BY THE SEA

A GUIDE TO THE COASTAL ZONE OF ATLANTIC CANADA

MODULE 1: INTRODUCTORY MODULE

ACKNOWLEDGMENTS:

FUNDING: Department of Fisheries and Oceans, Environmental Partners Fund of Environment Canada

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Comments and suggestions from the following people are gratefully acknowledged:

Diane Amirault, T.C. Anderson, Sophie Bastien-Daigle, François Bélanger, Mark Bonan, Yves Bourassa, David Boyce, Alyre Chiasson, Harry Collins, Simon Courtenay, Rosemary Curley, Ted Currie, Jean-Yves Daigle, Adrianne Dorrington, Ernest Ferguson, Phil Ferraro, John Foley, Christopher Hawkins, Denise Henson, Peter Hicklin, Bob Hooper, John A. Legault, Claude Léger, Maurice LeRoy, Allison M. Lowe, Don McAlpine, Mark McLean, Inka Milewski, Randy Milton, Michelle Parsons, Jon Percy, Jim Petrie, Terry Power, Rob Rainer, Lisa Richard, Pierrette Robichaud, Anne Senechal, Tom Sephton, Wendy Skeard, Bruce Smith, Rick Swain, Jacques Thibault, Jackie Waddell, Heather Walters, Judy White.

Également disponible en français.

Fisheries and Oceans / Pêches et Océans

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E9H 1J6

ENVIRONMENTAL PARTNERS FUND
Environment Canada / Environnement Canada
PARTENAIRES DE L'ENVIRONNEMENT

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Tabusintac, N.B., Canada

Cat. no. S-23-289/1996 E ©1996
ISBN 0-660-16410-8

THE MODULES

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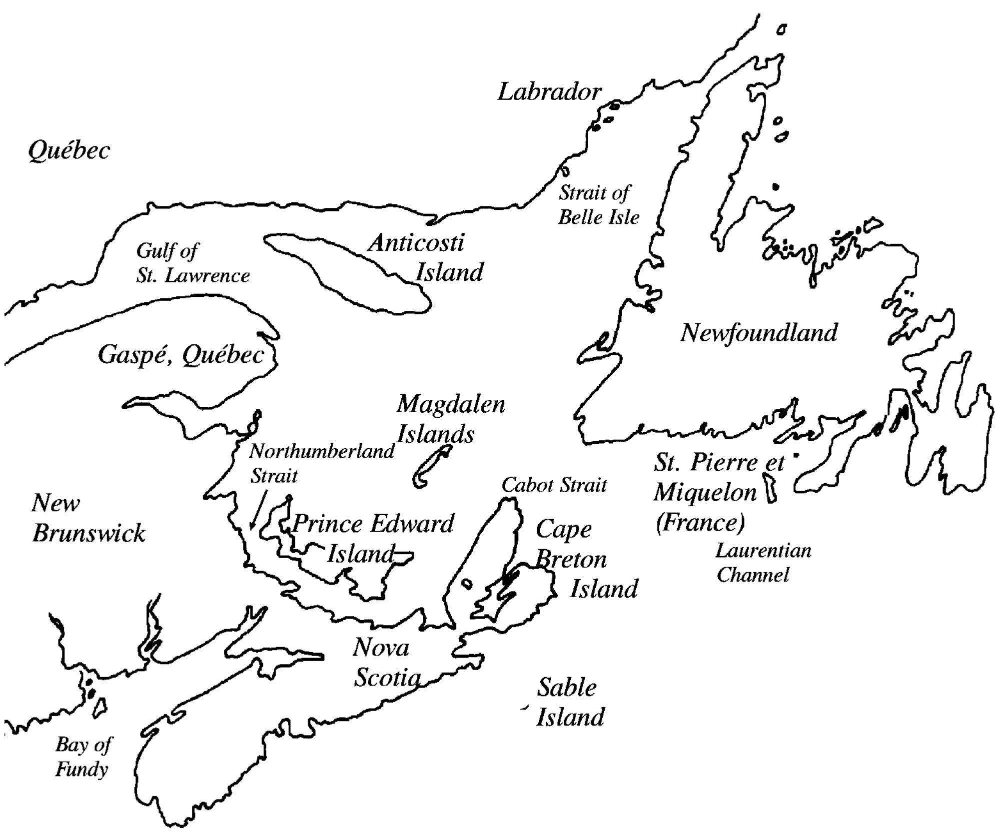
PREFACE

Almost 75% of our planet is covered by water. The name 'Earth' is somewhat of a misnomer given the extent of this liquid layer. Planet 'Ocean' may in fact be a better term. Of the landscapes and habitats that exist on Earth, the one that is present in every climatic region of the world is the coastal zone. The coastal zone is the meeting place between land and sea.

see activity 1

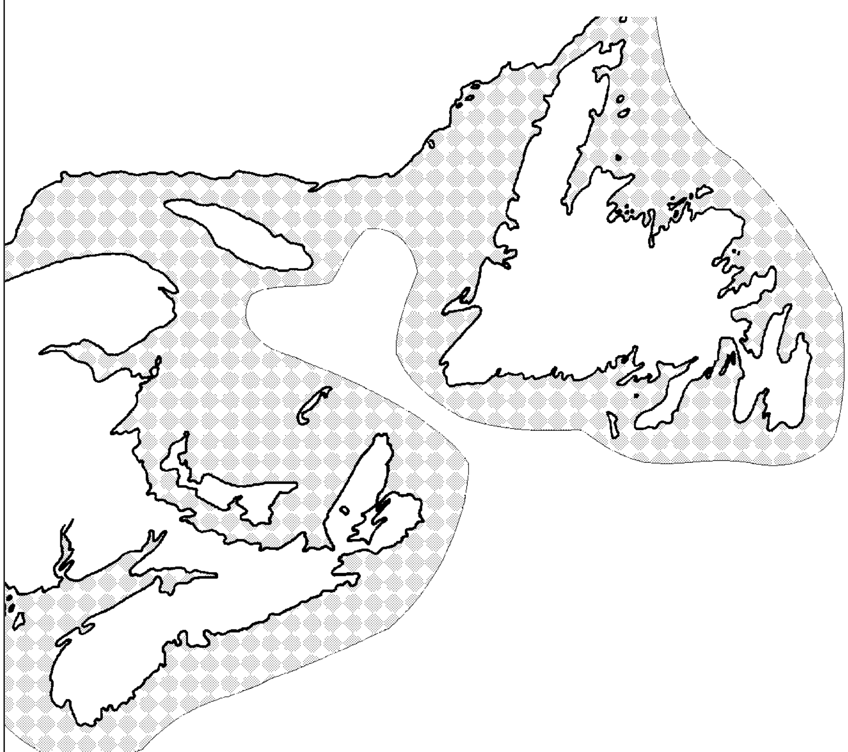
The coastal zone of Eastern Canada surrounds five provinces. If you walk the shorelines of New Brunswick, Nova Scotia, Prince Edward Island, Newfoundland, and Quebec you will discover a variety of different landscapes.



Sandy beaches, rugged rocky shores, extensive mudflats, vast salt marshes, cobblestone beaches, towering fjords, bogs, and islands and cliffs all fragment the coastline. These unique, individual areas are called ecosystems. An ecosystem includes all organisms in a specific area together with their physical and chemical environment. Their character is shaped by their geological past, the plants and animals that live there, and the ravages of wind and waves, and by salt and temperatures. Each ecosystem has an important role in shaping the coastal zone of Eastern Canada's Atlantic provinces.

The history and the natural, social, and economic development of Atlantic Canada are shaped by the coastal zone. The coastal zone provides a source of income, recreation, and a way of life that affects millions of people. It functions as a trade and transportation route. It supplies nurseries for fish stocks, contributes vast quantities of food, and supports an economy based on nature. Coasts also provide tourism dollars, by attracting people who want to explore these unique environments.

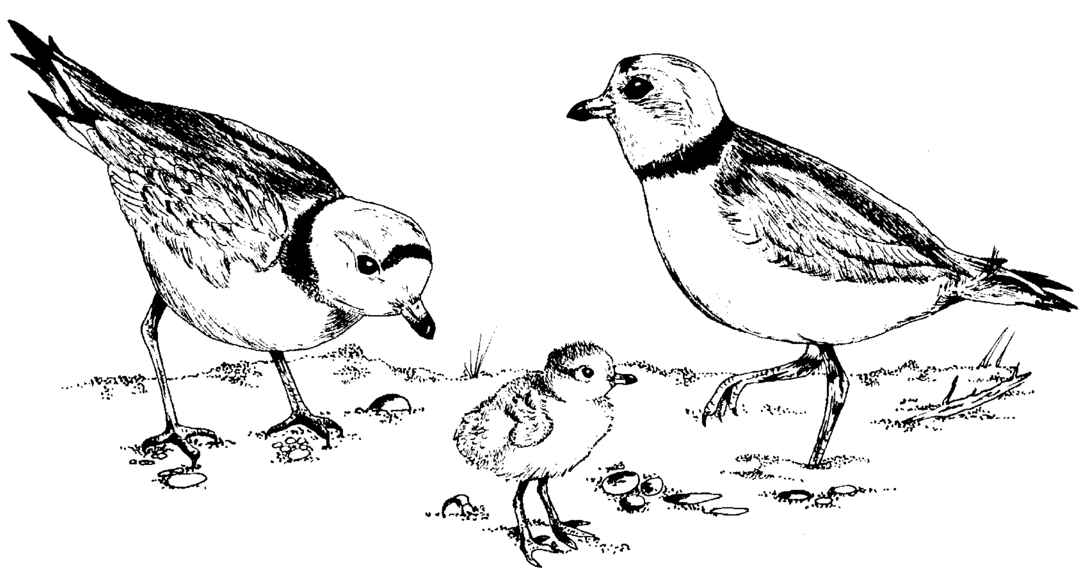
The coastal zone of Atlantic Canada as defined in this guide



The natural community benefits greatly from the coastal zone. The various ecosystems that border the coast provide a home for many different species of plants and animals, including staging, feeding areas, and nesting habitat for a variety of birds. Coastal ecosystems also help to maintain a healthy environment, by storing and funnelling nutrients into surrounding areas. This unique interaction attracts people who want to learn and conduct scientific research about the ecosystems of the coastal zone. For those who are concerned about decimated fish stocks, this guide will explain something of how various coastal ecosystems are crucial spawning or nursery grounds for fish and their prey species.

Although the coastal zone is rich in animal and plant life, it is very vulnerable. The health and stability of our ecosystems in the coastal zone are under constant threat. Sand is removed from dunes, salt marshes are filled in, and nesting habitats for endangered species are destroyed. For centuries, people have thrived on the abundance of marine life in the coastal zone. But recently, this abundance has diminished and so has the vitality of the human communities associated with it. If Atlantic Canada's coastal zone is to remain healthy, the different ecosystems must remain healthy and diverse. We need to be informed about the importance of the coastal zone for human and animal well-being. If we utilize its natural resources, we must do so in a sustainable manner, without causing irreversible damage. We must protect the coastal zone, so that our children and their children will be able to enjoy this unique area for years to come. **By the Sea-A Guide to the Coastal Zone of Atlantic Canada** can be your companion, to help you develop a greater appreciation for this unique environment.

The endangered Piping Plover, an increasingly rare beach nester.



About the Guide

This guide is about 11 ecosystems within the coastal zone of Atlantic Canada and their importance to our economy (fisheries, aquaculture, tourism) and well-being. Nowhere in Atlantic Canada is there a similarly comprehensive document available. With the guide, visit and explore estuaries, salt marshes, rocky shores, and beaches. Discover the formation of coastal ecosystems, their salt-tolerant inhabitants and their interrelationships with one another. Unravel the mysteries of these places while participating in action-oriented activities.

THE COASTAL ZONE

What is the Coastal Zone?

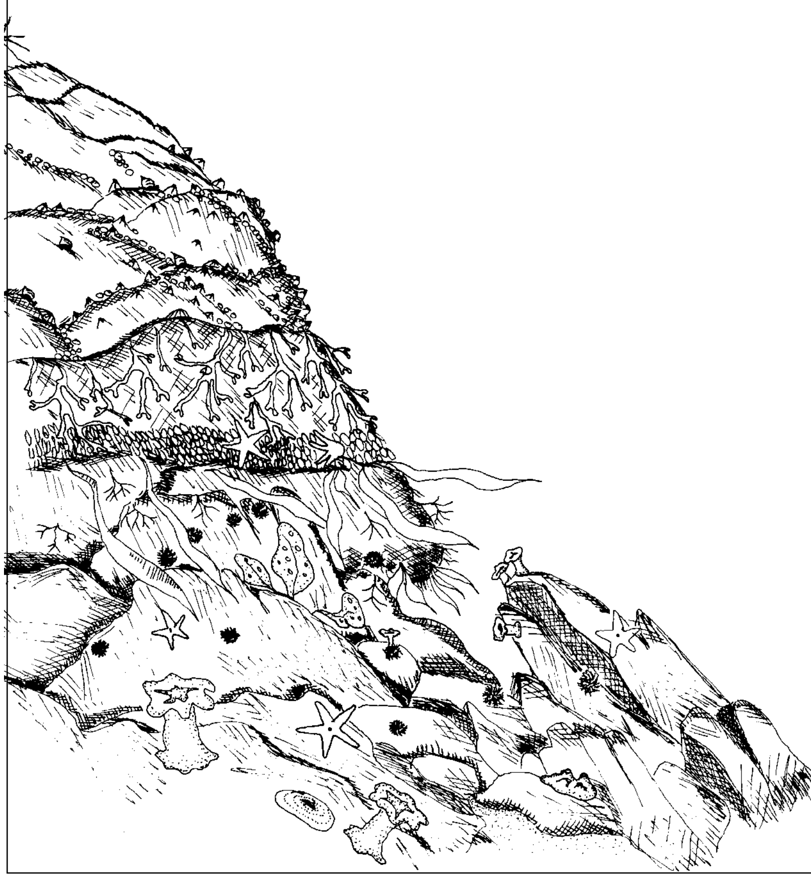
The coastal zone is a meeting place between land and sea. Here, the saltwater meets the freshwater and/or the land meets the ocean. Coasts are exposed to extreme physical forces, which ultimately affect the creatures that live there. At high tide, parts of the coastline can be under water. At low tide, the same area can be exposed to the elements of air, heat, or cold. During storms coastlines are ravaged by wind-driven waves, which crash against the shore with great force. Coastlines also experience the elements of rain and sun, which, with the tides, create an incredibly variable environment. Plants and animals must adapt to these variable conditions. Despite these seemingly harsh circumstances, the coastal zone is a rich environment. It provides a place to observe many unique species of plants and animals. Not only do creatures live there year-round, but many species visit the coastal zone during migration or spend part of their early life there.

