. Molluscs can be carnivores or can feed by filtering water. Some graze on microscopic algae that live on the estuary bottom and on the vegetation. Others feed on detritus from dead animals and plants. Molluscs are an important source of food for other animals that live or stay in the estuary such as the Winter Flounder, Mud Crab, Ducks (such as Scaup), and Raccoon.

False Angel Wing



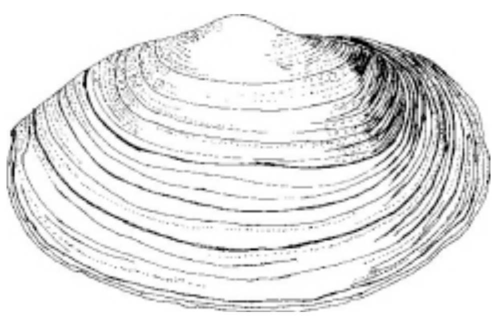
The False Angel Wing has very sharp rays that allow it to bury itself in the clay. 5 cm.

Ribbed Mussel



Ribbed Mussels are found mainly in salt marshes at the low tide line. They prefer brackish waters. 10 cm.

Soft-shelled Clam



The exterior of the Soft-shelled Clam is greyish white and chalky. This is the clam that squirts from the mud. 10 cm.

Bay Quahaug

The Bay Quahaug is a mollusc of muddy sediments. It is thick-shelled and greyish yellow and is also known as hard-shelled clam. 10 cm.

Short Yoldia

The Short Yoldia is a very slender mollusc. It lives mainly in muddy bottoms. 2.5 cm.

Baltic Macoma

The Baltic Macoma can feed on plankton when the tide is high and on detritus when the tide is low. 5 cm.

Common Periwinkle

The periwinkles are gastropod molluscs. They are very common in the estuary and also abundant along wharves. 3.1 cm.

Crustaceans

Lobster, Crabs, Sand Shrimp, and Amphipods (a type of small shrimp) are found in estuaries. They can serve as food for birds, fish, and mammals.

Crab and lobster

Crabs and lobsters feed on molluscs and other living or dead organisms. They use their claws to break shells. Lobsters can eat mussels, crabs, oysters, sea stars, and worms.

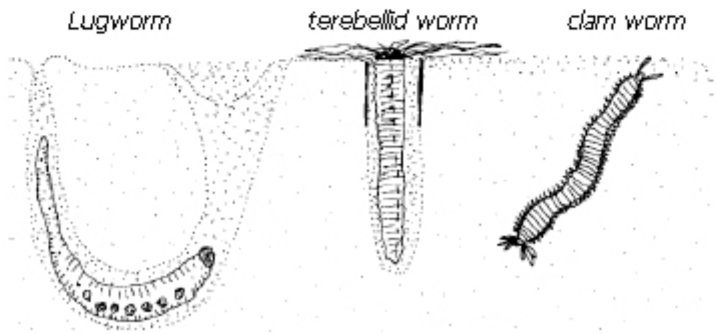
Crabs eat mussels. When mussels are cultivated using 'collectors' they are the size of a grain of pepper when first installed. Crabs are often found on these collectors.

A lobster of 8 cm can eat six oysters of 15 to 25 mm in length per day. A Mud Crab of 2 cm can eat one.

Worms

Worms are prey for a great variety of animals, such as crustaceans, fish, and birds. Some are carnivores, others eat seaweed or detritus (non-living materials). Some worms, like the clam worm, move freely through the mud, while others build permanent tubes through which they filter particles from the water.

Examples of worms feeding and their burrows



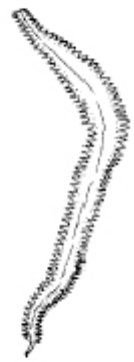
capitellid thread worm

The capitellid thread worm digs a burrow with two holes. It sucks in its food by creating a current of water. 10 cm.

mud worm

The mud worm has lashes on its two tentacles. It captures food from the bottom and transports it to its mouth. 10 cm.

red-lined worm



The red-lined worm is a very voracious predator with a trunk (proboscis). It resembles the clam worm but the tentacles on its head are poorly developed. 30 cm.

bamboo worm

The segments of the bamboo worm are longer than they are wide. The head is flat and has no tentacles. 15 cm.

clam worm

The clam worm has several well-developed antennae on its head, and a trunk armed with two hooks that it uses to capture its prey. 20 cm.

Acorn Worm

This worm-like creature is not a worm at all but belongs to the Hemichordata. It is found in muddy bottoms and is whitish-coloured. 15 cm.

Fish

Fish use the estuary for spawning, the development of fry (very small fish), and as nursery areas for juveniles. Many species have migratory patterns that take advantage of the plankton. Food, as well as shelter, is abundant in an estuary. The estuary is a transition zone for marine species travelling from the sea to rivers, and for freshwater species travelling from rivers to the ocean.

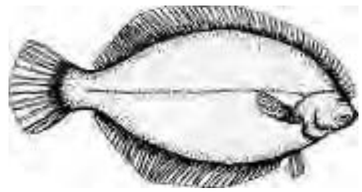
Catadromous and anadromous

The American Eel spends the major part of its life in fresh or brackish water, returning to the ocean to spawn in the Sargasso Sea, near the Bahamas. It's called a catadromous fish because it returns to the sea to breed. The Atlantic Salmon, the Striped Bass, the Gaspereau, and the Smelt are anadromous species-they spend the major part of their life in the sea or in brackish waters, returning to freshwater to reproduce.

Flounder

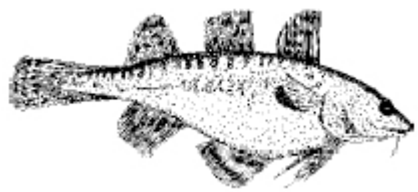
As it grows, the Winter Flounder undergoes a metamorphosis. The larval or young stages of the Winter Flounder resemble a 'typical' fish. As this fish grows, it will settle on its side on the bottom and the right eye will move gradually to the left side (or the other way around). The mouth seems to be askew. The Flounder's pigmentation follows the same evolution as if it always tanned on the same side.

The Flounder is especially tolerant of low salinity and temperature, and thus is frequently found in estuaries both as adult and young. Young Flounder bury themselves in the mud when the tide is low or when there is danger. They are almost completely camouflaged. With the incoming tide, they rise and let the water carry them into tidal creeks where food is plentiful.



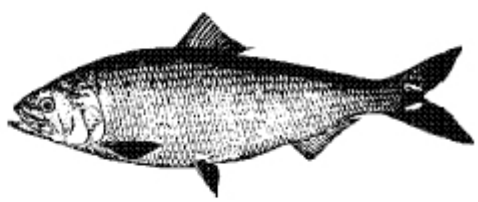
Atlantic Tomcod

The Atlantic Tomcod is a miniature cod that lays its eggs on gravel or sand at the outer edges of the estuary. To 30 cm.



American Shad

The American Shad strongly resembles the Gaspereau, however the migration to spawning grounds occurs later. 50 cm.

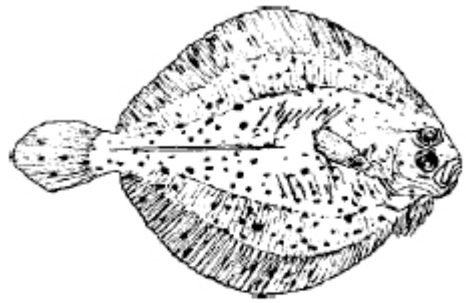


Smelt

The Smelt is a member of the Capelin family. It generally moves in groups and feeds on small zooplankton. To 35 cm.

Windowpane

The Windowpane has a very round shape in comparison to other Flounders found in the estuary. To 43 cm.



Blueback Herring

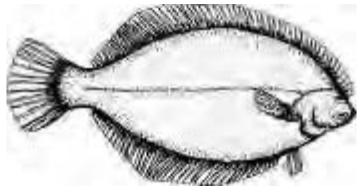
The Blueback Herring enters rivers to spawn at the beginning of June. The young descend to the sea towards the end of summer. Around 27 cm.

Smooth Flounder

The Smooth Flounder has smooth skin between its eyes. Its right side can change colour according to its environment. To 32.3 cm.

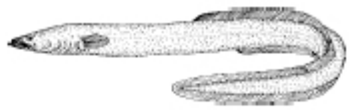
Winter Flounder

The left side of the Winter Flounder can change colour according to its environment. It has rough skin between its eyes and feeds on crustaceans, molluscs, and marine worms that live on or in the bottom of the estuary. 50 cm.



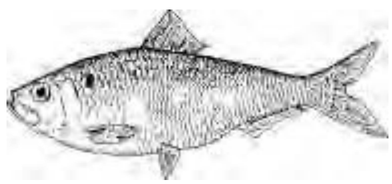
American Eel

Young Eels enter estuaries in July as elvers. They stay in rivers and estuaries for five to 15 years before returning to the sea to spawn. They feed at night on practically everything they capture. Around 100 cm.



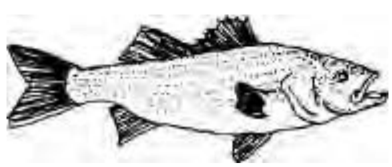
Gaspereau

The silvery body of the Gaspereau is compressed sideways. It can measure up to 30 cm.



Striped Bass

Striped Bass come from the ocean to reproduce in estuaries. The young stay there for a year, feeding on small invertebrates before descending to the sea. Can grow over 100 cm.

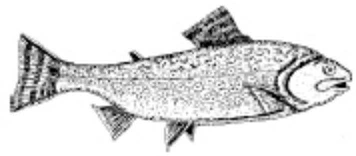


Atlantic Salmon

When they move into saltwater, small salmon take on a silvery appearance, which they will keep until they return to their native river to spawn. During their migration to their spawning grounds, Atlantic Salmon stay in estuaries to become accustomed to the weak salinity. During their migration to the sea, the smolt, or young salmon, spend several weeks in estuaries, feeding on small fish and invertebrates.

Brook Trout

Brook Trout ascend rivers in the spring. Some populations use the estuary during the winter. Up to 39 cm.



Birds

Birds are very mobile and their rhythm is associated with that of the tides, their food, and the movement of the water. Some birds, such as the Canada Goose, feed in the intertidal zone at low tide. Some, such as the Black Duck, feed in shallow waters. Cormorants, mergansers, and scaups feed in deeper water by diving from the surface. Terns, Osprey, and Kingfishers dive from above the surface.

Some birds' habitat and food

Bird	Habitat	Food
Double-crested Cormorant	coastal ecosystems	Rock Gunnel, sculpins, Sand Lances, Herring, Flounder, Atlantic Tomcod, American Eel, Sea Perch, American Shad
Osprey	ecosystem near estuaries	Gaspereau, Herring, Flounder, Perch, Atlantic Salmon, Small Birds and Rodents
Bald Eagle	ecosystem near estuaries	Crippled waterfowl, Dead fish, Steals fish from Osprey, Muskrat
Canada Goose	salt marshes, estuaries	Glasswort, Grasses, Eelgrass, Widgeon-grass, Sea Lettuce, Molluscs, Small Crustaceans
Kingfisher	ecosystem near water	Mainly Fish, Crabs, Mussels, Insects, Clams, Oysters
Herring Gull, Great Black-backed Gull, Ring-billed Gull	coastal ecosystems	Dead Fish, Molluscs, Crustaceans, Marine Worms, Sea Stars, Crabs, Young Birds, Marine Algae, garbage

Double-crested Cormorant

This cormorant is a goose-sized bird that has a snake-like neck. One of the few birds that have no oil gland for waterproofing. Look for it perched with its wings spread out to dry. 81 cm.

Osprey

The Osprey is a large bird and is sometimes called a fish hawk. It hovers in place and dives from great heights into the water for fish. To 64 cm.

Bald Eagle

Adult Bald Eagles have whitish (bald) heads and tails. Young birds are brownish until they are mature, at four to five years. To 94 cm.

Canada Goose

The Canada Goose has a white cheek patch. Listen for the familiar honking. To 114 cm.

Brant

Brant are smaller than Canada Geese and very fond of Eelgrass. Before the 1930s they were very numerous, until a disease nearly wiped out the Eelgrass. 64 cm.

Red-breasted Merganser

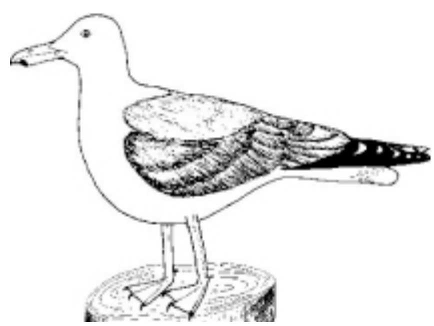
The Red-breasted Merganser has a greenish plume on the head. The whitish neck and wings are good field marks. It is sometimes called sawbill because of the tooth-like projections on the bill used for catching fish. 58 cm.

Greater Scaup

The Greater Scaup is one of several species of ducks that use the estuary for resting and feeding during migration. Look for its blackish green head and white flank especially in early spring. 46 cm.

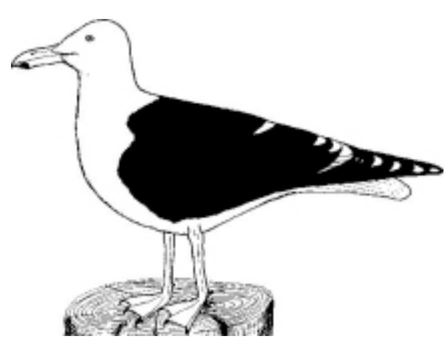
Herring Gull

The Herring Gull is smaller than the Great Black-backed Gull, and has black wings tips. Gull numbers have increased drastically due to human wastes. 64 cm.



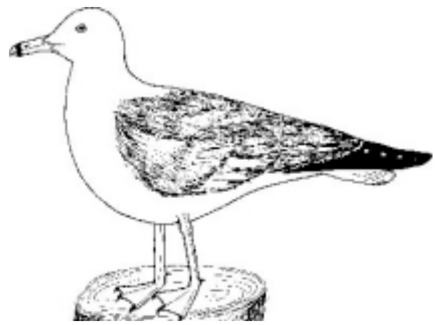
Great Black-backed Gull

The Great Black-backed Gull is the largest of our gulls, with all black wings and back. The young gulls are brown. 76 cm.



Ring-billed Gull

The Ring-billed Gull is slightly smaller than the Herring Gull. It has a black ring around its bill and is a newcomer to the east coast, attracted by human wastes. 45 cm.



ECOLOGY

Stress and Survival

Organisms that live in the estuary face two major challenges: variable salinity and how to stay put.

Most solutions are behavioural adaptations, such as burrowing or simply closing shop when there isn't enough water. Some organisms, such as fish, can move around and find an appropriate spot, while other organisms excrete the excess salt that enters their bodies.

Behavioural adaptations

The Blue Mussel closes its valves when the level of salinity becomes too low or the tide is out.

Some marine worms and amphipods bury themselves in sediments until conditions become adequate.

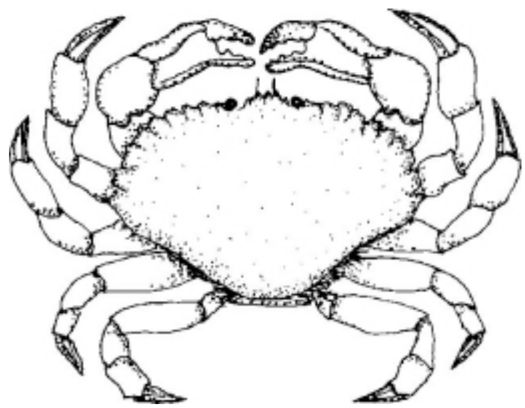
Some fish move about in the estuary to find the desired level of salinity.

Oyster larvae are incapable of swimming against a current, so they maintain their location in the estuary by dropping to the bottom when the tide is ebbing and rising to the top with the incoming tide.

The quahaug is well adapted to sedimentation problems. When its gills are obstructed by mud, it cleans them by expelling a great quantity of water.

Physiological adaptations (changes relating to their own bodies)

The majority of organisms living on or in the sediments, such as crustaceans, excrete the salt as rapidly as it's absorbed. Birds possess salt glands that excrete excess salt. Some other organisms (especially marine worms) contract their bodies to reduce the surface area that's in contact with the water and thus decrease the absorption of salt. The last option is to have an impermeable surface - but only birds, reptiles, and mammals have this. A clam or mussel can only make itself temporarily watertight. Organisms without any of these features are absent from estuaries.



Productivity

The estuary is full of life, especially during the summer season. In the winter, activity slows down.

