The **Stewardship** Series

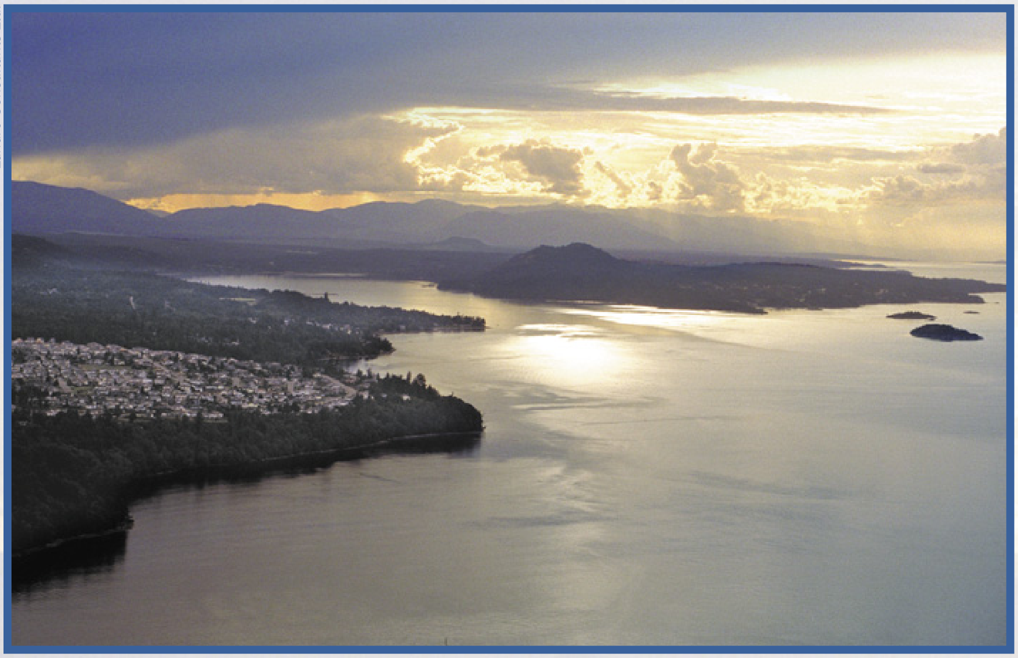
Coastal Shore Stewardship:

A Guide for Planners, Builders and Developers

on Canada's Pacific Coast

Canada

Province of
British Columbia



Lanarc Consultants Ltd.

Spectacular 1.37 Acre Private Oceanfront Point Of Land, Foreshore Lease Plus Dock - Protected Moorage! Sunny (South, Southwest, Exposures - Sunsets Forever!) Warm Ocean Swimming, Low Bank Sculptured Sandstone Foreshore! Easy Care, Totally Irreplaceable, Totally Beautiful!

(This is a real estate advertisement derived from an MLS listing describing a coastal property on Salt Spring Island, Spring 2002)

It is a beautiful picture – and yet the image created in this real estate advertisement is a distant mirage for most of us. It also conveys nothing of the responsibility that goes along with living on the shore. And you will notice that we have left out the price!

The shore, which is where the land and sea meet, is:

- changing constantly;
- crucial to the survival of sea life and many land creatures;
- highly attractive for industrial, residential and recreational development.

If we're to successfully balance the competing interests for this limited resource then we must understand:

- the dynamics that shape the coastal shore;
- the sensitivities of our particular part of the coastal shore;
- the rules that govern development; and
- the best methods for protecting the coastal shore.

This guide is one of a series. It is written for all those who have an interest in the coastal shores of British Columbia.

Good development will:

- save money, time and investment;
- manage risks properly;
- protect natural resources, such as fisheries; and
- ensure the survival of the natural environment for the future.

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Whether you are a homeowner, a developer, a businessperson, a senior government manager or a local government planner, we hope you find this document useful. We all must work together to ensure that coastal resources are cared for, protected, and wisely used.

Whenever a coastal system is damaged or degraded, even temporarily, its repair, recovery and restoration is a cost to everyone. Whatever is lost through our negligence or ignorance is difficult to regain. Whenever something is lost, we narrow the social and economic options for us and for future generations.

The alluring advertisement at the top of the page promises "Totally Irreplaceable, Totally Beautiful!" It's totally true.

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About the Chapters

Shores and people – whether you live, work or play along the coast, this chapter highlights some of the reasons why you should contribute to Coastal Stewardship.

Shores are shaped and reshaped every day by the effects of wind and waves, and the movement of sediment. Find out more about these processes, and how they influence the habitat and complex biological systems that are supported by different physical shore types.

Some shores are better able to absorb the impact of development than others. This chapter describes five basic shore types and highlights some of the development sensitivities of each.

The shorezone is complex—physically and biologically the jurisdictional rules can be equally complex. Local governments can have land use bylaws that govern use of the shores and, at the same time, provincial and federal agencies have legislation, policies and guidelines that also apply to these areas. This chapter identifies some of the legislation affecting shores and describes the roles of key shore management agencies.

This chapter provides "hands on", environmentally responsible information for those who plan to work or live near the coastal marine environment, and applies to both commercial and private endeavours.

Coastal living is an important part of the British Columbia lifestyle. This chapter identifies some of the excellent resources that already exist to help us live sustainably while reducing our impact on shores.

A Stewardship Context

Fisheries and Oceans Canada

Shores are "Living Systems"

This guide often refers to coastal shores as living systems. The planning and development of coastal areas requires a careful understanding of how these systems work. Shores usually change very gradually, but occasionally these changes are dramatic and seemingly unpredictable. We may not be able to forecast the timing or severity of storms or beach erosion but we have a good idea of what can be done to reduce the impacts on people, plants and wildlife. That is what this guide is all about.

Shores have structure, function and process. They are constantly moving, changing and evolving in response to the influence of such external natural forces as winds and tides. The form and dynamics of the physical shore create the conditions for the presence and survival of B.C.'s coastal plant and animal communities. If these biological resources are to be sustained and the integrity of our coastal ecosystems maintained, we must be careful how we use our shores. A cautious approach to development of our coastline recognizes that "when an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically." *(Taken from the Wingspread Consensus statement on the Precautionary Principle 1998)*

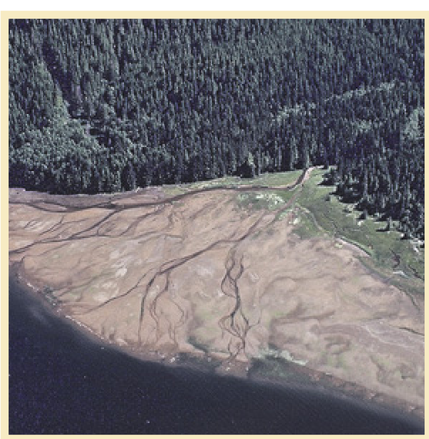
Note:

Text written *like this* identifies federal or provincial legislation.
Information written *like this* is available on the Internet - refer to the Website Address Insert included in this document for details.

Why a Coastal Shore Stewardship Guide for Planners, Builders and Developers?

Our coastline is home to many people, marine based industries and sensitive marine organisms. The first two interests demand greater access to these areas, yet the latter requires greater protection. The competition and conflict in these areas is increasing under the strain of greater commercial and industrial demands for access to foreshores, more and larger waterfront homes and exponential increases in recreational use of these areas. In order to address the needs of each of these interests, yet protect the basic functions and values that created these treasured areas in the first place, we must adopt an ecosystem-based approach to planning and management of these coastal shores.

This guide provides the basis for such an approach and is intended for use by anyone who regulates, designs, develops, builds, uses, lives, plays on or just loves the coastal shore. It is based on the principle that to properly manage and steward these crucial areas, we must first understand them better. Knowledge of coastal shore structure and function, and how the physical, biological and social elements of these dynamic transition zones are linked, is the basis of this document. Better stewardship demands better appreciation of this interconnectedness. While it will be obvious to most of us that developments in or on the foreshore will have environmental consequences, it may not be as obvious that they can also have economic consequences. It may also not be apparent that what we do in the backshore or upland will affect the coastline, often at great environmental, economic and social cost.



Canadian Wildlife Service

Estuarine marshes have tidal drainage channels that at low tide continue to hold water a few inches deep, providing food and shelter for fish fry and smolts as they gradually acclimate from freshwater to saltwater. Estuarine marshes are vital habitat for over-wintering waterbirds.

This is the most recent in a series of stewardship guides for planners and developers to focus on different ecosystem types. Coastal shores were chosen as the focus because of their extremely high value, sensitivity and the increasing conflict and competition for use of these areas. This document was also developed in response to demands for ready access to information on integrated planning approaches and best management practices for activities commonly undertaken in these areas

There is no static demarcation indicating a "shoreLINE" behind which certain things can be done, and beyond which they can't. Shores and their various components — backshores, foreshores, and nearshore marine areas — are interdependent dynamic systems, and are under considerable stress. The ecological complexity and value of these areas cannot be overstated. Neither can the natural ecosystem services these areas provide, such as temperature modification, waste assimilation, renewable and consumptive natural resource production. These areas can only continue to provide these basic ecological functions and values if we manage them sustainably.

The stewardship of coastal shores requires that we learn about the structure and function of shore systems and how their physical and biological elements are linked. We need to understand that what we do on shore can permanently affect the coastline. This guide covers marine shores; there are other resources for wise stewardship of lake and river shores.

Fisheries and Oceans Canada

Naturally formed barriers lessen the tremendous energy of storm force waves, protecting the habitat, resources and property behind them.

Why Should We Care About Shores?

Shores carry huge environmental, intrinsic and aesthetic values, but are under constant threat.

All of us are responsible for our shores, regardless of ownership and jurisdiction. Whether you are an individual landowner, developer, recreational boater, community planner, or politician, a share of the responsibility for protecting coastal systems is yours.

There are many reasons to care for our coastal shores.

Coastal Shore Values

Services and Resources: Fish, shellfish and marine plants supply us with food, medicinal ingredients and other useful commodities. Marine commercial and recreational activities support coastal economies through shipping and tourism. Healthy shore systems help moderate the effects of storms and cleanse and assimilate waste products. The sea sustains our lives.

Recreation: Fishing is one of the most popular recreational activities in British Columbia. Add in sea kayaking, surfing, sailing, swimming, playing on the beach, hiking, biking and bird watching and it becomes apparent how important coastal shores are to our recreational enjoyment. Who doesn't love going to the beach? Tourism, which is based substantially on our coastal recreation opportunities, is the second largest industry in the province.

However, recreation and tourism are focused on small bays, inlets and protected sandy beaches, a small percentage of the coast. By damaging or degrading these resources, we diminish our own opportunities for enjoying the coastal zone, and we limit the potential for future generations to do the same.

Property Values: Real estate prices are one way to reflect the value we place on shores. Whether for residential, commercial or industrial uses, the finite coast commands a premium. To protect this value, we must recognize that our actions can affect adjacent properties and even that of distant neighbours.

Aesthetic Values: Natural coastal landscapes have enormous aesthetic value. The public demands access to these areas through waterfront parks and walkways. The international film industry seeks out the unspoiled beauty of the B.C. coast. Our coastal economy recognizes this value through real estate prices, taxes and tourism - for example, the property or the hotel room with a sea view usually costs more.

Cultural Identity: Many coastal residents recognize their connection to coastal shores. Songs are written and stories are told about salmon, keeping time with the rising and falling tide, and west coast storms. The art of Emily Carr, E. J. Hughes or Roy Henry Vickers shows how this coastal heritage is valued by the people of British Columbia. Orca, eagles, bear and salmon symbolize the important aesthetic and spiritual connection to the coastal environment that is shared by First Nation and non-aboriginal peoples alike.

Oak Bay Marine Group

Our recreational use of the coast is focused primarily on protected bays and beaches. These areas are particularly sensitive to careless use or overuse.

Roy Henry Vickers

PINK SALMON, by Roy Henry Vickers is a representation of the salmon life cycle as it occurs in the creeks and rivers of the West Coast of British Columbia

Threats to our Coastal Shores

More People: The Georgia Basin has three times more people than 40 years ago – that number will double again in less than 20 years. More people means more demand for access to the coast, more pollution, more stress on wildlife habitat.

Public Health and Safety: Our activities which affect coastal shore processes and resources in turn affect public health and safety. These include beach or shellfish closures caused by elevated fecal coliforms, or health advisories related to chemical contaminants, or damage caused by erosion from severe winter storms.

Community Economics: The prosperity of coastal communities is tied directly to coastal processes and resources. An 80 percent decline in wild salmon catches since the peak season in 1987 has directly affected the economies and the social fabric of many coastal communities. Beach closures, poor water quality, and damaged shore protection structures contribute to higher costs and lower productivity for coastal communities.

Urban Shorelines: When natural shores are hardened with bulkheads, riprap, lockblock or other means, sediment movement changes along the shores and habitat is damaged or lost. Beaches can disappear, as can wildlife, plants and fish.

Cost: Ignorance of coastal processes can be expensive. Landowners spend thousands of dollars to install shore protection measures, only to find that they are "blown out" a few years later. Or worse, improper shore structures may trigger greater erosion, and thus a vicious cycle of competition between landowners and coastal forces. One has finite money and resources; the other a limitless supply of energy and time. When we choose to develop on the shore, we also are choosing a certain level of risk, and our insurance premiums reflect that. Nature always bats last.

Climate Change: Over the next century, climate change is expected to have a significant impact on B.C.'s coasts. We can expect winter storms to be more intense, with bigger waves and increased storm surges. These changes will lead inevitably to greater risk of flooding and erosion.

Ozone thinning has dramatic effects on all species with low tolerance to UV radiation. Higher UV radiation and increased temperatures affect photosynthesis and ultimately the aquatic food web. Global warming will melt the ice caps--changing sea level and salinity, along with atmospheric circulation patterns--thereby changing our climate. Warmer, drier winters and low precipitation in the fall could be disastrous for Pacific salmon, which need moderately high flows in the fall in local streams to spawn and sufficient cold water flow in winter to sustain incubating eggs.

The population of the Georgia Basin has risen steadily over the past 40 years, and is expected to double by 2023.

Maurice Jassak

image provided by seevancouverbc.com

Damage to poorly located waterfront property by natural processes can be extensive and expensive.

Mike Tarbotton

Revetments, like this lockblock wall, invariably fail by causing accelerated erosion at the base of the slope and/or behind the wall.