The coastal zone is grouped or classified in a number of ways. The easiest way to classify it is to observe 'what different areas are made of.' When we picture the coast we each see something different. Many people have images of sand and sun-'the beach.' Others think of rugged, rocky coasts, battered by waves. Some see extensive mudflats, while others see salt marshes. The coastal zone is all of these, a place of sand, mud, rock, and water, with unique assemblages of plants and animals. Despite their differences, there is one feature that all coasts have in common: the effects of the tides and the resulting alternate exposure to air and submergence in water.

Ecosystems of the Coastal Zone

In Atlantic Canada we have a variety of coastal ecosystems. In Prince Edward Island, extensive sandy beaches are found at Cavendish, along the province's north coast. In New Brunswick from the north tip of Miscou Island, along the Northumberland shore to Bouctouche in the southeastern part of the province, there are extensive barrier islands. These can be contrasted with the rugged, rocky shores of Cape Breton and southwestern Nova Scotia. Along the Bay of Fundy in New Brunswick and Nova Scotia some of the world's largest mudflats are found. In contrast, the southwestern New Brunswick coast has a variety of sandy and rocky shores. Along the west coast of Newfoundland large expanses of cobble beaches are found, along with towering fjords. Fjords are also present on Quebec's north shore. This variety in coastal ecosystems exists because of a diverse geology and a varying set of physical factors that work together to create the coast as we know it.

An ecosystem is more than a habitat. A habitat is where animals and plants live. An ecosystem includes all the organisms in a specific area (such as a beach) together with their physical and chemical environment (salt, temperature, currents, etc.). None of these ecosystems exists independently. While it may be difficult to define the boundaries of any coastal ecosystem, using the concept of an ecosystem provides a basis for looking at the coastal zone.



THE PHYSICAL ENVIRONMENT

Formation

The geology of any region is the result of a complex series of events and processes over time. These events can create landscapes that are unique within very short distances of one another. No two coasts are quite the same. For example, Grand Manan Island, situated at the mouth of the Bay of Fundy, has good examples of inaccessible rocky shorelines at the base of 100-metre cliffs and extensive sandy beaches only a few kilometres away.

During the past 1,200 million years Atlantic Canada has gone through many changes. In fact, the geologic history of Atlantic Canada can only be properly understood if put into the context of what has happened on a global scale.

Geological Formation

Geologists have been able to reconstruct the events that have shaped the present structure of Atlantic Canada, and hence its coast, through a span of 1,200 million years. During this time continents have been created and modified, oceans have appeared and disappeared, and mountains been built, eroded, and rebuilt.

Geological formation

If you look at a geological map of the region you will discover groups of rocks dating from 1,200 million years ago. At this point in time Europe and North America were fused together.

If you step back in time you will see how Atlantic Canada's coastline was formed.

Millions of years ago	Events in the history of lifeforms	Events in the history of Earth
1,200	Marine invertebrates, few with shells	The Avalon micro-continent: Quebec and New Brunswick arejoined with NW Europe.
600	Marine shelled invertebrates are common; first abundant animal fossils	Creation of a rift valley and the birth of an ocean.
500	First vertebrates	Iapetus Ocean separates the Canadian Shield from the Avalonian micro-continent.
400	First amphibians; first forests	Collision between Europe and North America; development of Caledonian Mountains.
300	Great forests and diffusion of winged	Formation of large coal deposits. insects
270	Reptiles flourish	Tensions in the Earth's crust create the Bay of Fundy; all continents merge into one: Pangea; Appalachians are born.
180	First birds and mammals; dinosaurs at their peak	Pangea breaks into two parts: Laurasia and Gondwana; birth of the Atlantic Ocean.
135	Extinction of dinosaurs; spread of flowering plants	The Atlantic Ocean continues to widen; Laurasia starts to break into two: North America and Europe/ Asia; Coastal Plain of the Gulf of Main and Scotian Shelf are flooded.
65	Spread of mammals	Building out of continental platform; emergence of Rocky Mountains; some coastal areas continue to be submerged. Western Newfoundland, Cape Breton Highlands, and Maritime Plain uplifted.
2	Appearance of first humans	Major glaciations; during the last glaciation, glacial deposits create Cape Cod, Georges Bank, and Grand Banks.

These events have resulted in a predominantly rugged and rocky coastline, characterized by indentations and occasional cliffs along the Atlantic coast of Nova Scotia and Cape Breton, the Fundy coast of New Brunswick, and virtually all of Newfoundland. The shoreline of the Northumberland Strait and upper Bay of Fundy, Minas and Chignecto Basins, are generally low-lying and dominated by softer rocks and sedimentary shores (sand and mud), and are a result of water-based processes such as wave action and sediment deposition from rivers.

Physical and Chemical Characteristics

The coastal zone in Atlantic Canada not only displays features that are directly linked to the past, but also present-day processes.

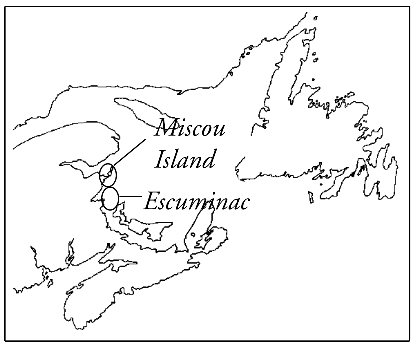
The coastal zone is in constant change.

Land subsidence (sea-level changes), currents, tides, and waves are the four major natural processes working to modify the coastal zone. Other elements are also at work-wind, ice, salt, sediment, temperature, and light. Generally speaking, the coastal zone is a high-energy environment, experiencing many natural abiotic processes that affect its existence.

The same abiotic (non-living) factors influence all coastal ecosystems, but to varying degrees. For example, in the estuary, salinity is a determining factor, whereas on a sandy beach, wind and waves are predominant. In this section the physical factors are dealt with in general. In the individual ecosystem modules these factors will only be discussed in direct relationship to the particular ecosystem.

Sea-level Changes

Thirteen thousand years ago the coast was nearly 30 metres above its present level. Eleven thousand years ago the sea-level was at a position equal to the present day. Seven thousand years ago the coastline was at its maximum emergence and located far offshore, 20 to 25 metres below today's mean sea-level. Since then, the sea-level has been rising. Higher water levels are eroding the shoreline 15 cm per century, along such areas as the Gulf of St. Lawrence coast.



Today sea-levels are rising relative to the land, thus drowning the coasts. The base of a coastal bog at Escuminac, New Brunswick, is one metre above mean sea-level. The base of a bog on Miscou Island, New Brunswick, is in places up to two metres below mean sea-level.

Sea-level changes

After the glaciers retreated, the weight of the ice was removed from the land. As a result, the land rose. This action is called isostatic rebound. We can see evidence of this process today, in the occurrence of raised beaches and shorelines throughout Atlantic Canada. Along the Bay of Fundy in St. Mary's Bay and in the Annapolis Basin, as well as in Newfoundland (Trout River, Gros Morne National Park), good examples of raised beaches can be found.

However, in general, the land is submerging:

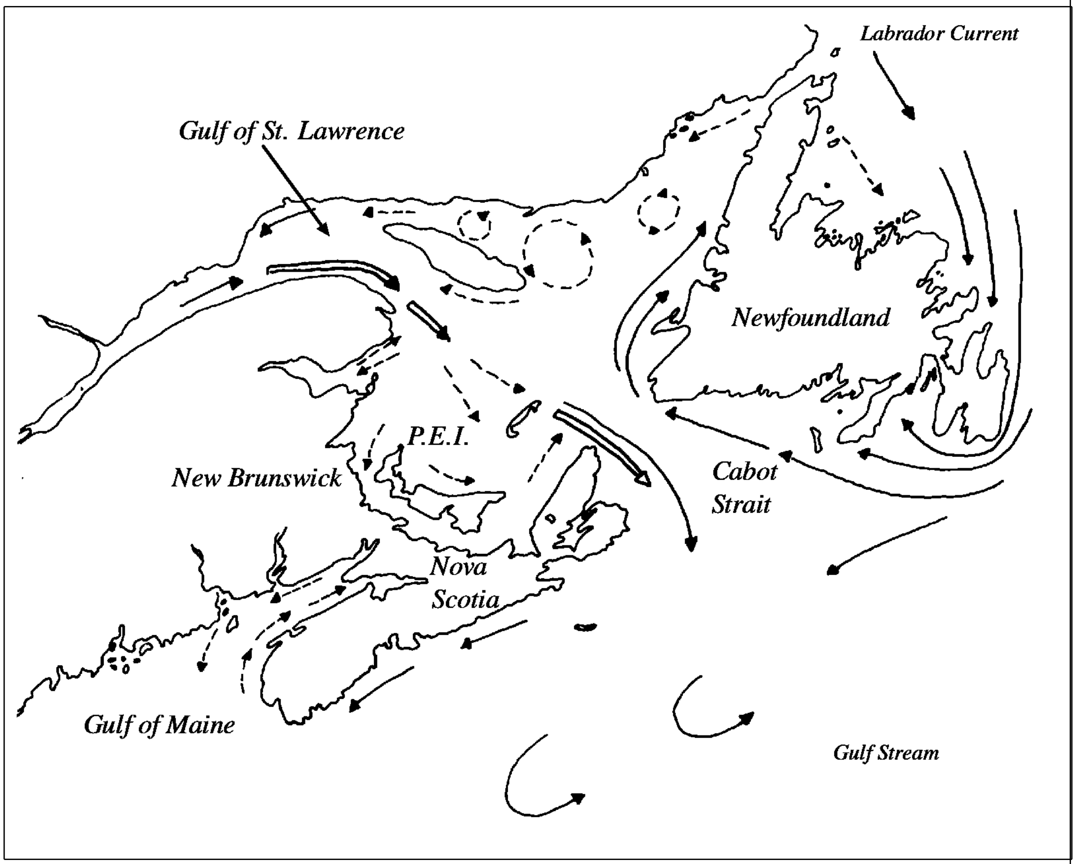
15 cm per 50 years	east coast of New Brunswick
30 cm per 50 years	Fundy coast
20 cm per 50 years	in the Halifax area

Rising sea-levels lead to increased erosion, salt contamination of freshwater wells, and reduced intertidal habitat. In our geological past, ecosystems such as beaches would have moved inland; today there are more roads and buildings in the way of their movement.

Currents

Currents are movements of water. They have unique temperatures, salinity, and chemical composition. Many organisms move with particular currents.

Currents



Warm Current versus Cold Current

The Labrador current is a cold current. It moves water with low salinity southward. The Gulf Stream current is a warm current. It moves water with high salinity northward. When the cold, nutrient-rich waters of the Labrador current reach the continental shelf they're forced upward. This upward movement or 'upwelling' (see section on upwelling) brings the nutrient-rich water to the surface, increasing phytoplankton activity and thus overall productivity.

Currents and Navigation

Currents are more complex in coastal situations where tides are significant. As the level of the water changes with an incoming or outgoing tide, so does the current. This can make navigational situations tricky. For example, the Bay of Fundy has an extremely large tidal range. In situations where islands and ledges restrict the movement of water, significant localized currents may be seen. This is true around the islands in New Brunswick, where tidal currents create a large whirlpool between Campobello Island, Deer Island, and the town of Eastport, Maine. Significant tidal currents are also produced in the head of the Bay of Fundy, at the entrance to the Minas Basin. Here rising and falling tidal waters surge around Cape Split.

Similar complex currents occur in St. Anns Bay, Cape Breton.

Ocean currents

Ocean currents are formed out at sea. They're generated by prevailing winds.

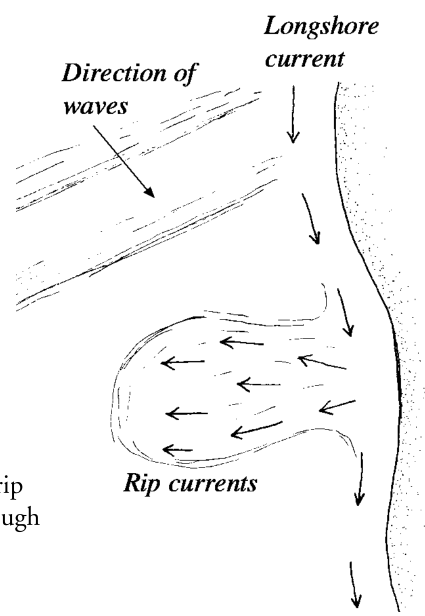
Tidal currents

Tidal currents result from the ebb and flow of the tide. An excellent example of this is the world renowned tidal bore that can be observed in the tidal rivers of the Bay of Fundy.