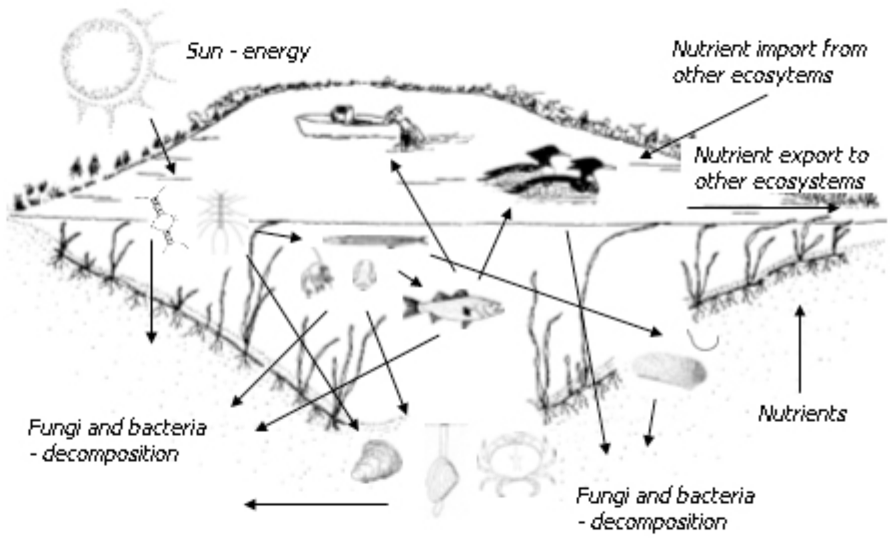
The sizable supply of nutrients from rivers, rocky shores, and salt marshes, combined with their warm temperatures and good penetration of sunlight, make estuaries very productive areas.

Food Web

Eelgrass and other plant matter from the estuary or from adjacent ecosystems enter the food chain in the form of detritus. Bacteria and fungi are found in the estuary bottom, on Eelgrass, and on seaweed. They're responsible for the decomposition of dead plants and animals. The bacteria and fungi are in turn eaten by worms. Fish feed on the worms and are in turn food for birds.

Food web

Arrow: indicates direction of food/energy



ESTUARIES AND US

Estuaries have significant economic importance. Some estuaries support substantial commercial fisheries, in addition to recreational fishing activities, wildlife activities, and aquaculture. Estuaries are also used as navigation routes.

Commercial Fishing

Fishing is a very ancient practice that was an important activity for the Mi'kmaq nation. In the past and today they fish for Atlantic Salmon, trout, and American Eel, among other species. They also collected Molluscs, such as Oysters and Soft-shelled Clams.

Smelt, American Eel, Gaspereau, and American Shad are fished commercially in the different estuaries of the region.

Molluscs such as American Oysters, Soft-shelled Clams, Bay Quahaugs, and Blue Mussels are fished commercially in the estuaries of Atlantic Canada.ZAAAE

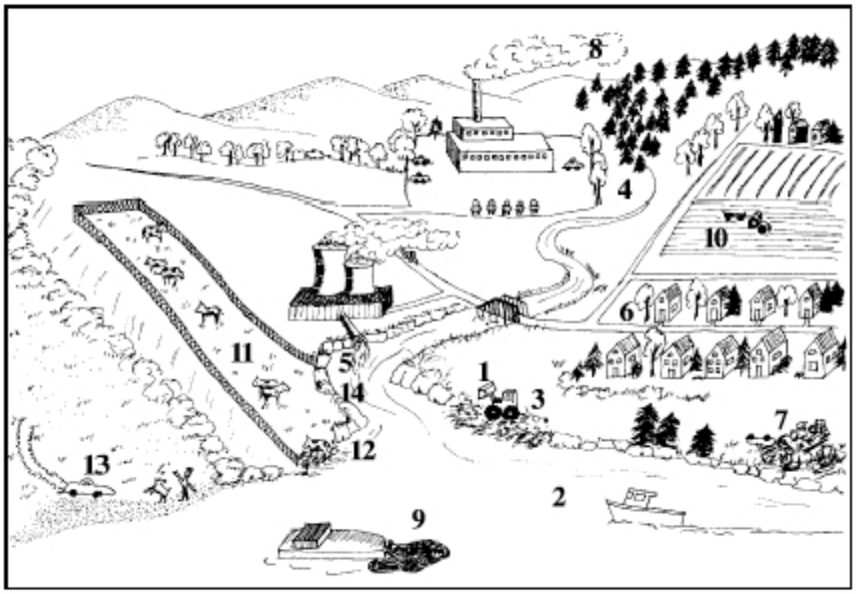
Recreational Fishing

Smelt, Striped Bass, Atlantic Tomcod, American Eel, and Mackerel can be fished in estuaries.

Problems in the Ecosystem

Coastal ecosystems are heavily used by people and often abused. Estuaries usually bear the brunt of human waste and contamination because they were and are the first areas of human settlement.

Some of the more measurable and visible human impacts



(1) infilling of marshes and thus elimination of habitat and other wetland functions, (2) dredging carried out in the water, (3) development along the shoreline, (4) waste from pulp and paper mills, (5) discharge from electrical generating stations, (6) untreated sewage from towns, (7) garbage and toxic wastes, (8) airborne toxins, (9) discharge of oil, (10) pesticides from agricultural run-off, (11) nitrate run-off from animal farming and excessive fertilizer usage, (12) shoreline erosion due to grazing by cattle, (13) vehicles driving through habitat and (14) soil erosion from agriculture and road building activity results in silt deposition. Improper installation of aquaculture stations also has negative impacts on estuaries.

We can see the effects of these human impacts in destroyed habitats as a result of development, poisoned shellfish made unfit for human consumption by bacterial contamination, industrially polluted fish nursery areas, and oiled birds washing up along the shore.

Some of the most polluted estuaries

People originally chose estuaries to settle because they provided sheltered sea ports, a good source of food, and rich pasture land for farming. Towns subsequently developed cities such as St. John's, Halifax, Dartmouth, Sydney, New Glasgow, Miramichi, and St. John are all located on estuaries and are very polluted.

Because estuaries receive water from rivers, all the pollution that is transported by those waters eventually reaches the estuary. Estuaries are affected by human activity of various types, whether domestic, manufacturing, or commercial.

Industrial and domestic wastes, agricultural activities, and the forest and transportation industries pollute our estuarine ecosystems. Many areas are closed to mollusc harvesting because of chemical and bacteriological contamination.

Chemical Contamination

In the estuary, sediments tend to settle. The chemical contaminants transported by rivers likewise settle to the bottom. Fish and crustaceans that feed on plants and molluscs can accumulate great quantities of toxic products. These hazardous chemicals can be lethal to marine life and cause abnormalities in organisms.

Bacteriological Contamination

A pathogenic bacterium can be harmful to human health. It can transmit diseases such as hepatitis and polio. These bacteria originate mainly from human waste. Molluscs are the organisms most contaminated by pathogenic bacteria. If people eat these molluscs they will get sick. This type of pollution is connected to the presence of nearby communities with no sewage treatment facilities. Some molluscs feed by filtering plankton and other microscopic animals from the water. If there are bacteria, the molluscs absorb them as well. Crustaceans and fish that feed on molluscs are not affected by the bacteria, but humans consuming the molluscs can get sick.

Chemical Contamination

In the Atlantic provinces of Canada, most of the paper mills are constructed near or upstream of estuaries and are significant polluters. Added to these are oil spills, pesticides, insecticides, and other pollutants coming from forestry, agricultural, and industrial activities.

All organisms are affected by chemical products. Osprey, Bald Eagles, and the Peregrine Falcon, for example, suffered sudden declines in their populations in the '60s due to the common use of DDTs, now prohibited in Canada. Recently their numbers have begun to increase although the Peregrine Falcon is still classified as an endangered species in Atlantic Canada today.

Some of the hazardous chemicals include: PCBs, dioxins, furans, heavy metals, pesticides, oil/hydrocarbons, and radionuclides.

Bacteriological Contamination

In many estuaries in Atlantic Canada, the collection of molluscs is closed partially or completely due to contamination with pathogenic bacteria.

Domoic Acid

The diatom *Pseudo-nitzschia multiseries* produces domoic acid, a neurotoxin that can accumulate in molluscan shellfish during their normal feeding process. Consuming such contaminated molluscs can be harmful to humans, causing Amnesic Shellfish Poisoning (ASP). This diatom blooms in many bays and estuaries throughout Atlantic Canada. In 1987, for the first time anywhere, domoic acid was observed as a cause of ASP in the Cardigan estuary of Prince Edward Island.

Harmful Algal Blooms (Red Tides)

Certain pigmented microscopic algae (for example, some dinoflagellates) can grow to high concentrations, forming 'blooms' that can sometime colour the water red. This is known as a 'Red Tide'. However, scientists now call this phenomenon a Harmful Algal Bloom (HAB). In Atlantic Canada, the 'red tide' dinoflagellates *Alexandrium tamarense* and *Alexandrium fundyense* produce a neurotoxin that can accumulate in the tissue of molluscan shellfish. Consuming these shellfish may cause Paralytic Shellfish Poisoning (PSP) in humans, which can result in sickness or even death.

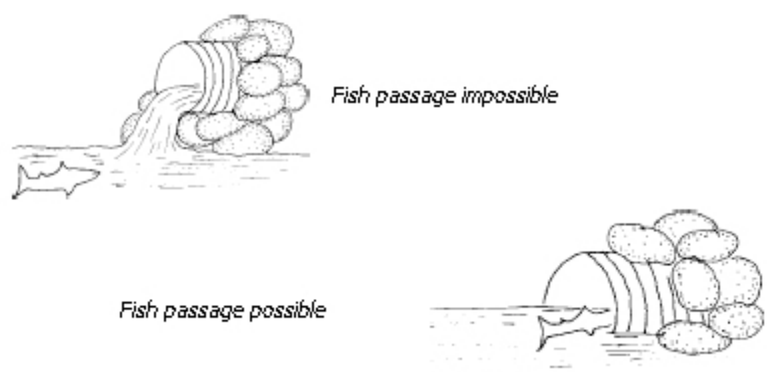
Habitat Destruction

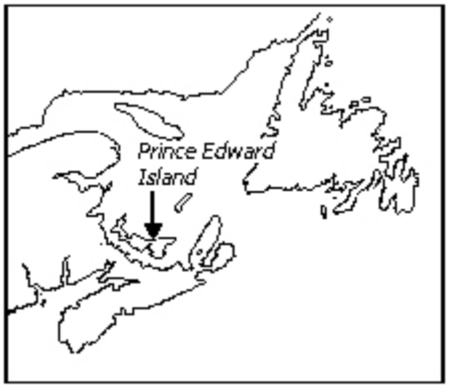
Aquaculture and fishing can also contribute to the pollution of estuaries. Excess feed from cages and feces alter the benthic habitat below aquaculture sites.

Without tight control, culture cages could cover the whole area of an estuary, altering the beauty of the landscape and limiting accessibility by preventing recreational activities, such as boating, windsurfing or swimming.

Habitat destruction can also be caused by poorly managed dredging done to create navigable routes, during dam construction, and for developments along the banks of estuaries.

Agricultural activities affect the estuary by causing siltation, which destroys fish spawning habitat and fill in wetlands.





Prince Edward Island has a long history of dam and pond construction initially, from various types of water-powered mills, and later for recreational fishing and waterfowl production. While most have fish ladders, a few have not as yet been fitted with them. The ladders help fish to migrate upstream to their spawning grounds. However some of the older ladders don't work very well. Improvements are ongoing.

Sediments

Sedimentation is a natural process, but it can be greatly accelerated by human action. Suspended sediments can affect larvae and young fish by interfering with their feeding mechanisms. Fish eggs can be smothered silt, which blocks the passage of oxygenated water into the egg mass. Silt can also erode the gills of fish and prevent them from breathing. Mollusc habitats have been destroyed by the accumulation of loose sediments because they prevent molluscs from feeding and breathing. Oyster spat need to attach to a clean surface in order to grow. Excessive sediment inhibits this process.

Domestic Wastes

Domestic wastes can also have a serious impact on estuaries. Plastic materials can be eaten by fish or capture them accidentally. Lost fishing gear, i.e. gill nets, results in 'ghost-fishing,' trapping and killing fish years after the gear has been abandoned or lost.

Nutrient Enrichment

Untreated sewage and detergents can cause increased productivity and algae growth due to the large amount of nutrients. This increased growth can cause eutrophication. Eutrophication is a process by which excessive algae growth and the subsequent death of these plants causes a depletion of oxygen, thus killing marine life or making life in the area impossible. The extent to which the breakdown of dead plant matter takes up oxygen is called the biological oxygen demand or BOD.

Excess nutrient input is a chronic problem in agricultural areas, where fertilizers and faeces from livestock gets washed into the water, causing eutrophication in rivers and estuaries.

Protection of the Ecosystem

It is important to understand that any change to an estuary can have considerable effects on the associated ecosystems in the coastal zone. Construction must be planned carefully, to ensure it will not cause damage. All modifications must be done in a responsible manner.

Many people and organizations who live near and work in estuaries think about how their actions might affect fish, wildlife, and plants. To date many things have been done to protect ecosystems in the coastal zone.

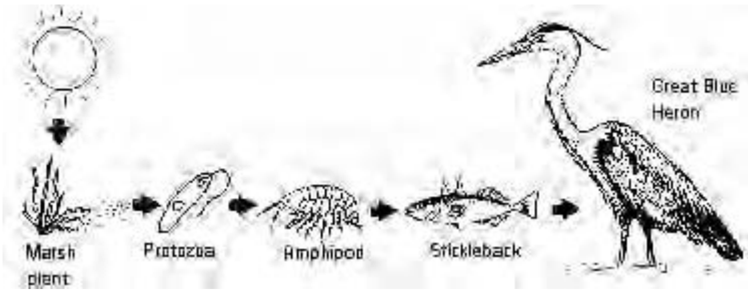
The amount of raw sewage entering ecosystems is reduced by the installation of septic tanks and sewage treatment facilities. There is a decrease in the amount of harmful substances entering estuaries because of a reduction in the use of pesticides and fertilizers. Road construction has improved, preventing siltation and blockage of rivers and streams. Oil and empty oil cans are now being recycled. Many federal wharves have collection facilities.

Some things still need to be done. Aquaculture sites need to be continually monitored so that there are no adverse effects on Lobster, Scallop, fish spawning grounds and seabird colonies. Both federal and provincial government are keeping a close eye on developments.

Then get proactive. Find out what you can do to protect your local estuaries. Clean-ups are familiar sites in most of the provinces and are mainly organized by local environmental groups. Join an estuary clean-up, or encourage people to use waste receptacles so that they don't dump their garbage in estuaries.

We can all do our part to protect this significant coastal ecosystem. You can begin by simply taking a walk along the shores of an estuary near you.

The food web



Drawing C — A food web

The basis of this estuarine food web is conversion of the sun's energy into food energy by marsh plants. When the plants die and decay at the end of the growing season, protozoa and other microorganisms coat the dead plant material. Small invertebrates, which feed on this detritus, are themselves eaten by fish, which in turn may be eaten by birds and mammals.

In the open ocean, microscopic algae known as phytoplankton float in the sunlit surface waters and convert the sun's energy to food energy. Phytoplankton cannot grow in the muddy water of some estuaries, however. Instead, most of the primary production in these estuaries is carried out by marsh plants, bottom-dwelling algae, and eelgrass that grow in abundance in the marshes and mudflats (the muddy land that is left uncovered at low tide) that are part of estuaries. These plants form the fuel of the estuarine *food chain*, which is the pattern in which plants are eaten by animals, which are in turn eaten by other animals, transferring food energy in the process (see Drawing C). A variety of different food chains then interconnect to form the estuarine food web.

Although one might guess that the next link in the food chain might be an animal feeding directly on the living algae or eelgrass, in fact this is rarely the case in estuaries. There are only a few conspicuous herbivores, or plant eaters, found in estuaries, and they are mainly waterfowl—like the Brant, a goose found in estuaries on all three coasts of Canada, which feeds on eelgrass, certain species of ducks that eat the seeds of the marsh plants, and the thousands of snow geese that gather in the Fraser and St. Lawrence river estuaries each autumn to feed on bulrushes and sedges.

So what follows estuarine plants in the food chain? What happens is that the estuarine plants die at the end of the growing season and decay gradually through fall and winter. The next step in the food chain is a rich assortment of microscopic fungi, bacteria, protozoa, and other microorganisms, which coat the dead plant material, called *detritus* (like a pile of rotting leaves or a compost heap). Small invertebrates, or animals without a backbone, such as worms, snails, clams, oysters, and shrimp, feed on this detritus, becoming the next step in the food chain. These invertebrates are then eaten by fish, amphibians, and birds, which in turn are eaten by larger fish, birds, and mammals.

Evidence of this type of food chain can be found during a visit to any estuary. Bufflehead are often seen diving in shallow water to find snails and other invertebrates living in soft estuarine sediments. In the Bay of Fundy and at the mouth of the Fraser River, shorebirds gather in flocks exceeding 100 000 birds to probe the mudflats with long bills in search of small invertebrates. Common Mergansers and Great Blue Herons find Pacific and Atlantic estuaries especially attractive places to catch small fish. Sandpipers fall prey to Peregrine Falcons that hunt along estuarine beaches, and Bald Eagles scavenge dead fish, birds, and mammals.

