BERMUDA ZOOLOGICAL SOCIETY

presents

Rocky Coasts

written by

Dr. Martin L. H. Thomas

Project Nature

Field Study Guides for Bermuda Habitats

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Rocky Coasts

(Second Edition)

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Field Study Guide

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A completely new edition of the first Project Nature guide
"The Rocky Coast" published in 1993

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Cover: A Typical Rocky shore in Bermuda
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Foreword

One can imagine few harsher places to survive, let alone thrive, than on the rocky coast of an oceanic island. Open to all the elements that nature can throw at them, the flora and fauna of this habitat have developed unique and specialized adaptations to survive. Consequently, the rocky coast of Bermuda teems with life and is not the barren wasteland between the ocean and land that one might first think. This Project Nature Field Guide explores the geology, plants and animals of this region of Bermuda and provides the visitor (and we are all visitors here) with a comprehensive yet simple way of understanding this extreme, wonderful environment.

This book is the most recent in a number of guides exploring the varied and unique habitats of the Bermuda Islands. All of these publications include field trips and activities to better understand our natural world. It is hoped that by encouraging people to explore, understand and enjoy our island home we will continue to aid our mission, inspiring care and appreciation of island environments.

As the Senegalese conservationist, Baba Dioum, once famously quoted: *"In the end we will conserve only what we love. We love only what we understand. We will understand only what we are taught."*

Dr. Ian Walker
Acting Principal Curator
Bermuda Aquarium, Museum and Zoo
March 2007

Acknowledgements

"The Rocky Coast" was the first in the series of Project Nature field study guides which resulted from the inspirational thoughts of Mary Winchell and Lyn Thompson 15 years ago. The first issue in this guide series and the next, The Sandy Coast, was the product of a team approach. Those involved in the writing included; Marg Hammond, Lyn Thompson, Felicity Holmes, Mary Winchell, Robin Trimingham, Wolfgang Sterrer, Dorte Westphalen, Jack Ward, Andrew Dobson, David Wingate and Mary Lodge. These first two guides were followed, after a seven year gap, by a third, "The Bermuda Forests" which showed a transitional approach. A team approach persisted in part but one of the team, Martin Thomas, assumed the responsibility for much of the text and for overall coordination of the project. At this point the focus of the series became much more ecological. The evolution of the series continued with the fourth guide, "Bermuda's Wetlands" which had a single author, a situation which continues to this day.

The first seven Project Nature field and study guides were produced with the encouragement and advice of Mary Winchell who was the Education Officer for the Bermuda Zoological Society for most of this period. Without her backing and considered advice, the project would undoubtedly have foundered and its evolution would have been much slower. When Mary Winchell left to pursue other interests, leadership was taken over by Holly Mitchell as new Education Officer. Holly continued this strong support for these publications until she left in late 2006.

Although this volume is in many respects a new beginning for Project Nature the design follows that of the latest in the series. This design has evolved greatly over the years to its attractive and functional present form. Much of the credit for the changes that have been made must be given to Liz Nash. Liz works from the basic manuscript to transform it into a greatly more readable and practical form. This involves the formatting of all the text, suggesting changes that will improve the document and the insertion of diagrams, figures, tables and text boxes. She also takes care of the printing and arranges for binding. Her efforts have resulted in a series of attractive publications that are produced at very low cost. We could not produce Project Nature without her expert help.

The illustrations are drawn from a very wide variety of sources and some have been especially drawn for these guides. We are especially grateful to Dr. Wolfgang Sterrer, Curator of the Natural History Museum for his permission to use illustrations from three of his publications, "Marine Fauna and Flora of Bermuda", "Bermuda's Marine Life" and the book "Bermuda's Seashore Plants and Seaweeds" which he co-authored with A.R. Cavaliere. Other illustrations of animals and plants have been contributed by Janet Percy, Andrew Dobson, David Wingate and the author. Full page habitat pictures have been drawn by Jo-Anne Stevens of the University of New Brunswick in Saint John, Canada. Some text illustrations are from the first edition of this publication; others are by the author. The now out of print book "Flora of Bermuda", by N. L. Britton, published in 1918 is an inspiration to all plant lovers in Bermuda and has been widely used in this series.

We are most grateful to the Bermuda Paint Company for their continued support of this series.

Introduction to the New Edition

As this group of publications progressed, feedback from users, and the accumulated experience of the authors and the assembler, showed that changes were required to make the guides more useful and easier to work from. In general the guides have become more focused and the illustrations have been improved and made more comprehensive. In particular, the descriptions of species have been condensed and moved to be presented right beside their illustration. Additionally, all the illustrations and descriptions of animals and plants are now presented in one section that forms a useful field identification guide. Suggested field trips have changed so that they take advantage of modern knowledge and lead students into a transition to further more advanced studies. This approach is also reflected in the text. The most recent innovation is the insertion of ‘summary boxes’ in the text that can be used both to quickly find the most useful passages of text and also to reinforce the main points being described. Example questions on the subject matter have also been added.

However, we have not deviated from several important principles embodied in this series. One of these is to prepare the publications in such a way that they can be sold for a very reasonable price. For this reason all the illustrations are in black and white, the only exception being the covers of more recent examples. The lack of colour in the illustrations of animals and plants is compensated by the brief but focused descriptions which highlight aspects of size, colour and behaviour. Furthermore, we have always included the geological background to the biological system covered. This is because geology and biology are very closely linked in Bermuda and cannot be considered in isolation. Additionally, we have maintained an up-to-date approach such that in several cases these guides are the only readily available source of information on new finds and knowledge. Bindings have greatly improved in durability and appearance.