Mike Tarbotton

Examples of Why We Should Care

Biodiversity and Species at Risk

B.C. has the highest diversity of native wildlife in Canada, with about 5,250 species of plants, 1,138 species of vertebrates, an estimated 60,000 invertebrate species and 10,000 fungi species. It is a major migratory route and rearing area for many salmon and birds. The continued health of shores and nearshore habitat is a necessity in sustaining the biological diversity of the province.

But many of our species are at risk of serious decline or extinction.

- ***Three populations of resident and offshore Orca whales***- threatened; causes unknown, but concerns expressed over high contaminant levels in tissues and conflicts with boats and vessel traffic.
- ***Right Whale*** - endangered; causes include collisions with ships, entanglement in fishing gear, habitat degradation, noise, climate change and pollution.
- ***Sea Otter*** - threatened; historically extirpated by fur hunting; abundance and range increasing through re-introductions.
- ***Marbled Murrelet*** - threatened; loss of nesting habitat in old growth forest, breeding populations widely dispersed.
- ***Ancient Murrelet*** - a species of concern; limited to a few large colonies, threatened by introduced predators (raccoons) and potential oil spills.
- ***Great Blue Heron*** -considered "vulnerable" in BC. Georgia Basin population has declined 3-5% per year since the 1960s. Colony-sites are extremely vulnerable to human and natural factors. Many incidences of colony abandonment due to human disturbance, land development activities or Bald Eagle disturbance and predation have been documented. Loss and degradation of foraging habitats in coastal areas are also a significant threat to herons.

The *B.C. Species and Ecosystems at Risk website,* located under the Ministry of Land, Water and Air Protection, provides more information and many links to other sources for details about species at risk in B.C.

A federal *Species At Risk Act* (SARA) has been in the making for almost 10 years and was passed in December 2002. For more information about SARA, check the *Government of Canada's Legislative Summaries* or *Environment Canada's site.*


Animal Wellness Magazine

Right Whale


Jane Watson

Sea Otter


Illustration Alexe Lohvinen

Marbled Murrelet


Canadian Wildlife Service

Great Blue Heron

Shellfish Closures

Shellfish closures are good indicators of the bacteriological health of the marine environment. Pollution from urban runoff, sewage discharge, agricultural drainage and other sources can easily contaminate shellfish areas.

The coast of British Columbia yields an abundance of filter-feeding bivalve molluscs such as clams, mussels and oysters. In 1998 alone, the harvest of wild and cultured bivalves was worth over $40 million to the B.C. economy. The opportunity to harvest continues to be lost in many areas of the coast, largely because of increasing fecal and chemical contamination. These closures, which have doubled in the last 25 years, are caused largely by E. coli or dangerous levels of toxins.

Alexe Lohvinen

Loss of Coastal Wetlands

Coastal wetlands and estuaries are among the richest biological areas in the world, supporting a wide range of marine and coastal fish, wildlife and plants. Additionally, wetlands can filter urban, industrial, and agricultural runoff and buffer adjacent land uses. They also can store and convey floodwaters, buffer storm impacts to foreshore structures and infrastructure, cycle carbon and provide the base of the marine aquatic foodweb. The value of the natural services, biological productivity and infrastructure investments attributable to the B.C. coastal wetlands would be in the billions of dollars annually.

Some estimates suggest that we have already lost more than 18 percent of our coastal wetlands. In some of our biggest estuaries the numbers are much worse: 54 percent lost in the Nanaimo Estuary, 53 percent lost in the Cowichan Estuary, 93 percent lost in Burrard Inlet. In the Fraser River Estuary, one of the most developed but most biologically important areas of the coast, 82 percent of the historic salt marsh habitat has been lost.

The major estuaries of the B.C. coast have played a significant role in the economic and cultural development of coastal communities.

Georgia Basin Ecosystem Initiative Environment Canada

Coastal Shore Systems

The Work of Physical Forces

Many physical forces shape the coast we see today. Some of these forces, such as continental drift, glaciation, climate and changes in sea level act over billions of years and cannot be observed directly. Others, such as wind, waves, and tides, can be seen at work whenever we visit the beach.

In geological terms, our coasts are transient. 15,000 years ago the Fraser River Delta did not exist; most of British Columbia was covered by ice almost to the peaks of the highest mountains, and sea levels were more than 100 m lower than today.

This section offers some basic information about the most important physical processes that shape the coast, including waves, currents, tides, and sediment movements.

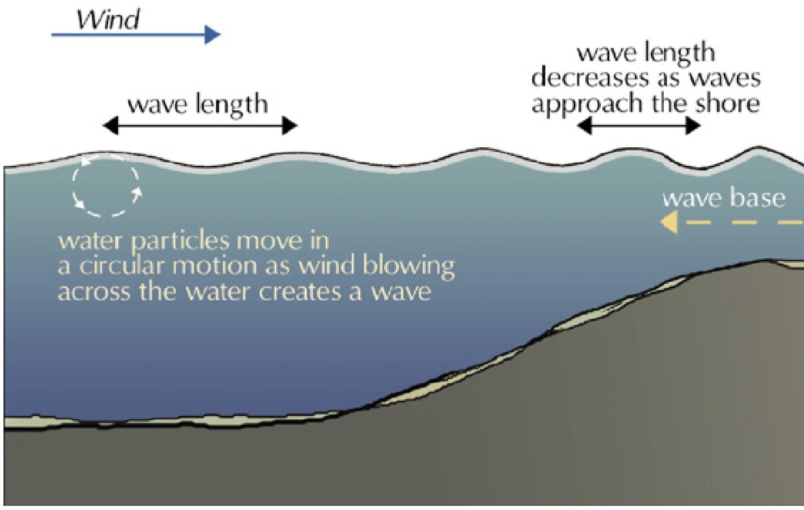
Coastal Processes

Three natural processes shape the physical characteristics of shores.

- *Waves* – Wind waves are the primary force in the coastal zone, creating most of the erosion, sediment transport and deposition that form beaches, sand spits, and other coastal shore features.
- *Sediment Movements* – Sediment, where it is available on the coastal shore, is constantly moving with the waves and currents towards, away from, and along the coast.
- *Water Levels* – Water levels on the coast vary according to the twice-daily tides, surges caused by storms, and, over longer periods of time, changes in western North American sea levels, due to climate change or other global events.

The people who live on Savary Island are acutely aware of the relationship between coastal processes and their own health, safety and economic well being. Formed only 10,000 years ago, Savary Island is an unconsolidated sand deposit that has been gradually decreasing in size as a result of coastal erosion.

Harriet Rueggeberg



Waves

Waves are the primary energy source that shapes coastal shores. The force exerted by waves is a function of the wave size, which in turn is a product of the velocity of the wind, the distance over which the wind blows (fetch) and the length of time the wind blows (duration). For this reason wave size, and therefore wave energy, varies widely along the B.C. coast, from sheltered environments such as Sidney Spit Provincial Park in the Strait of Georgia, to the exposed Pacific coast of Long Beach/Pacific Rim National Park or the west coast of Haida Gwaii. In spite of these differences, the physical processes that shape the shore are actually quite similar.

Andre Lemieux

Tsunamis

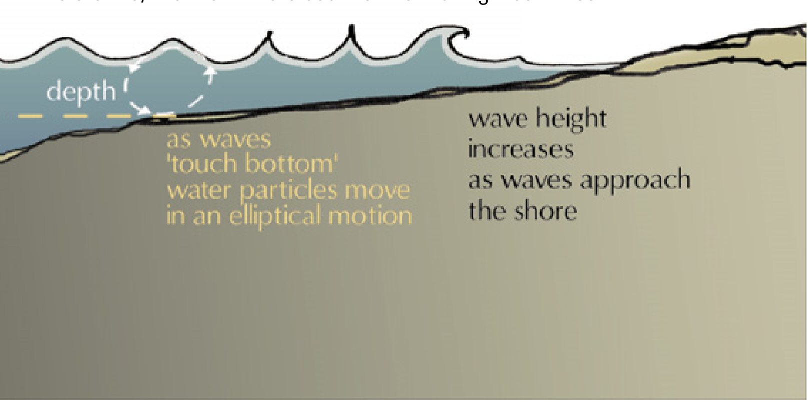
Tsunami is a Japanese word for "giant wave." Tsunamis are waves generated either by underwater earthquakes or landslides.

The largest tsunami to hit the British Columbia coast was the result of an earthquake centred about 100 km east of Anchorage, Alaska on March 27, 1964. The resulting tsunami took about four hours to reach the west coast of B.C. While in the deep ocean, this wave probably never exceeded 1 m in height, but as it reached shallow water it shoaled. At Port Alberni at the head of Alberni Inlet, the wave reached a height of 7 m and caused $10 million damage.

The 1975 Kitimat landslide resulted in an initial fall in sea level of 4.6 m followed by a rise of 7.6 m in a matter of minutes.

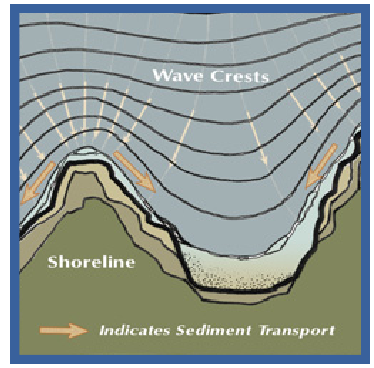
Wave Base Depth

The point where the wave first touches bottom is called the "wave base depth". If there is sediment available in this area then the waves chum up the sediment making it available for currents to move the sediment along the coast. Wave base depth increases with wave height (roughly 1 to 2 times wave height) and since wave height varies with different wave events, such as storms, the area where sediment is moving also varies.



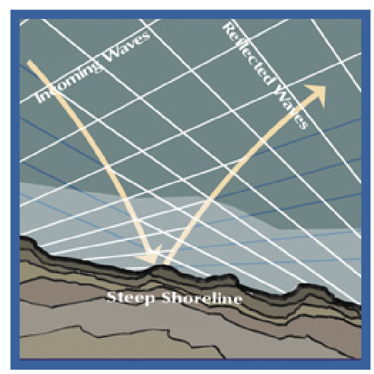
Three other important physical processes result from waves entering shallow water:

Refraction — is the bending of waves as they approach the shore. As waves enter shallow water and touch bottom, wave velocity decreases. If a wave approaches the shore at an angle, it refracts or bends as the inner end of the wave slows down sooner than the outer end. For this reason, waves usually hit a beach almost parallel to the shoreline even though they may have approached the coast at a sharp angle.

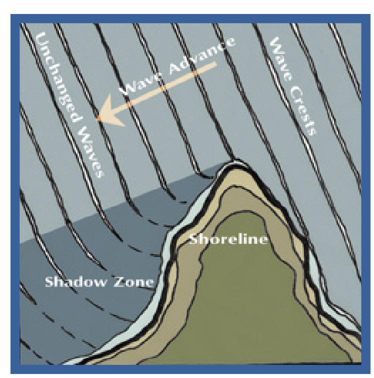


The result of refraction is that wave energy becomes concentrated at headlands and the seaward side of islands, and is diffused in embayments and the leeward side of islands. The net result is erosion where the energy is concentrated and sediment deposition where energy is diffused. For example, at Sidney Island, the predominant wind and wave directions are from the south and southeast. The large spits and intertidal lagoons that have developed on the north side of Sidney Island protect important habitats from the powerful energy of wind and waves.

Reflection — is the echoing of waves off a solid object. When a wave hits a steeply sloping bank, cliff or seawall, the wave energy is reflected back rather than being dissipated on the shore. Reflected waves can be as high as the incoming wave itself. The two waves interact and combine with each other, producing even larger waves. The bigger waves then create strong bottom currents close to the shore, creating increased seabed erosion close to these reflecting "structures." It is for this reason that seawalls often fail and fall over as the seabed in front is eroded away.



Diffraction — is the diffusion or spreading of waves in the lee of an island or headland. Although offshore islands or headlands may protect a stretch of coast from direct wave energy, the waves will penetrate into the "shadow zone" behind a barrier.



Water Levels

A tidal "wave" is a bulge in the ocean level caused by lunar and solar gravitational forces. There are two high tides and two low tides each lunar day (24hr 50min.). This cycle means hydrographers can predict tidal water levels many years into the future. They even estimated the tides (accurate to the minute) during Captain Vancouver's voyage to these coasts in 1792. This tidal rhythm affected the way that coastal areas were used long before Captain Vancouver's visit and is recorded in the following Tlingit (Tsimshian) legend:

Txamsem took his raven blanket and flew over the ocean with the firebrand in his hands. He arrived at the mainland and came to another house which belonged to a very old woman, who held the tide-line in her hand. At that time the tide was always high, and did not turn for several days, until the new moon came, and all the people were anxious for clams and other sea food.

Giant entered and found the old woman holding the tide-line in her hand. He sat down and said, "Oh, I have had all of the clams I need!" The old woman said "How is that possible? How can that be? What are you talking about, Giant?" "Yes, I have had clams enough."

The old woman said, "No this is not true." Giant pushed her out so that she fell back, and he threw dust into her eyes. Then she let the tide-line go, so that the tide ran out very low, and all of the clams and shellfish were on the beach.


Mike Tarbotton

So Giant carried up as much as he could. The tide was still low where he re-entered. The old woman said, "Giant, come and heal my eyes! I am blind from the dust." Giant said, "Will you promise to slacken the tide-line twice a day?" She agreed, and Giant cured her eyes. Therefore the tide turns twice every day, going up and down. (From Boas, 1916)

Tidal Facts

- The vertical distance between high and low tide in the open ocean is small, typically about 10 cm. However, as the tidal wave approaches the coast, it is reflected and amplified in the inlets and channels. In the Strait of Georgia, the tidal range increases as you move from Victoria (range 3.3 m) to Vancouver (range 5.1 m) and beyond to Toba Inlet (5.5 m).


Fisheries and Oceans Canada

- Tide height is measured from datum, which Canadian hydrographers define as the lowest normal tide.
- On a monthly cycle, the highest and lowest tides occur during full and new moons (spring tides)
- The lowest and highest tides of the year occur in December and June.
- In the winter, low tides occur mostly at night. In summer, low tides occur mostly during daylight hours. This is important to know for planning shoreline construction activities.
- In B.C., some of the most dramatic storm impacts occur during a combination of winter high tides and storm surges. Big waves can cause far more problems when they hit shore on an extreme high tide as compared to a low tide.
- Tides have a significant influence on the physical characteristics of coastal shores, moving heavy logs and debris, and sorting sediments throughout the tidal range.

Storm Surges

Storm surges occur when the wind and pressure generated by a storm act on a large body of shallow, coastal water. Surges can move rapidly with the storm system, and can be extremely destructive. In our local waters, storm surges are important factors in coastal flooding and shoreline erosion. When combined with spring tides and storm waves, they can have a major impact on our coast. Maximum storm surges in the Strait of Georgia are about 1 m high.