The estuarine food chain would quickly fall apart without the tides. As the bacteria and other microorganisms feed on the decaying plants, they use up much of the available oxygen in the water. This oxygen depletion would make it difficult for the estuarine invertebrates and fish to breathe, and they would eventually suffocate. However, regular incoming tides, occurring about every 12 hours, replenish the supply of oxygen for the animals that feed in the estuaries, and the outgoing tides carry away their wastes, to be used elsewhere in the estuary and nearby ocean.

Important Life-History Stages

The estuary plays an essential role in the life history of many fish and wildlife species. For example, our estuaries provide important rearing and feeding habitats for juvenile Chum and Chinook salmon. The brackish water of the estuary gives juvenile salmon time to gradually adjust to saltwater conditions before they migrate into the ocean.

Especially in larger estuaries such as the Fraser River and Skeena River, juvenile salmon spend several weeks feeding in sloughs and tidal channels as they slowly migrate out into the ocean in early spring. This feeding and rearing period represents an important life-history stage for juvenile salmon. Other fish species such as smelt and Starry Flounder spawn in the estuary and also use its protected backwaters for the nursing and rearing of juvenile stages.

Dungeness crab move into shallow subtidal areas of the estuary to burrow into soft bottom areas, seeking protection from predators while the crab's shell is soft during its moulting and mating stage. Juvenile Dungeness Crab will use the shelter and food provided by the estuary to go through various stages of development before moving offshore as adults.

All of our coastal estuaries provide essential resting and feeding habitat for waterfowl migrating from their northern breeding ranges along the Pacific Flyway to their southern wintering habitats. Without the critical resting and feeding habitats provided by estuaries, some species of migrating birds would probably disappear.

DUNGENESS CRAB

Habitat Types

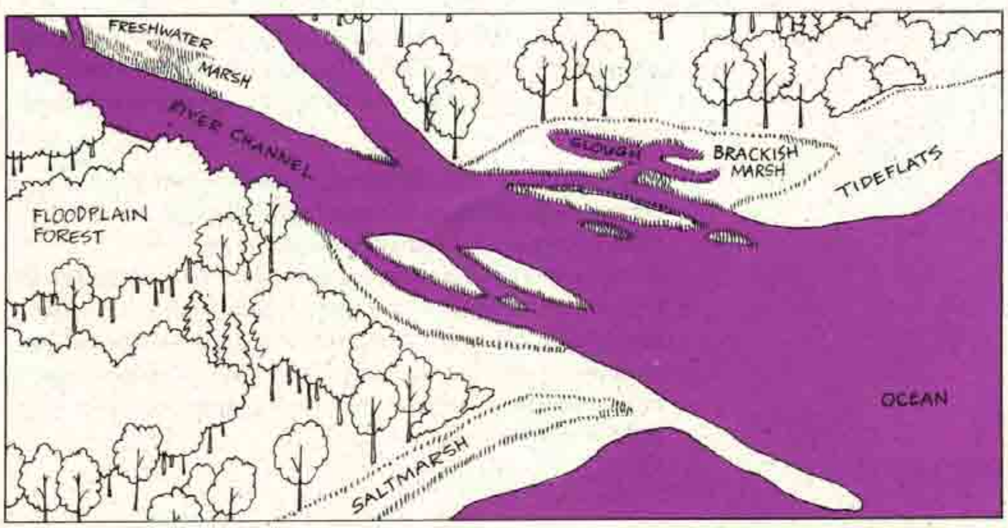
Habitats are generally classified according to the type of vegetation growing in an area. Animals are not usually used to classify habitats since birds, fish and other animals move from place to place, and are often inconspicuous and difficult to observe.

In this section, we'll describe four habitat types common to the Fraser River Estuary. We'll also describe where you can visit them, and suggest some appropriate field activities. The four habitats are:

- ☐ Brackish and Freshwater Marsh
- ☐ Saltmarsh and Tideflat
- ☐ Active Floodplain Forest
- ☐ Sloughs and River Channels

The first three habitat types can be easily recognized in the field by their distinct vegetation community. What is perhaps less obvious are the environmental factors that create just the right conditions for certain species of plants to grow and propagate. Environmental factors can be physical (light, temperature) or chemical (nutrients, salinity). The relationship between plants and environmental factors is one of the most important aspects of the estuary's habitat ecology.

FIGURE 2-1
Major Habitats of the Estuary



Physical Influences on Habitats

Although there are many different environmental factors influencing the growth and distribution of plants in the estuary, we shall discuss only two of the most important factors: salinity and flooding.

Salinity

Two of the habitat classifications listed above (brackish and freshwater marsh, and saltmarsh) are based on salinity. Plants are very sensitive to salinity, which is the amount of salt in their environment. Salt can make it difficult for some plants to nourish themselves and to maintain a balanced water level in their tissue.

Only certain kinds of plants can tolerate high levels of salt. Such salt-tolerant plants are present in saltmarshes. Many saltmarsh plants get rid of the salt they take up by releasing it through special salt pores on their leaf surfaces.

In Chapter 1, an estuary was defined as the place where the freshwater of the river mixes with the saltwater of the ocean. This mixing of fresh and saltwater creates a condition called brackish water, which contains some salt, but much less than seawater. Plants adapted to these brackish conditions are found in brackish marshes.

Plants that grow in freshwater usually do not like even a moderate amount of salt. Plants in these freshwater marshes are found in areas of the estuary where seawater cannot reach.

Salinity is a very important environmental factor because it determines the geographic distribution of the different types of marshes found in the estuary. Saltmarshes are found farthest away from the influence of freshwater, in areas where there is usually only seawater. Brackish marshes are found near the outer estuary where freshwater and seawater mix. Freshwater marshes occur only in the upper parts of the estuary, away from any influence of seawater.

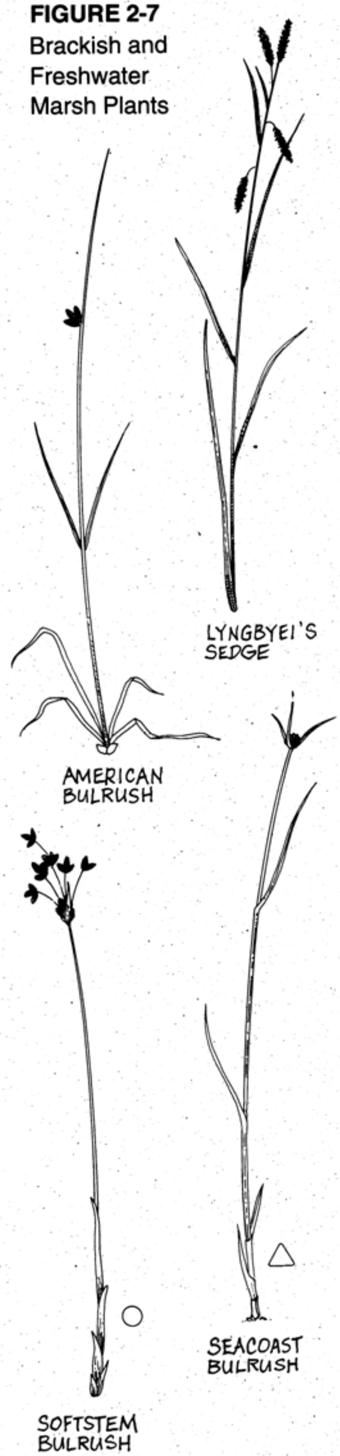
Flooding

Plants are also very sensitive to flooding. The longer and deeper an area is flooded, the less oxygen is available in the soil. Plant roots need oxygen to grow and survive. To overcome the shortage of oxygen in flooded soils, some species of plants have special oxygen storage cells and are able to bring this oxygen from their leaves and stems to their roots. However, when flooding is too deep or too long in duration, most rooted plants can no longer survive.

The degree of flooding depends on the elevation at which a plant is located. On higher areas of the outer delta, near the estuary's dikes, a plant would be flooded for a relatively short time, and perhaps only during the highest tides. Farther down the delta slope toward the lower intertidal zone, tidal flooding is longer in duration and greater in depth.

The outer delta certainly looks flat when viewed from the dikes. This is because the slope is very slight. Nevertheless, five or ten centimetres of rise or fall on the delta slope can begin to make a difference as to what type of plant can grow. Tidal marshes consist of distinct patterns of different types of plants, since their growth and distribution is easily influenced by small changes in soil elevation and flooding.

FIGURE 2-7
Brackish and Freshwater Marsh Plants



What are the features of this marsh?

Brackish and freshwater marshes are being discussed under the same heading because they are difficult to distinguish unless you are a biologist or experienced naturalist. Brackish marsh plants can tolerate freshwater for some periods of the year. As a result, there is considerable overlap between brackish and freshwater plant species.

Not only are these the most extensive marshes in the estuary, but they are also the most productive. Each year, our brackish and freshwater marshes produce an average of five metric tons of plant material per hectare. This amount of plant production is three times greater than that produced in saltmarshes.

At the end of the growing season, this plant production creates a huge supply of organic detritus, much of which is flushed out of the marshes with each tide. The organic detritus provides a nutritious food source which sustains life in tidal channels, sloughs and throughout the estuary.

Some of the Dominant Plants

Bulrush, Lyngbyei's Sedge, cat-tail, and Pacific Silverweed are some of the dominant plant types found in the brackish marsh. Figure 2-7 will help you identify these common marsh plants on your field trip to the lower estuary.

Bulrush can have either round or triangular shaped stems which are filled with a spongy tissue. The flowers consist of brown spikes with small overlapping scales. The round-stemmed bulrush shown in Figure 2-7 is the common tule or softstem bulrush (*Scirpus validus*). This plant is common to both brackish and freshwater marshes. Another common bulrush visible from the dykes in brackish marshes is the triangular-stemmed Seacoast Bulrush (*Scirpus maritimus*). The Three-square Bulrush (*Scirpus americanus*) which grows along the seaward margin of the outer delta marshes is an important food source for Snow Geese.

The most common sedge in the brackish environment is Lyngbyei's Sedge (*Carex lyngbyei*). Sedges tend to look much like grasses; however, there is a simple way to tell them apart. Sedges have stems with three sharp edges and soft joints (nodes), whereas grasses have round hollow stems with hard joints. Remember, "sedges have edges."

Cat-tails (*Typha latifolia*) are conspicuous tall plants with brown velvety heads. These plants are found near the dike, in ditches, and just about anywhere where there is fresh or brackish stagnant water. What you can't see are the massive root stocks, containing a core of almost pure starch, as much as corn but with less fat.

Pacific Silverweed (*Potentilla pacifica*) is often visible from a distance because of its feathery, silver leaves. This is a plant that can be found in brackish marshes, but it can also tolerate the higher salinities found in saltmarshes.


PACIFIC
SILVERWEED
CAT-TAILS

What are the features of the saltmarsh ?

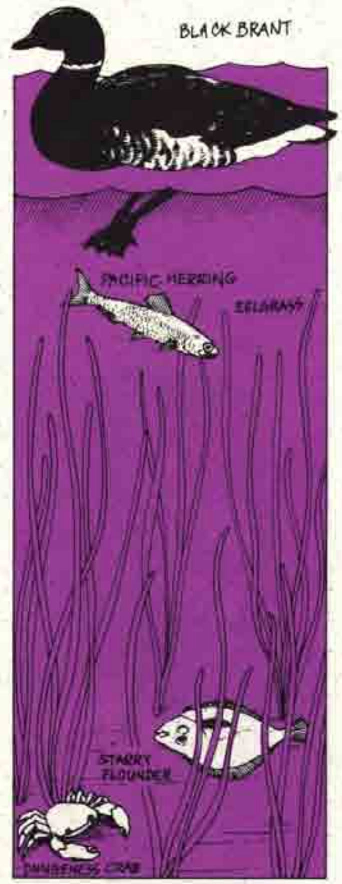
As with the brackish and freshwater marshes in the Fraser River Estuary, a large unvegetated tideflat extends seaward from where the saltmarsh ends. The tideflat at Boundary Bay is within easy reach, and in most places provides a firm surface to walk on. By contrast, the tideflats off Sturgeon Bank are located far from the dike and are very soft and muddy due to the fine silts originating from the Fraser River. Caution should be exercised wherever a tideflat is explored on foot. In this discussion, the tideflat habitat has been included with the saltmarsh habitat, because both can be easily explored and studied at the same time.

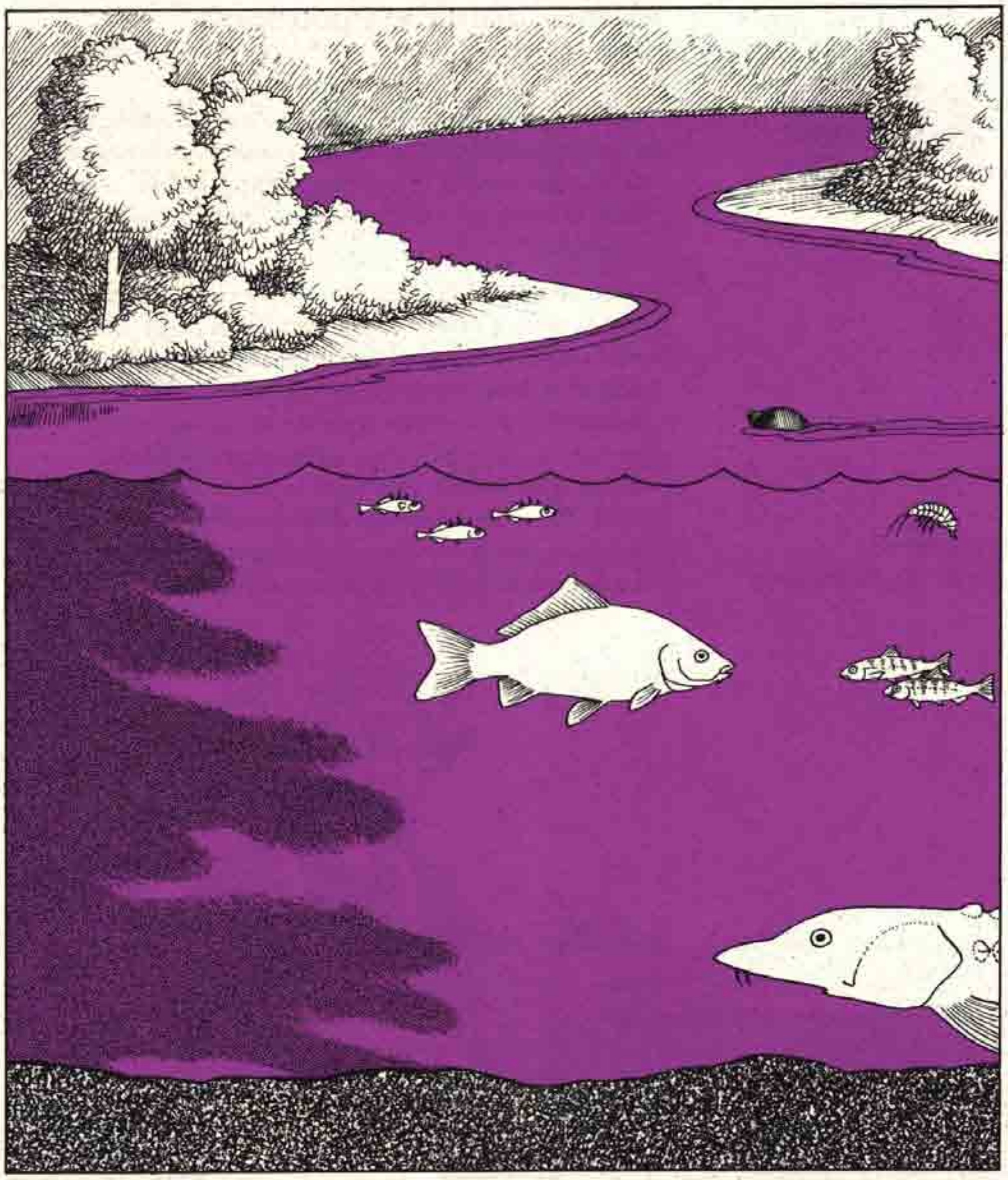
After visiting the brackish/freshwater marshes of Sturgeon Bank, the different appearance of the saltmarsh habitat will be quite obvious. Much of this difference is because the saltmarsh is constantly exposed to the salty effects of seawater. The salt tolerant plants growing in the saltmarsh are smaller and less productive than the plants of brackish/freshwater marshes. Also, the saltmarsh does not extend as far seaward from the dike as do the marshes of Sturgeon Bank.

What lives on the extensive tideflats ?

The tideflats beyond the saltmarsh habitat support large beds of eelgrass. Because these submerged aquatic plants can tolerate only brief exposure to the air, they occur near and below the lowest tide level. The eelgrass beds are too far away from the dike to be seen; but in winter, large piles of dead eelgrass leaves are washed inshore. In summer, eelgrass is easily seen after a short walk across the tideflat at, for example, Centennial Beach or White Rock Beach. Eelgrass beds are an important habitat for many small marine invertebrates as well as feeding Black Brant, flounder, Dungeness Crab and spawning Pacific Herring.