Because of the progressive changes, it became obvious that the first two volumes in the collection should be re-written to conform to the approach incorporated in later examples. This is the first of these two revisions.

In common with previous issues of Project Nature words in bold in the general text are defined in the glossary at the end of the book. Note that bold figure references in the general text are just for emphasis. In other parts of the book, for example, species descriptions, bolding is also used for emphasis only.

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Introduction to Rocky Coasts

General

The rocky coastlines of Bermuda are one of the main features of the island but their biology and ecology attract comparatively little attention. This is probably because on casual observation they appear to be almost barren of life and in many places they consist of almost sheer cliffs. Additionally, the tidal or wave washed parts of these shores tend to be very smooth and slippery in places and to consist of formidable jagged, small spikes of rock in others. The lowest part of a rocky coast is often called the **intertidal zone**, but this name can really only be applied to the area covered and uncovered by the tides. In Bermuda the true intertidal zone is very narrow, because the **tidal range** is small. Tidal range refers to the height difference between high and low tide levels. In Bermuda the tidal range averages 75 cm. A small tidal range of less than a metre (3 ft) is typical of oceanic islands such as Bermuda, whereas tidal ranges on mainland shores may be as much as 20 m (65 ft). Where there are large waves and/or spray, as is true especially for the south shore, the area covered and uncovered by seawater is much larger than the intertidal and is usually referred to as the littoral zone. In Bermuda the littoral zone may be as much as, at least, ten times higher than the intertidal zone. Another feature of the littoral zone is the presence of tidal pools, often called rock pools, of varying size depth and height above sea level.

Summary

Rocky coastlines appear to be rather barren of life and sheer cliffs are common. In reality the lowest parts, covered by tides or spray are teeming with a wide variety of life. The cliffs are extremely important nesting sites. Tidal pools form a third component of rocky coastlines.

The Importance of Grazing in the Littoral Zone

As we will see in this field and study guide, the barren appearance of the rocky coastlines, especially in the littoral portions, is the result of a very dynamic ecological situation, rather than a real paucity of life. In reality the **biodiversity** and activity of animals and plants on the rocky coasts is very high. The factor that is especially important in this regard in the littoral zone, is the very high intensity of **grazing**. Grazing is the process whereby vegetation and a few small animals or animal parts are cropped off by animals. The intriguing thing is that this very high amount of grazing is not readily visible to us. This is partly because the littoral area has a dual existence. Partly covered by water and partly exposed to the air. When covered by water it is available to a host of grazers that reside below the shore, but move in when it is covered by water. These include a variety of fishes particularly Parrotfish but also Doctorfish and Damselfish, and also marine invertebrates such as crabs, slugs and snails. Grazing is less intense when the littoral zone is exposed to the air. Resident snails are active grazers and some crabs emerge from the water to feed. This feeding activity on the exposed shore is much more active in damp weather and at night; another reason why we don't see it very much.

Summary

The apparent paucity of life in the littoral zone is the result of very intensive grazing by a wide variety of creatures, especially fishes, crabs and snails. This happens both when the shore is covered in water and when it is exposed to the air.

Ecological Advantages to the Littoral Zone

You would think that it is especially difficult for animals and plants to occupy a habitat that is alternately covered by water and exposed to the air. It is interesting that although there is high **biodiversity** in this system, the vast majority of it is derived from the sea. Apparently, it has been much easier for marine organisms to adopt a partially **terrestrial** life, than for land organisms to have a partially marine existence. The fact that many different **species** reside there, or in other words the **biodiversity** is high there, shows that there must be distinct advantages to this place as a home. This will be examined later, but in brief it is a place where light is rarely shaded, where the presence of water is predictable and where large **predatory** animals find it hard to make a home.

Summary
The shore is a good place to live because it is well lighted, there are few predators and water supply is totally predictable.

Three Ecological Systems

In looking at rocky coasts it is quickly evident that there are three very different ecological systems present. One is the littoral zone, present no matter whether the coast is steep or gently sloping, another is the tide pool habitat of all but sheer shores and the third is the cliff habitat above the reach of heavy splash or spray. Of these, the littoral zone is the most complex and is accorded the status of an **ecosystem**, the cliffs and tidal pools are more correctly called **habitats**.

Summary
There are three very different ecological systems along rocky coasts. These are the littoral habitats, the tidal pool habitats and the cliff habitats.

Tide pools differ from the open rocky shore in that they do not normally dry out at low tide or in calm weather when spray is absent, however a few very high ones may do this.

The cliff **habitat** as we all know is generally almost sheer and as such is inhospitable to a wide variety of life. However, this very characteristic gives it properties which some animals and plants can take advantage of. A very good example is as a nesting habitat for both marine and land birds. A nest site in a hole, or on a narrow ledge on a cliff is much less likely to be raided than one in a land habitat. Similarly, some plants that can gain a foothold on a cliff will not suffer there from the competition by a host of close neighbours.

Gently sloping rocky coastal habitats above high tide level can only exist on wave-swept shorelines. In a sheltered area a rock slope above the reach of seawater as tides, waves or heavy spray, will quickly be colonized by a variety of coastal plants and a layer of soil will develop. Such locations are beyond the scope of this guide but are covered, in part, in the Bermuda Forests volume and in part in the Project Nature, Teaching Guide to the Biology and Geology of Bermuda.