Serious storm surges occur in B.C. roughly every decade or two, but their effect can be dramatic. It is important to account for this 1 m sea level rise from storm surges when designing shore structures.

Rising Water Levels

There is some indication that climate change is causing sea levels to slowly rise. Over the long term, this will cause increased shore erosion as the coast continually adjusts to the new water levels.

Sediment Transport

Determining the sediment mass balance (the amount of sediment being added or taken from a beach) is a challenging technical problem. It is a function of both the availability of sediment as well as the force of energy to transport it. Currents and waves can move vast amounts of sediment along the coast. Interruptions to the system, such as cutting off a sediment source, can have profound effects. For example, the damming of many rivers on the western U.S. coast, which are primary sources of sediment, has caused the gradual loss of beaches along the coast. Similarly, very large storm events can cause the loss of an entire beach, as happened in Carmel, California in December 2002.


Joy Hillier

Longshore Drift

Two forces combine to create a movement of sediment parallel to the coast. The first is that most waves approach the shore at an angle, and although refraction bends the waves into a more direct approach, it can not bend them enough to make them break completely perpendicular to the beach. The second is a longshore current of water that moves parallel to the shoreline in the direction of wave movement. As sediment is churned up by the waves entering the shallow water, the longshore current transports it downshore where it settles, before being churned up and transported again. Longshore drift cells typically include a sediment source, a transport zone and a sediment deposition zone. These cells repeat along the coast, sometimes with smaller cells nesting into larger cells, and can be identified in a variety of ways:

- Interpretation of existing features. Typical sediment sources are rivers and eroding bluffs, and typical sediment deposition sites are protected bays and spits. The direction of a spit is an accurate determination of the net sediment movement. Interpreting erosion sources and deposition features may require specialized knowledge of coastal processes and a combination of map interpretation and field observations.
- Survey measurements. This process is the only way to obtain quantifiable information about the rates of erosion or accretion. Detailed surveys of a variety of locations are available through the *Geological Survey of Canada.*
- Review of archival aerial photos. Where available, archival aerial photos can help to identify changes in coastal morphology, nearshore elevation and other products of ongoing coastal sediment transport processes.

Cross Shore Transport

Another type of current on the coast is a cross shore current. Although longshore transport is more influential over the long term, cross shore transport is a more immediate process. Cross shore transport is usually the result of the winter/summer storm cycle wherein sediment is removed seaward during the winter and then slowly replaced over the summer.

What Direction is Sediment Moving?

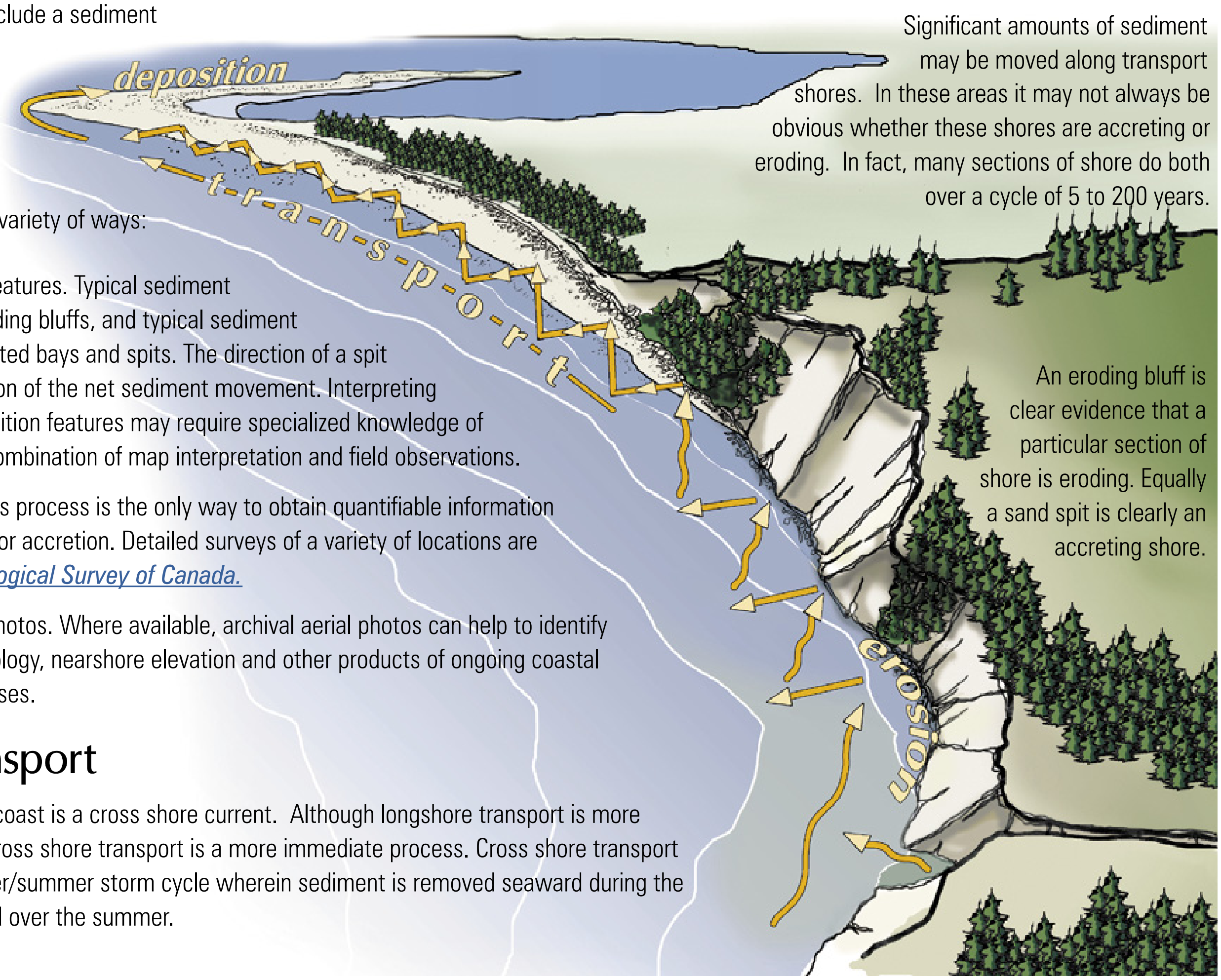
On most shorelines, wave and current direction change with the seasons and with storms. For this reason the same sediment may be transported past one point in the shore several times during the course of a year. However, the direction of net sediment transport (the balance of sediment moved one way versus another) is determined by the predominant wind direction. For example, in the Strait of Georgia the predominant winds (i.e. the ones with the most energy to move sediment) are the winter winds and storms from the south and south-east.

How Much Sediment is Moving?

The amount of sediment being moved is determined by its availability, the size of the material (for example, sand is more readily moved than gravel) and the size, or energy, of the waves and currents that reach the shore.

Erosion, Transport or Deposition?

Understanding sediment transport is essential for good coastal planning and stewardship. Ecologically wise decisions depend on information about the net direction of sediment movement, how much sediment is available, and whether the shoreline is accreting (building seaward), eroding (retreating landward), or more or less static. It is important to realize that even though an accreting shoreline, such as a sand spit, has a net gain of sediment it is also constantly losing sediment and will shift somewhat over time.



Significant amounts of sediment may be moved along transport shores. In these areas it may not always be obvious whether these shores are accreting or eroding. In fact, many sections of shore do both over a cycle of 5 to 200 years.

An eroding bluff is clear evidence that a particular section of shore is eroding. Equally a sand spit is clearly an accreting shore.

Energy and Sediment Dynamics

This table describes nine shore types based on the relative amount of energy they receive, which is based on the exposure to the dominant wind, and whether or not they are an eroding, transport, or accreting shoreline within their longshore drift cell. Although a high energy system in the Strait of Georgia is not comparable to a high energy system on the West Coast nevertheless they share many similarities. The table is adapted from the *Framework Plan for Coastal Zone Management* prepared for the Regional District of Comox-Strathcona.

Eroding Shores

Signs of an eroding shore include the presence of steep banks or bluffs; lack of vegetation (trees and shrubs are unable to get established) or tipped trees with exposed roots. The absence of a delta at a river mouth indicates the sediment is being "eroded" or removed at roughly the same rate that it is being delivered. A shore is most likely to erode where the underlying material is fine such as sand and gravel. An eroding shore may be on a steady landward march or may be more or less static for long periods of time, followed by a period of erosion.

Mike Tarbotton

High Energy

High energy shores are those that are exposed to the full force of predominant winds (i.e. those winds that dictate the direction of longshore transport) with a considerable fetch. In the Strait of Georgia a high energy shoreline is one that is perpendicular to and exposed to the predominant winter winds and storms from the south-east. The west coast of Vancouver Island and Haida Gwaii have high energy shorelines exposed to the western winter storms.

The volume of sediment movement along these shores can be very high, and they tend to have large beaches. Wind erosion can be considerable and as a result there may be a well established dune backshore on these shorelines, perched sand dunes on top of cliffs, and/or trees that are stunted or have a windswept profile.

Mike Tarbotton

In a high energy system, an eroding shoreline is very unstable and is characterized by the following:

- Provides huge volumes of sediment to the longshore system and the sediment is removed from the shore very quickly.
- May have sections of exposed soil where vegetation has been unable to become established.
- Vegetation is lost as roots are exposed and undercutting removes soil.
- Severe storms can cause dramatic erosion.

As a result, development in a high energy erosion shore should be avoided or located well back from the shore, existing native vegetation should be maintained to minimize the speed of erosion, and shore protection devices should be avoided as they are likely to quickly fail.

Medium Energy

Medium energy shores are those that are at an angle to, or parallel to, the predominant winds, where the force of the waves is reduced, or where the fetch is shorter. These shores may also be exposed to predominant summer winds. Although these do not have as much energy as the winter winds they may provide some balance to net sediment transport.

The volume of sediment movement along these shores can still be considerable but is less than a high energy shoreline.

Mike Tarbotton

In a medium energy system, an eroding shoreline is moderately stable. Sediment is introduced from streams and rivers and to a lesser degree from eroding shorelines. In general a medium energy eroding shore typically:

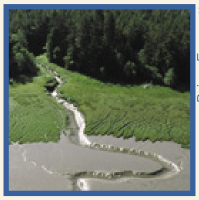
- Provides moderate amounts of sediment to the longshore system.
- Has pronounced river deltas but may be under water during high tide and is constantly shifting.
- Is mostly vegetated, which is effective in slowing the rate of erosion.

As a result, development should be located far enough back to accommodate natural erosion. Existing native vegetation should be maintained to ensure ongoing stability of slopes, and shoreline protection devices should be discouraged.

Low Energy

Low energy shores are those that are protected from the predominant winds; for example, shores that are in deep bays or inlets, or are protected by islands or headlands. These shores tend to be fairly stable as they are not subject to the erosive forces of wind-generated waves.

The volume of sediment movement along these shores is fairly low. Where sediment is available, these shores tend to accumulate sediment. Because they are sheltered, they tend to have high biological productivity and are also more susceptible to pollutants.



Brian Emmett

In a low energy system an eroding shore is stable with sediment introduced primarily from streams and rivers. In general a low energy eroding shore is characterized by the following:

- Provides little sediment to the longshore system.
- Shows signs of stability such as vegetated deltas.
- Has well established vegetation at the backshore.

As a result, development in a low energy erosion shore should be located far enough from the shore to protect against septic pollution, and existing native vegetation should be maintained to minimize any erosion.

Transport Shores

Transport shores occur between areas of erosion and sediment deposition. These sections of the coast are relatively stable, although they may alternately show signs of erosion and deposition over time. Large quantities of sediment may be moving past these shores so any blocking of this sediment movement can have significant impact on downshore shorelines many kilometres away.

Regional District of Comox Strathcona

In a high energy system, a transport shoreline is relatively stable although considerable "wobble," from periods of erosion and then deposition, may take place over time. In general. a high energy transport beach is characterized by the following:

- Huge volumes of sediment move past the shore.
- Shore structures that interfere with sediment movement will have significant impacts, including severe scouring and deposition, and the loss of downshore beaches.
- Severe storms may exaggerate the cyclical erosion and deposition of transport shores.

As a result, development in a high energy transport beach should be located far enough back from the shore to accommodate the natural shore "wobble." Existing vegetation should be maintained to prevent the shore switching to an unstable condition, and groynes should be prohibited.

In a medium energy system a transport shoreline is moderately stable but some "wobble," from periods of erosion and then deposition, may take place over time. In general a medium energy transport beach is characterized by the following:

- Large volumes of sediment move along the shore.
- Activities, shore protection devices or groynes that interfere with the movement of sediment will have significant impacts on the shore

As a result development in a medium energy transport beach should be located far enough back from the shore to accommodate the natural shore "wobble." Existing vegetation should be maintained to prevent shoreline instability and groynes should be prohibited.

In a low energy system, a transport shoreline is quite stable although localized erosion or deposition is possible. In general, a low energy transport beach is characterized by the following:

- Low volumes of sediment move along the shore.
- Tends to be highly productive aquatic habitat.

As a result, development in a low energy transport beach should be located far enough back from the shore to protect against contamination from septic fields and runoff, and existing vegetation should be maintained to protect the shore from localized erosion.

Depositional Shores

These shores are usually caused by the deposition of sediment as a result of decreased wave energy, increased sediment supply, and/or decreased water depth. They are characterized by low relief with features such as sand beaches, deltas, spits, sand dunes and beach ridges and are located typically in embayments and in the lee of islands or headlands. A large, steady supply of sediment is needed to create and maintain these features and an interruption to either can result in their loss. Depositional shores are prone to rapid changes in shape and volume.

Regional District of Comox Strathcona

In a high energy system, a depositional shore is moderately stable but very dynamic. These beaches are highly valued recreation areas but scarce. In general, a high energy depositional shore is characterized by the following:

- Huge volumes of sediment accumulate in the form of spits and beaches.
- Beaches may include sand dunes in the backshore, which are an integral part of the shoreline and are highly susceptible to damage.

The scarcity, fragility and value of these shorelines means they should be protected for public access and recreation. Development should be located far enough back from the shore so that backshore dunes and beach ridges are kept intact.

In a medium energy system a depositional shore is moderately stable and dynamic. These shores are also highly prized and scarce. In general, a medium energy depositional shore is characterized by the following:

- Large volumes of sediment accumulate in the form of pocket beaches.
- Its beaches may include beach ridges in the backshore, which are an integral part of the shoreline.