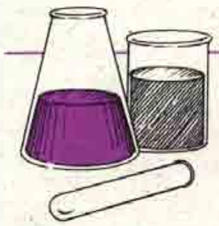
Large numbers of small marine invertebrates also live in the surface sediments of the tideflats. These invertebrates consist of marine worms such as Ragworms and Lugworms, burrowing shrimp and mollusks. So, although the tideflats look rather lifeless, there are actually hundreds of small invertebrates living below each square metre of sediment surface.





4. AQUATIC POLLUTION

Water is essential to aquatic habitats in estuaries because it provides many of the life-sustaining chemicals required by aquatic plants and animals. So we should be concerned about the potential effects of pollution on the estuary's aquatic habitat. This chapter describes some of the characteristics of pollutants.



What is Aquatic Pollution?

When we talk about a pollutant, we mean a substance that is not normally found in the environment, or is present in such large amounts that it can do harm. Pollution can be found in water, in sediments, and even in fish and other aquatic life.

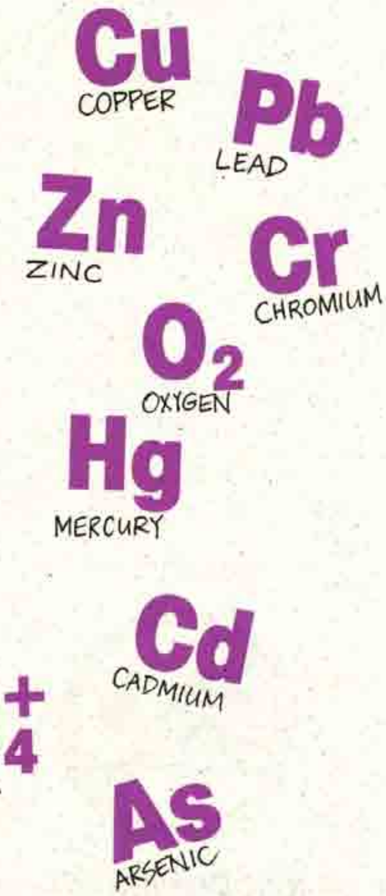
Some pollutants in an estuary are toxic to aquatic life even in minute amounts. For example, a single salt-grain-sized amount of copper (a toxic metal) dissolved in a bathtub of water would be harmful to fish. The same tiny amount of dioxin (a toxic organic contaminant often produced by pulp mills) in a swimming pool would endanger humans, if they were to take a drink of this water. There are numerous different inorganic and organic chemicals, along with various biological substances, that can degrade the quality of an estuary's water.

FIGURE 4-1
Water Quality Sampling

Inorganic Pollutants

Inorganic pollutants may include nutrient chemicals such as ammonia, and metals such as copper, lead, zinc, chromium, cadmium, arsenic and mercury. Nutrients and even metals occur naturally in fresh and sea water, and in proper and small amounts are essential to aquatic life. But when concentrations become too high, these chemicals can be harmful to life. Copper, for example, is an essential element in the blood of crabs and shrimp; yet when copper levels are elevated, it can kill the animal. Certain concentrations of ammonia dissolved in the water can be deadly to fish under certain conditions.

Sediment particles which are suspended in the water can serve as "attachment sites" for dissolved metals. This means that metal pollutants such as lead or mercury can become concentrated on suspended particles. Metals will then accumulate where these contaminated sediments settle out of the river flow and are deposited on the bottom. In this way, water pollution can contaminate mudflats and other places where sediment settles.



Organic Pollutants

Naturally occurring organic matter exists in particulate or dissolved form, and comes from living and dead plants and animals. This natural organic matter does not normally become a problem, because it is quickly recycled in the estuary by microorganisms and small detritus-eating invertebrates (see Food Chains and Food Webs in Chapter 1). However, even organic matter can cause pollution when too much accumulates and the estuary's natural recycling capacity is overloaded.

Too much organic matter stimulates the growth and activity of large numbers of bacteria and other microorganisms. As the bacteria "feed" on the organic matter, they use up much of the available oxygen in the water. This oxygen depletion can make it difficult for fish to breathe, and will often lead to their death.

Some organic pollutants are human-made, and these are of particular concern when they do not easily break down in the environment. PCBs (Polychlorinated biphenols, found in the cooling oil of large transformers); some pesticides (used to kill agricultural and garden pests); and dioxins and furans (chemical byproducts of industries such as pulp mills) are toxic organic pollutants that, once introduced into the environment, do not easily break down into harmless components.

Dioxins are an environmental hazard not only because they are very toxic, but also because they can be long-lasting in the environment. Natural recycling processes do not work very well with dioxins. Rather than being broken down into harmless products after they enter the estuary, they are often taken up and concentrated in aquatic organisms. This concentration of toxic substances in aquatic plants and animals is called "bioaccumulation," and is a potentially serious problem in any ecosystem.

Biological Pollutants

Biological pollutants consist of harmful bacteria, viruses and parasites that come from disease-carrying human and animal wastes. When these pollutants enter the estuary, they can be dangerous to people who come into contact with the water. Biological pollutants can cause a number of health problems in humans, including intestinal disorders (e.g., gastroenteritis), blood diseases (e.g., hepatitis) and parasitic infections (e.g., tape worms). To avoid the spread of human disease organisms, sewage is chlorinated (a disinfection process) before being discharged into the estuary during the summer months.

Those of us who like to eat oysters, clams and mussels must also be concerned about biological pollutants. This is because these animals feed by filtering large amounts of estuarine water through their gills. If the water is contaminated with biological pollutants, these animals will concentrate the pollutants in their body and pass them on to the person who eats them. This is precisely the reason why Boundary Bay, along with all other areas of the estuary, has long been closed to the harvesting of molluscan shellfish.

Bioaccumulation

As discussed in the section on dioxins, "bioaccumulation" is the term used to describe the uptake and retention of chemical contaminants which aquatic plants and animals obtain from food, water or sediments. Bottom-dwelling organisms such as worms, clams and groundfish that feed off the river bed can easily take up pollutants that have settled out with the sediment. Toxic organic pollutants which are not easily degraded by natural means tend to remain inside the bodies of these bottom-dwelling organisms.

Consider the case of a toxic chemical that is discharged into the estuary. It may enter the estuary in a number of ways: from a discharge pipe, from a ditch, from surface or groundwater, or even from the air. Once the chemical enters the water, it is usually diluted to a concentration that is too low to measure with even the most sensitive instruments. However, by providing numerous attachment sites on its surface (Figure 4-2), an organic sediment particle can concentrate the toxic chemical.

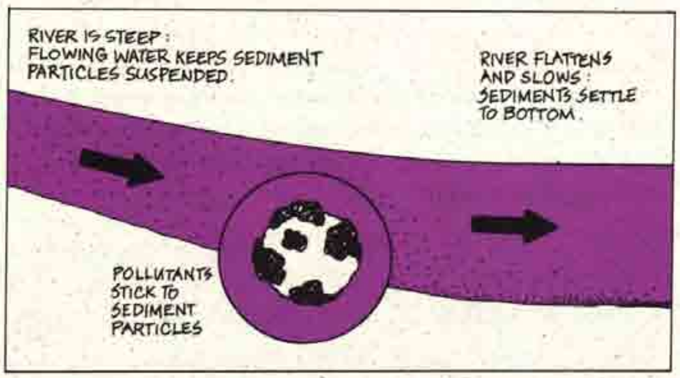
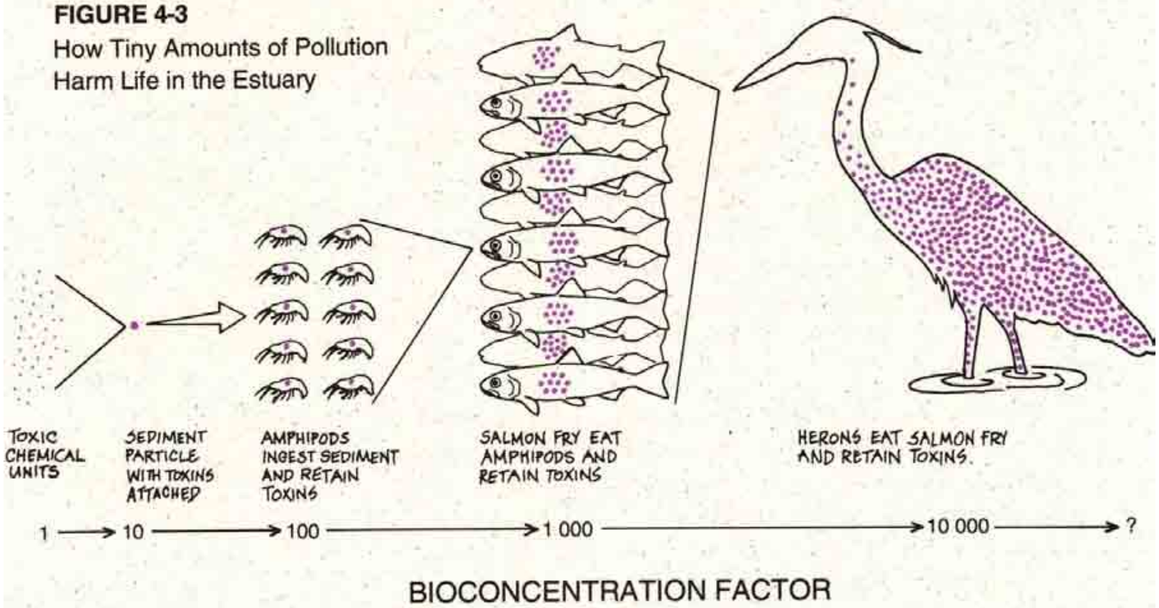


FIGURE 4-2
Pollution of Sediment Particles and River Bottom

The process of bioaccumulation is illustrated on the following page, Figure 4-3. In this example, a dissolved toxic chemical is concentrated ten-fold as it is attached to organic sediment particles which eventually settle to the bottom. There, bottom-dwelling amphipods are shown to consume ten of these contaminated particles. A small fish feeds on ten of these contaminated amphipods, and a Great Blue Heron then feeds on ten of the contaminated fish.

FIGURE 4-3
How Tiny Amounts of Pollution Harm Life in the Estuary



At each step of the food chain, the toxic contaminant is bioconcentrated ten-fold. By the time the toxic chemical reaches the Great Blue Heron, it has been biomagnified ten thousand times from its original minute (unmeasurable) concentration in the water. The unfortunate animal (perhaps a Bald Eagle, crow, seagull or coyote) that eats one of these sick or dead herons may have its life threatened as a result.

OTHER FACTS AND FIGURES

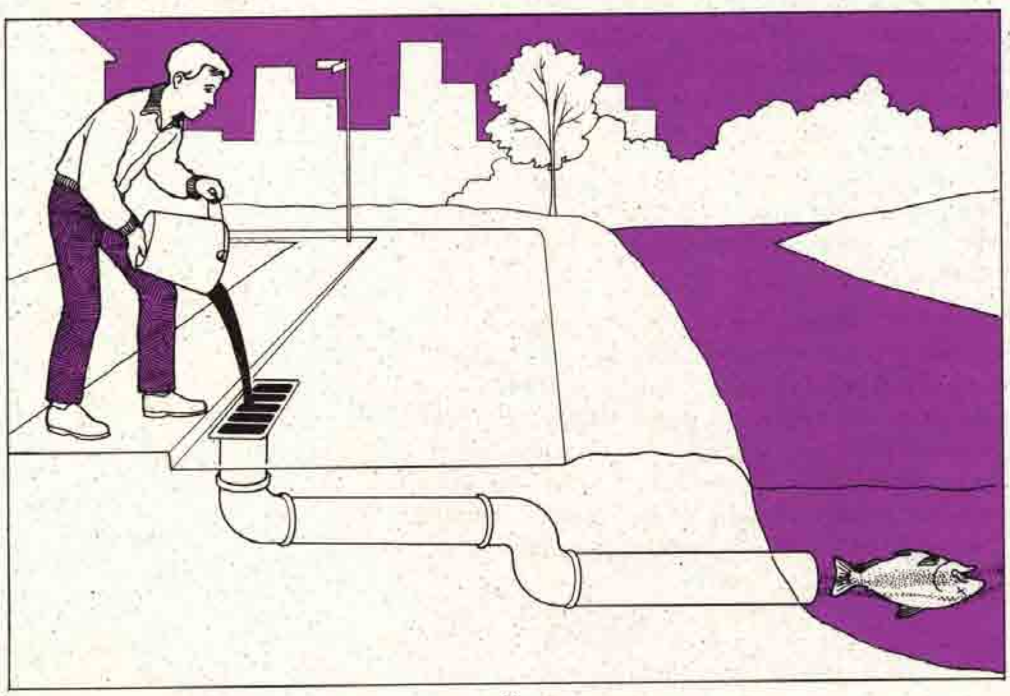
Down the Drain!

Many common household products contain substances that are toxic to aquatic life. Household chemicals such as toilet and oven cleaners, bleaches, household paints and thinners, insecticides, camping fuels and antifreeze all contain toxic chemicals.

Many people don't realize that these products are toxic to aquatic life and most of us don't know how to properly dispose of these hazardous materials once we are finished with them. As you can see in Figure 4-5, the worst way to get rid of left-over products is to flush them down the toilet, pour them into the kitchen sink, or dump them into a curbside stormdrain. If we do this, these toxic chemicals will eventually end up in our estuary where they can harm the aquatic life.

If you do not want toxic chemicals in household products to harm your estuary, dispose of them properly. Contact your local municipal hall or the Recycling Hotline (see Appendix 3) to find out the best way to dispose of your household chemicals.

FIGURE 4-5
Never Use a Storm Drain for Disposing Waste Materials!

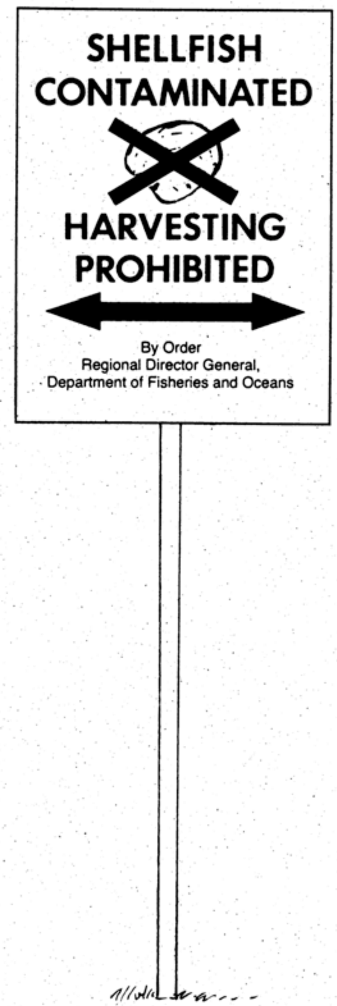


Too Much of a Good Thing!

It is a well known fact that animal manure serves as an excellent soil fertilizer by providing plant nutrients to enhance the growth of crops. However, too much nutrient supply in aquatic ecosystems will often result in problems. This was the case during the 1980's, when heavy rainfall flushed large amounts of nutrients (animal manure and other agricultural fertilizers) into drainage canals and sloughs that eventually fed into the Nicomekl and Serpentine Rivers. These nutrients stimulated excessive growths of algae. When the algae died off in the fall, there was a large biological oxygen demand which rapidly depleted the dissolved oxygen levels in the river water. This sequence of events resulted in major fish kills in the Serpentine and Nicomekl Rivers.

When animal manure is flushed into local drainages, it can introduce high numbers of coliform bacteria into adjacent parts of the estuary. Both the Serpentine and Nicomekl Rivers drain into Boundary Bay. The continuous high levels of coliform bacteria discharged each year into Boundary Bay have resulted in chronic bacterial contamination of molluscan shellfish. As a result, shellfish harvesting has been banned since 1962, eliminating one of the most important oyster production areas in British Columbia.

FIGURE 4-6



Freshwater Estuaries

Sometimes, freshwater from rivers mixes with large freshwater bodies creating a "freshwater estuary" that functions like typical brackish estuaries.

Not all estuaries contain brackish waters. But, sometimes, freshwater from rivers mixes with large freshwater bodies creating a "freshwater estuary" that functions like typical brackish estuaries. These estuaries occur where massive freshwater systems, such as the Great Lakes in the United States, are diluted by river or stream waters draining from adjacent lands.

Although freshwater estuaries do not contain saltwater, they are unique combinations of river and lake water, which are chemically distinct. Unlike brackish estuaries that are tidally driven, freshwater estuaries are storm-driven. In freshwater estuaries the composition of the water is often regulated by storm surges and subsequent seiches (vertical oscillations, or sloshing, of lake water). While the Great Lakes do exhibit tides, they are extremely small. Most changes in the water level are due to seiches, which act like tides, exchanging water between the river and the lake. Stratification and mixing of water in freshwater estuaries is also due to changes in temperature differences between stream water and lake waters. The shallow waters of streams responds quicker to changes in temperature changes than deeper lake waters. These changes affect the temperature of the water, its pH, dissolved oxygen and the salinity of the water of the two water bodies, thus influencing the chemistry of this type of estuarine system.