Tidal currents, or rather their strength, can determine how large an entrance to a lagoon will be, and how much water will be stored in the lagoon during flood tides.

Longshore currents

Longshore or littoral currents are produced by waves that approach a shore at a slanting angle. This action creates powerful currents, which move parallel to the shoreline.



Rip currents

Rip currents are strong, narrow, seaward-flowing currents that result from the breaking of waves. After being heaved against the shore these currents move at right angles away from the beach. They're also called rip tides. Rip currents may extend 60 to 750 m, with enough speed to carry swimmers out to sea.

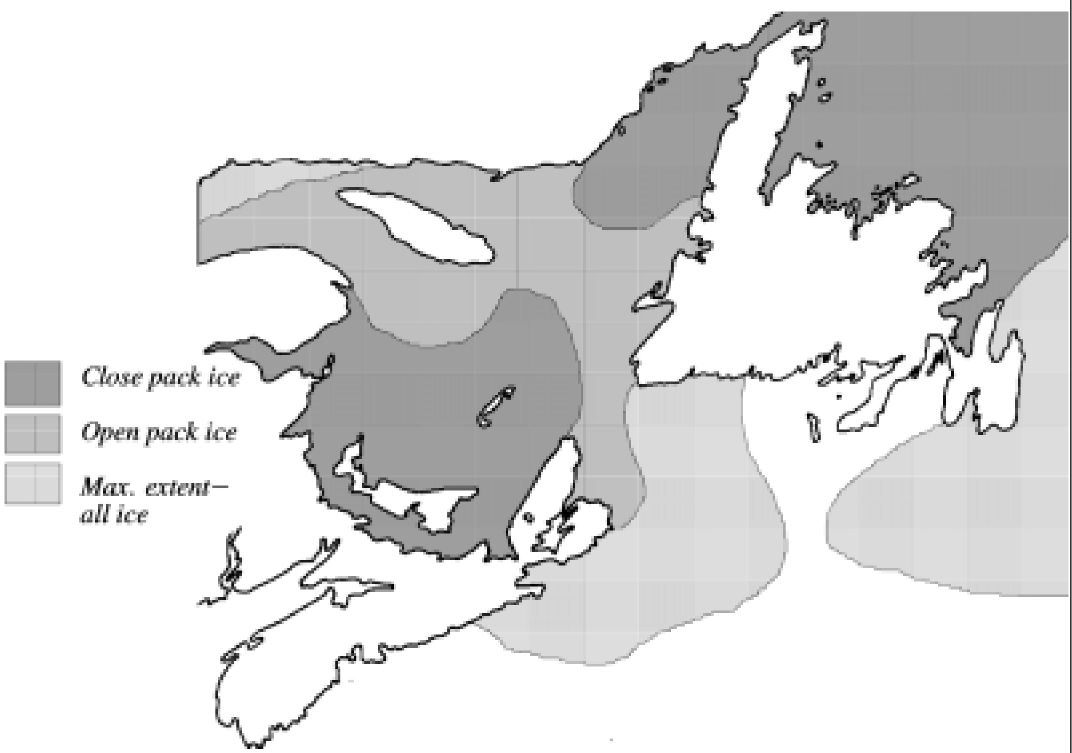
Ice

The duration of ice cover in the different Atlantic provinces varies considerably. A few weeks after ice breakup there is no visible sign of ice action on most beaches. In fact, the coast is ice-free for at least eight to nine months of the year. Southwestern Nova Scotia is virtually ice-free year round, whereas the Bay of Fundy and Gulf of St. Lawrence have ice on the beaches and in the nearshore zone for up to four months of the year. In central Labrador ice is on the beach for up to seven months.

Pack ice covers large areas of water in the Gulf of St. Lawrence, as anyone traveling to or from Prince Edward Island or Newfoundland from December to April can attest. The presence of ice off a coast prevents the formation of waves and limits the fetch distance. Ice can actually protect the coastal zone, because it absorbs wave energy and reduces the effects of wave action.

Shore ice starts to build up in December. Ice from the sea can be blown onshore by the wind. The pushing and melting of onshore ice affects only a small portion of a coastal ecosystem and does not greatly alter its overall shape.

Ice Cover in Atlantic Canada



Ice Rafting

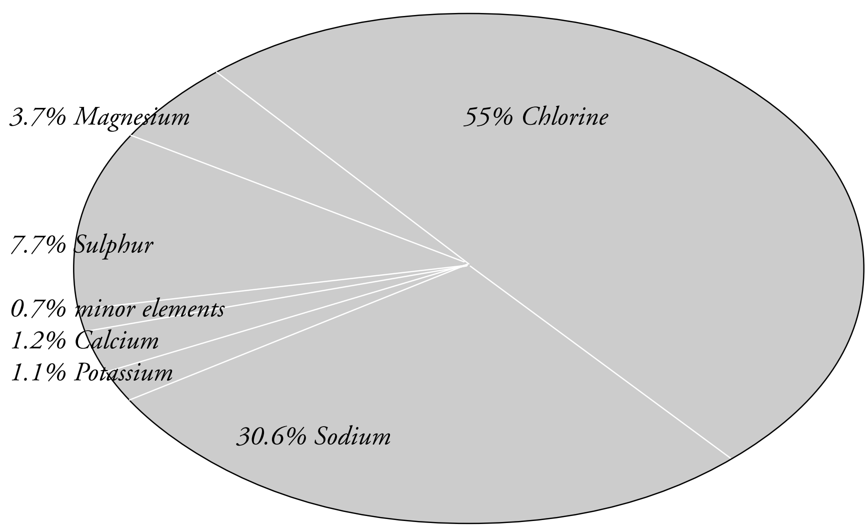
Rafting occurs when ground blocks of ice begin to refloat. Frozen into the base of the ice blocks are sediments. As the ice moves so do the sediments. This process is very effective at moving large amounts of muddy sediment in the tidal areas of Atlantic Canada. It's less effective at moving coarser sediments, such as cobbles, but it can do so. It isn't uncommon for boulders to be moved short distances across tidal flats. This movement may be a mixture of rafting, sliding, and pushing. Mudflats are commonly littered with cobbles and boulders that are buried in the sediment or lying on top.

Salt

see activities 3, 11

Salt comes from the Earth. It is believed that when the Earth was first formed, water dissolved mineral salts from the land and washed them into the ocean. Mineral salts have more ingredients than ordinary table salt (sodium chloride). They include potassium, magnesium, sulphur, calcium, and other minor elements. Over very long periods of time the ocean gradually became saltier. This process is still occurring today.

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

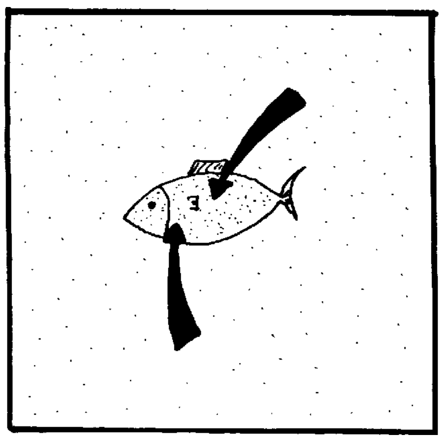


Living in a salty world-the vertebrate solution

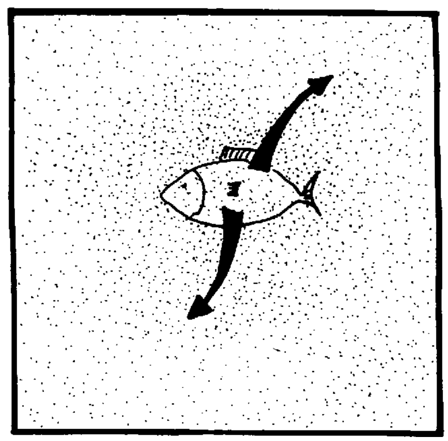
The salt concentration in the blood of aquatic vertebrates is almost the same whether they are freshwater or saltwater vertebrates: somewhere in between what is found in saltwater and in pure freshwater. This probably reflects their common ancestry back in geological time. When a fish is in saltwater, its blood is less salty than its surroundings. Its gills and skin are in close contact with the water. There is a tendency for water to flow from the less salty to the more salty-out of the fish. If a saltwater aquatic animal is placed in freshwater, its blood is more salty than its surroundings. The water will tend to move from the less salty to the more salty-but this time it's into the fish. The movement of water across a permeable membrane, such as skin, is called osmosis. Osmosis is a physical process that regulates the flow of water (from high concentrations of salts to low concentrations of salts and vice versa) in order to balance salt levels on either side of a membrane.

see activity 37

Saltwater fish in freshwater



Freshwater fish in saltwater



Depending on which environment the animal normally lives in, it has adapted to deal with constant movement of water either into or out of its body. A saltwater fish deals with the constant loss of water by drinking sea-water. Specialized cells located in the gills excrete excess amounts of certain salts, while their kidneys excrete other types of salts. High concentrations of salts can be toxic to organisms. A freshwater fish handles the excess water by urinating a lot; their kidneys work like water pumps. If we move a saltwater organism into freshwater, its internal organs often cannot work fast enough to control the water movements across its gills and it will gain too much water-in effect bursting its own cells-and die. Similarly a freshwater fish in saltwater will dry out simply because it cannot stop the flow of water through its gills and skin. It will dehydrate and die surrounded by water.

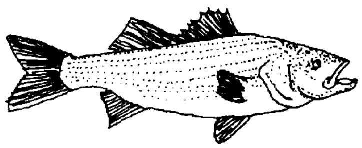
More about fish

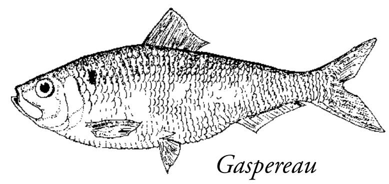
Fish that migrate between these two environments must completely change their physiology before going into a river from the sea or vice versa. Atlantic Salmon moving to sea from their birth river spend weeks in an estuary (where the salt is diluted with freshwater); here they adapt to the salty environment before heading out to the open ocean. When they go back upstream to spawn, they again spend weeks in the estuary preparing their bodies. This is a tremendous cost in energy for a fish. Can you imagine changing your physiology every time you take a bath or dive in the sea?

see activities 37, 39

Some fish that use the estuary

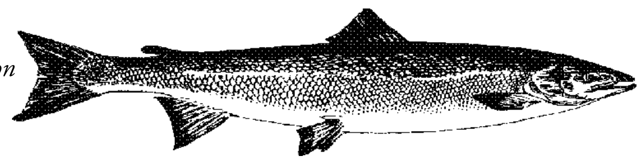
Striped Bass





Gaspereau

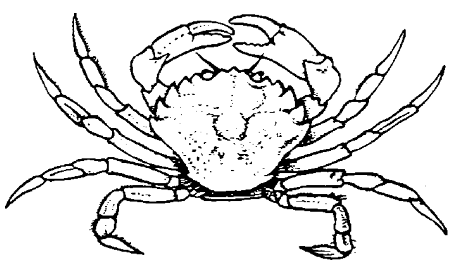
Atlantic Salmon



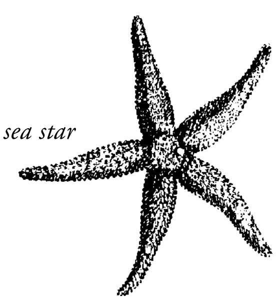
Living in a salty world-the invertebrate solution

Most invertebrates in saltwater can handle the same high concentrations of salts in their bodies as found in their environment. The few invertebrates that cannot have evolved special adaptations to deal with changing salinity levels. The best example is the Green Crab. It's able to regulate the amount of salts it passes out of its body through its urine. Other animals have little ability to deal with changes in salinity. Sea stars are one such case. If you put a sea star in sea-water of increased salinity, it will begin to lose mass. But if you put a sea star in water with decreased salinity, the opposite happens. It gains mass as the cells expand.

Green Crab



sea star



Sediment

The type of sediment or rock present in any area will influence the type of ecosystem that can be found. Sediment determines the ability of organisms to find a place to hold on. For example, seaweed can't grow on sandy or muddy sediment, but only on rocky bottoms.

Temperature

In contrast to the darkness of the deep ocean, the shallow waters of coastal ecosystems can create warm and sunny places for plants and animals to grow. Temperatures can vary greatly in coastal ecosystems. They can change drastically during one day and be quite different from place to place. Temperature is a major factor that influences many life processes, such as reproduction.

Temperature, salinity, and thermocline

Salinity is defined as the total amount of dissolved material in parts per thousand by mass in 1 kg of sea-water, or ppt. Salinity in the open ocean is 33¸37 ppt (33 g of salt per 1 kg of water), while in coastal areas it's 33¸34 ppt. The principal factors influencing salinity are precipitation and evaporation, with lesser factors being run-off, melting ice and snow, and the formation of ice. When ice forms the salts are left behind. As all rivers run toward the sea, the coastal zone serves as a collection point for freshwater precipitation. Precipitation that falls on land and doesn't soak into the soil runs off into the ocean. When this water mixes with the ocean water, the resulting salinity of the coastal waters is less than the ocean.