Since the biology of the littoral part of rocky shores differs from tidal pools and cliffs, each will be treated in separate parts of this guide, however, the geological background is the same for all.

Summary
Rocky coastlines are vulnerable to pollution by floating trash and oil from the sea and to material washed down from the land. Oil is especially harmful, smothering life and persisting for years. Man adds to the pollution stress by gathering organisms for shell collections and food.

Conservation Aspects

As we all know lots of trash and spilt oil floats at the surface of the sea, and when it comes ashore much ends up stranded, or stuck, onto the rocky surface. Probably the most harmful pollutant to rocky coasts is oil, which adheres very firmly to the rock and also penetrates countless burrows of marine creatures as well as coating seaweeds and entering shells of clams and snails. It can cause virtually complete mortality in littoral areas. Once ashore, heavy black oil deposits form solid layers that may persist for many years. You will find places like this all around Bermuda. Especially severe

Summary
Do not collect anything but garbage from the rocky coastline. Even dead shells are an important part of the environment.

storms can hurl oil and debris high up onto cliff faces where it is also harmful and unsightly. Added to pollution from the sea is that from the land, toxic materials spilt close to shores will move down under the influence of gravity and influence the rocky shoreline. So although the land and sea both combine to create the good biological environment of the shore, they can also, with the help of man, do the reverse. Man has also exerted a harmful influence in several other ways. Some people love to collect shells and unscrupulous ones will even take live specimens. This has led to a serious decline in some attractive rocky coast inhabitants. Another harmful practice is that of collecting intertidal creatures for human food. In the past this led to the **extirpation** of one species.

With this in mind do not collect anything except trash from the rocky shore.

Summary

Because common names vary from place to place and a single name can also be used for two different organisms, we always use scientific names along with common ones. Scientific names, consisting of two words can also tell us something about the organism, such as habitat or colour.

Identifying Animals and Plants

Identification of animals and plants must be done on the spot either with the help of some knowledgeable person, or by the use of the picture keys included in this book. Identification also brings up the problem of naming the organisms that you see. People tend to shy away from scientific names and to use only common names. There is, however, a problem with this approach. Common names for a single species vary greatly from place to place and one name may be applied to two different organisms. To get around this we try to use scientific names because in this system one name applies to the same thing all over the world. This avoids confusion and allows us to compare our observations with those of others elsewhere. Scientific names consist of two parts, which may be Latin, Greek or a mixture of the two languages. They look difficult, but with a bit of experience they are easily remembered and often tell us something about the organism. For example, we have already introduced the word littoral as meaning between the tides. When we look at the periwinkles, which are rocky shore snails, we find that the word littoral crops up in several of their scientific names. Examples are *Littorina* and *Nodilittorina* which will be discussed later in this book. Another, thing that often appears in scientific names is the place where they were first described. For example, the name *barbadensis*, probably indicates that the organism was found in the Barbados. This, however, in by no means always the case, for example the Red Anemone of rocky shores is called *Actinia bermudensis*, but is found over a wide area of semi-tropical shores on the mainland and in the Caribbean. Colour may also be indicated; one of the nerites, another group of littoral snails, has *versicolor* as its second scientific name, indicating that its shell is patterned in various colours, similarly *rustica* is used in the name of a shell with a rusty brown appearance. However, it must be admitted that some scientific names are quite formidable, a little plant the Coast Spurge has a big name *Euphorbia mesembrianthemifolia*. This may be informative to a plant expert but has little meaning to us!

Chapter 1. Geological Background

The More Distant Past

In order to understand the geological events that shaped Bermuda's rocky shoreline we must go back many million years but not nearly as far as the birth of Earth itself which was probably about 5 billion years ago. We will in fact go back 110 million years by which time the oceans were fully formed and the continents had moved close to their present positions and approximated their present shape. The movement of continents is a very important process, and is associated with the events that produced Bermuda.

Summary
The origin of Bermuda is associated with continental drift. The outer solid layer of the Earth, the crust, is floating on molten magma beneath as a series of plates called tectonic plates. Two of these plates are moving apart at the centre of the Atlantic Ocean. Where they diverge is the Mid Atlantic Ridge, there new crust solidifies and earthquakes and volcanoes occur. 110 million years ago it is likely that one of these volcanoes produced Bermuda.

The outer solid layer of the Earth, usually referred to as the **crust**, is relatively thin and is floating on the molten **magma** beneath. Although the magma is quite viscous, huge, slow, convection currents constantly move it in large vertical loops called cells. There are many cells in the Earth beneath the crust. As the magma moves beneath the crust, the friction causes a very slow but steady movement of the crust. The crust over each cell beneath is always in motion. Since Earth does not change in size and the cells have different direction of motions, it follows that there must be tremendous forces applied to the crust. This has resulted in the presence of a number of distinct units of crust on surface of the Earth. These are called tectonic plates. Their differing directions of motion, called **continental drift**, means that in some places the plates are colliding while in other places they are drawn apart, while in yet others they slide along each other. Thus there are **collision junctions, spreading junctions** and **sliding junctions**. The approximate sizes and positions of the tectonic plates are shown in **Figure 1.1**.

Summary
Tectonic plates move apart at spreading junctions. Collision junctions are where tectonic plates move together. At collision junctions, one plate slides beneath another and this can cause earthquakes and tsunamis such as that in the Indian Ocean in 2004.