An example of a freshwater estuary can be found on the south-central shore of Lake Erie in Erie County, Ohio and it is called the Old Woman Creek Reserve. The Old Woman Creek National Estuarine Research Reserve is part of a national network of coastal reserves established as living laboratories for long-term scientific research and estuarine education.

Estuaries are unique places that are valuable to the environment and to society.

Estuaries are places like no other. Each with its own specific characteristics, but all playing vital roles in the environment and in our lives. Some examples of estuaries' unique and important features are:

- Each estuary can make up an individual ecosystem. Look on a world map. The Mississippi Delta estuaries in the Gulf of Mexico are different from estuaries in San Francisco Bay, California. However, estuaries are also interconnected with other surrounding environments (oceans, lakes, forests, grassy plains) and nearby human communities.
- Estuaries are constantly changing and are areas of transition. Life is dynamic and diverse in estuaries. Some animals and plants specialize in, or adapt to, living in the unique conditions of estuaries.
- Estuaries vary widely around the world. Earth's changing geology, flowing water and different weather patterns help create many diverse types of estuarine habitats.
- Rivers provide nutrients, organic matter, and sediments to estuaries. Rivers flow downstream delivering fresh water from streams, small rocks and silt, and leaves and other vegetation debris. Nutrients support life in the estuary.
- Estuaries can filter small amounts of pollutants and runoff. Vegetation helps filter and trap silt. However, too much nutrient or sediment input will create an unbalanced situation causing the health of the ecosystem to decline.
- Estuaries act like huge sponges, buffering and protecting upland areas from crashing waves and storms and preventing soil erosion. They soak up excess water from floods and stormy tidal surges driven into shore from strong winds.
- Estuaries provide a safe haven and protective nursery for small fish, shellfish, migrating birds, and coastal shore animals. In the U.S., estuaries are nurseries to over 75% of all fish and shellfish harvested.
- People enjoy living near estuaries and the surrounding coastline. They sail, fish, hike, swim, and enjoy bird watching. An estuary is often the center of a coastal community.

Why is Change Important to Estuaries?

- Estuaries change constantly. Change is necessary for healthy estuaries. Estuarine organisms have adapted to tolerate the changing conditions of estuaries.
- Tides are necessary for healthy estuaries as they flush the systems and provide nutrients to keep the food webs functional. However, tides create constantly changing conditions of exposure to air and inundation to water.
- Estuaries can be classified according to their water circulation as salt-wedge, fjord, slightly stratified, vertically mixed and freshwater.
- The depth and location of an estuary affects and changes conditions such as temperature and number of organisms present.
- Weather patterns, seasonal cycles and climate change affect and change conditions in estuaries. The Earth's climate is warming at a faster rate than normal. This warming is causing sea level to rise, which may ultimately result in flooded and lost estuaries.

Estuarine Dynamics

The Constantly Changing Estuary

Estuaries change constantly. Change is necessary for healthy estuaries. Estuarine organisms have adapted to tolerate the changing conditions of estuaries.

Estuaries are dynamic, constantly changing places. Changes in estuaries are caused by tides, water circulation, waves, wind, weather, and climate. Survival for estuarine organisms can be difficult, but many estuarine animals and plants have adapted to tolerate the varying conditions of estuaries. Changing conditions are an integral and necessary part of healthy, functioning estuaries

Tides Create Cyclical Changes in Estuaries

Tides are necessary for healthy estuaries as they flush the systems and provide nutrients to keep the food webs functional. However, tides create constantly changing conditions of exposure to air and inundation to water.

Earth's gravity holds our oceans and seas to its surface. At the same time, the sun and the moon's gravity forces pull on the oceans. Water on one side of Earth is pulled toward the moon and bulges out (creating a tidal bulge). Another tidal bulge on the opposite side of Earth occurs because the water on that side, being farther away from the moon, is not pulled toward the moon as strongly as is the earth. As Earth rotates, different places on the planet's surface experience the tidal bulge, and therefore experience changes in water levels. This daily rise and fall of the oceans are called tides.

Tides flood as the waters rise on the coast, pushing seawater into an estuary. Tides ebb and the waters flow out to sea. Tides ebb and flood on cycles over a 24-hour period. Each day, estuaries can have one or two high tides, plus one or two low tides. Animals and plants must adapt to this daily water level change, or they won't survive. Tides are necessary for healthy estuaries as they flush the systems and provide nutrients to keep the food webs functional.

As the tide ebbs and flows, the intertidal zone is once exposed to the elements and then inundated by tidal waters. In addition to the alternating wet and dry conditions, organisms must adapt to the waves that are in constant action in this zone.

Do you think there are differences in tidal range, the change between low and high tide, around the world? In Katchemak Bay in Alaska, spring tides can have a 20-22 foot tidal range between extreme low and high tides. Grand Bay in Mississippi experiences a much lower tidal range (1- 2 feet) in the spring.

Classifying Estuaries - By Geology

coastal plain | bar-built | deltas | tectonic | fjords

The features of an estuary are determined by a region's geology, and influenced by physical, chemical, and climatic conditions. For example, movements in the Earth's crust elevate or lower the coastline, changing the amount of seawater that enters an estuary from the ocean. The coastal elevation also determines the rate of fresh water that flows into an estuary from rivers and streams. The amounts of seawater and fresh water flowing into an estuary are never constant. The quantity of seawater in an estuary changes with the changing tides, and the quantity of fresh water flowing into an estuary increases and decreases with rainfall and snowmelt.

Estuaries are typically classified by their existing geology or their geologic origins (in other words, how they were formed). The five major types of estuaries classified by their geology are coastal plain, bar-built, deltas, tectonic and fjords. In geologic time, which is often measured on scales of hundreds of thousands to millions of years, estuaries are often fleeting features of the landscape. In fact, most estuaries are less than 10,000 years old (Levinton, 1995).

Coastal plain estuaries, or drowned river valleys, are formed when rising sea levels flood existing river valleys. Bar-built estuaries are characterized by barrier beaches or islands that form parallel to the coastline and separate the estuary from the ocean. Barrier beaches and islands are formed by the accumulation of sand or sediments deposited by ocean waves.

A delta, characterized by large, flat, fan-shaped deposits of sediment at the mouth of a river, occurs when sediments accumulate more rapidly than ocean currents can carry them away. When the Earth's tectonic plates run into or fold up underneath each other, they create depressions that form tectonic estuaries. Fjords are steep-walled river valleys created by advancing glaciers, which later became flooded with seawater as the glaciers retreated.

Classifying Estuaries by Water Circulation

Estuaries can be classified according to their water circulation as salt-wedge, fjord, slightly stratified, vertically mixed and freshwater estuaries.

Water circulation is important because it transports animals and plants, mixes nutrients, oxygen and sediments, and removes waste. Water carried by waves and the moving tides shape life in an estuary.

Estuaries are often classified based on their water circulation pattern.

- **Salt-wedge** – An estuary with a wedge-shaped layer of saltwater which lies below a fresh water layer. A salt-wedge occurs when a rapidly flowing river discharges into an estuary with weak ocean currents. A sharp boundary is created between the salt and freshwater layers. Fresh water floats on top and a wedge of saltwater lies on the bottom because the saltwater has a higher density than the fresh.
- **Fjord** – An estuary with restricted flow due to a series of sills and channels carved by glaciers. Glaciers carved deep channels and then melted and left shallow barriers, or sills, at the estuary floor near the ocean. These sills restrict estuary water from circulating between the estuary and the open ocean. Only the lighter freshwater near the surface flows over the sill and out toward the ocean.
- **Slightly Stratified** – An estuary where saltwater and freshwater mix at some, but not all depths. Lower layers of water near the estuary bottom typically remain saltier than the upper layers near the water surface. Higher salt content (salinity) is greatest at the mouth of an estuary near the ocean.
- **Vertically Mixed** – An estuary where the saltwater and freshwater mix at all depths. This occurs when a river's fresh water flow is low and the ocean's tidal currents are moderate to strong. The water salinity in a vertically mixed estuary is the same from the top of the water to the bottom of the estuary.
- **Freshwater** - Freshwater estuaries are semi-enclosed areas of the Great Lakes, where the lake waters become mixed with inflowing rivers or streams.

Water Depth and Estuary Location

The depth and location of an estuary affects and changes conditions such as temperature and number of organisms present.

Shallow estuarine waters allow great temperature changes. The sun heats up the estuary during the day, and cool waters from rivers and the sea enter the estuary by night. Tides also affect estuarine temperatures. At high tide, the deeper, lower reaches of the estuary remain cool, and only the top layers are heated by the sun. As the tide goes out, heating occurs more rapidly. Some estuarine organisms can withstand the variable estuarine temperatures, while others can not and attempt to escape.

In estuaries in temperate or polar regions there are high temperature differences which can result in a low number or plants and animals. In estuaries in tropical areas, where water temperature is more stable, the number of plants and animals is less affected.

Weather, Seasons and Climate Create Change in Estuaries

Weather patterns, seasonal cycles and climate change affect and change conditions in estuaries. The Earth's climate is warming at a faster rate than normal. This warming is causing sea level to rise, which may ultimately result in flooded and lost estuaries.

Weather patterns, seasonal cycles and climate change affect and change conditions in estuaries such as structure, temperature and water quantity and quality.

When wind blows across water, waves are formed. Waves carry energy and help stir up and mix nutrients, silt and decaying matter in an estuary. Large waves, often caused by storms, travel in from the ocean and carry lots of energy. This energy is released when the waves crash and pound into barrier reefs, sandbars and the open shore. The pounding energy can wash away sediments. Waves can also pound logs and debris that disturb sediment and sessile animals such as mussels and barnacles shores.

In addition to waves, currents caused by wind can cause changes to estuaries. Currents move sand and sediment in and out of estuaries and can erode away shorelines. Currents move floating organisms, such as phytoplankton and jellyfish, and plants through an estuary. Currents also deposit sediment, replenishing barrier islands and sandbars.

Seasonal cycles cause change in estuaries by bringing varying amounts of rainfall, changing temperatures, and sunlight. In some parts of the U.S., spring brings much rain. This deluge of freshwater flow can flush estuaries of excess debris and stir rich nutrients. Often, summer brings hot and dry spells which can cause parts of estuaries to become still and stagnant creating low oxygen content and high temperatures. In northern estuaries, winter can bring ice sheets which scour and gouge algae and invertebrates off rocks, or freeze and kill off shellfish populations.

Seasonal storms, such as hurricanes, can tear up shorelines, redistribute sand from one place to another, remove sediment and mud, deposit debris and dead material that can suffocate living vegetation, and tear up vegetation. Strong winds drive storm surges and crashing waves into land, damaging habitats and pushing salt water up rivers. However, storm surges can be helpful to estuaries by removing dead vegetation.

In addition floods result in reduced salinity, and drought can result in higher salinity. Estuarine organisms cope by moving out of unfavorable areas, shutting up shells, digging borrows and excretion of excess salts.

Recently scientists have discovered that the Earth's climate is warming at a faster rate that normal. This warming is likely caused by human activities that create excess carbon in the atmosphere. This change is also slowly warming the Earth's oceans. This warming is causing glaciers to melt, while also causing ocean water to expand as it heats up. These two factors are raising sea levels and threatening to flood estuaries. This sea level rise is happening relatively quickly and is decreasing the health of our world's estuaries.

Productive Ecosystems

Estuaries are some of the most productive ecosystems in the world.

Life in estuaries is complex and diverse. Organisms are not distributed evenly throughout different estuaries, nor are they distributed evenly throughout all parts of estuaries. Can any organism live in any area of an estuary? The answer is no. Organisms are adapted to live in certain types of estuaries and in certain estuarine conditions. Estuaries, and the plants and animals that live in them, can be described and grouped in many different ways, including by habitats, by tidal zones, by their role in the food web and by their native land.

Estuarine Habitats

Estuaries can have many different types of habitat. Some common estuarine habitats are: the water column, oyster reefs, coral reefs, kelp and other macroalgae, rocky shores and bottoms, soft shores and bottoms, submerged aquatic vegetation, coastal marshes, mangroves, deepwater swamps and riverine forests.

Habitat is home. It is where there is shelter and safety, where there is a suitable food and water supply, where there are associated plants and animals. Estuaries can contain several types of habitats, which define the types of organisms that live there. Some common estuarine habitats are:

- **Water Column** – The water column is the area of water from the seafloor up to the water surface. The water column contains free swimming, or pelagic, organisms and plankton (tiny drifting and floating organisms). The water column is a part of all bays, sloughs, lagoons and coastal areas; and is therefore part of an estuary.
- **Oyster Reefs** – Oyster reefs are communities of oysters formed by many individual oysters growing in clumps on the shells of dead oysters or other hard surfaces. Oyster reefs can be found around the entire coast of the country, except on the shores of the Great Lakes.
- **Coral Reefs** – Coral reefs are communities of many small individual, interconnected corals. One corals is made of a hard shell in which a small animal, called a polyp, lives. Most coral reefs are found on the shores of Hawaii, Florida and throughout the Caribbean and Pacific Ocean.
- **Kelp and Other Macroalgae** – Kelp and brown algae are a type of large seaweed called macroalgae. Kelp communities grow on hard surfaces at the seafloor and extend up to the water surface, like underwater trees, to create forests. Kelp forests are found on the west coast of the U.S. Other types of macroalgae may form dense beds across the bottom of the estuary.
- **Rocky Shores and Bottoms** – Rocky shores and bottoms are hard surfaces made of stones, boulders and bedrock. Rocky shores may have high waves and strong winds (high energy). Rocky bottoms are often flooded with exposure to air occurring only when the tide goes out.. Rocky shores and bottoms are commonly found along the west and northeast coasts of the country.
- **Soft Shores and Bottoms** – Soft shores and bottoms are low-lying sand beaches, muddy shores and mudflats made of sediments that have mixed with detritus (think of muck or ooze). Some contain submerged and upland vegetation, some do not. Many different benthic communities (or bottom dwellers) flourish in the soft shores and bottoms including burrowing worms, snails, crabs and clams. Soft shore and bottom habitats are found along coasts across the country.
- **Submerged Aquatic Vegetation** – Submerged aquatic vegetation, also called SAV, are beds of leafy rooted, grass-like plants with tiny flowers, found in shallow waters where light can penetrate. They survive underwater (subtidal areas) or in

areas that are both flooded and partially exposed by the tides (intertidal areas). SAV is found along coasts across the county.

- **Coastal Marshes** – Coastal marshes are composed of upright plants that live above the water surface, often with their roots submerged. Some examples of coastal marsh plats are cattails, grasses, and sedges. Coastal marshes are found across the county.
- **Mangroves** – Mangroves are trees that can survive in very salty areas. They are commonly identified by their unique roots which project from the muddy bottoms at the shore to the tree’s trunk. Mangroves grow in clusters and their roots form a complex maze along the coast. Mangrove forests grow along the coasts of the Gulf of Mexico and in the Caribbean.
- **Deepwater Swamps and Riverine Forests** – Deepwater swamps and riverine forests are flooded, forested wetlands growing near edges of lakes, rivers and sluggish streams. They are different from other forests because they can survive in areas with prolonged flooding. Deepwater coastal swamps and riverine forests are found across the country, but are most common along the Atlantic and Gulf Coasts and throughout the Mississippi River valley.

Tidal Zones

Estuaries can also be divided into tidal zones (supratidal, intertidal and subtidal zone) subject to changing water levels, temperature, oxygen content and levels of light.

With the incoming and ebbing tide, life exists in zonal habitats. Zonation describes the different zones or areas of the estuarine environment. Different organisms live in different zones depending on what conditions they are adapted to.

- **Supratidal Zone** – The supratidal zone is the area above the high tide water line that extends upland. This area is seldom covered by water. Some part of this zone can receive moisture from wave splash. Land-based or terrestrial animals and plants survive here if they can tolerate some seawater or brackish water. Marine animals and plants survive here if they can tolerate exposure to air. Some examples of organisms in the zone include: various trees, and shrubs, mammals such as deer and fox, birds, reptiles and much more.
- **Intertidal Zone** – The intertidal zone is the area that is exposed to the air at low tide and submerged at high tide. This area can include many different types of habitats, including steep rocky cliffs, sandy beaches or vast mudflats. Organisms in the intertidal zone are adapted to harsh extremes. Water can be high due to tides, rain and run off, and this water can be very salty at one time and very fresh another. These areas can also become very dry when tides are low for extended periods of time. Temperatures can range from very hot with full sun to freezing in colder climates. Some examples of organisms that live in the intertidal zone include: shore birds, marsh grasses, shrimp and fish (when water is present), snails, mussels and oysters, burrowing worms and much more.
- **Subtidal Zone** – The intertidal zone is the area below the low tide water line. This area is always covered by water. This area can include many different types of habitats, including soft and hard bottom, submerged aquatic vegetation beds and coral reefs. The organisms here can not tolerate very long exposure to the air or sun. Some examples of organisms that live in the subtidal zone include: eel grass, algae, fish, starfish, shrimp, crabs, dolphins and much more.

Unwanted Visitors

Invasive species are those that do not naturally live in an estuary, but were introduced, often accidentally, by humans. Invasive species compete with native plants and animals for shelter and food and weaken the ecosystem.