Increases in temperature and decreases in salinity lower the density of the water. Therefore, a surface layer of less salty, warmer water can float on a layer of colder, more saline water. Colder water is heavier than warmer water. As water at the surface cools down it sinks. The sinking water is replaced by adjacent water beginning a chain reaction, in effect creating a current. The different layers of water, determined by differences in temperature, are called thermoclines. Increases in temperature and decreases in salinity lower the buoyancy that organisms experience in water, because they lower water density.

Temperature facts

Temperature changes can alter the physical properties of sea-water. Colder water, for example, has a greater capacity to hold gases in solution (i.e., oxygen, CO_2).

The greater range in water temperature and the winter freeze-up in the Gulf area have an effect on the local fishery. Fishing can't be done in the ice and the start of the fishing season in the spring is tied to the movement of the ice out of the Gulf.

Light

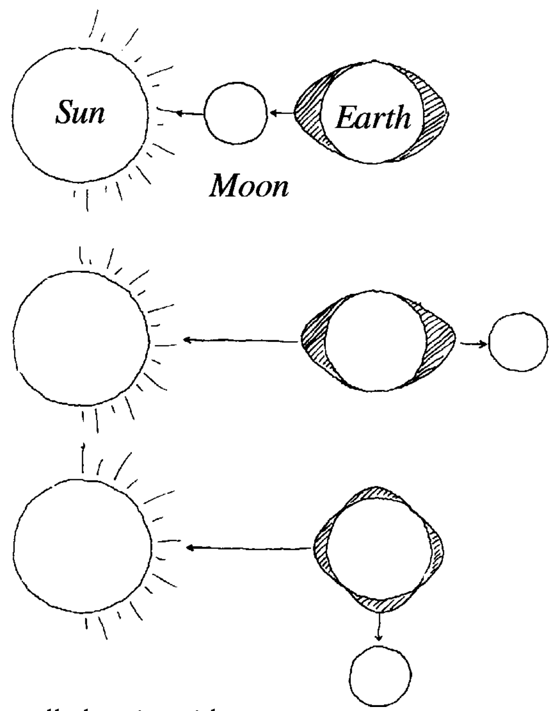
Light is crucial for photosynthesis. Only where light is present can plants grow. Phytoplankton production is directly linked to the intensity of light. Light reaches to a certain depth. This depth can be reduced by suspended sediments in the water.

Tides

Tides are caused by the gravitational pull of the sun and moon on the waters of the Earth. Because the moon is so much closer to the Earth than the sun, its influence is much greater.

see activities 4, 14

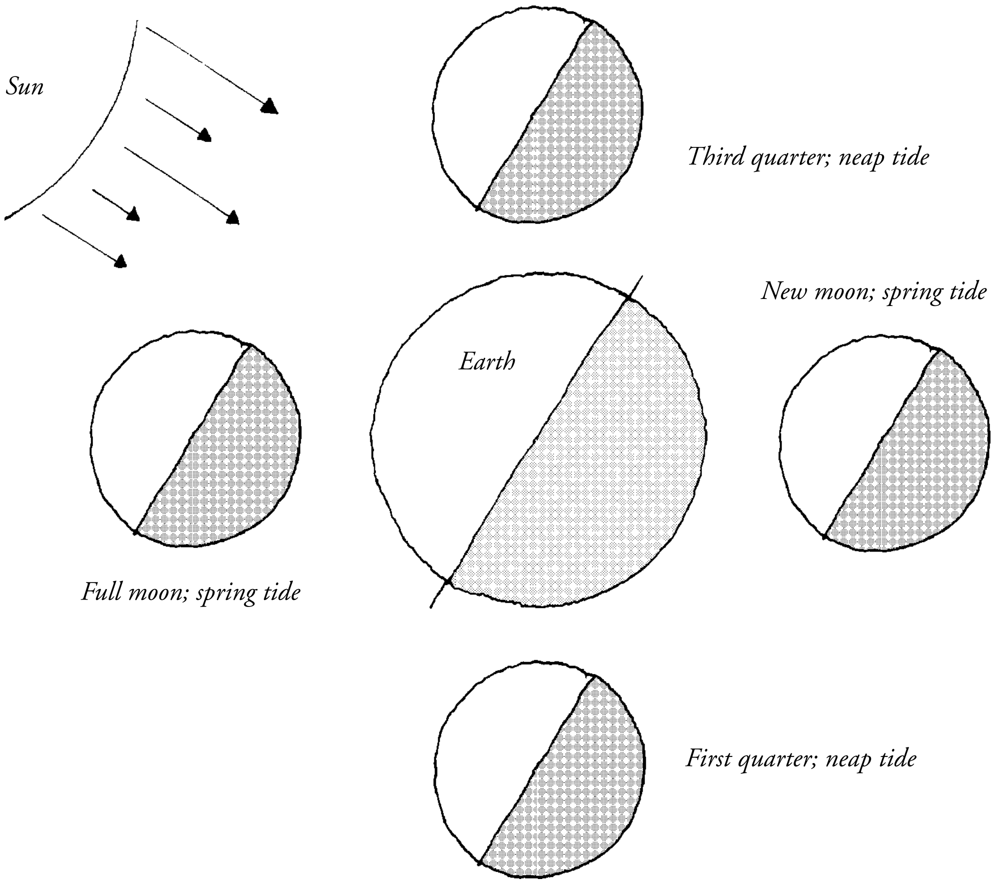
The moon takes 24 hours and 52 minutes to travel around the Earth. For most of Atlantic Canada this produces two high and two low tides each day. These are called semi-diurnal tides. Each tide is six hours and 13 minutes apart. The tides change by about an hour each day, due to the extra 13 minutes in each one.



When the sun and moon and Earth are in a straight line, during the times of a full moon and new moon, the gravitational pull on the Earth is the greatest. It creates high tides that are very high and low tides that are very low. These are called spring tides.

When the sun and moon are at right angles to each other they pull in opposition to one another, and the difference between high and low tides is not very great. These tides are called neap tides.

The phases of the moon



In places like the Bay of Fundy, where the mouth of the bay is wide and deep and the head of the bay is narrow and shallow, a tide advances a large volume of water that has to fit into a small space. As a result, even during neap tides the water rises higher and falls lower along the shore than in other places in Atlantic Canada.

Tides can also generate currents that assist in eroding the shore and moving nutrients.

Many people depend on the timing of tides for fishing, clamming, and nature study.

Tidal ranges in the Gulf vary as much as 0.7 to 3.0 metres and in the Bay of Fundy from 5 to 15.3 metres.

Waves

The impact of waves on a coastal ecosystem depends on their force, and the physical make-up of the ecosystem. A storm with strong waves can visibly alter a beach ecosystem. But the same powerful waves hitting a rocky shore might not change the landscape in any apparent way. The size of waves depends on the force of the wind, the wind's duration, and the distance (fetch) over which the wind moves.

The Force of Waves

Waves are characterized by moving water. This moving water sometimes travels at significant speeds towards the shore. Waves can pound the coast with an impact of more than 200 kg/m2. This powerful force has the ability to take all life away from the shore. But organisms have developed specific adaptations to keep themselves in place.

Approximately 8,000 waves per day strike a beach. Wind-made waves originate in deep water far from shore. Waves increase in size by resonance-that is, the wind and water interact rhythmically. This is similar to a child being pushed on a swing who goes higher and higher as the pushing continues. When waves leave the generating area they're called swells. Beaches can act as buffers to wave energy by dissipating or reflecting this energy.

In the nearshore, as the water becomes shallower, waves transfer their energy to the bottom. As waves move towards shore they 'feel' the bottom and are pushed upward. When this occurs, the top (crest) of the wave builds (increases in height), curls, and eventually collapses. It runs up the shore and transfers its energy to the beach. When the water reaches the shore, it moves back down the slope of the beach, creating a backwash and associated current. This process transfers sediment, plant and animal material, and beach debris into the nearshore. Other currents, waves, and wind help to move this deposited matter to other locations.

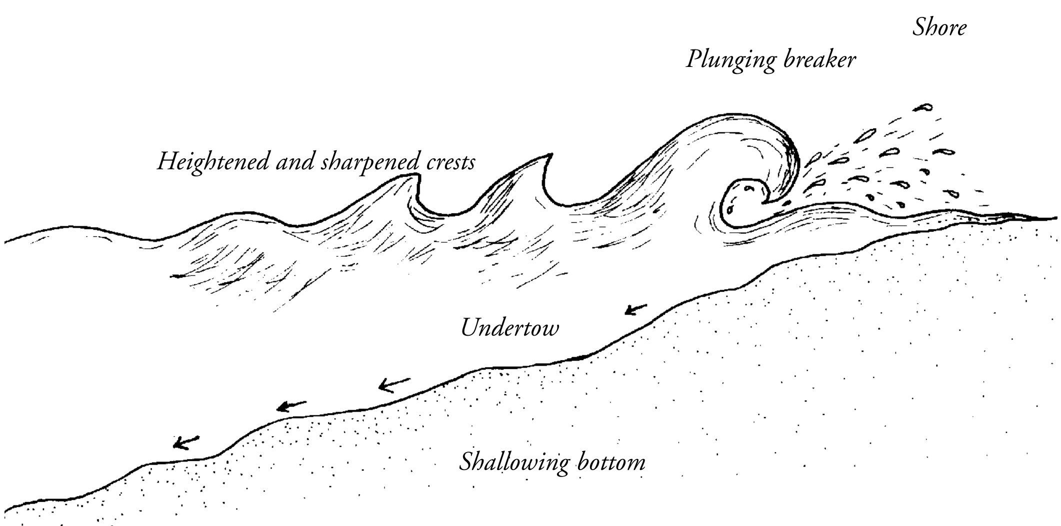
Constructive and destructive waves

Waves can be constructive or destructive. They can build up a beach or tear it down. Constructive waves force a powerful surge of water up the beach. In the process they return material to the shoreline, which builds up the surface of the beach and reduces the seaward slope. Destructive waves have a weak swash and tend to comb material down the beach. The maximum height of a beach is determined by the upper limit of the swash action.

The swash zone is the part of the beach that is covered and uncovered by successive waves. The beach face is called the swash slope. The swash consists of two components. A shoreward-moving component, termed the uprush (swash), gets its energy from the wave. It forms a wedge of turbulent water that thins as it moves up the beach. A seaward-moving component, termed the backwash, gets its energy from gravity and forms a thin sheet of water that percolates off the beach as it heads back to the ocean.

Breakers are formed when long swells advance against opposing winds over shallows. Plunging breakers have the greatest impact on cliffs and sea walls, where they strike with a force of seven tons per square foot. Spilling breakers crash gradually and are produced by steep, wind-backed waves. Surging breakers flood rather than break and are common where the slope of the beach is steep. They cause their greatest destruction in undercutting cliffs, which eventually break off and fall.

Formation of breakers



Large breaking waves often throw cobbles up above the limits of the swash. This action builds ridges at the back of the beach that are considerably higher than the high tide level.

Waves combined with wind, currents, and tides affect many coastal ecosystems. They move sediments and erode already existing headlands to form cliffs. Wind and waves can also erode islands. Eroded material is deposited in sheltered areas to form salt marshes. Currents move sediments to form spits and sand bars. Where a river meets the sea, an estuary is created.

Wind

Wind creates waves and carries salt inland. The size of the waves in deep water is determined by the direction of the wind, and by the fetch.

The southeast coast of Canada to midway up the coast of Labrador can be considered storm wave coasts. In these areas, short, high waves are frequently generated by local gale-force winds in winter and less often in summer. In fact, waves are higher here than in tropical areas.

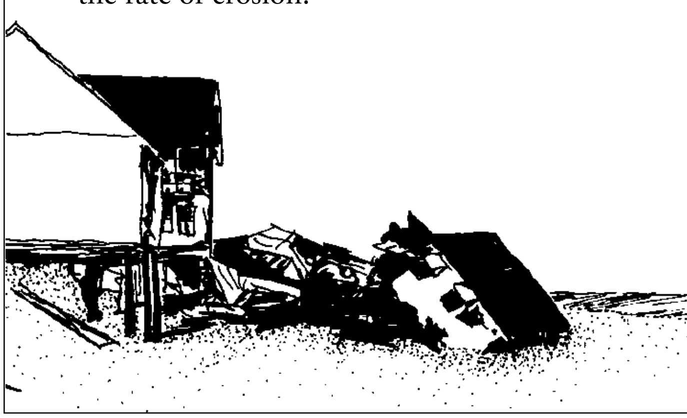
In the Gulf of St. Lawrence and the Bay of Fundy waves are generated locally by wind. Here the fetch is far less than in the Atlantic Ocean. With a short fetch, strong winds and high waves usually occur together. On the Atlantic coast, waves come from much farther offshore. They're not necessarily accompanied by the wind that created them. They might have originated far offshore, from a tropical storm.

Storms

During a storm, increasing wave power can cause beach erosion. Even steep beaches may not be able to reflect the energy of the waves. As a result, they absorb this energy, which results in a greater than usual movement of beach material. A beach will often change more during the few hours of a storm than in weeks or months of calm weather. On many beaches, winter storms can remove a layer of sand, exposing cobbles or boulders. In the summer, constructive waves often replace the blanket of finer sediment.

Shore Erosion

Shore erosion is a result of waves and currents that strike, bulldoze, and heave the land in its path. With the help of weathering and gravity, waves and currents continuously transport and deposit eroded debris. Smaller particles are carried away by winds, tides, and currents. The larger objects such as cobbles and boulders remain. The land along the edge of the sea is always at the mercy of waves and currents. Glacial debris in the form of boulders significantly slows the rate of erosion.