The junction zones between plates are locations of great geological activity, which can vary through earthquakes, volcanic activity, mountain building, hot springs and many other happenings. We only have to think back to the last few days of 2004 to see some of these events in action. At that time huge earthquakes under the ocean in southeast Asia, deformed the sea bed and resulted in huge waves called **tsunamis**. Both the earthquakes and the tsunamis caused very severe damage and very heavy loss of life along coastlines in that area, most notably in Indonesia, Sri Lanka, India and neighbouring countries. This is an area where two tectonic plates collide and a collision junction exists, just offshore. Since the plates never stop moving, one has to buckle down beneath the other. This is shown diagrammatically in **Figure 1.2**. Naturally, there is great friction in the collision zone and things do not change smoothly, instead unimaginably high pressures build until something gives and an earthquake happens. At this time, Earth's crust close to the collision zone may rise or fall at least 30 m (100 ft) and the displaced water forms a huge wave, the **tsunami**.

The above very recent example is typical of events along a collision junction. At a spreading junction the geological activity is still violent but not nearly so catastrophic. The situation is shown in **Figure 1.3**. To explain the origin of Bermuda we need to refer to the spreading junction

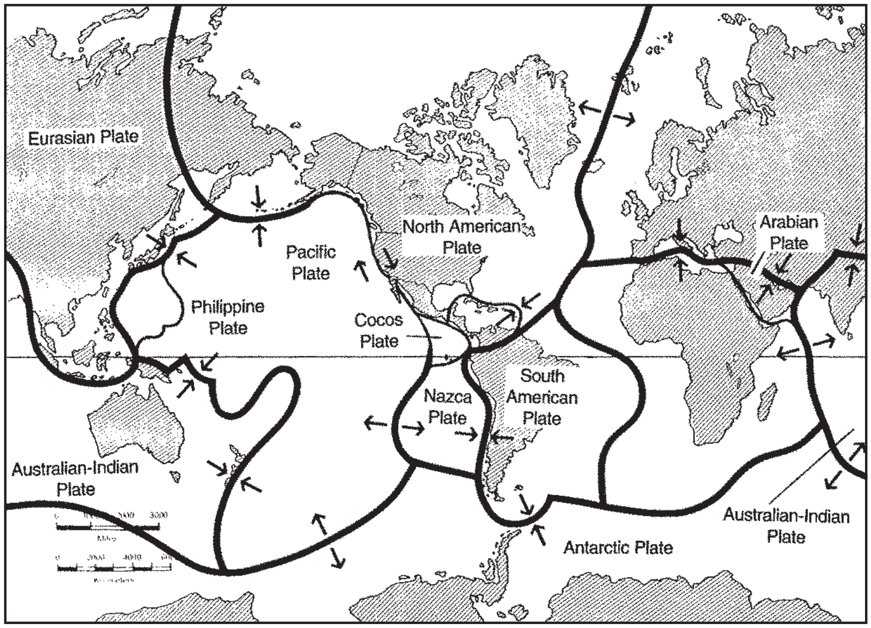
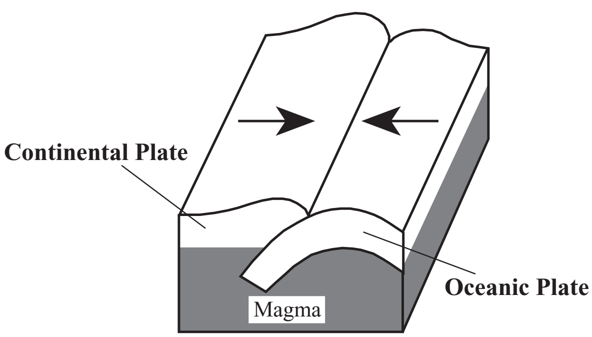
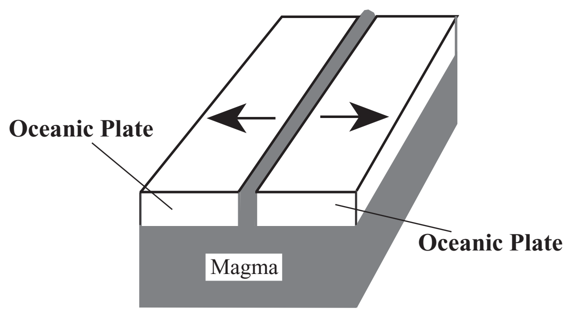


Figure 1.1. Earth's Tectonic Plates and their motions

running roughly north and south down the middle of the Atlantic Ocean. Here the European and North American plates spread apart. As you would expect, molten magma from beneath moves up to fill the gap and in the process forms a ridge of underwater mountains, called the **Mid Atlantic Ridge**, as shown in **Figure 1.4**, along with the occasional volcano. The rock



1.2. Collision Junction



1.3. Spreading Junction

formed from the solidification of molten magma is hard, black and called basalt. Earthquakes are frequent but usually very small. The island of Iceland lies on the ridge and feels dozens of small tremors a day. There you can observe the spreading zone on land in a large rift valley. Additionally, there are several volcanoes, and not long in the past a new island called Surtsey rose from the sea off Iceland's south coast. You may think Iceland would be a poor place to live but there are great benefits to their location. There is an endless supply of hot water all year round which can be used for heating, swimming pools and heavy industry.

To return to the Mid Atlantic Ridge it is thought that about 110 million years ago a large volcano erupted there, just to the west of the actual spreading zone. It is thought that it rose to be above, or close to the surface of the ocean.