The scarcity and value of these shorelines mean they should be protected for public access and recreation. Development should be located far enough back from the shore that backshore beach ridges are kept intact.

In a low energy system, a depositional shore has a stable backshore but the shoreline advances as sediment accumulates. They include estuaries and provide highly valuable habitat. In general, a low energy depositional shore is characterized by the following:

- Sediment is trapped with little sediment loss to longshore drift.
- Often forms features such as estuaries, mud flats and tidal marshes.
- Highly productive aquatic habitats.
- Very sensitive to contamination that accumulates in fine sediments.

As a result, a low energy depositional shore should be protected for its high habitat values. Development should be avoided and the shore should be protected from contamination from septic fields and runoff.

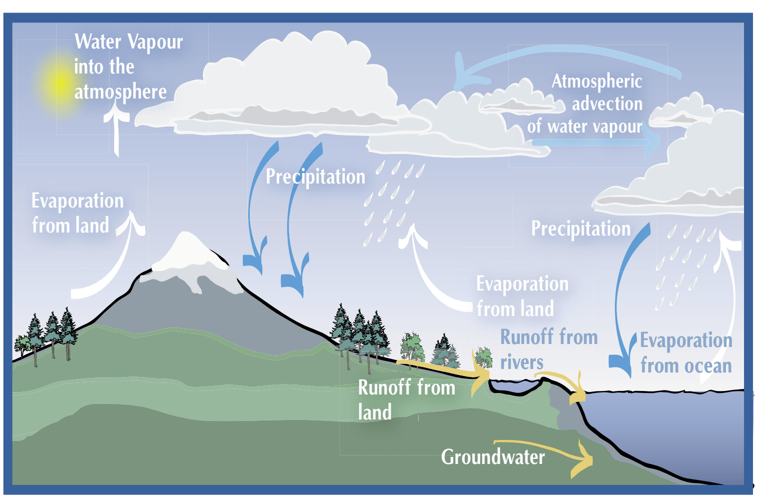
Water Quality

The waters of the deep Pacific Ocean control the water quality of much of B.C.'s northern and central coasts, including the west coast of Vancouver Island. The flushing of tides, winds, and ocean currents means that the rate of exchange of seawater on our exposed coasts is generally much higher than the exchange that occurs in our "inland sea."

Charlie Gibbs

Within the Strait of Georgia, the conditions are more varied. The water in the middle and upper Strait has limited exchange with the waters of the offshore Pacific. Within this "inland sea," pollution from the land and air can accumulate and have a significant impact on water quality. Smaller inlets, coves and bays within the Strait are even more likely to be affected by nutrients and toxins added by human activity.

In the natural process, energy from the sun evaporates water mainly from the sea into the atmosphere. Winds carry the water over the seas and land. If the atmosphere cools, the water returns as precipitation. Where the water falls on land, it travels downhill over the surface or as groundwater, and eventually reaches the sea. Over eons, the water travelling over or through land picks up soluble materials from minerals and biota on land and carries them to the sea.



Pollution from the Air

Rain or snow picks up toxics emitted into the air by human activity. Large quantities of pollutants in the atmosphere may change concentrations in these pollutants in coastal seawater.

Leaded gasoline, which was phased out in the late 1970s, is the major source of lead in the deeper water sediments of the Strait of Georgia. Most of this lead was deposited by atmospheric transport.

Pollution from the Land

In settled areas, chemicals and nutrients added by human activity also end up in the ocean:

- A pipeline leak in central British Columbia, for example, can deliver toxics into the Strait of Georgia through rivers and airborne pollution.
- An abandoned mine in Howe Sound pollutes a nearby stream -- but the stream flows to the ocean and the toxic materials accumulate in the nearshore sediment.
- Sediment runs off from sites disturbed by forestry, agriculture, road building, and land development. Sediment carried by rain into streams is eventually carried downstream. It adds minerals, organic material and sediment-borne pollutants to the seawater, which can change the chemistry of nearshore waters. The direct sediment discharges from riverine sources also shape and determine the function of coastal estuaries. In Haida Gwaii, up to 70 percent of sediment comes from stream channel erosion related to human activities.
- Chemicals and fertilizers from farming, if not applied correctly, can runoff farmland and end up in the sea.
- Poorly maintained septic systems can contribute nutrients, fecal coliforms and toxins to the nearshore environment.
- Stormwater runoff from urban areas, streets and highways can carry heavy metals and toxics that have significant impacts on water quality. The increase in impermeable surfaces such as driveways and roads makes it harder for the stormwater to infiltrate and be cleaned before it reaches our streams and rivers.

Pollution in the Water

- Oil spills, though infrequent, can have devastating local effects on specific coastal areas. The impact of spills can be particularly harmful for wildlife, and may linger for many years.
- Ocean dumping can lower water quality.
- Water based industries such as aquaculture and marine log storage can be a source of chronic pollution.

For more detailed information about pollutant sources and their control, refer to Chapter Five, entitled "Working with the Coastal Shore", pages 50 through 77 of this guide.

What Happens?

In larger estuaries, where freshwater input from rivers and streams is large compared with the natural exchange of seawater, significant pollution can occur. Small bays with restricted flushing are most sensitive to the effects of pollution from runoff and land uses.

Fisheries and Oceans Canada

Changes in water quality can affect nearshore biotic communities in a variety of ways:

- An increase or decrease in nutrient concentration will alter growth of aquatic plant communities and plankton.
- An increase in suspended sediments can shade out seagrasses. Lost seagrass can modify the transport of sediment along a shore and affect adjoining areas.

  Sediment runoff from upland development to nearshore areas can dislodge or bury attached organisms, smother vegetation, reduce light penetration and photosynthesis, eliminate food sources for filter feeding organisms or make it difficult for visual feeders to "see" their prey.
- In poorly flushed areas, excess nutrients can cause rapid algal growth which uses up most of the available oxygen in the water, causing distress to fish and other animals. The effects of nutrient excess can be seen in enclosed bays with storm discharge input. An example is Victoria Harbour, where the water occasionally turns bright green with plankton blooms as days lengthen in spring.
- Pollution, oil slicks and toxic blooms can affect our use and enjoyment of beaches and coastal areas.
- Toxic bacteria, viruses and protozoa can make fish and shellfish unfit for human consumption.
- High concentrations of toxic chemicals can reduce the ability of fish and shellfish to reproduce and maintain the natural species composition of the local ecosystem.

How Much is a Lot?

Because of the massive volumes of water involved in the ocean, water quality in coastal areas is slow to change. The Strait of Georgia alone contains about 1,000 km^3 of water. Despite this, comparatively small amounts of pollution from sewage or stormwater runoff can create localized problems for shellfish, waterfowl and other biota as well as people.

Our oceans form the largest ecosystems on earth but their capacity to assimilate waste is finite. Dilution is not the solution to pollution. Source control is clearly the best approach.

What Should We Expect in the Future?

The most severe changes in water quality will be in populated areas. The Georgia Basin, which is already home to 74 percent of British Columbia's population, is expected to reach 4 million people in less than 20 years.

As our population grows, the need to protect water quality means that we must:

- Address the impacts of urban sewage.
- Manage storm water runoff and non-point source pollution better.
- Control nutrient inputs into poorly flushed areas.
- Control waterborne and industrial sources of pollution.

Without extreme care, the Georgia Basin can expect an increase in water quality problems. As the population increases, the ability of the Basin to absorb and treat our wastes will be tested. This guide outlines planning and coastal development "best practices" that can help to reduce the pollution issues associated with increasing coastal settlement.

Scott Nickerson   Environment Canada

Killer whales - Sentinels of Marine Ecosystem Contamination

Killer whales are long lived and occupy a position at the top of marine food chains. They are therefore vulnerable to accumulating high concentrations of contaminants that are persistent, bioaccumulative and toxic (PBT compounds). Compounds of particular concern include the banned polychlorinated biphenyls (PCBs) and many organochlorine pesticides, as well as new chemicals with similar properties. These contaminants have been associated with immune system disorders, skeletal malformations, reproductive tract lesions, tumours, and altered endocrine function in marine mammals.

BC's killer whales are among the most chemically contaminated marine mammals in the world. These animals and their prey use large areas for habitat, so they are considered "integrators" of contaminant information in the environment – their bodies help monitor marine ecosystem health. Their levels of contamination also represent a combination of local and global sources of contaminants, since many PBT compounds move through the environment by atmospheric transport.

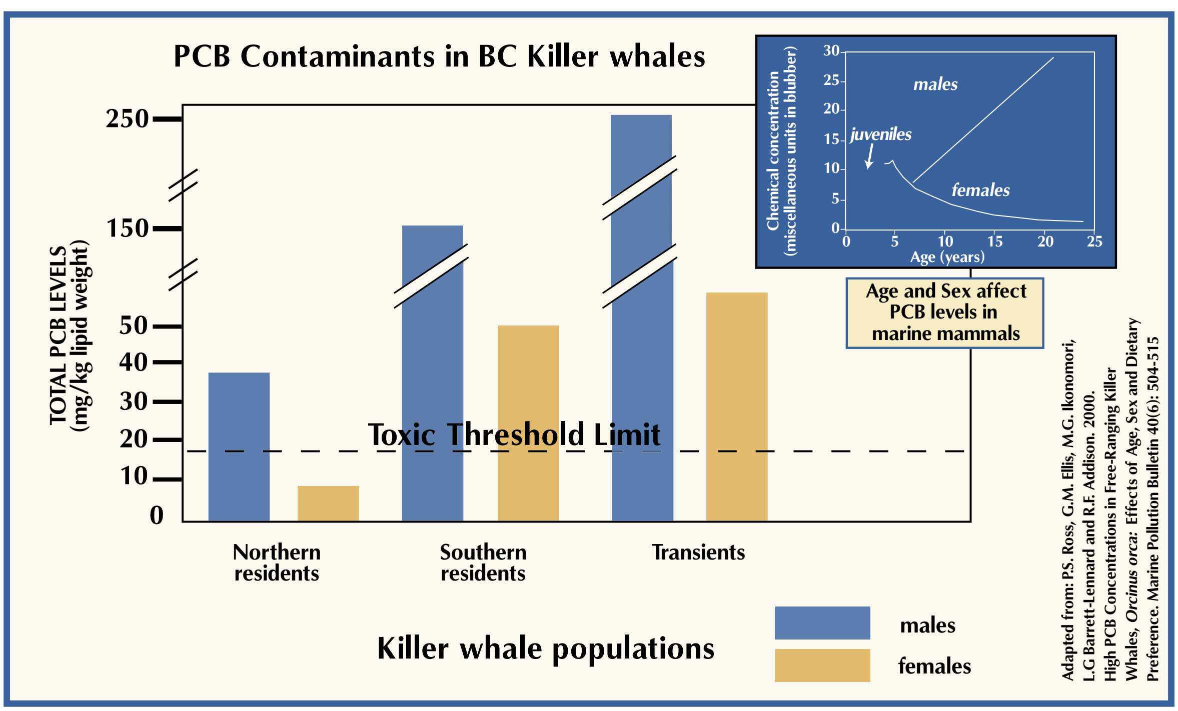
Studies have shown that dietary preference, sex and age of Killer whales affect the level of contaminants in their tissues (see graph). Resident populations eat primarily salmon, while transient populations feed almost exclusively on seals, sea lions and porpoises. These latter prey are at a higher trophic level and as such, accumulate contaminants more than fish.

Also, as males grow older, they become increasingly contaminated with a complex mixture of these fat soluble chemicals. Females, on the other hand, transfer a large portion of their contaminants to their offspring via nursing. Their young can therefore be exposed to high concentrations of harmful substances, at a time when they are most sensitive.

Graeme Ellis

Killer whales require an abundance of clean and healthy prey- primarily salmon or smaller marine mammals, many of which feed on salmon. In British Columbia, however, the persistence of banned contaminants, leakage from old contaminated sites, continued use of new or unregulated compounds, and atmospheric deposition of contaminants from distant sources all contribute to the contamination of the marine food chain.

Protecting salmon and salmon habitat represents a critical part of protecting resident killer whale populations. This requires citizen-based as well as local, regional and international efforts to reduce the release of harmful chemicals into aquatic environments, both freshwater and marine. Direct inputs as well as indirect runoff and deposition must be addressed in order for such efforts to be effective.



Adapted from: P.S. Ross, G.M. Ellis, M.G. Ikonomori, L.G Barrett-Lennard and R.F. Addison. 2000. High PCB Concentrations in Free-Ranging Killer Whales, *Orcinus orca*: Effects of Age, Sex and Dietary Preference. Marine Pollution Bulletin 40(6): 504-515

Aquatic Nuisance Species in British Columbia

Non-indigenous, non-native, exotic, or alien species are being transported regularly in aquatic environments around the world. Sometimes they become a nuisance in their new-found "host" environments by growing in explosive proportions or by transporting diseases for which there are few or no resistance factors. Non-indigenous species may aggressively compete with indigenous species for habitat, food, or simply prey on them or spread disease. Either way, they can cause serious biological and economic damage.

Aquatic nuisance species are of concern in British Columbia, not only because of the extent of the province's marine coastline, but also because of the large network of freshwater lakes and rivers which support commercially important species and recreational activities.

There are numerous pathways by which non-indigenous species can be introduced into BC coastal systems. These include ballast water, the pet and aquarium trade, live seafood, aquaculture, and transportation of pleasure boats from infested areas such as the Great Lakes.

There is limited documentation of the status of non-indigenous nuisance populations in the province. European Green Crab (Carcinus maenas), Zebra Mussels (Dreissena polymorpha), Eurasian Water Milfoil (Myriophyllum spicatum), Purple Loosestrife (Lythrum salicaria), Common Carp (Cyprinus carpio), Spartina (Spartina alterniflora), and Atlantic Salmon (Salmo salar) are among the nuisance species that have been observed in BC. There are many others that have the potential to reach BC waters including Chinese Mitten Crab (Eriocheir sinensis) and New Zealand Mudsnail (Potamopyrgus antipodarum).

Although some species have not arrived in large numbers, the potential for harm should be understood. It is important to learn about species like these that may threaten existing native plant and animal populations in BC.

Learning to recognize such species is aided through pictures and descriptions and is an significant step to controlling their spread. If you suspect a species to be non-indigenous, collect it in a plastic bag and freeze it, recording all information on the habitat you found it in and contact your nearest Fisheries and Oceans or Ministry of Water, Land and Air Protection office for further information. Biology departments of universities should also be able to help with identification.