Upwelling

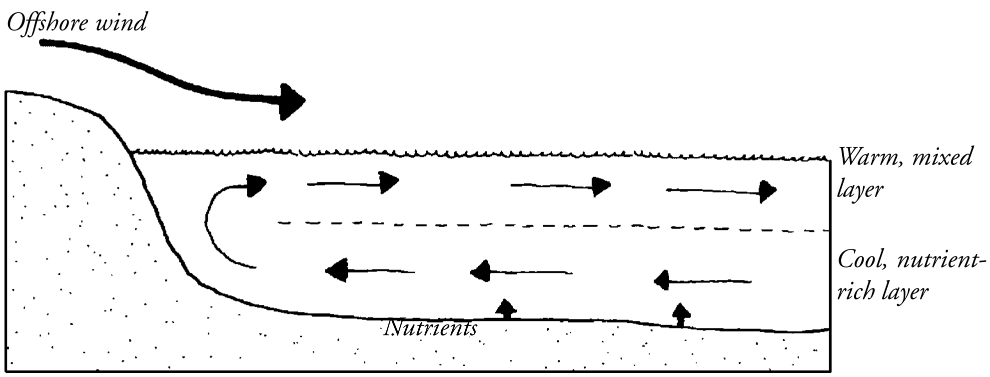
Upwelling is a physical process that brings cold, nutrient-rich waters from the ocean bottom to the surface. The ocean bottom is relatively rich in nutrients because of the accumulation of dead organisms and sediments. As the surface water warms and phytoplankton grow, they use up nutrients. Upwelling results in an increased growth of phytoplankton and food for fish, whales, and other organisms. It's estimated that 50% of the world's supply of fish comes from upwelling areas, even though these areas only make up about 1% of the ocean.

In the coastal zone upwellings occur constantly. They are the result of wind mixing, river run-off, tidal mixing, and temperature stratification.

Upwellings

Wind Mixing

When the wind blows parallel or at a slight angle to the coast, the water is moved away from shore by the coriolis effect (a force that causes objects to turn to the right in the Northern Hemisphere and to the left in the Southern Hemisphere due to the rotation of the Earth). The water is then replaced by cooler water from the ocean bottom. The continental shelf is one of the areas where this phenomenon occurs constantly.

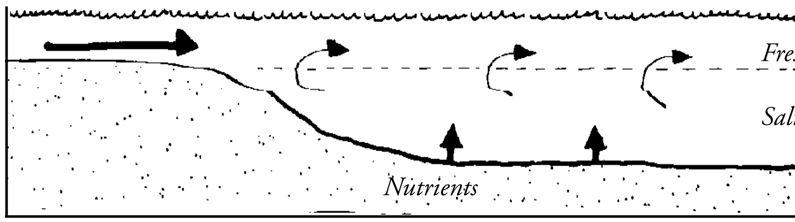


Temperature Stratification

With warming air temperatures, the upper water layer warms up and does not mix with the colder water below (stratification). As the air temperatures cool down, the surface water cools down as well and sinks. The sinking water is replaced by the water from below, carrying nutrients upwards. This is also called convective mixing and occurs throughout the coastal zone. An example of this is the meeting of the cold Labrador current with the warm Gulf Stream current over the Grand Banks, well known for its nutrient-rich waters.

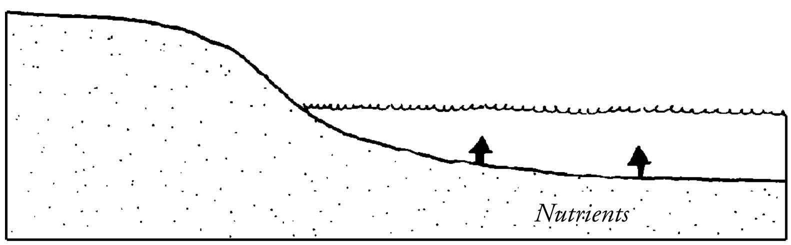
River Run-off

Freshwater flowing seaward from rivers is lighter and stays on top. The volume of this surface water is greater. This is compensated for by an inward flow of nutrient-rich water from farther down, which rises to the surface. This kind of upwelling occurs in estuaries.



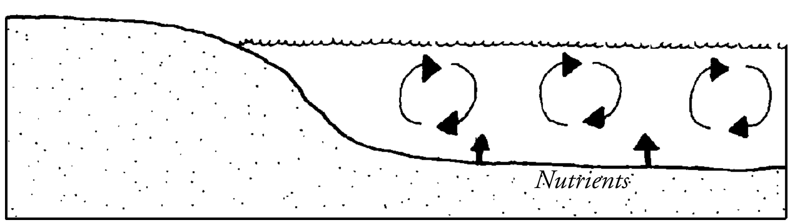
Tidal Mixing

In areas influenced by tides, the nutrient-rich, cool water is constantly mixed with warmer surface water. This mixing, also known as turbulence, occurs throughout the coastal zone, especially in the Bay of Fundy.



Low tide

High tide



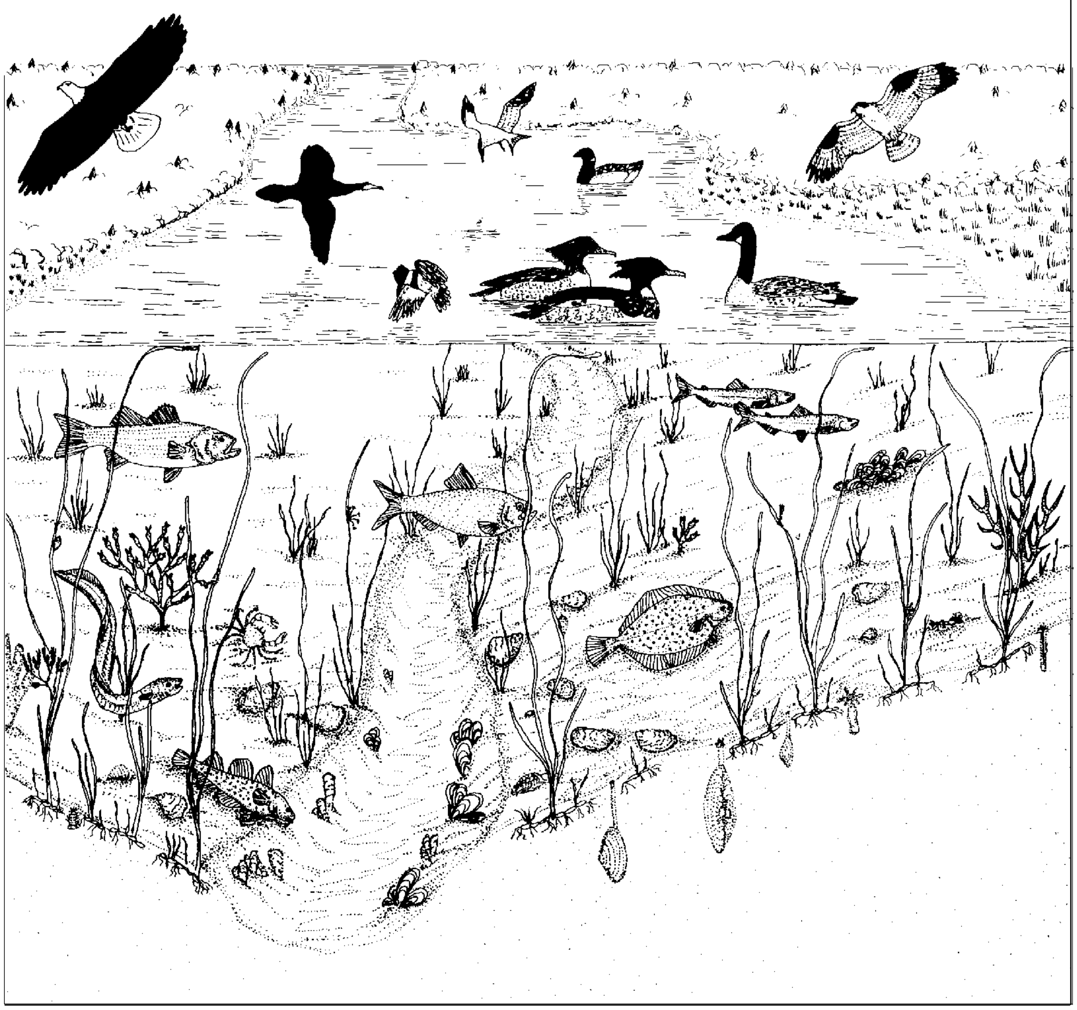
(Drawings after Mann, 1982)

BIOLOGICAL FEATURES

Geological history and present-day abiotic processes have created and are creating our coast. The physical processes such as salinity, currents, temperature, or the availability of freshwater make these areas very rich in animal and plant life. Over 200,000 different plants and animals live in the ocean. In the coastal zone organisms have adapted to different sets of conditions. Although each ecosystem has unique plants and animals living there, some species, like plankton, are common to all ecosystems in varying degrees.

Animals adapt to an area where they find appropriate food, water, shelter, and space. In order to live there, they must adapt to abiotic factors, such as temperature, light, and waves, and biotic factors such as predation. Their chances of survival increase the more adapted they are. Key adaptations might include how they move, feed, defend themselves, and reproduce.

Life in an estuary



Categories of Marine Life

Two major zones can be distinguished, the benthic and the pelagic zone.

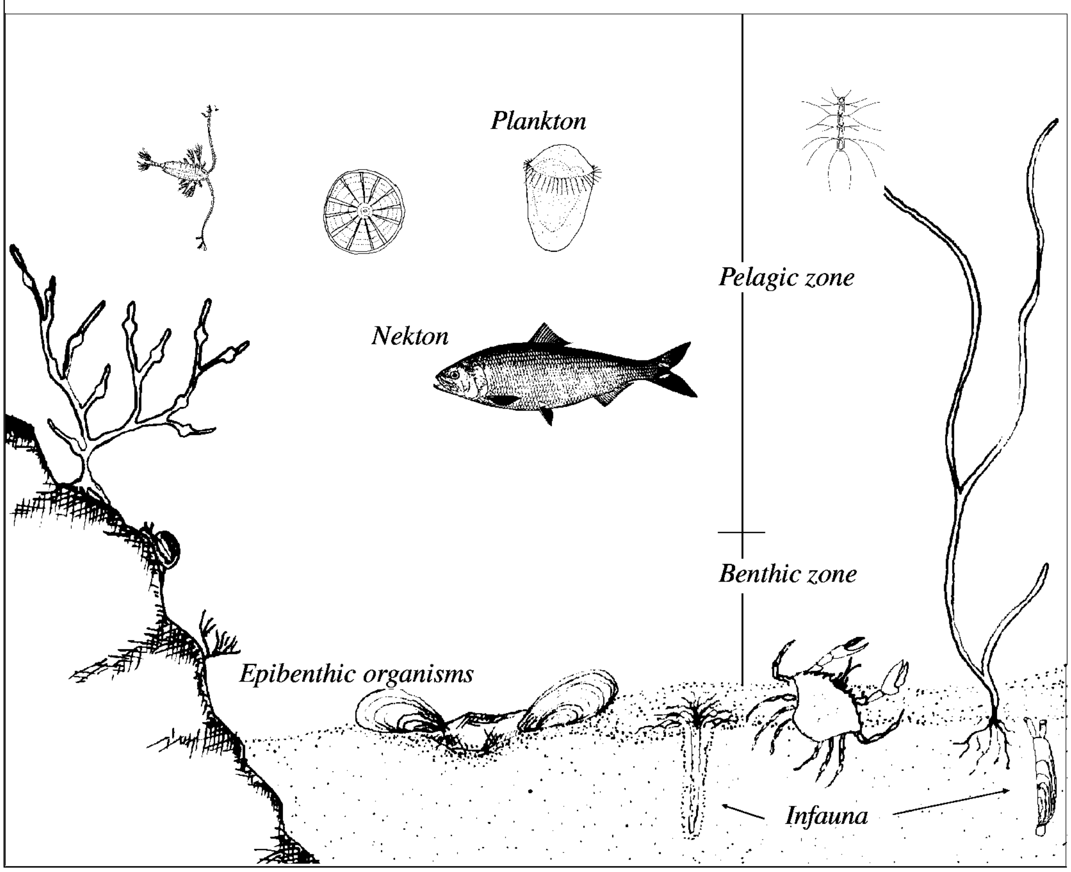
Benthic zone (the bottom)

Organisms that live on or in the bottom deposits are called benthic. They include seaweed, clams, worms, mussels, crabs. Epibenthic organisms, such as crabs and seaweed, live on the bottom either attached or free-moving. The infauna includes organisms that burrow into the sand or mud, such as clams and worms.