Summary

An island like Bermuda, created on the best edge of the Mid Atlantic Ridge would move slowly westward as the plate enlarged. Islands created in this way are Ridge Islands. Other islands are created above 'hot spots' in the crust well away from the ridge; these are Hot Spot Islands. It is possible that Bermuda is a hot spot island created about 30 million years ago since some of the magma has been dated at that age. However, deeper magma may be 110 years old.

Since the plates are moving apart there, the volcano slowly moved to the west of the spreading zone and became dormant. We know that the rate of spreading in that area is constant at about 4 cm (1½ in) per year. This sounds so little as to be unnoticeable, but in 110 million years the distance moved is very large, in fact about 2,000 km (1,200 miles). Islands formed in this way are called **ridge islands**. Although this volcano is thought to have formed Bermuda, and has been called Mount Bermuda, this is not the end of the story. In the first 80 million years of its life, the volcanic island destined to be Bermuda moved 1200 km (750 miles) towards the west away from the Mid Atlantic Ridge. At that time the volcano passed over a very active spot in the

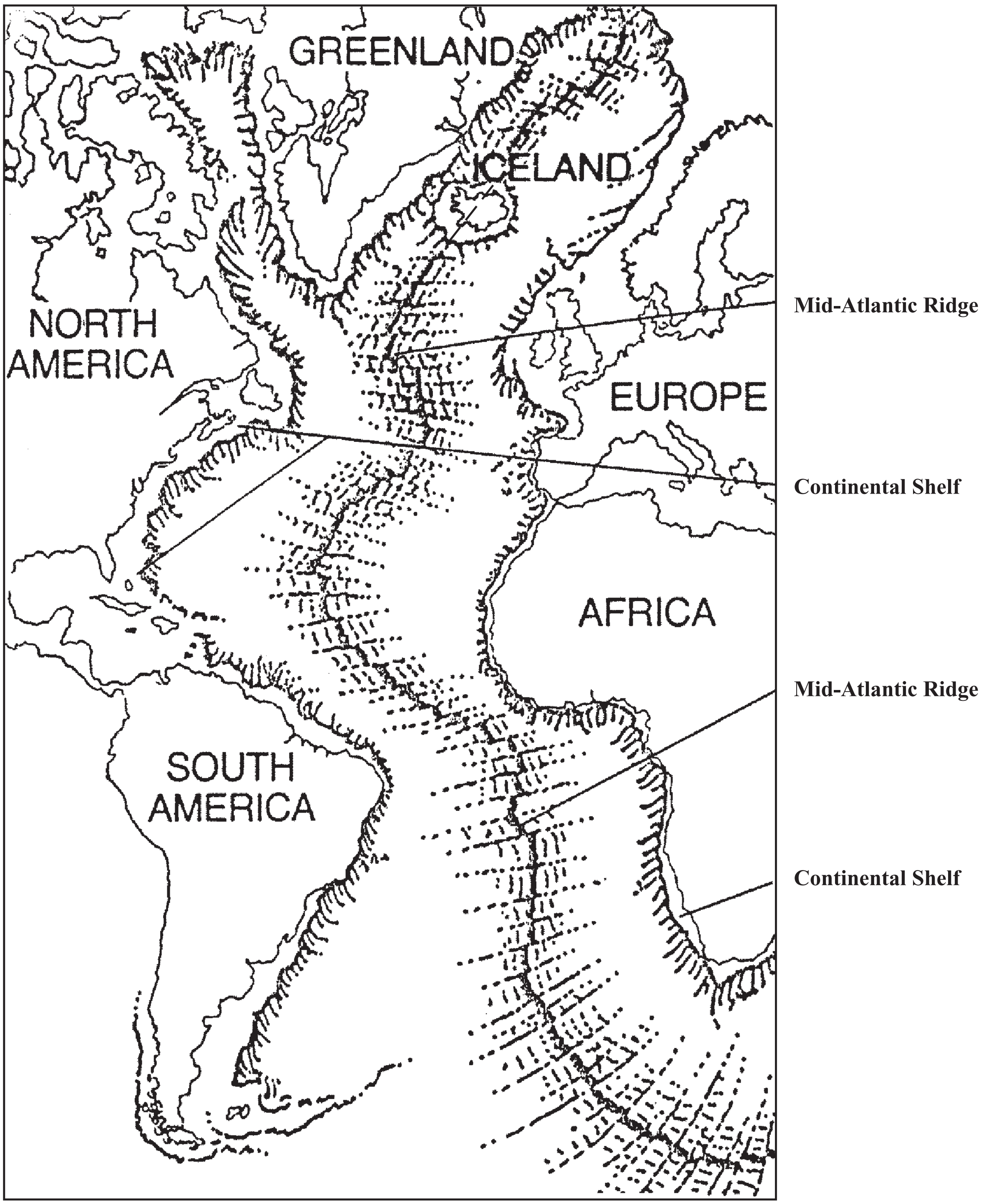


Figure 1.4. The Floor of the Atlantic Ocean showing the Mid-Atlantic Ridge

Earth's magma and erupted a second time. This second phase of volcanic activity is thought to have enlarged Mount Bermuda into the Bermuda Seamount consisting of three volcanic peaks, which now form the Bermuda Pedestal, the Plantagenet or Argus Seamount and the Challenger Bank. Only the Bermuda Pedestal now rises above the sea surface. There is another theory that proposes that Bermuda arose at this **hot spot** rather than on the ridge. If this can be shown to be true then Bermuda is a hot spot island rather than a ridge island and would be 30 million years old rather than 110. Following the formation of the Bermuda Seamount it has moved a further 800 km (500 miles) away from the Mid Atlantic Ridge, without any further volcanic activity.