It is important to not transport live species from one coastal area or waterway to another. Remove any aquatic weeds or animals from your boat, recreational gear and drain the water from your boat before moving to a new area. Be aware of laws that regulate the transport of non-indigenous species. Remember that it is usually impossible to eradicate an established non-indigenous species. Preventing their introduction is the key.

Zebra mussels, an invader from Europe, arrived on the West Coast after infesting the Great Lakes. The prolific, tightly growing colonies are a detriment to marine life as they cement themselves to living creatures, weighing them down so that they can no longer move. They also colonize man-made objects such as water intakes, completely clogging up the pipes.

The European Green Crab is an efficient predator. It feeds on clams and oysters as well as juvenile crabs and other shellfish. It poses a menace to the aquaculture industry and native wildlife by competing for limited food supplies.

Spartina alterniflora, Smooth Cord Grass, is native to the Atlantic Coast, colonizing tidal marshes. It is considered non-native and invasive on the Pacific Coast .

The Connection between Physical Processes, Habitat and Species

British Columbia's coast supports a great variety of marine plants, invertebrates ,fish, migratory birds and marine mammals. It is one of the richest and most diverse temperate environments in the world.

This is no accident. British Columbia's coastal habitats - ranging from lush kelp forests to mudflats and salt marshes in quiet bays - provide the physical diversity that supports abundant biological communities.

These biological communities are created and influenced by combinations of physical, chemical and biological factors. The major physical factors, which include slope gradients, substrate size, wave exposure, salinity, temperature and tidal elevation, are illustrated on the following page.

Biological interactions, such as predation and competition for food and space, also influence the composition and distribution of nearshore plants and animals. For example:

- The lower limit of mussels in the intertidal zone is usually controlled by sea star predation, while the upper limit of barnacles is determined by their tolerance to heat and exposure.
- Rooted vegetation (eelgrass and marshplants) helps to stabilize sand and mud substrates and provides cover and attachment surfaces for a diverse fish and invertebrate community.
- Sea Otters, which are a threatened species, can have drastic effects on sea star populations by competing for sea urchins, a food source favoured by both.

Plants and animals can also influence the physical characteristics of a shore environment. For example:

- Large fringing kelp beds on exposed coasts dampen the influence of wave energy.
- Worms and other organisms in mudflats process large amounts of substrate, altering sediment chemistry and organic content. These organisms can also secrete mucus-like material, which helps bind and stabilize finer substrates, making them less susceptible to erosion.
- The root systems of dune grass species serve to bind and stabilize backshore areas against the erosive power of both wind and waves.

Will Megill

D. Kent

Charlie Gibbs

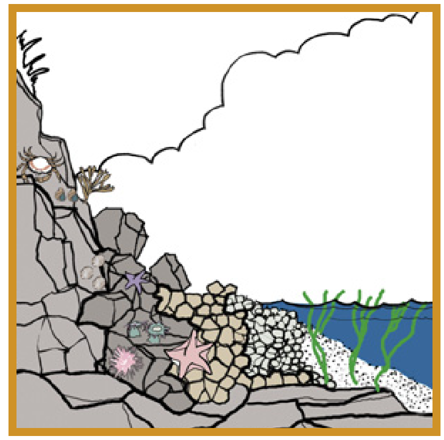
The British Columbia coast is home to the world's largest octopus, the biggest barnacle, the heaviest starfish and one of the largest coastal concentrations of killer whales.

Major Physical Factors

Foreshore slope, substrate size, wave exposure, salinity and tidal elevation can influence the composition of biological communities throughout the intertidal and nearshore zone, in measurable ways.

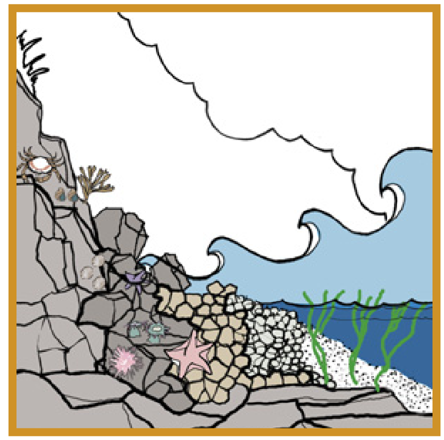
On the British Columbia coast, the effects of these physical factors are apparent. The larger rivers and abundant winter rainfall generate considerable salinity gradients in many nearshore areas. In the Strait of Georgia, low energy sediment shores (gravel, sand, mud) are common while rock and mixed rock and sediment shores dominate the outer coasts. Island archipelagos, fjords and inland seas such as the Strait of Georgia provide a wide range of wave exposures.

Substrate



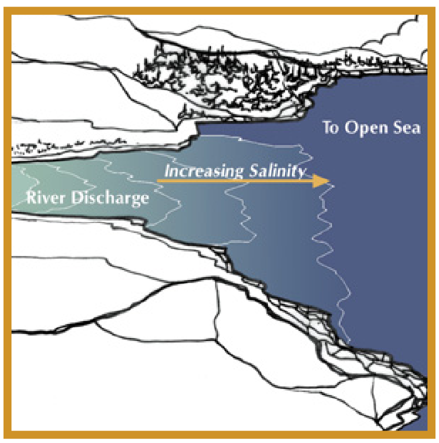
Bedrock and large rocks support the growth of attached algae and invertebrates. Sand and finer substrates do not provide suitable attachment habitats for these types of organisms. Worms, bivalves and other invertebrates dominate habitats of mud and sand. Rooted plants and single celled plants grow as a mat on the surface of this sandy substrate. This environment provides habitat for many sessile and some mobile invertebrates as well as a carbon source to fuel the nearshore aquatic food web.

Wave Exposure



The characteristics of different shore types also influence biological communities above the high tide line. On exposed shorelines, such as Long Beach on the west coast of Vancouver Island, a fringe of stunted trees and shrubs grows immediately above the driftwood logs, marking the upper limit of storm waves. This fringe of vegetation is adapted to high winds and salt spray and shelters larger trees located further inland. In contrast, in protected coastal fjords, the coastal forest grows right to the high water mark.

On exposed shores, plants and animals usually attach themselves firmly to bedrock or boulders, or adapt to survive in rapidly shifting, smaller substrates (cobbles, pebbles and sand). On more sheltered shores, smaller cobbles and pebbles are not often moved and smaller organisms are not dislocated by wave action. The plants and animals that attach to these smaller substrates can thrive.

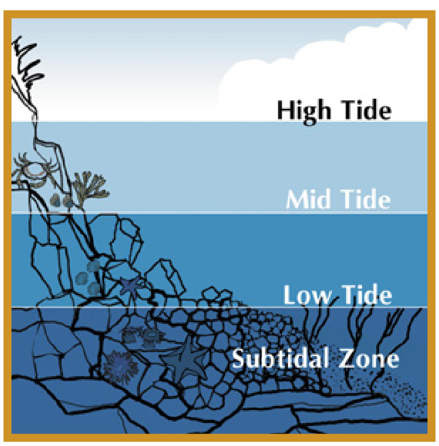


Salinity and Temperature

Plants and animals growing in river estuaries adapt to low and rapidly changing salinity levels. For example, the giant kelp does not grow in the Strait of Georgia because it cannot tolerate the summertime combination of low salinity and warmer waters.

Estuarine marsh and shrub distribution is related directly to salinity levels and patterns of seasonal flooding. This coastal fringe vegetation provides unique habitat for many birds and mammals, stabilizes the soil, and helps prevent movement of sediment-bound contaminants into the marine environment. Dunes and dune grasses function in a similar manner on exposed beaches.

The fate of Pacific salmon depends on brackish estuaries, since the fish must make the transition in them from freshwater to saltwater and back again, in order to reproduce.



Tidal Elevation

The range of tides influences the vertical distribution of plants and animals in the intertidal and shallow subtidal zones. Upper limits of many species are often determined by tolerance to air or wave exposure. Lower limits are highly influenced by competition and predation between plants and animals inhabiting these areas.

The diversity and survival of British Columbia's coastal species depend on the continued, healthy ecological function of coastal habitats and the nearshore processes that create and sustain them:

- Estuaries are key feeding habitats for black and grizzly bears as well as for eagles and migrating birds.
- Coastal bays and estuaries are important overwintering areas for ducks, geese and swans.
- Beaches, estuaries and mudflats are vital feeding areas for shorebirds during spring and fall migrations and over the winter.
- Each spring, herring spawn on nearshore marine plants such as kelp and eelgrass. The adhesive eggs sticking to the plants are washed with well-oxygenated water as the plants move back and forth with wave action and tides. This abundant source of protein attracts thousands of migrating birds.

Impacts to These Connections

Coastal managers often say "No people, no problem." Human activities can alter the connections between species and habitat, disrupting ecological function. This can happen very quickly - overnight in some cases - or take a long time.

- A new seawall built above a sandy beach increases wave action that erodes the existing beach. This affects the beach spawning habitat of sandlance or smelt, which in turn are food sources for many larger fish, including salmon.
- Walking a dog or jogging on a beach can disturb birds from their normal routines. This can be most harmful during spring migration when waterbirds need to build up fat reserves for the long journey north. Birds that are constantly disturbed may abandon an important feeding area and move to less productive habitat. This could affect their long term survival.
- Installing a retaining wall or groyne perpendicular to the shore can disrupt longshore sediment movement, which affect shoreline and habitat characteristics several kilometres away.
- Clearing backshore for new coastal developments can remove marine riparian vegetation - grasses, sedges, shrubs and trees found at or near HHW. This can eliminate: food sources (insects) for juvenile salmon; temperature regulation for intertidal species; absorption of wave energy; and provision of foreshore diversity and structure that provides microhabitats for many species. Removing upland vegetation also destroys perching habitat for birds such as kingfishers and eagles.
- Clearing backshore can also de-stabilize upland sediments, causing erosion. Adding sediment to nearshore areas by erosion can change the elevation and seaward profile of the area, making it more subject to wave erosion. Erosion can also necessitate dredging and more disruptive activities to maintain navigation channels.

Cumulative Impacts

A cumulative impact occurs when one change to the environment is added to other past, present and foreseeable future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

The shorelines in the populated regions of B.C. are subject to an ever-increasing number of small-scale developments and human-induced changes. The clearing of a single waterfront property may have little effect on surface rainwater runoff from a coastal bluff to the sea. A groyne may disrupt a very small amount of longshore sediment movement. A seawall hardens and straightens only a small portion of the shore.

But, over time, these small insignificant impacts, when combined with each other and those of other shoreline users, can become a large impact. Couple this with the fact that we tend to repeat these insults all along the coast and the scale of the problem becomes apparent. The cumulative impacts are synergistic and become very significant.

Changes to coastal systems caused by human activity stress natural systems. While some changes may not be significant, and coastal systems, being complex, are somewhat resilient, the consequences of other stressors can be catastrophic . The cumulative effect of too many stressors such as our coasts are experiencing today may simply be too great for the natural systems to adapt or respond to. Chronic chemical pollution from stormwater runoff, for example, or continuous erosion from backshore clearing and grubbing or slope failures can easily overstress natural systems and cause a chain reaction of unintended consequences.

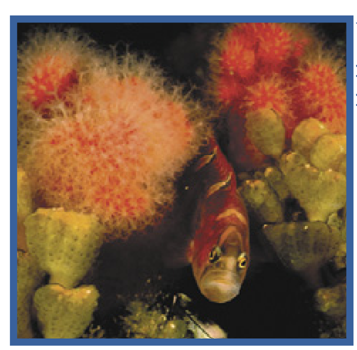
It is important to understand that cumulative effects are not inevitable. Ten properly sited and designed docks may have less impact than a single, poorly designed one. We can minimize cumulative impacts when we better understand the physical and biological processes described in the previous pages. Siting a structure or adopting best design standards and management practices are intended to mitigate the impacts these structures can have on such things as longshore drift, erosion or shading.

Because the number of people living and working along the shore is increasing so rapidly, ***we need to get it right.***

Marine Sensitive Areas

The concept of marine sensitive areas is a way of focusing action on the most important, unique, sensitive or representative marine areas for protection from impacts. These areas are sensitive because of the nature of the processes that occur in them and/or the unique or fragile habitats and species that they support. Typical areas are shown in the accompanying photographs.

Some marine sensitive areas are found in national or provincial parks or wildlife areas, but their particular marine features have received little attention - until recently. The governments of B.C. and Canada along with non-governmental organizations are taking a variety of steps to protect marine sensitive areas. For example, the governments of B.C. and Canada are developing a joint strategy for establishing a network of Marine Protected Areas throughout B.C. (see page 42 in "Planning and Approvals"). The federal government also recently passed the *National Marine Conservation Areas Act*, and several sites are being considered by Parks Canada for designation as NMCAs.



Mo Morrogh

Critical habitat may be highly vulnerable to human disturbance.

Shoreline areas with a high rate of (active) sediment transport are vulnerable to interruption of sediment transport mechanisms.

Regional District of Comox Strathcona

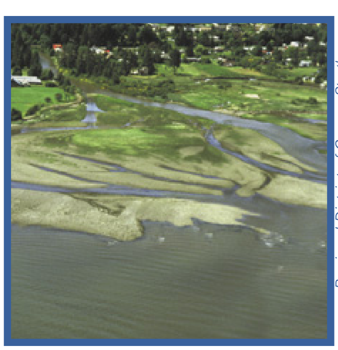
Areas where water does not circulate well or where exchange is limited are particularly susceptible to changes in freshwater and chemical inputs, and to activities that alter circulation patterns.

Fisheries and Oceans Canada

Areas of fine sediments and shallow depth that are close to freshwater input are vulnerable to chemical contamination.

Regional District of Comox Strathcona

Habitats formed by the long-term interaction of complex physical processes are slow to recover from disturbance or disruption of any of these processes.



Regional District of Comox Strathcona

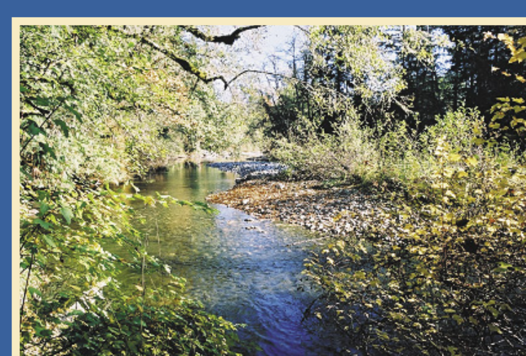
Salmon get a helping hand

It took eight truckloads of gravel to save the salmon spawning grounds of a river in northwest B.C. The river had been dammed 50 years ago when a pulp mill was built on its banks. Gradually the dam eliminated the supply of fresh gravel and sediment from upslope and upstream areas to the spawning and rearing grounds downstream. In due course most of the spawning habitat disappeared and the few fish that returned to the river were actually competing for spawning areas, laying their eggs on top of each other's.