Organisms in an estuary can be grouped by their origins. Organisms native to an estuary are those naturally found living and reproducing there. Non-native organisms, or invasive species, are those that do not naturally live in an estuary, but were introduced or migrated there over time. Invasive species are often accidentally brought to an estuary by people. Once there, they may take over shelter and food resources and local animals and plants may have to struggle harder to succeed in living and maintain a strong population. Invasive species can drive out native species, which may change the ecosystem itself, and may damage the economies of coastal communities. Because they are not normally found there, invasive species often do not have a common predator and it may be very difficult to remove them once they are established in an area.

Many invasive species are found in the U.S. A few examples of well known estuarine invasive species include: Eurasian watermilfoil, hydrilla, purple loosestrife, Asian carp, Chinese mitten crab, European green crab, lionfish, northern snakehead, nutria and zebra mussel.

How are Estuaries Connected to My Life?

- Estuaries are important parts of our lives; interconnected to our economy, hobbies and culture, and an important part of our coastal and ocean ecosystems.
    - Estuaries provide commercial economic benefit to the U.S. in the form of seafood sales and jobs.
    - Recreational activities – such as fishing, birding, boating and hiking – are enjoyed by millions of Americans each year in estuaries bringing income to coastal communities.
    - Estuaries offer cultural importance to Americans. They are often city and trade centers, they are an important source of food, the buffer communities from storm surges, and they have a long history of cultural use by Native Americans.
    - Estuaries are vital ecosystems providing diverse habitat and nursery areas for many important organisms.
- Because we are all connected to the nation's coasts, our activities have many affects on estuaries, many of which are negative.
    - Anthropogenic disturbances to estuaries include coastal development, introduction of invasive species, pollution via runoff, over fishing, dredging and filling, dams and global climate change.
    - From government agencies and laws – established to protect estuaries – to volunteer citizens groups, our coasts are protected, restored and conserved in many ways.
    - There are many things you can do around your home an in your community to keep estuaries clean.

Estuaries are Vital to Humans

Estuaries are important parts of our lives; interconnected to our economy, hobbies and culture, and an important part of our coastal and ocean ecosystems.

Estuaries are important parts of our lives. Whether you live near the coast or many, many miles inland, you need estuaries and your actions affect estuaries. Estuaries are interconnected to our economy, hobbies and culture. Estuaries are a vital part of our coastal and ocean ecosystems

Commercial Economic Benefits

Estuaries provide commercial economic benefit to the U.S. in the form of seafood sales and jobs.

Fancy steamed shrimp or fried catfish for dinner? Chances are they were caught in an estuary. Estuaries provide many benefits to you and your loved ones, whether you live on the coast or in an inland state.

In 2006, the U.S. exported over $3.9 billion in seafood. Estuaries provide habitat for over 75% of the U.S. commercial sea catch. Without estuaries, the trade of seafood, which is so vital to the U.S. economy, would not exist.

Estuaries support jobs and income for many Americans each year. Think about all those who make their money from commercial activities in estuaries. Shrimp trawlers, crabbers and other commercial fishing boats fish in and near estuaries. The seafood they bring in is processed and distributed fresh or frozen by trains, boats, airplanes and trucks across the U.S. and the world. Approximately 85,000 people in the U.S. were employed in the seafood processing and wholesaling sectors in 1999.

There is also commercial value in some other, unexpected estuarine organisms. For example, oysters and clams can be crushed and use as fertilizer. Also, an extract of the horseshoe crab's blood is used by the pharmaceutical industries to ensure that their products (such as intravenous drugs and vaccines) are free of bacterial contamination.

Recreational Benefits

Recreational activities – such as fishing, birding, boating and hiking – are enjoyed by millions of Americans each year in estuaries bringing income to coastal communities.

Recreational fishing in estuaries by small boat angler is hugely popular in the U.S. Also, many Americans also enjoy bird-watching, boating, visiting the beach, sight seeing, botanical studies, hiking and camping in and near estuaries.

Estuaries provide a place for families and friends to enjoy their hobbies and spend time together in unique and beautiful areas. And, these activities, often called eco-tourism, support local economies near estuaries. Fishermen buy fresh bait, tackle and food. Boaters pay marina fees and perhaps hotel fees. Tourists eat in local restaurants and buy locals goods. Coastal and marine waters contribute $30 billion to the U.S. economy through recreational fishing, and provide a tourism destination for 89 million Americans each year

Some students visit estuaries, on trips or vitually through online field trips, to experience their beauty and learn about the complex processes that take place in estuaries.

Cultural Importance

Estuaries offer cultural importance to Americans. They are often city and trade centers, they are an important source of food, the buffer communities from storm surges, and they have a long history of cultural use by Native Americans.

To many communities, estuaries are rivers of life. Estuaries are close to cultural and population hubs like New Orleans, San Francisco and New York City. Over 50% of the U.S. population lives near the coast.

Seafood provides an important food source for the country. U.S. consumers spent an estimated $69.5 billion on fishery food products (via restaurants, carry-outs, retail sales for home consumption, etc.) in 2006. Besides fish and shellfish, many different types of kelp and algae can be eaten or used in processed foods.

Salt marsh soils and grasses buffer floods, absorb excess water and slow down storm surges. They protect and buffer coastal shores, towns and communities from ocean waves and storms.

Many Native Americans historically, and still today, rely on estuaries for their way of life. Historically, tribes traded shells (wampum) as currency. They used shells as gifts, decoration, tools and spearheads. Local clay was used for making pottery (pots, cups, plates). Coastal reeds were utilized for basket weaving, cooking, mats, and building homes. Hunting and fishing in and near estuaries occurred with hewn out log canoes, hook and lines, casting nets, hand made spears, bows and arrows depending on the seasonal variety of animals and fish. Present day tribes still rely on fishing and shellfish for food and income.

Humans Activities Impact Estuaries

Because we are all connected to the nation's coasts, our activities have many affects on estuaries, many of which are negative.

Do you live in the high mountains, arid deserts, or near fertile farm fields? Where ever you live, your actions affect estuaries. Everything that drains from the land feeds into many different estuaries and the oceans. Everyone lives in the watershed of an estuary. A watershed is the land area that drains into a stream, river, lake, estuary, or coastal zone.

What lakes, rivers or streams are near your home? And, where does the water in those channels travel? Wastewater (water from your yard, showers, dishwasher, etc.) drains downstream from your home or community and eventually into rivers and bays. On a map, trace water's path from your community to the ocean. Your water use affects estuaries every day. Keeping our rivers and streams clean keeps our estuaries and oceans clean.

Anthropogenic Disturbances

Anthropogenic disturbances to estuaries include coastal development, introduction of invasive species, pollution via runoff, over fishing, dredging and filling, dams and global climate change.

Anthropogenic means relating to or resulting from the influence of humans on the natural world. Because we are all connected to the nation's coasts, our activities can create disturbances to estuaries. The following are human induced, or anthropogenic, disturbances to estuaries.

- **Coastal development** – Concrete structures like bulkheads “harden the shoreline”. This means that land near the coast that once made up wetlands and estuaries is changed to hard surface and can no longer absorb storm surge and provide shelter or food for the animals and plants that exist in coastal regions.
- **Invasive species** – Purple loosestrife, nutria, snakehead fish, green crabs, and zebra mussels are just a few invasive species wreaking havoc on estuaries. Many invasive species were introduced by humans though ballast water exchange or through dumping of aquaria containing non-native fish. Many exotic species compete for food and shelter, prey on native species or push native species out of their natural habitat.
- **Polluted runoff** – When water runs downstream from cities, farms and factories, this runoff can carry many things harmful to estuaries such as excess nutrients, raw sewage and manure and chemical waste.
    - In an estuary, excess nutrients can cause eutrophication. Eutrophication can lead to large algae blooms. When the algae die off and decompose they use up all the dissolved oxygen, creating anoxic conditions that can kill fish. Excess nutrients can come from many sources, including runoff from crop land that carries excess fertilizer, or runoff from farms that carries animal waste.
    - Raw sewage can carry disease-causing organisms that, when in estuaries, can kill fish and other organisms and can be harmful to humans who use the estuary.
    - In an estuary, chemical waste can also kill or harm plants and animals. Chemical waste can come from many sources including motor oil discarded in storm drains, pesticides from crops and factory spills or waste.
- **Over fishing** – Over fishing reduces the number of commercially valuable estuarine organisms, not only impacting the diversity of the ecosystem, but also impacting local economies. Also, some types of fishing can have a negative effect on estuary bottoms and the organisms living in them (the benthic communities), on juvenile fish and on by-catch, altering the estuarine food web.
- **Dredging and filling** – Filling and draining of wetlands, and dredging deep navigation channels through estuaries and wetlands ultimately destroys and damages habitat. They also change water and sediment flow.
- **Dams** - Changing river water flow can restrict sediment deposits and nutrient availability downstream, fish migration, and can increase saltwater intrusion into underground water tables.
- **Global climate change** – Scientists are confident that the Earth’s climate has entered a period of more rapid change than experienced over the past 1,000 years. Climate change can result in changes in the amount and timing of freshwater inputs to estuarine ecosystems, changes in temperature of the air and water, increases in sea level, more frequent and intense tropical storms, and changes in coastal currents. All of these changes can cause stress to estuarine organisms, can change where estuarine species are found, can alter estuarine processes and the physical and chemical patterns and make-up of estuaries.

Things You Can Do to Protect Estuaries

[S]ometimes when we wonder [why], we can make things begin to happen".

Estuaries require everyone's help and hard work to keep them clean and safe. There are many things you can do to help protect estuaries and to conserve the valuable natural resource in estuarine ecosystems.

Around the House

- Use lawn fertilizer sparingly, or not at all. Follow product directions carefully. You'll keep it from washing into our streams and waterways.
- Leave grass clippings on the lawn. Clippings decompose and are efficient, natural fertilizers.
- Cut grass to proper height. A little more height is healthy, leading to a deeper root system and less erosion.
- Use native plants. Gardening and landscaping with plants native to your area reduces the need for watering and fertilizing your garden.
- Think before you pour. Too many hazardous products flow from drains through sewage plants into coastal rivers and estuaries.
- Keep septic systems working properly. Pump every three years to assure proper working condition.
- Use lawn care products sparingly, or not at all. Always follow the directions carefully. If these products wash into streams, roadside ditches or street gutters, it can affect plants and animals far from your home.
- Create nontoxic pesticides. A bit of soap and water added to strained chili pepper powder does the job, and keeps harmful chemicals from ending up in nearby waterways.
- Explore safe alternatives to harsh household products. Baking soda or table salt, for instance, are safe substitutes for abrasive cleaners.
- Clean up after your pets. Animal waste adds to run-off, making water unhealthy.

- Walk, bike, carpool, use public transportation. Use your car less by combining errands.
- Use less electricity. Conserve water and lessen fossil fuel consumption.

Along the Waterfront

- Protect waterside trees and shrubs. These trees and shrubs are a protective gift along the water's edge and should not be cut, pruned or altered.
- Plant buffer strips. Restore riverside grasses, shrubs and trees to filter pollutants, sediments and excess nutrients from ground and surface water.
- Avoid erosion. Place mulch over disturbed soil in heavily used areas.
- Pave less. Hard surfaces hasten run-off and erosion.
- Curb run-off. When storm water is a problem, create a path or ledge to both capture run-off and filter pollutants through sand.

On the Beach

- Fish respectfully. Follow "catch and release" practices and keep more fish alive.
- Respect life on the rock. If you turn over rocks at the beach, remember to put them back so that animals that live on top, like barnacles, stay on the top and those that live on the bottom stay on the bottom.
- Have fun on the beach, but leave it clean. When you leave the beach or park, your trash should too. Be sure to bring enough bags to take all trash with you.
- Don't trample. To view life in coastal regions, use a canoe or kayak so you don't destroy sensitive habitats.
- Watch out for contamination. Support periodic testing to make sure that pesticides aren't contaminating golf course waters, adjacent creeks and groundwater.
- Eliminate poisons. If you hunt or fish, use nontoxic alternatives to lead shot, sinkers and jigs.

On your Boat

- Keep it friendly. Waves destroy shorelines and increase erosion. For environmentally friendly boating, observe posted speeds and "no-wake" signs.
- Secure loose items. Don't let items blow overboard and add to marine debris.
- Watch out for leaks. Be vigilant about harmful oil leaks from boat engines.
- Mop up. Use environmentally friendly cleaning products, and don't clean up by tossing debris out to sea. Trash, chemicals,

plastic bags and fishing lines can pollute or strangle vulnerable marine life.
- Respect habitat. Treat the homes of vital marine life with care. Habitat and survival go hand-in-hand. When habitat disappears, some plants and animals do too.

In your Community

- Share your knowledge. Spread the word about America's estuaries. Share what you know about protecting them with your families, students, community leaders and others.
- Take action! Organize a stream or beach cleanup. Encourage your local newspaper to write a story, or ask an expert to speak at your community organization or local school.

Why Are Estuaries Important? Ecosystem Services

In addition to providing economic, cultural and ecological benefits to communities, estuaries deliver invaluable ecosystem services. Ecosystem services are fundamental life-support processes upon which all organisms depend (Daily et al., 1997). Two ecosystem services that estuaries provide are water filtration and habitat protection.

Habitats associated with estuaries, such as salt marshes and mangrove forests, act like enormous filters. As water flows through a salt marsh, marsh grasses and peat (a spongy matrix of live roots, decomposing organic material, and soil) filter pollutants such as herbicides, pesticides, and heavy metals out of the water, as well as excess sediments and nutrients (USEPA, 1993).

One reason that estuaries are such productive ecosystems is that the water filtering through them brings in nutrients from the surrounding watershed. A watershed, or drainage basin, is the entire land area that drains into a particular body of water, like a lake, river or estuary. In addition to nutrients, that same water often brings with it all of the pollutants that were applied to the lands in the watershed. For this reason, estuaries are some of the most fertile ecosystems on Earth, yet they may also be some of the most polluted.

Estuaries and their surrounding wetlands are also buffer zones. They stabilize shorelines and protect coastal areas, inland habitats and human communities from floods and storm surges from hurricanes. When flooding does occur, estuaries often act like huge sponges, soaking up the excess water. Estuarine habitats also protect streams, river channels and coastal shores from excessive erosion caused by wind, water and ice.

Unlike economic services, ecosystem services are difficult to put a value on, but we cannot do without them, and thus, they are essentially priceless.

Adaptations to Life in the Estuary

mangrove trees | blue crabs

Mangrove trees and blue crabs are some of the estuarine species that have adapted to unique environmental conditions. In almost all estuaries the salinity of the water changes constantly over the tidal cycle. To survive in these conditions, plants and animals living in estuaries must be able to respond quickly to drastic changes in salinity.

Pickleweed (*Salicornia sp.*) is an edible halophylic (salt-loving) plant that tolerates the unique and constantly changing environment of the salt-marsh estuary. **Click on image** for more details and a larger view.

Plants and animals that can tolerate only slight changes in salinity are called stenohaline (Sumich, 1996). These organisms usually live in either freshwater or saltwater environments. Most stenohaline organisms cannot tolerate the rapid changes in salinity that occur during each tidal cycle in an estuary.

Plants and animals that can tolerate a wide range of salinities are called euryhaline. These are the plants and animals most often found in the brackish waters of estuaries. There are far fewer euryhaline than stenohaline organisms because it requires a lot of energy to adapt to constantly changing salinities. Organisms that can do this are rare and special. Some organisms have evolved special physical structures to cope with changing salinity. The smooth cordgrass *(Spartina alterniflora)* found in salt marshes, for example, has special filters on its roots to remove salts from the water it absorbs. This plant also expels excess salt through its leaves.

Unlike plants, which typically live their whole lives rooted to one spot, many animals that live in estuaries must change their behavior according to the surrounding waters' salinity in order to survive. Oysters and blue crabs are good examples of animals that do this.

Oysters can live in the brackish waters of estuaries by adapting their behavior to the constantly changing environment. **Click on image** for more details and a larger view. (Photo: Apalachicola NERRS site)

Natural Disturbances to Estuaries

This pair of images illustrates the destructive power that hurricanes can have on estuarine environments. This barrier island in Pine Beach, Alabama, was severed following hurricane Ivan's landfall in late 2004. The image on the left was taken on July 17, 2001. The image on the right was taken on September 17, 2004, soon after Hurricane Ivan reached the Alabama mainland. **Click on either image** for a larger view.

Estuaries are fragile ecosystems that are very susceptible to disturbances. Natural disturbances are caused by the forces of nature, while anthropogenic disturbances are caused by people. Natural disturbances include winds, tidal currents, waves, and ice.

Anthropogenic disturbances include pollution, coastal development, and the introduction of non-native species to an area.

We like to think of natural places as being stable over time, but, in fact, they are not. Natural habitats are continually disturbed by natural processes, followed by periods of recovery. When a natural disturbance is followed by an anthropogenic disturbance or vice versa, a habitat may become so damaged that it never recovers.