Luckily volcanic activity and earthquakes are largely things of the past for Bermuda as it is now situated in a very stable area of the Earth's crust. However, earthquakes are still possible and the last one occurred on March 24, 1978. It was centred 370 km southwest of Bermuda and measured 5.8 on the Richter Scale. There was no significant damage.

The More Recent Past

The Bermuda described above certainly had rocky coasts at times, but over the time period involved there would have been huge changes in sea level as the climate went through cooling and warming phases. The cooling phases, called ice ages, were times of lowered sea level as water evaporated from the oceans, and was deposited in huge polar ice caps. In warmer times ice caps melted and the sea rose again. Organisms carried in ocean currents would have settled on the basalt shores of ancient Bermuda but would have been repeatedly eradicated, either by being covered in deep water or by being exposed to the air for long periods. We can assume that these old shoreline communities died out and passed nothing on to modern Bermuda.

Summary

Long ago Bermuda probably had black, basalt rocky shores and some black sand beaches. However, the rocks we see along shores today have a fairly recent origin. They result form the deposition by marine reef animals and plants of a very thick layer of limestone, which caps the old volcano. This limestone mainly formed by crustose algae and corals, has been eroded to form sand.

The period which shaped modern Bermuda was about the last 900,000 years. At the start of this time, the world was in the last ice age, known as the **Pleistocene** epoch. The climate was cool but warmer periods also occurred and the southerly location of Bermuda meant that at times sea temperatures were high enough for reefs to form around the edges of the volcano. They probably supported some corals but also a variety of the hard, red seaweeds called **crustose coralline algae**. Crustose coralline algae still build the bulk of Bermudas reefs and can exist in much cooler waters than hard coral. These seaweeds form a very hard layer on the underlying rock because they extract calcium carbonate or lime from the seawater where it is present in large amounts. This calcium carbonate in their tissues makes them hard and protects them from grazing. Over time thick layers of **limestone** are laid down by these algae, corals and other creatures that have coverings or skeletons composed of calcium carbonate. In warmer periods as sea level rose, the top of the Bermuda Seamount would slip slowly beneath the surface but the growth of the crustose coralline algae and corals, a process called **bio-deposition**, would keep pace with rising sea level, so that over time a thick limestone cap developed on top of the basalt of the old volcano. The older, dark, hard basalt was thoroughly coated so that it is now only visible at depths of over 200 m (650 ft) down the sides of the Bermuda Seamount. At least 75 m (240 ft) of limestone was deposited over the basalt.

There were at least four long cycles where the climate alternately warmed and cooled. The cool times would expose the top of the seamount and corals and algae died but were quickly re-established in the warmer periods. During warmer times, the coral laid down in the past was exposed to the actions of a variety of marine organisms that scrape away or burrow into the limestone rock. This process removes rock and creates limestone sand and is called **bio-erosion**. Sand was also created by physical **erosion** resulting from waves, moving rock, wind, rain and gravity. The amount of sand available increased through time until it was very large.

The Last 20,000 Years

Twenty thousand years or so ago the last really cold period began to warm up, and sea level and temperature rose fairly steadily, however, the limestone top of the seamount was exposed to the air along with the limestone sand created previously. The winds were very strong at times, and dry sand was readily blown into hills called **dunes**. At first these formed **mobile dunes** which moved downwind, (See Project Nature - Sandy Coasts for details) but they soon became vegetated by plants whose seeds were carried in the wind or floated on the sea. Others may have come from birds visiting or migrating from the mainland. These dunes were very large, especially round the edge of the then, much larger, island. Over thousands of years, the sand dunes exposed to slightly acid rain were converted to a different type of limestone rock than that laid down by sea creatures, this new rock is called **aeolianite**, a term which means 'formed by the wind'. The process whereby sand is converted to rock is called lithification and takes place when the rainwater dissolves some limestone from the surface of sand grains, to redeposit it again when evaporation results in saturation of the water with calcium carbonate. Aeolianite rock can be considered as fossilized dunes. Where cliffs or road cuttings expose vertical sections of the rock, the surfaces of old dunes can be clearly seen as lines in the limestone. Almost all the limestone rock exposed in Bermuda today is aeolianite. In only a few places can limestone of marine origin can be seen at the surface. Aeolianite, is mostly porous and quite soft and as a result is fairly easily eroded back to sand. The coastlines of Bermuda reflect this ongoing process. Over time headlands where waves impinge with greater force, gradually wear away and the resultant sand is swept into bays, thus with time, coastlines tend to straighten. However, lower areas and those with softer limestone, may form bays as sea levels change and erosion proceeds.

Summary

The last ice age caused a huge lowering of sea level as water was tied up in polar ice. This exposed a much larger Bermuda than we know today to the air. Huge quantities of sand were blown into a large complex of dunes, particularly along the coasts. These dunes later solidified as rainwater converted them to aeolianite rock. It is this aeolinite that forms the great majority of the coastal rocks we see today.

It seems likely that early rocky shorelines tended to be fairly gently sloping, following the contours of coastal dunes, with many fewer cliffs than are seen today. However, on headlands, vigorous wave action, eroded the shore back into higher aeolianite deposits producing steeper higher slopes. In these situations wave action in the intertidal zone cut in to the bottom of the slope, steepening it further. As the profile of the shore, became vertical, forming cliffs, the waves formed an erosional notch at the base called a **wave-cut notch**. Such notches are common on headlands along Bermuda's exposed south shore. This situation is shown in **Figure 1.5**. They weaken the cliff above, which then collapses to produce new cliffs.