Pelagic zone (the water above the bottom)

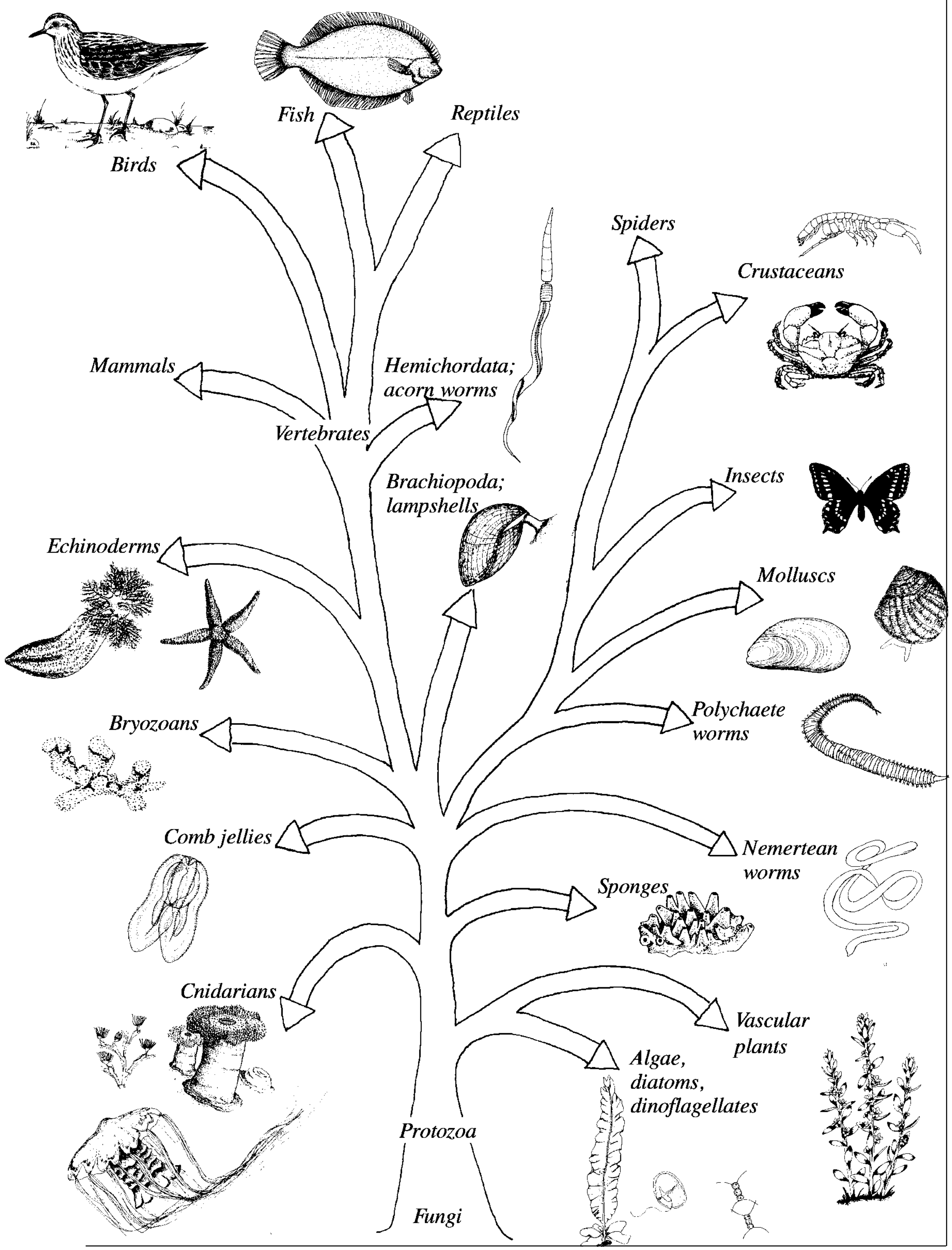
Animals that are strong swimmers and live in open water and middle layers of the water are called nekton. They include squids, whales, and adult fish. Plankton are organisms that move passively with the water currents, and inhabit the upper layers of the pelagic zone.

Categories of marine life



The Inhabitants

A Classification Tree for the Coastal Zone



Plankton

Plankton refers to the living material that floats in water. The word comes from the Greek word 'plankton,' meaning 'wanderer.' Plankton is typically found in the upper regions of the water column. It's made up of two groups. The largest group consists of phytoplankton, which are tiny microscopic plants. The smaller group consists of tiny animals called zooplankton. Plankton may be unicellular (one-celled) or complex multicellular organisms, such as jellyfish. Planktonic creatures move passively and are almost incapable of controlling their movements. Although some can swim, they're typically at the mercy of waves and tides.

About 75-85% of the organic material on the planet comes from phytoplankton. About 80% of the world's oxygen is produced by phytoplankton.

Phytoplankton

Phytoplankton are minute plants, primarily microscopic algae such as dinoflagellates. They are mostly transparent and possess floating devices. Phytoplankton are the link in the food chain at which inorganic nutrients are converted into organic material through photosynthesis. They are able to manufacture their own food, but they depend on other tiny microbial organisms, such as bacteria and fungi. These organisms convert organic substances (other plants and animals and their wastes) into inorganic nutrients such as nitrogen and phosphorus. These inorganic nutrients are needed in sufficient quantities for phytoplankton to produce their food.

Even though they are microscopic, phytoplankton are found in sufficient numbers to feed the rest of the ocean. As producers, they are more important than seaweed. There are few areas in the oceans where attached plants can grow and receive enough light for photosynthesis. Free-floating phytoplankton do not have that problem. They don't need to attach themselves. But they must stay up in order to survive. Diatoms store oil in their cells to increase their ability to float. Spines increase their surface area and the formation of spiral chains increases their ability to remain in a specific water column.

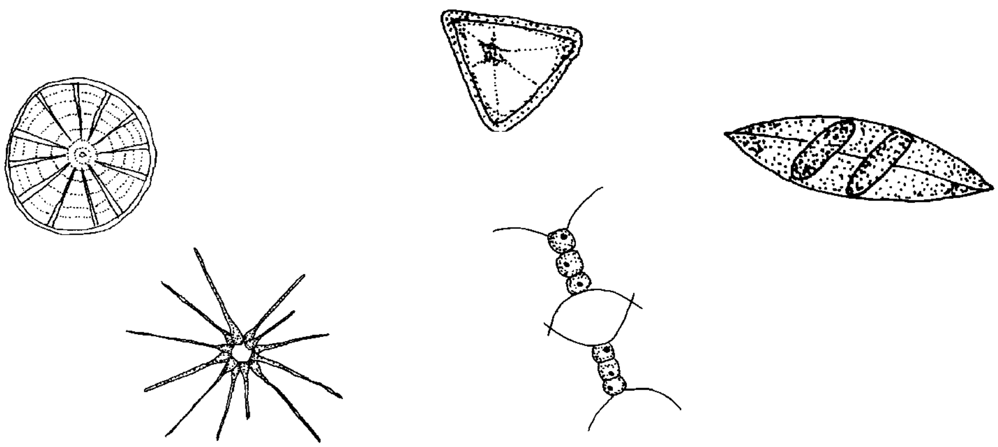
Diatoms and dinoflagellates

Diatoms

98% of phytoplankton are made up of diatoms.

Diatoms are single-celled organisms with a glass-like (silicon dioxide) skeleton. These silicon shells sink to the ocean floor. In some areas, where the shells have collected over time, they are mined to be used in toothpaste, diatomaceous (Fuller's) earth, flea powder, and silver polishes. Diatoms are made up of two 'valves.' They're circular like a button or elongated like a football. They can form chains and multiply up to three times a day. These tiny organisms are between 0.5 and 0.05 mm in size.

Some diatoms



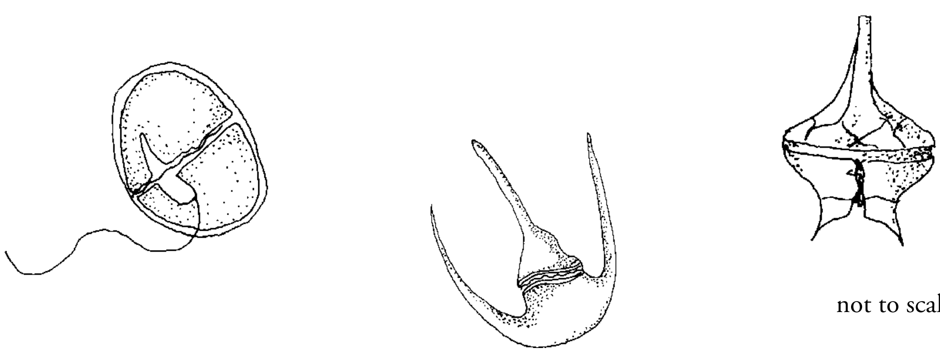
not to scale

Dinoflagellates

Dinoflagellates are also single-celled organisms, but they have two whip-like flagella and spin as they move. They can be armoured or unarmoured. Certain dinoflagellates cause red tide, a plankton bloom that colours the water red.

Some dinoflagellates produce light as a byproduct of their chemical processes (called bioluminescence). They flash intermittently, especially when they're moved. In the spring their populations can be very dense and every movement can leave a trail of light.

Some dinoflagellates

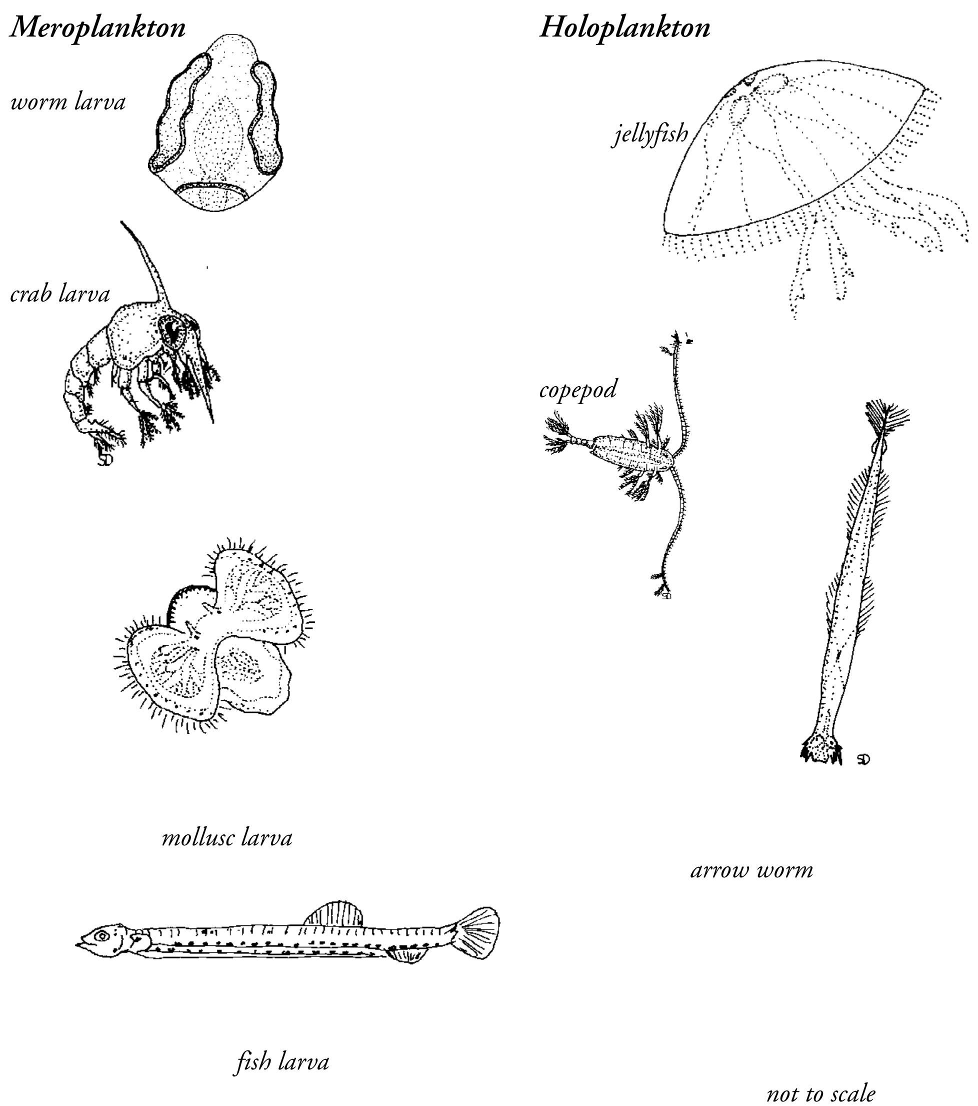


not to scale

Zooplankton

Although these tiny animals are abundant in coastal ecosystems, you will need a microscope to see most of them. Zooplankton are divided into two groups. The first group is composed of permanent zooplankton that spend their entire lives as plankton (holoplankton). Unicellular animals, copepods, amphipods, and even jellyfish belong to this group.

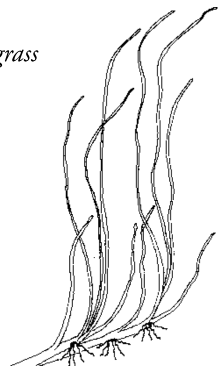
The second group consists of temporary zooplankton that spend only a part of their lives as plankton (meroplankton). They include the larvae of marine worms, molluscs, crustaceans (such as the crab), and fish. Meroplankton are especially susceptible to pollution, because they absorb metals and other particles that accumulate and concentrate in the food chain, such as DDT or PCBs.



Plants

Plants are a major building block of the coastal zone. They modify this zone by trapping sediments, slowing down currents, producing food, and providing shelter to many organisms. Whether it's Eelgrass in estuaries, cord-grasses in salt marshes, algae beds on rocky shores, or Marram Grass on beaches - plants are crucial to the coastal zone.