Dead floating plant material, called wrack, is often deposited on salt marshes by high spring tides, smothering all of the plant life beneath it. **Click on image** for more details and a larger view. (Photo: Weeks Bay NERRS site)

One type of natural disturbance is the continual pounding of ocean waves. In many estuaries, barrier beaches protect inland habitats from wave erosion. If these beaches are destroyed, salt marshes and inland habitats adjacent to the estuary may become permanently damaged. Waves can also dislodge plants and animals, or bury them with sediments, while objects carried by the water can crush them. Large storms are especially destructive to estuaries, particularly in areas like Florida and the Carolinas, where barrier beaches are common.

A common disturbance to estuaries in nontropical regions is winter ice (Bertness, 1999). Ice can freeze on an estuary's shoreline, or float freely in the water. When slabs of free-floating ice make contact with the shore, they have a scouring effect, dislodging and killing the plants and shoreline animals that lie in their path. When sheets of ice form on the shore, especially in salt marshes, they can trap plants and grass stalks inside them. During high tides, these ice sheets are lifted up, or rafted, inland to the high marsh. These rafts carry both ice and tufts of plants inshore. When the rafts settle down at low tide, they can smother inshore vegetation or scrape it from the soil. Further damage is caused as these sheets of ice and vegetation are rafted and dragged across the marsh with the ebb and flow of the daily tides.

Another natural disturbance in salt marshes is the burial of vegetation by rafts of dead floating plant material, called wrack. Wracks can be quite large—up to hundreds of square meters, and up to 30 centimeters thick. The spring high tides often move these wracks into the high marsh, where they become stranded (Bertness, 1999).

The Future: Managing, Protecting and Restoring Estuaries

Estuaries are biologically and economically invaluable natural resources. Assaulted by natural and anthropogenic disturbances, estuaries, and the plants and animals that call them home, are in danger of disappearing if actions are not taken to protect them.

During the last century, millions of acres of estuarine habitats have been destroyed; many more are in poor health and in danger of being lost. In 1996, 62% of estuaries had good water quality (USEPA, 1996). By 2000, only 49% of estuaries had good water quality (USEPA, 2000). How we choose to treat our estuaries today will have an enormous impact on their existence in the future.

Recognizing the value and importance of estuaries and the dangers facing them, Congress created the National Estuarine Research Reserve System (NERRS) in 1972. NERRS is dedicated to protecting a system of estuaries that represent the range of coastal estuarine habitats in the United States and its territories. The system protects more than one million acres of estuarine land and water in 17 states and Puerto Rico. NEERS sites serve as laboratories and classrooms where the effects of natural and human activities on estuaries can be monitored and studied by scientists and students. In addition, all estuaries, whether or not they are in the National Estuarine Research Reserve System, are protected under every U.S. state's coastal zone management program. Many states have designated estuaries as areas to preserve or restore for their conservation, recreational, ecological, historical, and aesthetic values.

When we have failed to protect estuaries, another course of action is to restore them. Restoring habitats involves removing pollutants and invasive species from the water and surrounding lands, reestablishing natural ecosystem processes, and reintroducing native plants and animals. The goal is to rebuild the estuary to a healthy, natural ecosystem that works like it did before it was polluted or destroyed.

Many species, like these great egrets, nest and breed in estuaries around the world. If estuarine habitats are not protected, these magnificent birds, and many other species, may face extinction as their habitats disappear. **Click on image** for a larger view.

Section giving information on the Tantramar Marshland

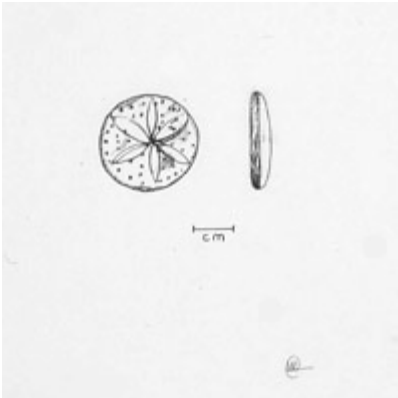
Natural Environment

Situated at the upper end of the Bay of Fundy, straddling the modern-day border between the Provinces of New Brunswick and Nova Scotia, the Tantramar Marshes area form one of the largest tidal saltmarshes (20,230 hectares) on the Atlantic coast of North America. The marshland zone consists of broad expanses of flat lowlands. Barely above mean sea level, the marshes exhibit deep silts deposited by centuries of tidal flooding. Flanking and interspersing the marsh are pronounced upland ridges that rise some 30-50 metres above the marshes. The low elevations and the long history of tidal flooding of the marsh floor also means that natural drainage is poor creating shallow lakes and bogs, some of which carry an extensive cover of sedges and expanses of tree cover such as hackmatack (Tamarack or Eastern Larch). Slow moving, deeply incised meandering rivers form an important part of the landscape, all of which provides a rich and productive habitat for wildlife and the great populations of migratory birds that stop on the marshes as they fly between summer habitats in Northern Canada and winter habitats in more favourable climate zones to the south. The grasses that dominated the marshes before they were replaced by European settlers were necessarily salt tolerant species such as cord grass (Spartina altinaflora) which formed a growth pattern that bound the silty soils tightly together, stabilizing the surface against excessive erosion. Within the tidal zone on the seaward edges of the marsh, and in the lower tidal reaches of the streams flowing from the marsh, the exceptionally high tides characteristic of the Bay of Fundy produced a remarkable nursery and habitat for many species of freshwater and estuarine life. For more on the scientific study of this environment visit the **Coastal Wetlands Insititute**.

First People and the Marsh

The marshes have a long history of human occupance. For at least 5,000 years prior to European contact, indigenous peoples harvested the plants, wildfowl and small mammal resources that abounded where the fresh and saltwater meet. Native oral tradition alludes to the Tantramar Marshes as a meeting place as Mi'kmaq bands moved seasonally between seacoast and forest to collect essential food and other resources. This pattern meant that they established temporary encampments on the margins of the marshes. They also established well traveled portage routes crossing the Chignecto Isthmus through the marshes thereby linking the Bay of Fundy with the Northumberland Strait. Their presence as the first people of the area continues in the survival of certain place names, such as Westcock, believed to be an English corruption of "Vestkack," possibly meaning "Great Marsh" and "Chignecto," the name given to the isthmus on which the marshes rest, which seems to derive from the Mi'kmaq term "Sinunikt" or "Siknikt" meaning foot cloth, possibly associated with native legend.

Click on the image to enlarge.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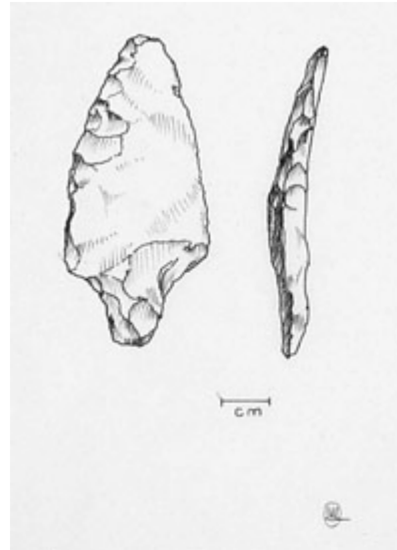
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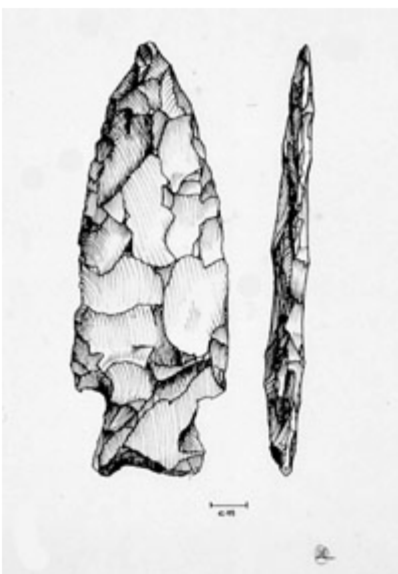
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Acadian Settlement

When French Acadian settlers arrived on the marshes in 1672, they heard the sound of tidal waters rushing up the marsh channels, responding to the 13 meter tidal range of the Bay of Fundy. The Acadians were also struck by the noise of the abundant migratory waterfowl. The combination of these distinctive sounds led them to name the marshes `Tintamarre', translated as a place of cacophonous din. It is also known that the French settlers at Annapolis had implemented dyking techniques similar to those used in the areas of western France from whence they had come, and as these Acadian settlers and their descendants spread to Cobequid and into the Minas Basin and later initiated new agricultural settlement at the mouths of the Tantramar, Aulac and Missiguash Rivers, they naturally introduced this technique to these marshes as well. The agricultural productivity of the reclaimed marshes soon led to a thriving trade in cattle and other agricultural products with the region's fishing settlements at Le Havre, Canso and Louisbourg, and externally with New France and New England.

As in other Acadian settled areas of the region, a scattered series of small hamlets eventually emerged, most of which were located on higher ground either on the ridges or on "islands" that stood above the areas prone to flooding. Acadian farmers necessarily devoted much effort to creating and maintaining the dykes that served to protect their fields and pastures. Particularly crucial in this technique were the aboiteau or sluice gates that were installed where the rivers crossed the dykes. The *aboiteau(aboideau)* was a wooden outflow with a form of clapper gate hung vertically so as to open under the flow pressure of the fresh water from upstream, but shut tight against a sill when the tidal flood surged up the river or creek thereby preventing the salt water from back flooding above the dyke. The purpose of this technology was to allow the salinity of the marshes to be progressively reduced so that European crops and grasses could be grown.

The French hold on the region was a tenuous one following the Treaty of Utrecht in 1713 which granted much of Nova Scotia to the British. The Isthmus of Chignecto, with its position at the head of the Bay of Fundy, formed one of a series of uneasy frontiers in the contest between the French and the English for control of the region. For the Acadians living on or near the Marshes, these events formed an unwanted intrusion on the demands of everyday life. Their preoccupation was with the maintenance and extension of their marsh agriculture and with trade that was as much dependent upon markets in Boston as it was with supplying the French colonial bastion at Louisbourg.

In Nova Scotia an uneasy stalemate between the British and French prevailed. The first fall of the French fortress of Louisbourg in 1745 and subsequent troop movement through the Chignecto region increased suspicion about the loyalty of the Acadian population. The Treaty of Aix-la-Chapelle in 1748, while restoring Isle St. Jean (present day Prince Edward Island), Isle Royale (Cape Breton Island) and Louisbourg to French control, also paved the way for increased British settlement of peninsular Nova Scotia and forced Acadians unwilling to take the oath of allegiance to the British Crown to resettle in French territory west of the Missaguash River at Chignecto. These geopolitical events led the French authorities to build two defensive positions: Fort Gaspereaux on the Northumberland side of the Chignecto isthmus, and the larger Fort Beausejour on the Fundy side, which were operational by 1755. At about the same time the British authorities constructed Fort Lawrence on an adjacent ridge so that these two defensive positions faced each other in the middle of the marsh.

In 1750, Abbé Le Loutre, who had arrived in the region as a Catholic priest to the Mi'kmaq and who had assumed control of the local area, ordered the destruction of the village of Beaubassin in an effort to drive the Acadian population into French territory. The refugee Acadian population in the Tantramar area was reluctant to provide military service to the French garrison at Fort Beausejour, preferring to maintain neutrality. Indeed, when the fort was eventually captured by a British force from adjacent Fort Lawrence, the capitulation of the French force was in part the result of pressure from Acadians within the fortress who threatened to turn their arms against the French garrison unless it surrendered. The climax came in June of 1755 with the British launching the assault on Fort Beausejour by marshaling their forces from Fort Lawrence along with those landed from a fleet of some 37 ships. The attack came after the British established a bridgehead on the Missaguash north of Fort Beausejour near Pont à Buot, which later became the hamlet of Point de Bute. Over several days they secured the site. After meeting only token resistence, they commenced lobbing bombs at Fort Beausejour thereby inducing the French to capitulate. Thus ended the French colonial presence in Chignecto in 1755.

For the Acadians the consequences were drastic. Their choices were to escape into the hinterland or suffer deportation by the British. As a result of these events, almost all Acadian settlements in and around the Marshes were burned to the ground either by the British or by the Acadians themselves. Consequently, except for the modern dykes, many of which probably stand where Acadians had constructed theirs, little physical evidence remains to allow us to capture an image of Acadian settlement.

The Marsh Economy and Society in the 20th Century

To understand the dominance of hay on the marsh, we need to look at the nature of supply and market forces. First, the marshes once drained, were highly productive of marsh grasses and imported grass species suitable for hay production. The costs of producing hay were low, farmers frequently took more than one crop off in a season, storing hay until market conditions were at their peak. Second, demand for hay as a feed for horses soared in the pre-automobile era, particularly as industrial and urban uses increased. Tantramar hay found four major markets. The first of these was to supply horse feed to lumber camps in various parts of New Brunswick and Nova Scotia as the extensive forest lands of these provinces witnessed a major boom. Second, considerable amounts of hay were exported to Newfoundland for the exploitation of forest resources. A third market was to the coal mines of Cape Breton where Tantramar hay was used for fodder for pit ponies. Well into the 1930s and 1940s, Cape Breton proved a reliable market. A further market was the supply of urban horse transport, including livery stables as far afield as Boston.

Technological innovation in the form of the internal combustion engine dealt a death blow to the Tantramar hay economy in the 1920s and 1930s. As horse transport gave way to the automobile and as Maritime manufacturing stagnated in favour of concentration in Ontario and Quebec, the price of hay plummeted. From a high of $28 per ton in 1920, the price had fallen to $7 by 1938. Other commodity prices fell too, not increasing again until the late 1930s. By 1943, however, the combined affects of a rapidly declining hay market, brought on as automobiles and trucks, and other heavy equipment replaced horse power, and failure to fund routine maintenance of dykes due to the Great Depression, left the Tantramar region's farm economy in difficulty. This situation produced fears of a collapse of the essential infrastructure of the marshes and in response both the Sackville and Amherst Boards of Trade lobbied the federal government for aid to repair the dykes. With the end of the Second World War these efforts led to the Maritime Dykelands Reclamation Committee, and after 1948 through the federal Department of Agriculture, the Maritime Marshlands Rehabilitation Act (MMRA).

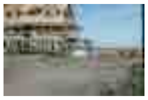
In spite of these efforts, the role of agriculture on the marshes underwent a profound change in the post war period. The demise of the hay economy required producers to rethink their agricultural options and the marshes came to serve as pasture for cattle rather than as a basis for hay exports. These changes made the many hay barns that dotted the marsh obsolete, and through the 1960s and 70s many of these buildings fell prey to fire, or were carried away by those who sought the then fashionable weathered "barn board" siding to complete a household decorating project. It is also the case that the numbers of active commercial farm operations shrank dramatically and most farm families derived an increasingly important share of their livelihood by other forms of employment.

As their agricultural role declined, attention turned to seeing potential of the Marshes as a habitat for wildlife, particularly birds. The combined interests of the Canadian Wildlife Service, whose Atlantic headquarters are located in Sackville, and the presence in Amherst of a regional office for Ducks Unlimited, an international organization dedicated to preserving and recreating habitat for waterfowl on behalf of hunters and other constituencies, played no small role in these efforts. Several areas of the marshes were re-flooded in order to return them to a more natural state for migratory birds. Economic development authorities centred in the communities adjacent to the marshes sought to exploit the new notion of eco-tourism as a means to attract visitors to the area, particularly bird-watchers. These developments were further underscored when a portion of the marsh that abutted Sackville enhanced its downtown by establishing a Waterfowl Park with an extensive boardwalk to enable residents and visitors alike to reconnect with this habitat.

Introduction: Coastal Wetlands in Atlantic Canada

The loss and fragmentation of coastal wetlands in Atlantic Canada, including saltmarshes, brackish marshes, barachois ponds, and small intertidal estuaries, is one of the most severe and publicized cases of wetland loss in Canada.

It has been estimated that 65% of salt marshes in the upper Bay of Fundy have been lost, mostly by dyking and draining for conversion to agriculture since European settlement. Many remaining areas have been further degraded by construction of barriers and culverts which limit the movement of tidal waters.



In recent years, the popularity of beaches along the Northumberland Strait has resulted in many coastal wetlands being filled or drained for residential development.

Web Site Tip:

Click on the thumbnails for full size images and descriptions.

Salt marshes are integral components of Maritime Canada's coastal ecosystems, serving as important areas of primary production for coastal food chains, and habitats for wildlife such as fish, insects and birds. The loss of coastal wetlands has probably resulted in declines in populations of birds that are dependent on them. Of particular concern are the impacts of habitat loss for birds such as the Willet and Nelson's Sharp-tailed Sparrow, whose populations in the Maritime provinces may be less than 2,500 and 750 pairs, respectively.

Salt Marsh Conservation

Environment Canada, and its partners in the Eastern Habitat Joint Venture are actively trying to ensure the conservation of salt marshes in Atlantic Canada through acquisition and stewardship.

Acquisition of the most critical salt marsh habitat may occur through the purchase of land which is currently owned by private individuals To date EHJV partners have conserved over 1,200 ha of critical salt marsh habitat in Atlantic Canada. Some of these lands are incorporated in National Wildlife Areas such as the case for the Mary's Point section of Shepody National Wildlife Area.