Summary

The first limestone coastlines were probably quite gently sloping, following the profile of the old dunes. However, shorelines exposed to heavy waves were eroded at the base to form a wave-cut notch. This notch weakened the rock above which gave way to form, first a low cliff then higher ones as the notch cut further back into the land.

In Harrington Sound, another process results in the formation of cliffs from steep rocky coasts. In sheltered places such as sounds, wave action is light but, in some, a notch still forms. However, in this case, the erosion is bio-erosion resulting from the action of organisms burrowing into the limestone. In this case the main culprit is the Date Clam (*Lithophaga nigra*); the scientific name lithophaga means 'rock eating'. Many other organisms are also involved (See Project Nature, The Ecology of Harrington Sound). These **bio-erosional notches**, as depicted in **Figure 1.6**, may go back many metres into the cliff face and result in large landslides or rock-falls.

In Bermuda, yet another process has resulted in rocky shores and cliffs. To explain this situation we must go back to the action of rainwater on a dune landscape. We have already explained that rain percolating down through the sand can result in the formation of aeolianite. Heavy rain, however, will also run down slopes and disappear underground where the sand or limestone is very porous. Such a situation could, over time, produce caves and underground ponds, some of which were very large. Later, the roofs of some of these collapsed as coastal erosion proceeded to expose them, or surface erosion weakened them. This sequence has produced some coastal rocky shores and cliffs but also those in very sheltered inland, saltwater ponds.

Thus interactions of geology, biology and time have created a huge variety of rocky shores and cliffs in Bermuda, some in places where cliffs would not normally occur.

Summary
In sheltered Harrington Sound, the cliffs were formed by notching too. However, in this case the notch was cut by animals and is called a **bio-erosional notch**.

Summary
In sheltered Harrington Sound, the cliffs were formed by notching too. However, in this case the notch was cut by animals and is called a **bio-erosional notch**.

Erosion of Rocky Shores

If we look back far enough, as explained above, it is certain that the first shoreline of what would become Bermuda was entirely rocky and not only that, but the rock was hard, black basalt very different from the limestone shores we see today. As time progressed and erosion took place, some black sand beaches appeared. Later, however, as we have seen, the black basalt was covered with a layer of almost white limestone entirely derived from **bio-deposition** by marine organisms, both animals and plants. The limestone was more easily eroded than the basalt, both by physical factors such as wave action and by organisms (**bio-erosion**) and great quantities

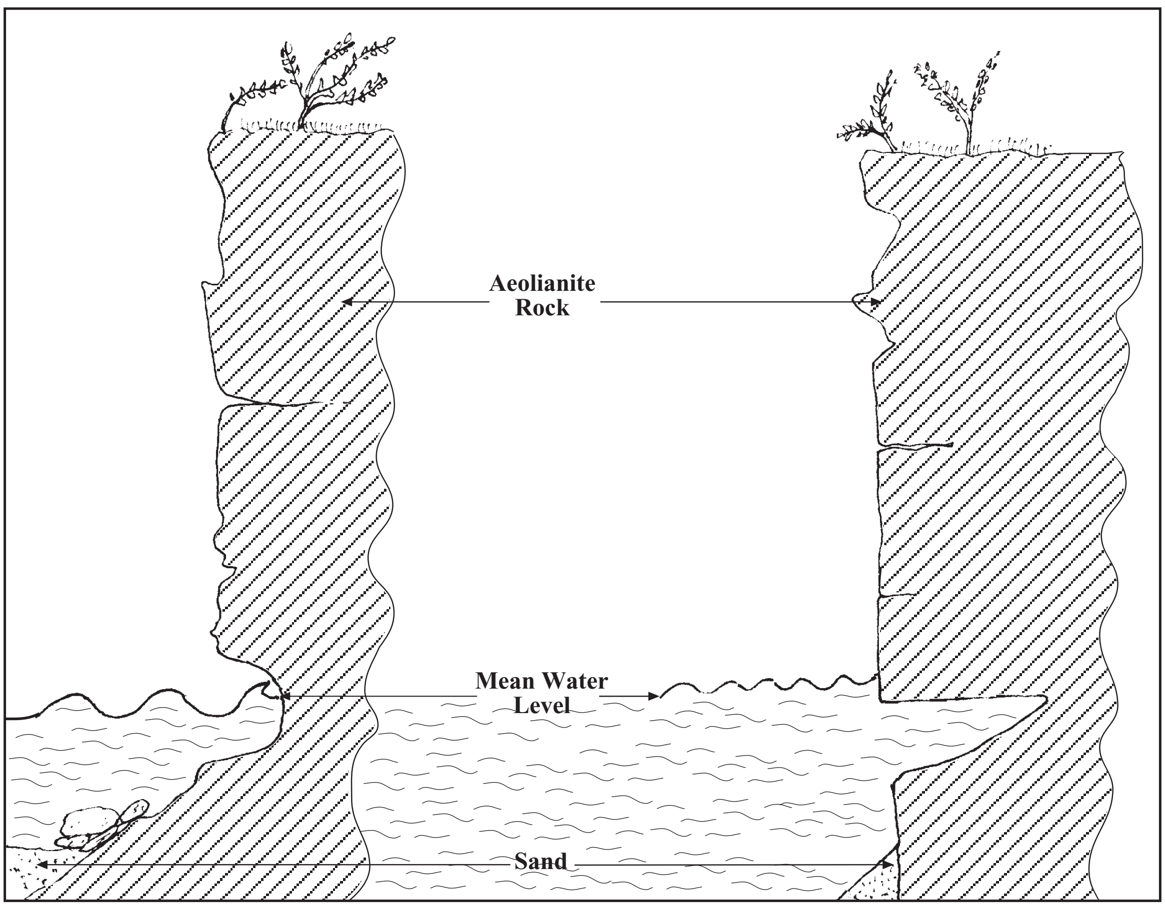


Figure 1.5. Wave Cut Notch (left) typical of the south shore and Bio-erosional Notch as found in Harrington Sound (right). Note the position of mean water level as shown by the wavy line.