A Coho would arrive first, dig a redd, and lay her eggs. Then a Chinook would appear a few weeks later, dig up that redd, and deposit her eggs, leaving the Coho eggs to float up and get eaten by the trout.

So two years ago the local residents decided to give Nature a helping hand. They trucked in and deposited over 70 cu m of clean gravel into the river, below the dam. Almost as soon as they put it in, they saw the Steelhead beginning to spawn. Within two weeks, the heavy spring rains and high flows had sorted and redistributed the gravel, creating new spawning areas all along the lower river and into the estuary.

It will be some years before the residents will know if the technique worked, since salmon don't return to their spawning streams for two to six years. But early indications are that the gravel deposit was a simple way to restore spawning habitat lost because of the dam, which was built long before more stringent controls were in place.



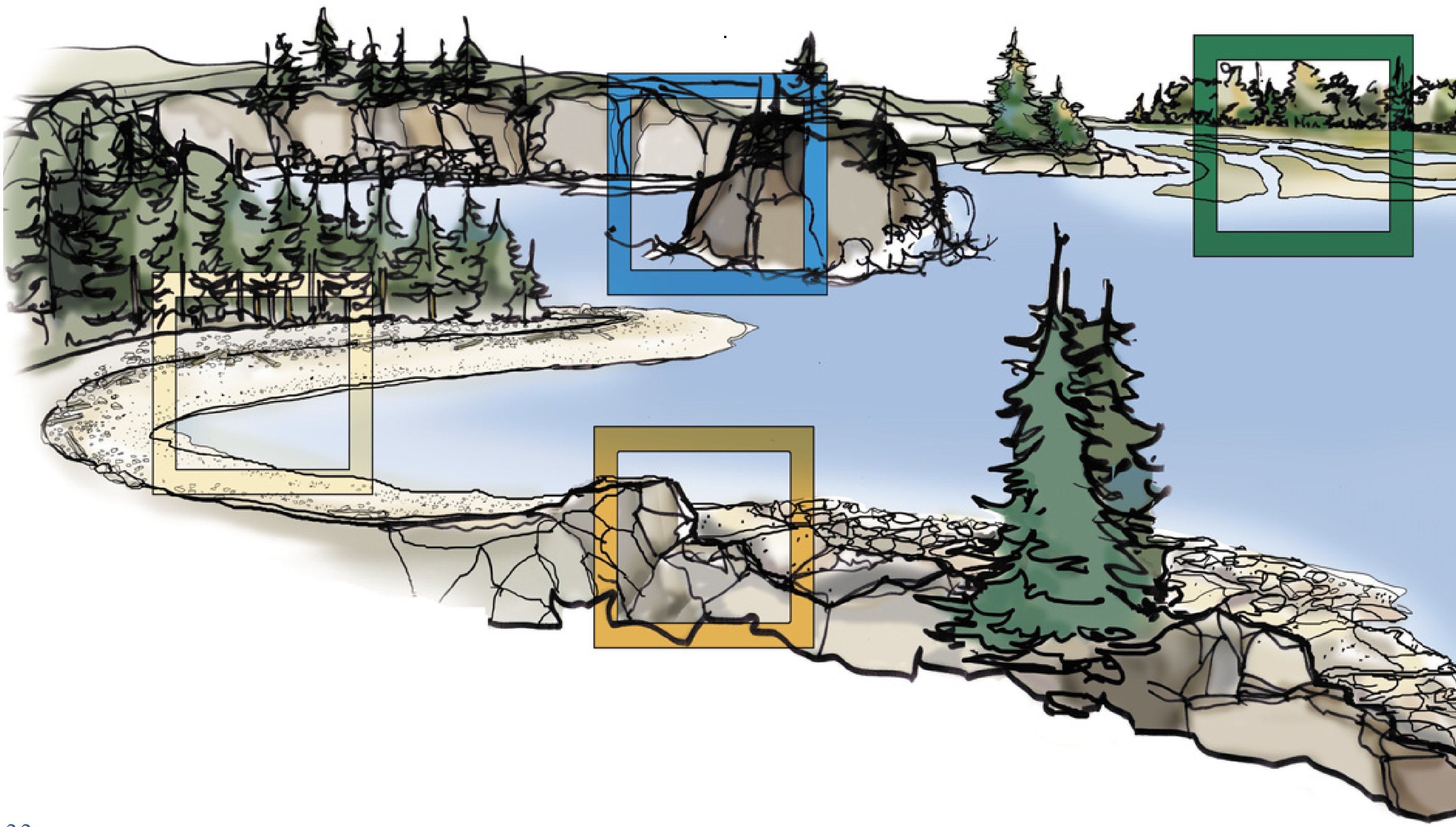
Harriet Rueggeberg

Different Shores-Different Concerns

Shore Types

We have described the physical forces that shape shores and the biological communities that inhabit them. We learned that in order to protect our shores, we need to understand the impressive power of tides, wind and waves, and the delicate balance of plants and animals that live under the influence of these systems.

It is also important to know that there are different types of shores, and that each shore type has a different ability to accommodate disturbance. Some are stable and robust; others are fragile and easily destroyed. This section describes the physical and biological attributes of these different shore types. For each shore type we describe development sensitivities and offer a checklist that will provide guidance for local and regional land planning decisions.



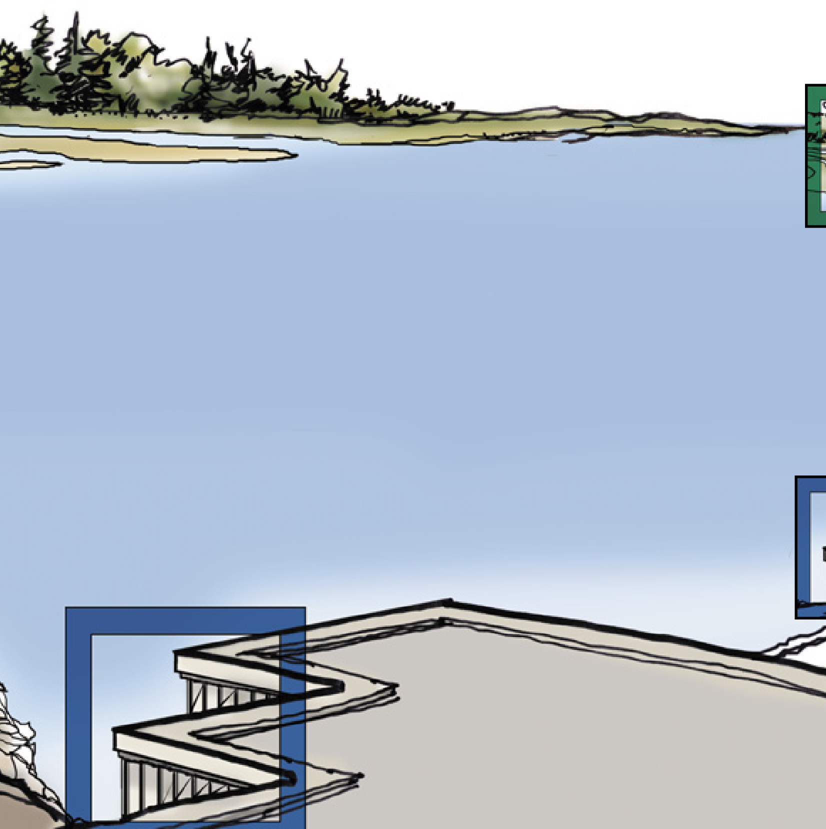
Shore Classification

A great deal of effort has gone into classifying shores into shore types. Such classification systems help to support coastal planning and management efforts. For example, most of British Columbia's shores have been classified to determine their sensitivity to oil spills while some, notably estuaries, have been classified and colour coded with respect to their fish habitat values. These classification systems also contain management prescriptions that outline where and under what circumstances development activities may be acceptable.

Federal and provincial management agencies have developed fairly detailed shorezone classification systems. For the purpose of this document, these systems have been simplified to five shore types. Knowledge of these five shore types will help in making environmentally sound decisions on the use of B.C.'s coast.

Care has been taken to ensure that this simplified classification can be matched back to the federal/provincial classification systems so that local planners can correlate their plans with existing coastal mapping, and so that coastal communities will be able to build on existing resources available through federal and provincial coastal programs.

Five icons are used throughout this chapter to identify these five shore types.

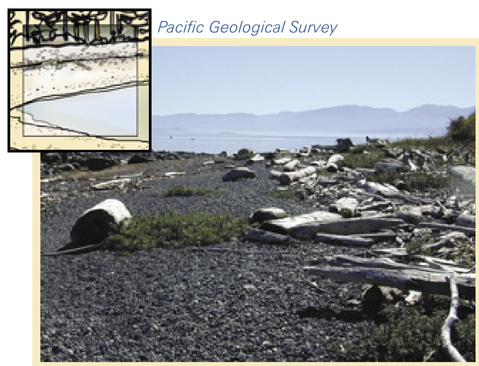


Archipelago Marine Research Ltd.

Rocky Shores *are usually very stable and cover much of the B.C. coast. They are quite resistant to change and provide habitat for a variety of intertidal organisms.*

Regional District of Comox Strathcona

Rock and Large Sediment (Boulder/ Cobble) Shores *occur where cobble or heavy gravel sediment is available from eroding rock benches or cliffs. If the sediment includes some finer material, a dense cover of stable shore vegetation will grow.*



Pacific Geological Survey

Sediment (Sand and Gravel) Shores *are formed where a great deal of smaller particle sediment is available from sources such as sandstone bluffs. Often these shores are very sensitive to disturbance and can change very quickly.*

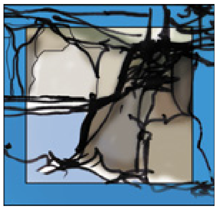
Regional District of Comox Strathcona

Rivers and streams that carry upland sources of fine sediment can form estuary deltas in a relatively short period of time. ***Estuaries and Mud Flats*** *are very sensitive to change.*

Fisheries and Oceans Canada

The Stanley Park Seawalk is an example of an ***Altered Shore****, which is common in urbanized areas of the Georgia Basin.*

Rocky Shores



A rocky shore typically consists of a solid rock bench across the intertidal zone, that may or may not extend up to the high tide line. Thin gravel and boulder veneer deposits are often found on these benches, but usually cover less than 10 percent of the intertidal area. This type of shore can also be a near vertical rock cliff that may extend above and below the intertidal zone. Sand, gravel and cobble sediment deposits often form small beaches near the high tide line. Rocky shores are resistant to erosion and do not provide a significant supply of unconsolidated sediment to the coast.

Main Physical Features

The main physical characteristic of rocky shores is the limited amount of sediment. These shores generally resist erosion, although sandstone shores may still be subject to erosion. Rocky shores have a more noticeable movement of sediment on to and off beaches than movement along the shoreline. These shores:

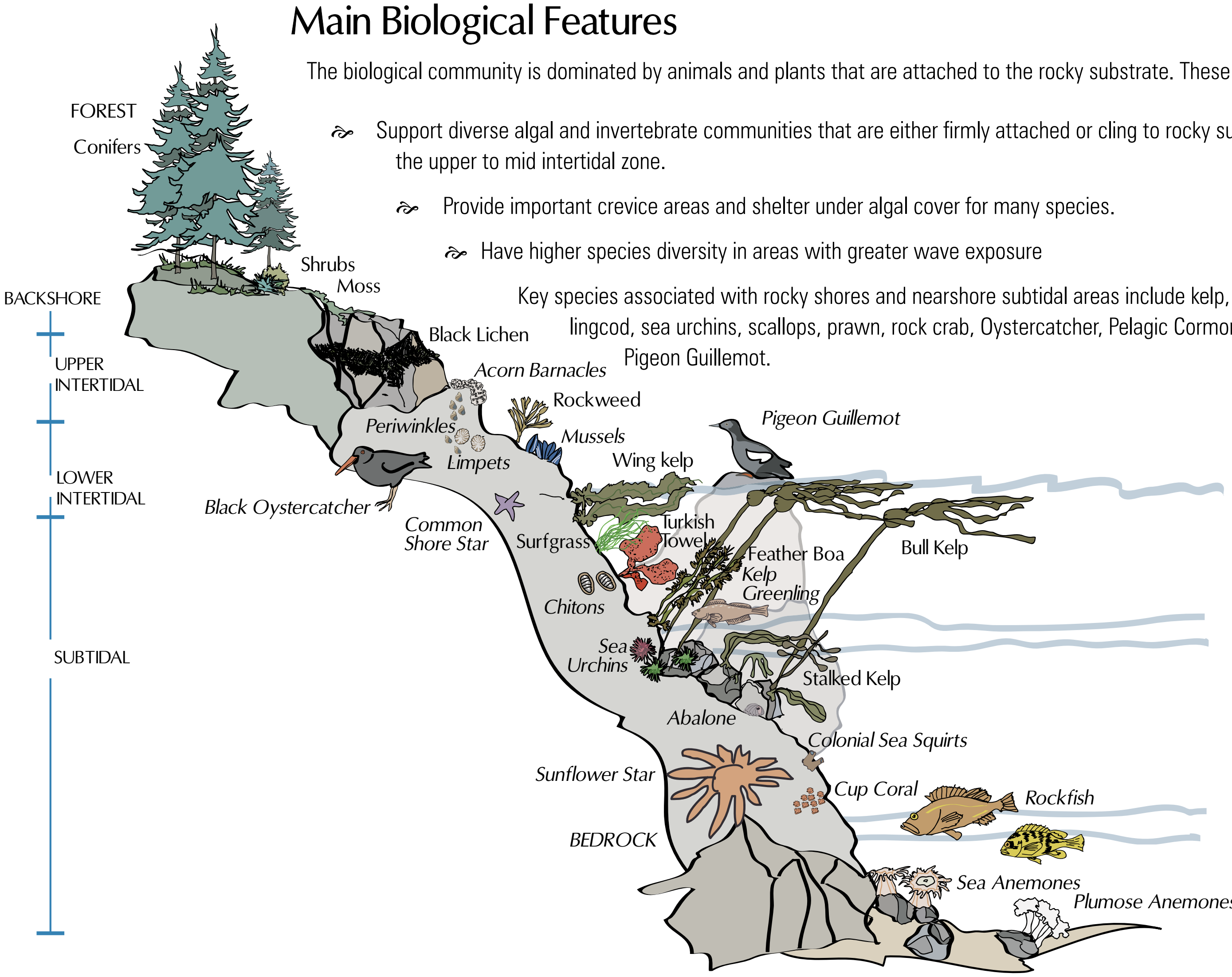
- Have very limited sediment supply.
- Are very stable over human time scales (i.e., 100s of years). Geological processes (1000s or millions of years) usually determine their foreshore shape.
- Have low sediment transport rates along the shore, ranging from 0 to 500 cubic metres/year.