Eelgrass



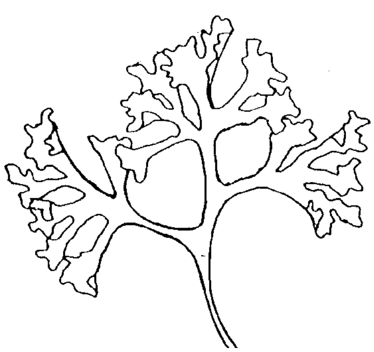
Beachgrass/ Marram Grass

Seaweed

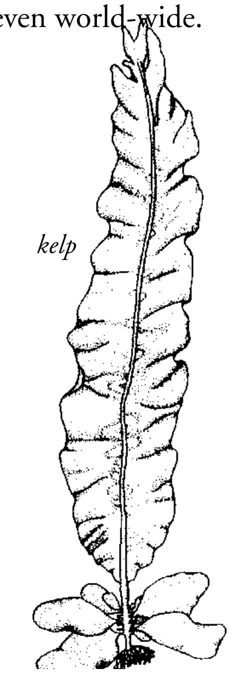
Seaweed thrives in the ocean waters of Atlantic Canada. This area, termed boreal, provides a transition between the Arctic and the temperate marine environments of the northwest Atlantic Ocean. Here, the water temperatures are just right, less than 20½C, to ensure a well-developed seaweed community. Most seaweed permanently attaches itself to rock or gravel, while a smaller number are free-floating. It flourishes in the intertidal and subtidal zones, which are turbulent, high-energy communities that provide a lot of light and nutrients. Seaweed is the primary producer in the intertidal zone. It also provides food and protection for plants and animals that live on and under it when the tide is low. The most common seaweed in Atlantic Canada can also be found in Cape Cod (even the tropics), the Arctic, and even world-wide.

Some seaweed

Irish Moss



kelp

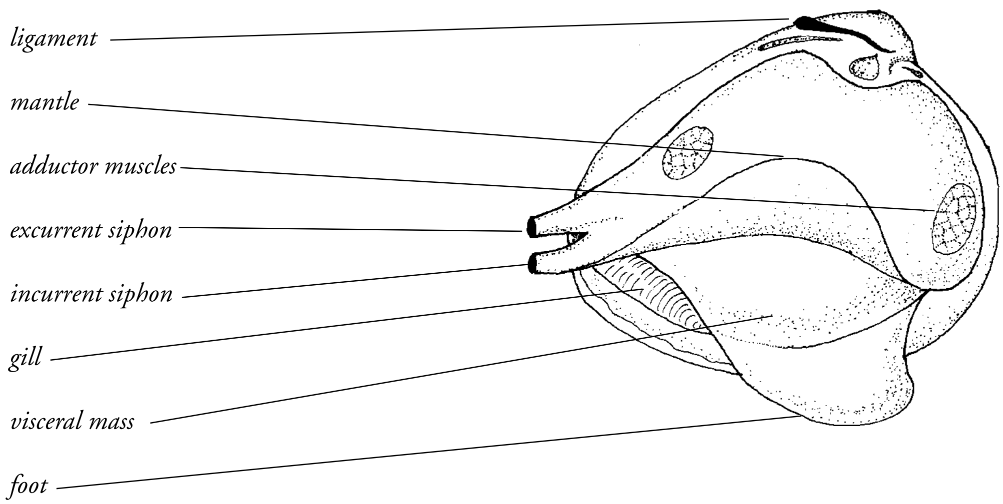


Molluscs

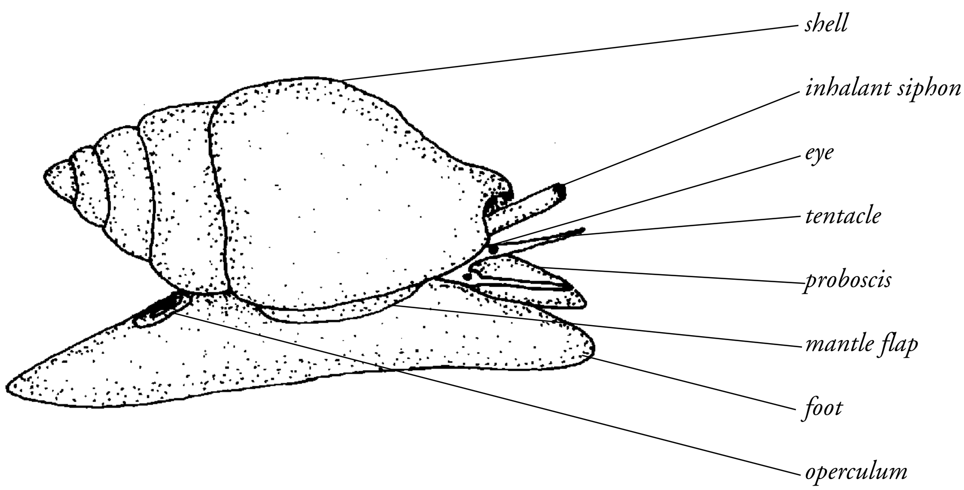
Molluscs are one of the largest groups of animals. They are characterized by their soft bodies. Some molluscs, such as snails and oysters, are protected by a hard exterior shell made of calcium. While squid have an internal shell, sea slugs lack a shell completely. Molluscs have three distinct body zones: a head-foot that contains the brain and the sensory and motor organs; a visceral mass that houses the internal organs; and a foot, the muscular lower part of which the animal creeps with. The mantle, an extension of the body wall, secretes the shell.

The body parts of bivalve and gastropod molluscs

Bivalve



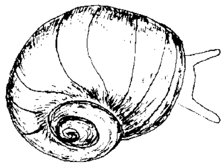
Gastropod



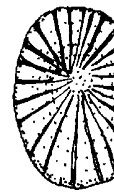
Single-shelled molluscs-gastropods

Gastropod means 'belly-foot' and refers to the flattened foot of certain molluscs. They use their flattened foot to grip the surface of rocks. Single-shelled molluscs have a spiral shell. The colour and shape of the shell can help you distinguish the different genera and species. The most common gastropod is the periwinkle. The periwinkle is a herbivorous snail that eats seaweed and small algae off the surface of rocks. It uses its tongue, called a radula, to scrape the surface of rocks as it crawls along. Other gastropods include limpets, whelks, and sea slugs.

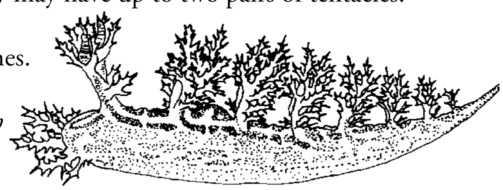
periwinkle



limpet



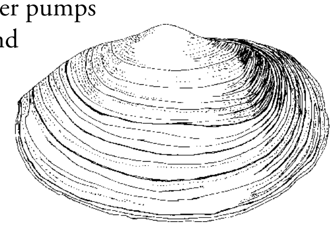
Some gastropods, such as sea slugs or nudibranchs, only have shells when they're embryos. They are shell-less as adults. Their upper surface is ornamented with tubercles, gills, or club-shaped respiratory structures called cerata. They may have up to two pairs of tentacles. They're carnivorous, feeding on sponges, tunicates, bryozoans, hydroids, and sea anemones.



nudibranch

Bivalved molluscs

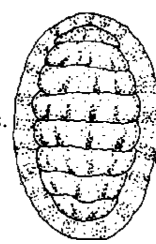
Bivalves have two shells or valves that are joined by a ligament and adductor muscle. The valves enclose a soft body that consists of a visceral mass, a hatchet-shaped foot, gills, and a mantle lobe. A pair of siphons work together to bring oxygen and food into the body and expel wastes. One siphon pumps water in to the mollusc and the other pumps water out. Bivalved molluscs include mussels, clams, oysters, and scallops. Mussels attach themselves to rocks with silky threads secreted by the foot. Clams bury themselves in the substrate and use their siphons to access the water and their food.



Soft-shelled Clam

Many-shelled molluscs-chitons

These molluscs are oval-shaped and flattened with eight valves along their backs.

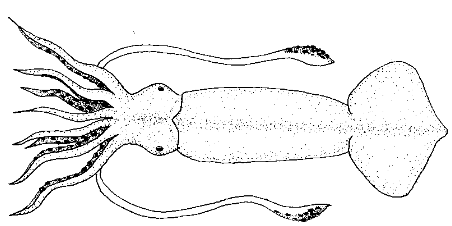


chiton

Head-footed molluscs-cephalopods

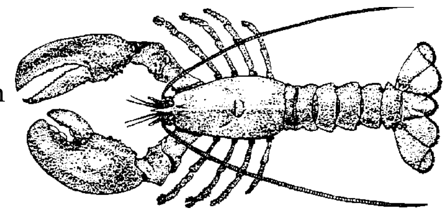
Squids have an internal shell, whereas octopuses have no shell at all. The foot, which is divided into arms, is wrapped around the head.

Common Short-finned Squid



Crustaceans

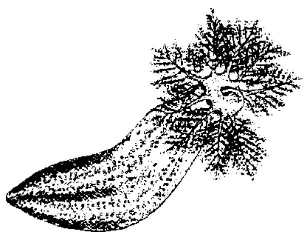
Crustaceans can be microscopic or weigh up to a kilogram. They include lobsters, crabs, shrimps, barnacles, isopods, amphipods, and copepods. They get their name from their hard shells. They're often called 'insects of the sea.' Amphipods are shrimp-like crustaceans. 'Amphi' means 'both' and 'poda' means 'feet,' indicating that they use their feet for both swimming and walking. They're heavily preyed upon by fish and whales.



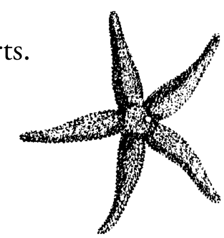
lobster

Echinoderms

Echinoderms or 'spiny skins' include sea stars, sea cucumbers, sea urchins, and sand dollars. They have a skeleton made of calcium in the form of rods, plates, or spicules just below the skin. Their water vascular system of canals enables them to feed and they move by the aid of their tube feet. Echinoderms are well-known for their amazing ability to regenerate lost or damaged body parts.



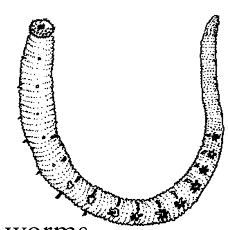
sea cucumber



sea star

Worms

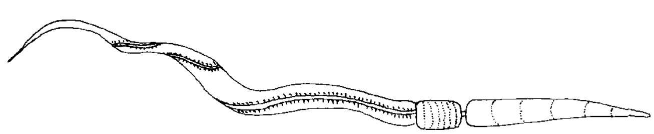
For the purpose of easier understanding, all worms are grouped together. It should however be clear from the above classification tree that marine worms are composed of many different groups of organisms. They're as different as molluscs are from crustaceans.



Lugworm

Hemichordata, included under this grouping, are actually not worms at all. They're worm-like creatures classified as something in between chordates and invertebrates.

acorn worm



ECOLOGY

The word ecology comes from the Greek word 'oikos,' meaning 'home.' First coined by Ernest Haeckel in 1869, ecology has come to mean the 'scientific study of the interactions between organisms and their environment.' These interactions determine the distribution and abundance of organisms. The 'environment' consists of all factors outside the organisms that influence them. These factors can be physical (ice, temperature, wind, etc.), chemical (nutrients, minerals, etc.) or biological (competition, predator-prey relationships, etc.). Physical and chemical factors are often referred to as abiotic or non-living characteristics. Biological factors are referred to as biotic or living characteristics.

Stress and Survival (Adaptations)

Plants and animals in the coastal zone are exposed to different abiotic factors that make adaptations necessary. They require ways to avoid drying out during low tide, hold on or stay in one place despite wave action, and cope with changing salinity levels. These are just a few of the necessary adaptations required to survive life in the coastal zone. Each organism living in the coastal zone is well adapted and many of these adaptive mechanisms are quite astonishing. They are discussed in the relevant sections for each ecosystem.

Productivity

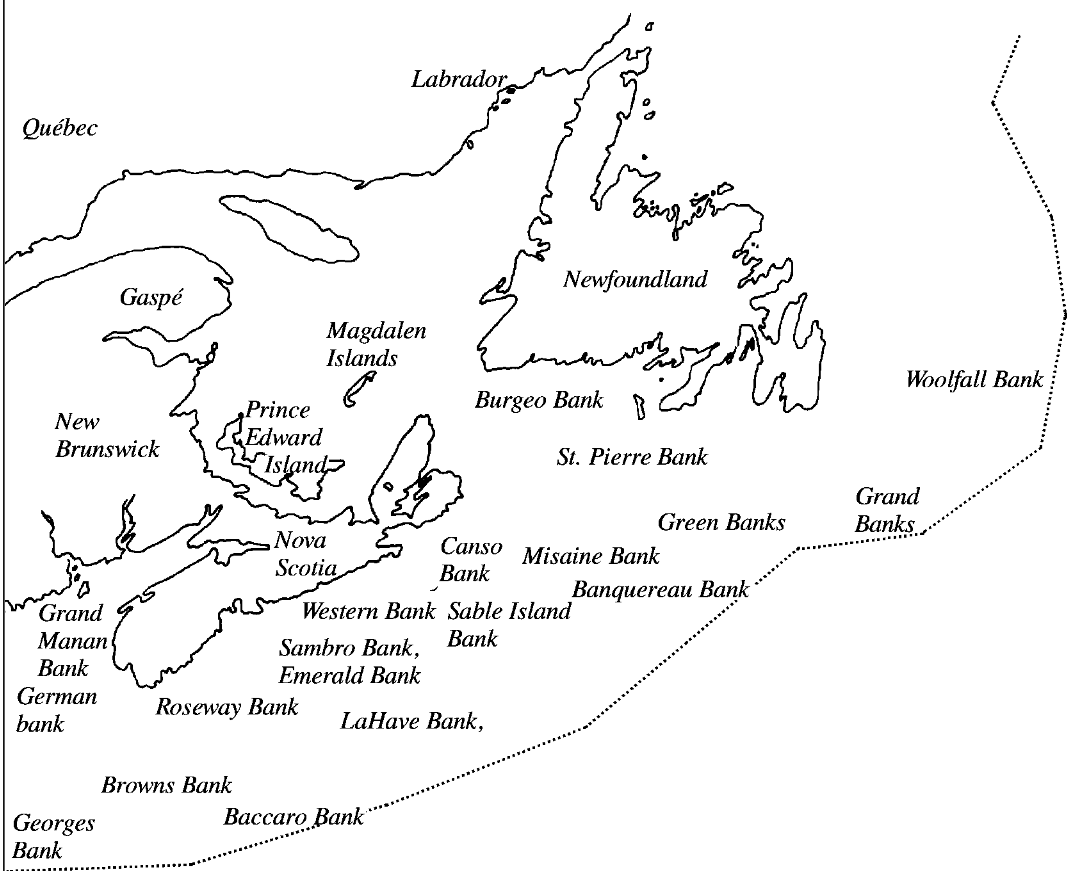
Primary productivity is the rate by which energy from light is utilized to produce organic matter, i.e., how fast plants grow. Secondary productivity is the rate of production of biomass (weight of living organisms) by heterotrophs (animals, bacteria, fungi). These concepts related to productivity are important measurement tools for marine biologists.