Acquisition of other salt marshes may also occur through the donation of lands to conservation agencies such as the Nature Conservancy of Canada, PEI Nature Trust, NBNature Trust, Nova Scotia Nature Trust, Ducks Unlimited Canada. Through the federal Eco-Gifts program the donation of ecological sensitive lands to conservation groups qualifies for a tax deduction. For more information on the Eco-Gifts program visit the web site EcoGifts, or contact the Atlantic Region Eco-Gifts Co-ordinator in Sackville, N.B.

Stewardship Agreements also allow for the protection of salt marshes. Through these agreements private landowners retain ownership to their land and are provided technical assistance by which to preserve their salt marshes. This may also include interpretative materials and signage explaining the importance of salt marsh habitats. Brunswick Mining and Smelting has protected 200 ha of salt marsh in Bathurst NB through the creation of the Daly Point Nature Preserve.

Salt Marsh Restoration

Many salt marshes have been drained for agriculture or degraded through the improper installation of culverts. However these salt marshes can be restored or rehabilitated. The John Lusby salt marsh which is part of the Chignecto National Wildlife Area is former dykeland that was restored when the dikes were breached. Environment Canada in co-operation with other government agencies, and conservation groups associated with the Gulf of Maine Council are identifying opportunities to restore salt marsh function. Salt marshes may be restored through relatively simple activities such as enlarging culvert sizes, or plugging drainage ditches. More complex restoration projects involve breaching dikes on unused agricultural lands.

National Marine Conservation Areas of Canada

National Marine Conservation Area System

Who?

Parks Canada is responsible for National Parks and National Historic Sites . It is also charged with setting up a national system of marine protected areas, the National Marine Conservation Areas Program, to represent the full range of marine ecosystems found in Canada's Atlantic, Arctic and Pacific oceans, and the Great Lakes.

Why?

Canada has over 243,000 km of coastline along three oceans and another 9500 km along the Great Lakes - the longest coastline in the world. The vast marine ecosystems off these coasts are varied, productive - and precious. We have a responsibility, both at the national and international levels, to protect examples of this marine heritage for present and future generations.

What?

National Marine Conservation Areas, or NMCA for short, are marine areas managed for sustainable use and containing smaller zones of high protection. They include the seabed, the water column above it and they may also take in wetlands, estuaries, islands and other coastal lands.

NMCA are protected from such activities as ocean dumping, undersea mining, and oil and gas exploration and development. Traditional fishing activities would be permitted, but managed with the conservation of the ecosystem as the main goal.

NMCA s are established to represent a marine region and to demonstrate how protection and conservation practices can be harmonized with resource use in marine ecosystems. Their management requires the development of partnerships with regional stakeholders, coastal communities, Aboriginal peoples, provincial or territorial governments and other federal departments and agencies.

The NMCA Program is designed to:

- represent the diversity of Canada's oceanic and Great Lakes environments
- maintain ecological processes and life support systems
- provide a model for sustainable use of marine species and ecosystems
- encourage marine research and ecological monitoring
- protect depleted, vulnerable, threatened or endangered marine species and their habitats
- provide for marine interpretation and recreation
- contribute to a growing worldwide network of marine protected areas

How?

National Marine Conservation Areas are established in a manner set out in the National Marine Conservation Areas Policy and guided by the national system plan , Sea to Sea to Sea. As Parks Canada's goal is to represent each of the 29 marine regions, establishment of new NMCAs is focused on the unrepresented regions.

The steps in the establishment of a new NMCA are as follows:

1. Identifying representative marine areas (candidate sites) takes into consideration:

- geologic features (such as cliffs, beaches, and islands on the coast; and shoals, basins, troughs and shelves on the seabed)
- marine features (tides, ice, water masses, currents, salinity, freshwater influences)
- marine and coastal habitats (wetlands, tidal flats, estuaries, high current areas, protected areas, inshore and offshore areas, shallow and deep water areas)
- biology (plants, plankton, invertebrates, fish, seabirds and marine mammals)
- archaeological and historic features

2. Selecting a potential NMCA from the candidate sites identified involves looking at:

- quality of regional representation
- relative importance for maintaining biodiversity
- protecting critical habitats of endangered species
- exceptional natural and cultural features
- existing or planned marine protected areas
- minimizing conflict with resource users
- threats to the sustainability of marine ecosystems
- implications of Aboriginal claims and treaties
- potential for education and enjoyment

- value for ecological research and monitoring

3. Assessing the feasibility of a NMCA requires the cooperation and support of:

- other federal departments and provincial or territorial governments
- local communities, regional stakeholders and Aboriginal peoples

Extensive local consultations are undertaken. Working groups or advisory bodies may be set up to develop and assess proposals. Proposals may also be considered within other appropriate planning processes.

4. Negotiating an agreement

If the feasibility study demonstrates support for the initiative, a federal/provincial or federal/territorial agreement will be negotiated to set out the terms and conditions under which the NMCA will be established and managed.

5. Establishment of a NMCA

NMCA s are established under the Canada National Marine Conservation Areas Act .

Where?

Currently, there are two operating sites within the NMCA program: Fathom Five National Marine Park in Georgian Bay, Ontario, and Saguenay-St. Lawrence Marine Park in Quebec. The latter was established by special complementary federal and provincial legislation allowing for co-operative management with the Province of Quebec (Saguenay-St. Lawrence Marine Park Act). The Lake Superior National Marine Conservation Area is in the planning stages for operations.

Marine Protected Areas

Canada's Commitment to Marine Protection

Canada's history has been defined by its surrounding marine environment. The Arctic, Pacific and Atlantic Oceans are important to our culture, our economy, and our national identity. Of equal significance are internal waters having large marine components such as the St. Lawrence Estuary and the Gulf of St. Lawrence, Hudson Bay and James Bay.

The richness and biodiversity of Canada's oceans provide enormous potential for both present and future generations. Our continental shelf is one of the largest in the world. The marine ecosystems found there have a remarkable diversity of species, including commercial and non-commercial fish, marine mammals, invertebrates and plants. Canada's oceans provide numerous opportunities for commercial, recreational and aboriginal fisheries; tourism; transportation; mineral production; education; and biological and technical research.

In recent years, growth in Canada's ocean sector has resulted in increased pressures on the ocean environment. The biodiversity and ecological integrity of many marine ecosystems are being threatened. There is a need to proactively conserve and protect marine ecosystem functions, species, and habitats for future generations.

Achieving sustainability in the harvest of living ocean resources ultimately depends on healthy, productive ecosystems. A new approach to oceans management is needed, one that takes an ecosystem approach rather than a sectoral one. In recognition of this, the Government of Canada works with other countries to address concerns about the marine environment. Internationally, Canada has demonstrated its commitment by endorsing conventions that pursue the goals of conservation and protection, including the United Nations Convention on Biological Diversity and the Global Program of Action for the Protection of the Marine Environment from Land-Based Activities.

It is equally important that the Government of Canada work with Canadians to manage activities in or affecting the marine environment. This vision of oceans management is embodied in the *Oceans Act*, which came into force in January 1997. The Act confirms Canada's role with respect to oceans management, specifying the need to integrate marine conservation with development activities to maintain healthy ecosystems.

Working together with interested Canadians, the Minister of Fisheries and Oceans will lead and facilitate the development and implementation of a national strategy for the management of estuarine, coastal, and marine ecosystems. The Oceans Strategy will be based on the principles of sustainable development, integrated management and the precautionary approach.

In addition to the Oceans Strategy, the *Oceans Act* identifies three complementary initiatives for the conservation and protection of the oceans. These legislated initiatives are:

- the Marine Protected Areas program, which entails leading and coordinating the development and implementation of a national system of marine protected areas, including designating areas for special protection for reasons specified in the *Oceans Act*.
- the Integrated Management program, which entails leading, facilitating and implementing plans for the integrated management of all activities or measures in or affecting estuaries, coastal and marine waters; and
- the Marine Ecosystem Health program, which entails establishing marine environmental quality guidelines to support the implementation of these plans.

Marine Protected Areas

Definition under the *Oceans Act*

Canada's *Oceans Act* (Section 35 (1)) states:

A marine protected area is an area of sea that forms part of the internal waters of Canada, the territorial sea of Canada or the exclusive economic zone of Canada and has been designated under this section for special protection for one or more of the following reasons:

a. the conservation and protection of commercial and non-commercial fishery resources, including marine mammals, and their habitats;
b. the conservation and protection of endangered or threatened marine species, and their habitats;
c. the conservation and protection of unique habitats;
d. the conservation and protection of marine areas of high biodiversity or biological productivity; and
e. the conservation and protection of any other marine resource or habitat as is necessary to fulfill the mandate of the Minister (of Fisheries and Oceans Canada).

Marine Protected Areas

Program Overview

Canada's marine ecosystems are vast and diverse, supporting many different activities. Marine Protected Areas under the *Oceans Act* must, therefore, satisfy a range of needs in a variety of jurisdictional settings. As a result, the Program uses a flexible approach to the design and management of these areas. The National Framework for Establishing and Managing Marine Protected Areas provides the general approach to MPAs across Canada. Specific program details concerning the conservation, protection and use of the marine environment and its resources will be developed and implemented at the DFO regional level.

Management plans for individual MPAs will be developed with involvement of local resource users, and interested and affected parties. They will set forth details on such issues as partnering responsibilities, funding arrangements, jurisdictional coordination, zoning, protection standards, regulations, permissible activities, enforcement, monitoring and research, and public awareness. MPAs will differ from one another; some may be strict no-take zones while others may be sustainably managed zones. This type of flexible approach is needed in order to meet the range of conservation and protection requirements of MPAs.

To ensure that MPAs are part of a comprehensive initiative to protect the health and function of marine ecosystems, they should be developed and established within the context of integrated management planning. Such planning considers the protection of each area in light of both environmental and socio-economic effects.

Objective

To conserve and protect the ecological integrity of marine ecosystems, species, and habitats through a system of Marine Protected Areas, as per the *Oceans Act*.

Goals

- To proactively conserve and protect the ecological integrity of each MPA site.
- To contribute to the social and economic sustainability of coastal communities by providing for uses which are compatible with the reasons for designation.
- To further knowledge and understanding of marine ecosystems.

Marine Protected Areas

Developing a National System of Protected Areas for the Marine Environment

Canada's *Oceans Act* (Section 35 (2)) states:

For the purposes of integrated management plans ... the Minister (of Fisheries and Oceans) will lead and coordinate the development and implementation of a national system of marine protected areas on behalf of the Government of Canada.

The Department of Fisheries and Oceans, Parks Canada and Environment Canada (Canadian Wildlife Service) all have mandated responsibilities to create protected areas in the marine environment. Since the *Oceans Act* names the Minister of Fisheries and Oceans as the lead federal authority responsible for oceans, DFO will lead in the development of a national system of marine protected areas* incorporating the programs of all three departments. Since management of marine ecosystems is a shared responsibility, it is essential to work together to conserve and protect these areas.

The different federal protected area programs share a common objective: to further conservation and protection of living marine resources and their habitats. By coordinating the policies, programs and prospective sites amongst the different federal agencies, the integrity and health of Canada's estuarine, coastal and marine waters will be better maintained. The booklet Working Together For Marine Protected Areas: A National Approach describes the federal programs in greater detail.

Federal Departments and Programs

Fisheries and Oceans:

- Marine Protected Areas

Program Focus

- Conserving and protecting marine species, habitats and ecosystems

Parks Canada:

- Marine Conservation Areas

Program Focus

- Protecting representative examples of natural and cultural heritage

Environment Canada (Canadian Wildlife Service):

- Migratory Bird Sanctuaries
- National Wildlife Areas
- Marine Wildlife Areas

Program Focus

- Protecting major marine and nearshore areas for wildlife, research, conservation and public education

Canadian Wildlife Service
National Site

Habitat Conservation

Marine Wildlife Areas

To address coastal and offshore conservation issues, the Canada Wildlife Act was amended in 1994 to extend provisions for National Wildlife Areas to be identified as Marine Wildlife Areas (MWAs) beyond the 12 nautical mile territorial sea limit out to the 200 nautical mile exclusive economic zone limit.


Tufted Puffin © Michael Dunn, CWS

At present, there are several candidate sites under study including the Scott Islands off British Columbia. The Scott Islands archipelago will be the first MWA officially established in Canada. It will protect more than 2 million seabirds that nest there each year, including 55 percent of the world's population of Cassin's Auklets. The site is already an internationally recognized Important Bird Area and is one of the single most vital locations in all of the Northwest Pacific Ocean ecosystem not just a national treasure, but an international obligation for Canada on the global environmental stage.

Many birds depend on offshore coastal habitats for breeding, feeding, moulting, migratory stopovers, and overwintering. Offshore habitats include:

- the waters surrounding islands where birds nest
- polynyas (openings enclosed in ice)
- upwelling areas, where cold, heavy subsurface water rises toward the surface, especially along the western coasts of continents, displacing the surface water
- seamounts (elevations of the sea floor)

Coastal habitats include:

- sheltered, rocky bays
- salt, brackish, and freshwater marshes
- mudflats
- river estuaries

Environment Canada invites partnerships in conservation, research, and education aimed at protecting marine wildlife and their habitats.

SPECIES AT RISK ACT (SARA)

Background

The *Species at Risk Act* (SARA) was proclaimed in June 2003, and is one part of a three part Government of Canada strategy for the protection of wildlife species at risk. This three part strategy also includes commitments under the *Accord for the Protection of Species at Risk* and activities under the *Habitat Stewardship Program for Species at Risk*.

In addition, it complements existing laws and agreements to provide for the legal protection of wildlife species and conservation of biological diversity. The Act aims to prevent wildlife species from becoming extinct, and to secure the necessary actions for their recovery.

The Act recognises that the protection of wildlife species is a joint responsibility and that all Canadians have a role to play in the protection of wildlife. It applies to all federal lands in Canada; all wildlife species listed as being at risk; and their critical habitat.

Purpose

The purposes of the Act are to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species, and encourage the management of other species to prevent them from becoming at risk.

More specifically, the Act will:

- establish the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as an independent body of experts responsible for assessing and identifying species at risk;
- require that the best available knowledge be used to define long and short-term objectives in a recovery strategy and action plan;
- create prohibitions to protect listed threatened and endangered species and their critical habitat;
- recognize that compensation may be needed to ensure fairness following the imposition of the critical habitat prohibitions;
- create a public registry to assist in making documents under the Act more accessible to the public; and

- be consistent with Aboriginal and treaty rights and respect the authority of other federal ministers and provincial governments.

SARA is a result of the implementation of the Canadian Biodiversity Strategy, which is in response to the United Nations Convention on Biological Diversity. The Act provides federal legislation to prevent wildlife species from becoming extinct and to provide for their recovery.

What the Act means to you

Given the sheer variety and geographic distribution of protected species, the *Species at Risk Act* has the potential to touch the lives of millions of Canadians—from commercial fishers and aquaculturalists to recreational fishers and even recreational boaters. If you own property on or near water—whether for a home, cottage, farm or business—your activities could have an impact on the *habitat* of a species at risk.

Many aquatic species are listed under the Act—including the Atlantic and Pacific blue whales, Inner Bay of Fundy Atlantic Salmon and the leatherback turtle. Review the list of aquatic species currently protected under SARA.

Sharing the responsibility

Under SARA, Fisheries and Oceans Canada must produce recovery strategies and action plans for aquatic species listed as endangered or threatened. Once a species is added to the list and protected officially under SARA, a recovery strategy must be developed. For endangered species, this strategy must be developed within a year of the listing; for threatened or extirpated (extinct in Canada) species, it must be developed within two years.

These recovery strategies and action plans will detail the specific steps that need to be taken to protect identified species. We at Fisheries and Oceans Canada are determined to work as closely as possible with stakeholders—the people affected—to make sure that our strategies and plans are practical, effective, and in keeping with a sound fisheries management approach.

Critical habitat for aquatic species

The *Species at Risk Act* (SARA) makes it illegal to destroy the critical habitat of species at risk, and can impose restrictions on development and construction projects. Whether you're installing a culvert, starting a new dredging operation, or developing a hydroelectric power dam, you need to know about SARA.

What is critical habitat?

Simply put, critical habitat is vital to the survival or recovery of wildlife species. The habitat may be an identified breeding site, nursery area or feeding ground. For species at risk, these habitats are of crucial importance, and must be identified and included in recovery strategies or action plans.

The fishing industry

Members of the commercial fishing industry are among the Canadians most directly affected by the *Species at Risk Act* (SARA). Fisheries and Oceans Canada recognizes this and has worked closely and constantly with fishers to inform them of the Act and its implications.

In reality, the consequences of SARA will vary considerably depending on where you fish and what you catch. Possible changes could include restrictions on bycatch; fishing gear modifications; fishing area closures; fishing season closures; and closures or reductions in traditional fisheries.

Importantly, any new measures will be defined through the recovery strategies and actions plans currently under development—in collaboration and consultation with the fishing industry.