Main Biological Features

The biological community is dominated by animals and plants that are attached to the rocky substrate. These shores:

- Support diverse algal and invertebrate communities that are either firmly attached or cling to rocky substrate in the upper to mid intertidal zone.
- Provide important crevice areas and shelter under algal cover for many species.
- Have higher species diversity in areas with greater wave exposure

Key species associated with rocky shores and nearshore subtidal areas include kelp, rockfish, lingcod, sea urchins, scallops, prawn, rock crab, Oystercatcher, Pelagic Cormorant and Pigeon Guillemot.



Adapted from a sketch by Archipelago Marine Research Ltd.

Lanarc Consultants Ltd.

The "Malaspina Galleries" on Gabriola Island are sandstone cliffs that have eroded over time to create a series of hollows and caves. Because of the deep water adjacent to these cliffs almost no sediment remains.

Mike Tarbotton

Much of B.C.'s coast is characterized by rock ramps or platforms with little sediment.

Mike Tarbotton

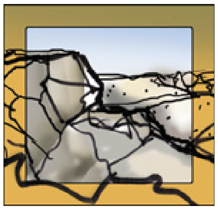
This is primarily a rocky shore that has a shallow slope and a thin veneer of sediment.

Development Sensitivites

Rocky shores are very stable and are not formed by large amounts of sediment. They are generally considered good areas for upland development. Care is warranted though because intertidal and shallow, subtidal biotic communities on rocky substrates can be diverse and very susceptible to certain types of disturbance.

- Rocky shore communities are relatively insensitive to changes in sediment process, particularly in more exposed areas where sediment is quickly dispersed by wind and wave action.
- Intertidal communities are particularly sensitive to impacts that scrape and abrade the rocky surfaces including trampling in intensely used areas.
- Microhabitats, created in the spaces between rocks, different sized rocks and the understorey of larger kelps, are important in rocky shores. Microhabitats contribute to species diversity and provide shelter for both predators and prey species important in the ecosystem.
- Structure-forming species such as kelp are important components of rocky intertidal communities. Harvesting of these species can lead to undesirable changes in community structure and reductions in abundance of these important physical habitat features.
- Intertidal and subtidal algae found in these areas are sensitive to the shading effect of pile docks or floating structures.
- Biological recruitment to rocky areas that have been disturbed by development activities can be quite rapid (two to three years).
- Even bedrock cliffs can be subject to faults, so structures should be set back far enough from the crest of the slope to ensure geotechnical stability.

Rock and Large Sediment (Boulder/Cobble) Shores



Rock and large sediment shores are usually found on rocky coasts where loose sediments overlay 10 to 40 percent of the intertidal shore area. These sediments usually form thin layers of cobbles or heavy gravel. The main source of these sediment deposits is wave erosion of the adjacent rock bench or cliffs.

Coastal cliffs or bluffs formed of unconsolidated materials can be a major source of sediment on rock and sediment shores. Large sediments such as boulders or cobbles do not usually move along the shore but form what is called a "lag deposit" on top of the solid bedrock.

Main Physical Features

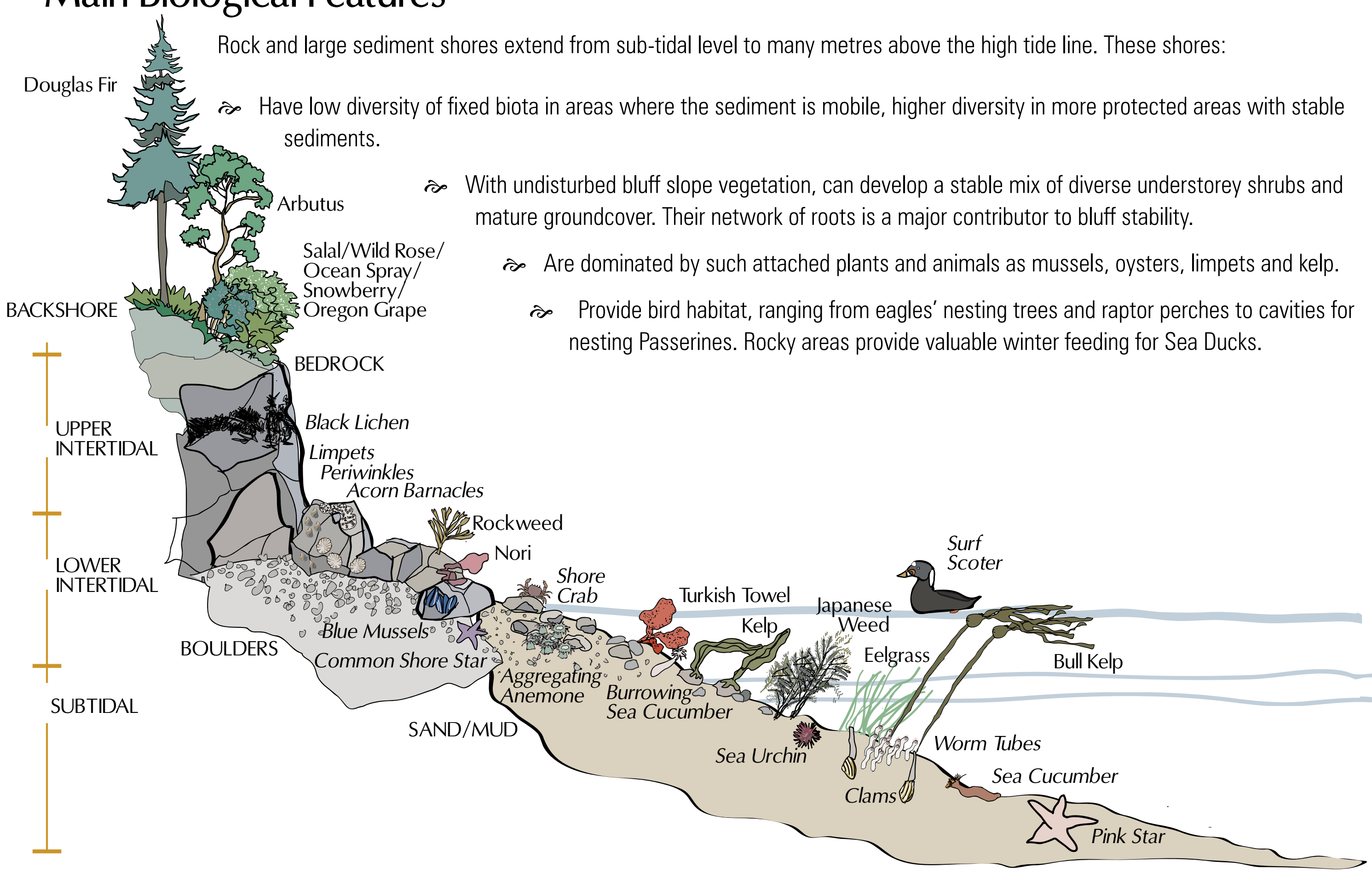
For rock and large sediment shores, onshore/offshore and longshore sediment transport are both important transport processes. This shore type actually reflects a variety of different conditions. Generally these shores:

- Are moderately resistant to erosion.
- Have a limited sediment supply except where there are upland bluffs.
- Are usually stable over human time scales (e.g. 100s of years).
- Have their foreshore shape determined by geological processes (1,000s or millions of years).
- Have sediment transport rates along the shore that are usually small, ranging from 100 to 2500 cubic metres/year.
- Have characteristic features such as rock terrace or cobble/boulder beaches with driftwood accumulations in the high intertidal and backshore.

Main Biological Features

Rock and large sediment shores extend from sub-tidal level to many metres above the high tide line. These shores:

- Have low diversity of fixed biota in areas where the sediment is mobile, higher diversity in more protected areas with stable sediments.
- With undisturbed bluff slope vegetation, can develop a stable mix of diverse understorey shrubs and mature groundcover. Their network of roots is a major contributor to bluff stability.
- Are dominated by such attached plants and animals as mussels, oysters, limpets and kelp.
- Provide bird habitat, ranging from eagles' nesting trees and raptor perches to cavities for nesting Passerines. Rocky areas provide valuable winter feeding for Sea Ducks.



Adapted from a sketch by Archipelago Marine Research Ltd.

Lanarc Consultants Ltd.

This rocky shore has a small amount of loose sediment overtop. The sediment supports the growth of vegetation and provides a broad range of habitat.

Mike Tarbotton

Mature vegetation growing close to the water's edge is characteristic of this shore type.

Brian Emmett

The larger shore sediments on this type of shore tend to resist movement.

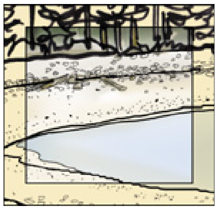
Development Sensitivities

Rocky backshore areas are quite stable and are generally considered good areas for building upland development. Stability and erosion is always a concern on coastal bluffs even if the underlying area is bedrock. Assessment of stability should focus on areas with sediment.

Abrasion, shading and loss of habitat features such as crevice space and structure-forming plants and invertebrates are major concerns in rocky areas. Impacts to sediment processes that produce and sustain sensitive habitats such as eelgrass beds are also major concerns in intertidal and shallow subtidal sediments. Conservation of riparian (waterside) vegetation is important on coastal bluffs.

- If sediments move during storms, annual or seasonal algae such as Enteromorpha (sea lettuce) and mobile invertebrate species living on the surface will dominate.
- If sediments are stable (more protected or deeper areas), perennial algae such as Fucus (bladderwrack) and attached invertebrates will dominate.
- These shores, and the associated biotic community, have a long recovery time following oil spills, particularly when oil is trapped on the bedrock below layers of boulder and cobbles.

Sediment (Sand and Gravel) Shores



Sand and gravel shores are found on both steeply sloped shores, and coastal plains that have a significant supply of loose sand, gravel or small cobbles. These materials erode easily and are readily transported by wave and current action. Coastal cliffs (bluffs) are often a major source of beach sediment. Features such as spits and coastal lagoons can be created when the sediment associated with longshore drift accumulates. Finer sediments, including gravel and sand, are often moved down the coast by wave action and accumulate as pocket beaches in sheltered bays between headlands, or as gravel beaches near high water in small indentations along the coast.

Sand and gravel shores are highly sensitive to human interference and interruption of longshore transport processes. Breakwaters, groynes and modifications to the onshore/offshore movement of sediment transport can have serious effects. Coastal plain shores are also susceptible to flooding during high tides, surges and storm waves.

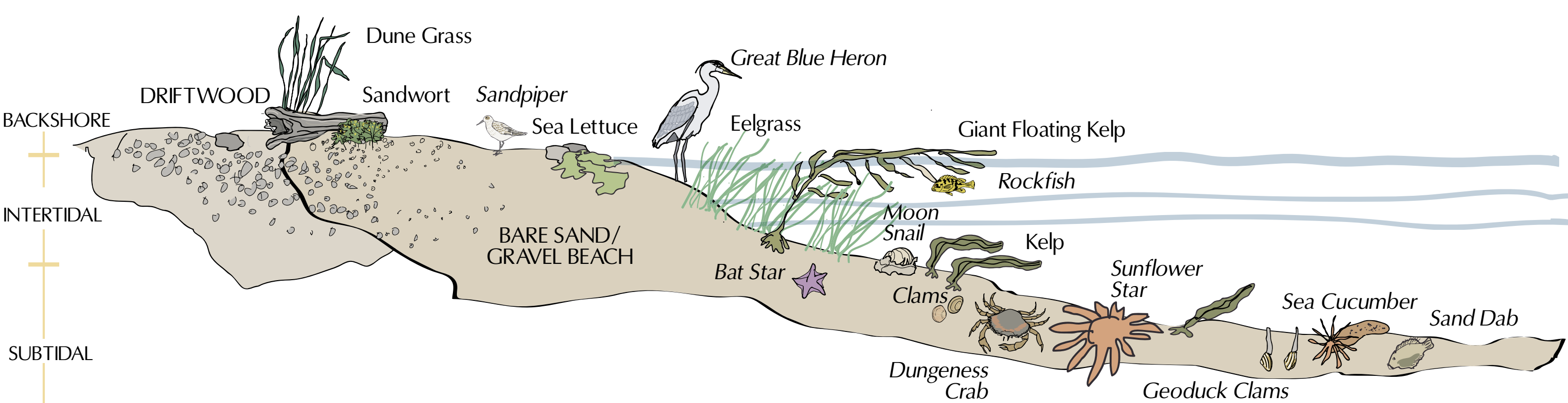
Main Physical Features

Sediment shores occur where there is a supply of steadily eroding small particle size sediment from coastal bluffs or rivers. These shores are very dynamic and their features can change quickly with large storms. Low-lying sandy shores may be prone to backshore flooding. Generally these shores:

- Have easily eroded sediment.
- Have a large supply of loose sediment.
- Are very dynamic on a human time scale.
- Have foreshore shape determined by wave and tide action.
- May have very large sediment transport rates along the shore depending on wave exposure. Sediment transport rates range from 1,000 to 1,000,000 cubic metres/year. Think of 40,000 truckloads of sediment rolling past these shores each year!
- Have rates of longshore sediment transport that are usually larger than onshore/offshore transport.

Main Biological Features

- The intertidal and nearshore biological communities of sand and gravel shores are dominated by burrowing invertebrates such as worms and clams that live in the sediment, and attract large concentrations of birds such as Scoters and Goldeneye.
- Large mobile invertebrates, such as sea stars, may also be present. These animals can move quickly in response to shifting sediments.
- Eelgrass, a rooted perennial plant, often grows in meadows in sand/mud substrates in protected areas. Disruption to sand and gravel shores can have a devastating impact on eelgrass beds.
- Backshore vegetation (dune grasses, salt adapted plants and shrubs) forms a distinct habitat zone and is important in stabilizing the upland sediments and preventing erosion.



Adapted from a sketch by Archipelago Marine Research Ltd.

Mike Tarbotton

Sand and gravel shores are constantly changing as winds and waves move sediment along the shore.

Mike Tarbotton

A detailed analysis of physical shore systems is required to determine if a sediment shore is likely to erode or accrete. Refer to pages 8-13 for more information about sediment dynamics.