Productivity in aquatic communities is mostly influenced by the availability of nutrients, light, and the intensity of grazing. In general the productivity of the coastal zone is incredibly high, due to the occurrence of upwellings.

The upwelling, or upward movement, of these nutrient-rich waters causes a plankton bloom. Fish and whales take advantage of this excellent source of food. Some of the best fishing areas on the coast of Atlantic Canada are located in areas where upwellings occur.

Fishing banks and 200-mile limit

Labrador Québec Gaspé Québec Newfoundland Magdalen Islands Prince Edward Island NewBrunswick Woolfall Bank Grand Banks Green Banks St. Pierre Bank Burgeo Bank Banquereau Bank Misaine Bank Sable Island Bank Canso Bank Sambro Bank, Emerald Bank Western Bank Nova Scotia LaHave Bank, Baccaro Bank Browns Bank Roseway Bank Georges Bank German bank Grand Manan Bank

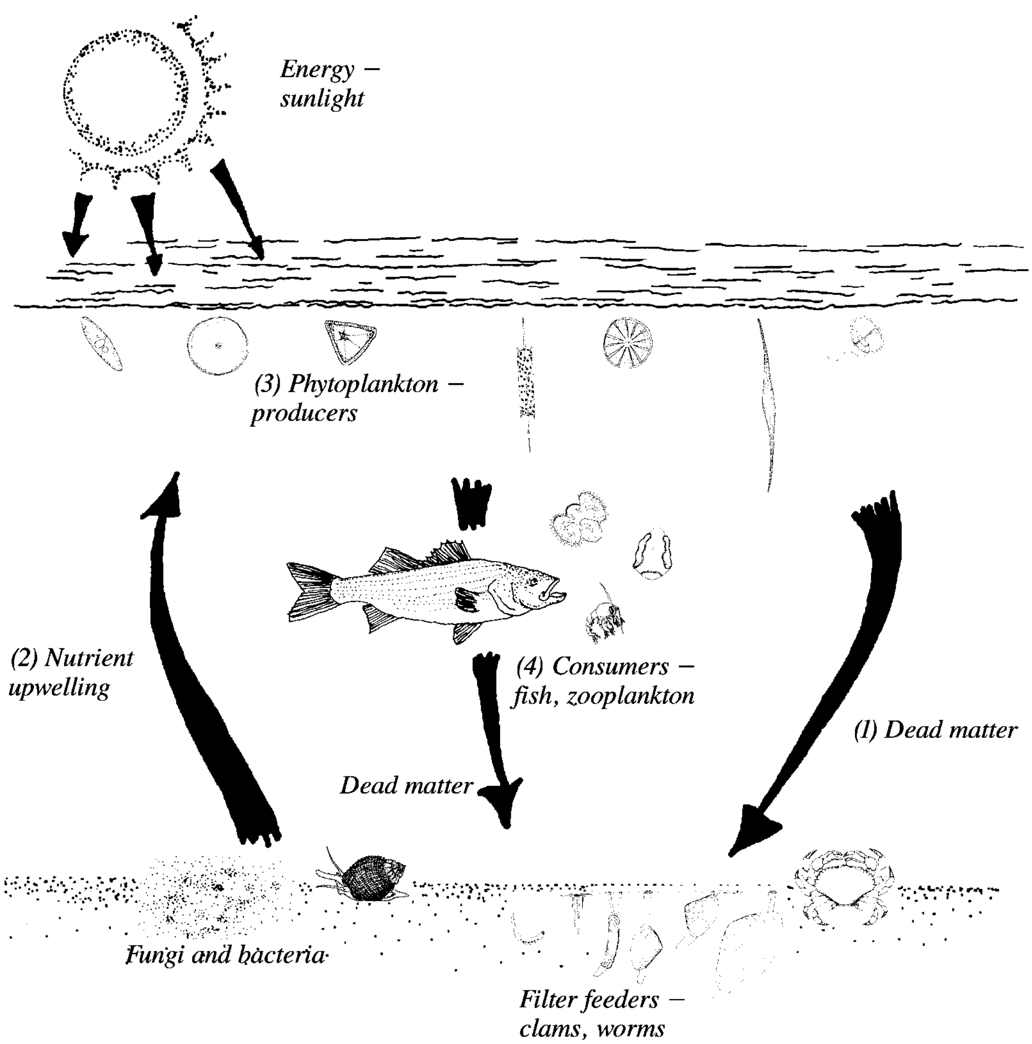


Nutrient Cycling in the Coastal Zone

Coastal ecosystems are more productive than the open sea. (1) After they die, plant and animal remains sink to the bottom where they're broken down into nutrients. (2) Physical processes such as tidal currents, wind, and river currents cause turbulence, resulting in upwelling of nutrients from the bottom to the top of the water. (3) Phytoplankton reproduce in the sunlight, near the surface of the water. Upwelling brings the nutrients back to the surface, making them available to phytoplankton, which need the nutrients to grow and reproduce. (4) Phytoplankton in turn are food for zooplankton and filter feeders such as clams. Coastal waters are especially valuable fish habitat, because fish benefit from the abundance of organisms.

Nutrient cycling in the coastal zone

Energy - sunlight(3) Phytoplankton -producers(2) Nutrient upwelling(4) Consumers - fish, zooplankton(1) Dead matter Dead matter Fungi and bacteria Filter feeders - clams, worms



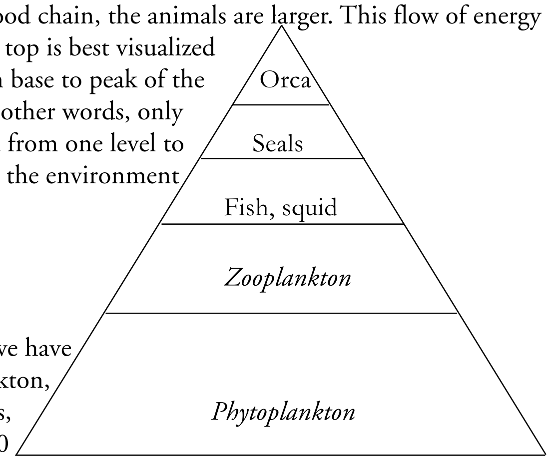
Food Chains and Food Webs: Who Eats Whom?

A food chain describes the flow of energy in the form of food from one species to another in a linear way.

A food web (interactions between species and other ecosystems) is composed of several food chains. Eelgrass and other plant matter from the estuary, or from adjacent ecosystems, enter the food chain in the form of detritus. Detritus is the organic debris from decomposing plants. Bacteria and fungi play a vital role in recycling plants, by helping to decompose and release nutrients back into the ecosystem. Without bacteria and fungi, other creatures in the food chain would run out of essential nutrients. In turn, these small but essential organisms are food for molluscs and marine worms. Phytoplankton and other plants (the producers) play an important role in the food web, not only as a source of food, but also as one of the links that convert inorganic nutrients to organic material.

Food Pyramids

The bottom of the food chain has the organisms that are smallest in size, but largest in number. As you go up each level in the food chain, the animals are larger. This flow of energy from the bottom of the food chain to the top is best visualized as a pyramid. The transfer of energy from base to peak of the pyramid is governed by the 10% rule. In other words, only 10% of the available energy is transferred from one level to the next. The other 90% is lost as heat to the environment at each level of the pyramid.



For example, following the 10% rule, if we have a food chain progressing from phytoplankton, to zooplankton, to fish and squid, to seals, and finally to Orcas, it would take 10,000 kg of phytoplankton to make 1 kg of Orca.
This inefficient use of energy limits the number of Orcas that can live and reproduce. Therefore, Orcas must work very hard to get the food they need. It is energetically advantageous to feed on organisms close to the base of the food pyramid. Other whales, the baleen whales, feed directly on zooplankton. The 10,000 kg of phytoplankton needed to make 1 kg of Orca will make 100 kg of baleen whale. This explains why Blue Whales, the largest animals in the world, are plankton feeders.

Links in the Coastal Zone

Energy Transfer

Energy is transferred from one ecosystem to another, with the tides and currents, in the form of nutrients, species, sediment, and organic material. An energy transfer also takes place via food webs. This happens when an animal uses a specific ecosystem for feeding, then leaves that ecosystem for a different ecosystem where it deposits faeces or is eaten by another animal.
The following 'connections' are all forms of, or factors that are needed for, an energy transfer to take place within and among the ecosystems of the coastal zone.

Water Connection

Ocean water is everywhere in the coastal zone and it moves constantly. The same water can be in an estuary during one part of the day, cover a mudflat some time later, then pound a rocky shoreline. Water is a vehicle to carry nutrients, sediments, chemicals, or anything that can be moved. Most of the processes in the coastal zone are linked to the presence of water.

Sediment Connection

Through physical and chemical processes rocks are constantly being broken down. A sand particle may well have been part of a rocky shore at one time. It might be broken down even further, to become part of the silty sediment of a mudflat. Sandy and muddy sediments are constantly moving.

Nutrient Connection

Nutrients enter the coastal zone in many ways. They enter through the breakdown of organic matter, such as when organisms and plants die and decompose. They enter from food webs when nutrients get released from faeces. They also enter from the land, from human sources. Estuaries, salt marshes, and intertidal systems provide sources of nutrients for the nearshore environment.

Plankton Connection

Both phytoplankton and zooplankton are present in water, everywhere in the coastal zone. These small organisms are crucial to coastal life, by forming the base for all food webs. They are not restricted to any one coastal ecosystem because they are free-floating and dependent on the tides and currents.

Plant Connection

Intertidal seaweed has an interesting and fundamentally important relationship with the nearshore. Rockweed, for example, grows prolifically on rocky shores. In turbulent seas it breaks loose from its holdfast and moves offshore. Here rockweed forms large algal mats, which provide a temporary habitat for many animals, especially juvenile fish and lobster. Over time these mats raft back to shore, where they become stranded at the high tide mark. Here the seaweed decomposes, and the products of this decomposition (nutrients) are washed back into nearshore waters, providing food for primary producers like seaweed, phytoplankton, and filter feeders such as scallops, clams, and mussels.

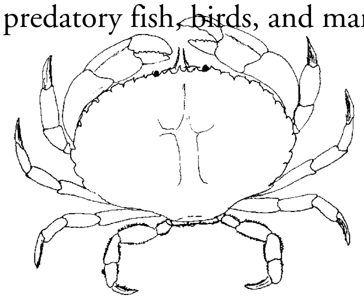
Similar to rockweed, salt marsh grasses also release nutrients into the coastal waters. They grow prolifically in summer and in the fall they die and begin to decay. As they decay, they release nutrients. Tidal waters that flood the marsh regularly transport these nutrients into the nearshore ecosystem.

Species Connection

Most animals travel great distances. Many species of fish use one coastal ecosystem for spawning, then relocate to the nearshore or offshore area. Salmon, for example, use the estuary as a transition area before entering freshwater rivers, or after spawning when they leave the freshwater river to return to the ocean. Birds, such as puffins or shearwaters, use the land for rearing their young. Once nesting is over, they live the entire rest of the year on the water.

A myriad animals live at the bottom of the ocean. The most common bottom dwellers are invertebrates, such as lobsters, crabs, worms, and molluscs. They produce incredible volumes of eggs and larvae. These in turn are food for other invertebrates, predatory fish, birds, and mammals that use the nearshore ecosystem.

Jonah Crab



THE COASTAL ZONE AND US

The coastal zone plays an important role for all of us. We are all influenced by the ocean, whether we live in Atlantic or central Canada. Fish, shellfish, and seaweed products are used almost everywhere. We have grown so used to these products that we often don't realize where they actually come from. Did you know that we consume a steady diet of seaweed? The next time you eat ice cream, cookies, or cottage cheese read the ingredients and look for seaweed extracts such as algar and carrageenin.

Coastal zones also provide a livelihood for people living close by. The sea shapes our history and culture. Stories, songs, and myths about our relationship with the sea make us uniquely 'maritime.'

However, we often take our coastal zone for granted. We dump our garbage in the sea, fill in salt marshes, and destroy dunes. In order to appreciate and protect our coastal zone we must understand the intricate web that exists along the shoreline of Atlantic Canada, how each ecosystem plays a vital role in the overall health of our coastal zone. By the Sea-A Guide to the Coastal Zone of Atlantic Canada is the beginning to understanding the importance of the coastal zone in our lives. Hopefully, it will enrich your perception of life along the shore. Happy exploring!