Mike Tarbotton

A single winter storm can pull large amounts of sediment from the higher shore areas into an intertidal area. This process is reversed gradually over the summer as the sediment is built up again as longshore currents carry sediment from nearby beaches and estuaries.

Development Sensitivities

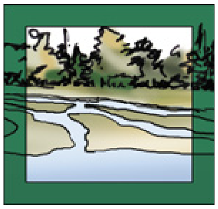
Building is a risky activity on sand and gravel shores and can be costly to your pocketbook and the environment. Because sand and gravel shores are very dynamic, they are also sensitive to human activity, particularly activities that disrupt sediment processes. These could include seawalls, groynes, wharves or docks, or upland development that is located poorly. Species such as eelgrass, and their associated biological communities, require fine substrates and are therefore sensitive to changes in sediment processes that result in erosion, accretion or changes in sediment size.

Marine birds and fish may also be affected by changes in invertebrate community composition, as infaunal organisms are important food sources for them. It is difficult and often impossible to compensate for losses or alteration of these types of habitats.

Sand and gravel shores provide many opportunities for coastal tourism and recreation. Recreational beaches occur infrequently since they are created only where there is a constant local supply of eroding sand and rocky headlands that trap sediment. Development pressure is generally greatest near these beaches and the possibility of damage can be acute.

- Many shorebirds rely on the seasonal sediment dynamics of beaches for foraging. Shoreline protection structures such as revetments and seawalls can affect these seasonal processes.
- It is important not to remove vegetation. It helps protect against erosion of backshore areas.
- Boat wakes can contribute significantly to erosion in protected areas.
- Intertidal and subtidal eelgrass beds, which often are found in these areas, are rooted in the fine sediment and are particularly sensitive to disturbances that may uproot them (propeller wash, dredging). They are also sensitive to changes to the sediment processes that either erode substrate and dislodge the plants or deposit lots of sediments that smother the plants. It is difficult to compensate for losses to eelgrass habitat, as recruitment processes are not well understood and ideal growth conditions are hard to reproduce.
- Along the north coast where gravel beaches provide the only passable route for vehicles, it is especially important to be aware of the potential for environmental damage. Driving on beaches crushes the flora and fauna that live on and immediately under the surface, and can destroy spat eggs or species such as surf smelt that use the beaches for spawning.

Estuaries and Mud Flats



Estuaries are formed where a river enters the ocean. Rich nutrients and fine sediments carried by the rivers, the variety of habitat created by the formation of deltas, and the mixing of fresh and salt water make estuaries highly productive. They are important nursery habitats for many kinds of fish and invertebrates.

Estuaries come in many forms. They include large flat deltas such as the Fraser River Estuary, and steep river mouths such as those found at the head of many coastal fjords. The form of the estuary depends on a number of factors: the river's flow and volume, the topography and water depths near the river mouth, and the type, size and availability of sediment in the catchment area. Typically, large rivers with a relatively flat mouth, such as the Fraser, form extensive deltas made up of fine sand and silt sediments. Steep rivers may also form small deltas if there is an upland source of erodible material. In these situations, the sediment on the delta is usually much coarser gravel and cobbles.

Main Physical Features:

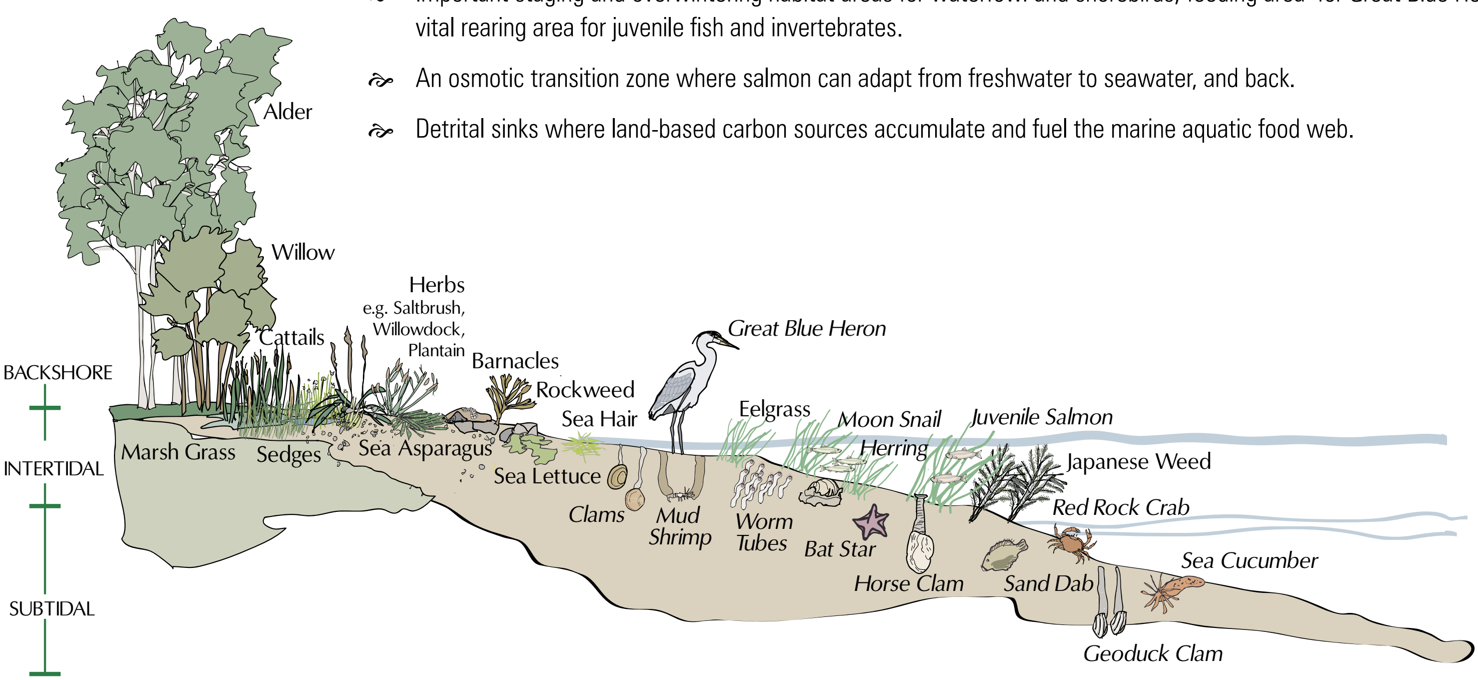
Estuaries are formed by complex and dynamic physical processes. In general, estuaries:

- Have a physical form determined primarily by river flow, river sediment supply, tides, wind and longshore sediment transport
- Are very dynamic - they can change rapidly, often over periods of less than a year, and often as a result of major storms or flooding.
- Are formed by complex physical processes and are extremely sensitive to disturbance if these processes are disrupted

Main Biological Features

Many estuaries are characterized by highly productive and brackish salt marshes, and other distinct vegetation communities (estuarine swamps and meadows) that adapt to seasonal flooding and salty soils. Their intertidal and subtidal biological communities can survive with rapid changes in temperature and salinity. Estuaries provide important rearing and feeding areas for many fish species including juvenile salmon as well as waterfowl. They are also vital habitats for several mammals including deer and Black and Grizzly bear. Estuaries contain:

- A variety of biological communities that can survive rapid changes in water temperature and salinity.
- Salt marshes and other brackish vegetation that provide cover, detritus and produce invertebrates used as food sources by fish and waterfowl.
- Important staging and overwintering habitat areas for waterfowl and shorebirds; feeding area for Great Blue Heron; vital rearing area for juvenile fish and invertebrates.
- An osmotic transition zone where salmon can adapt from freshwater to seawater, and back.
- Detrital sinks where land-based carbon sources accumulate and fuel the marine aquatic food web.



Adapted from a sketch by Archipelago Marine Research Ltd.

Fisheries and Oceans Canada

Estuaries provide habitat for a wide variety of wildlife. Deeper portions are frequently major shipping centres and home to a variety of industries and commercial interests.

Regional District of Comox Strathcona

Sediment dynamics in estuaries can be dramatic. The delivery of sediment downstream can change the shape of the shore in a very short period of time.

Lanarc Consultants Ltd.

The upland parts of many coastal estuaries along the B.C. coast provide productive agricultural lands.

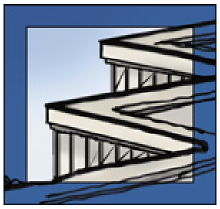
Development Sensitivities

Estuaries and associated vegetation features (eelgrass, marsh plants) are extremely sensitive to anything that disrupts the complex physical and chemical processes by which they are formed (changes in freshwater flow, sediment input, and longshore processes). Once disturbed, recovery is very slow and where habitats do re-establish, they are often different than the original habitat and will not support the same species.

- Estuaries are particularly sensitive to metal and organic contaminants that bind to fine sediments and are often transported to estuaries by rivers. This is because fine sediments tend to be deposited in these areas. Storm drains and sewer outfalls can be significant sources of sediment- bound contaminants in urban areas.
- These areas are often crucial to the life cycles of many birds and mammals (eagle, bear, and waterfowl), particularly in British Columbia where so many species depend on migratory salmon.
- Intertidal and subtidal eelgrass beds, which often are found in these areas, are rooted in the sediment and are particularly sensitive to disturbances that may uproot them (propeller wash, dredging) or changes to the transport of sediment. It is difficult to compensate for losses to eelgrass habitat as recruitment processes and ideal growth conditions are not well known.
- Maintenance of coastal riparian vegetation is important in order to maintain the integrity of carbon cycling and sediment flow to upper intertidal marsh areas.
- Estuarine areas with restricted tidal circulation, such as tidal lagoons, can be particularly susceptible to changes in freshwater or chemical (nutrient) inputs and to physical disturbances that affect water circulation patterns.
- Estuarine marsh vegetation provides carbon and physical habit for invertebrates that nourish juvenile salmon.

Changes in elevation, caused by dredging or filling, will alter physical habitat features and substrate quality, which encourages establishment of nuisance invasive species such as purple loosestrife or cordgrass.

Altered Shores



These are shores that have been modified by human activity. Only a small percentage of British Columbia's shores has been modified, but that percentage tends to be in some of the most productive coastal habitats. People tend to settle in the same areas that are most favourable to marine life - sheltered bays, estuaries, gently sloping shorelines, and so on. Hence, the impact of human activity is significantly greater in some B.C. coastal ecosystems, such as the Georgia Basin, than simple percentages would indicate.

Furthermore, the degree of modification is particularly high in areas such as sheltered bays and estuaries where communities, harbours and ports tend to be located. Altered shores are the only shores that are increasing over human time scales.

Main Physical Features

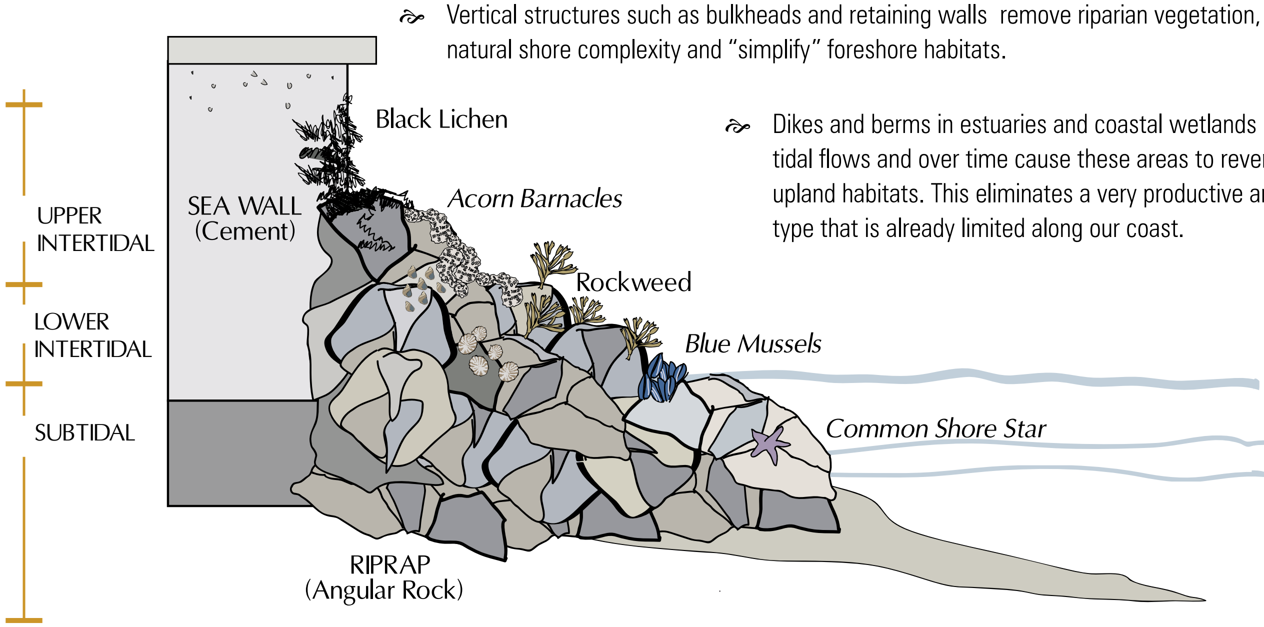
Generally, these human-made shores:

- Are built of imported large rock (riprap), concrete, steel or wooden piles.
- Tend to be straight, hard and impermeable.
- Alter local water action and sediment transport patterns either deliberately (as part of their design and function) or inadvertently.
- Usually involve foreshore filling, which buries underlying natural substrates and biological communities.
- Often require maintenance dredging (e.g. deep-water ports), which constantly impacts benthic (bottom dwelling) communities and sediment patterns.

Main Biological Features

Altered shores are typically less diverse biologically than natural shores - for example:

- Structures with smooth surfaces, such as steel piles or concrete seawalls, have a lower surface area than natural shorelines, and often are poorly colonized by algae and invertebrates.
- Riprap embankments provide more surface area, but habitat spaces tend to be of uniform size. Even though algae and invertebrates colonize these crevices, diversity is limited.
- Pile structures such as piers and docks can provide cover for fish and nesting habitat for birds such as the Purple Martin, but can also shade out underlying marine plants.
- Dikes and seawalls accelerate local erosion at the toe of the slope, prevent the accretion of sediment and the establishment of low bench marshes that provide food for fish.
- Vertical structures such as bulkheads and retaining walls remove riparian vegetation, eliminate natural shore complexity and "simplify" foreshore habitats.
- Dikes and berms in estuaries and coastal wetlands eliminate natural tidal flows and over time cause these areas to revert to backshore or upland habitats. This eliminates a very productive and diverse habitat type that is already limited along our coast.



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