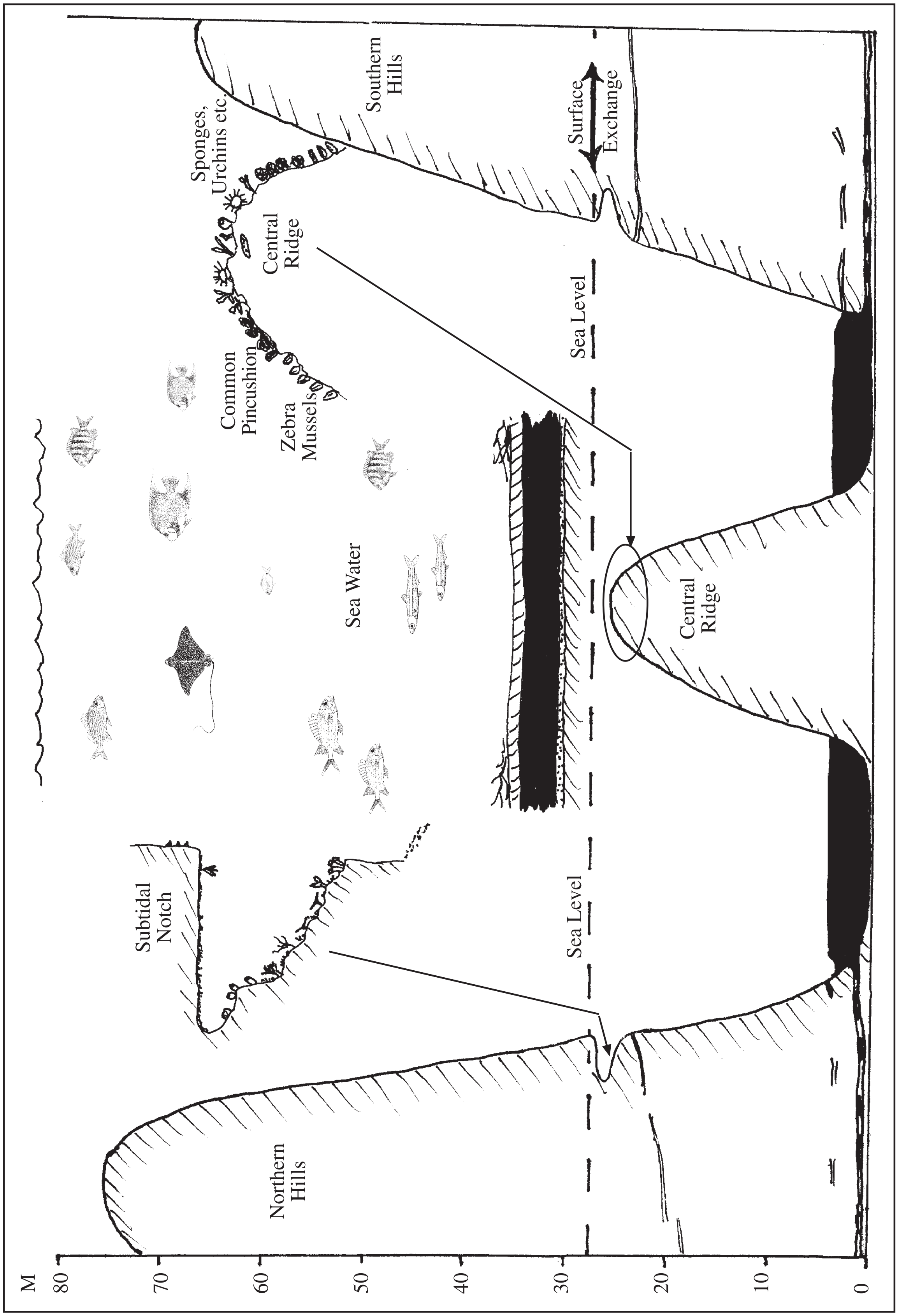


Figure 1.6. Harrington Sound at present.

of limestone sand resulted. Sandy shores became more common, but also new rocky shores were created by the solidification of the sand into **aeolianite** limestone rock which, in turn, was eroded back to sand. Thus there was recycling of sand and rock that is still taking place.

Shoreline physical erosion, as explained above, is mainly concentrated on headlands, where heavy wave action cuts a **wave-cut notch**. Such notches are clearly visible in the intertidal part of headlands along the south shore of Bermuda. In time these notches can become deep enough to weaken the cliff above and it crashes into the sea below. The erosion on headlands produces both sand and rock rubble. Wave action sweeps the sand into bays where it enlarges beaches, it also grids the rock rubble together to produce more sand. Over time headlands are worn back to give a straighter coastline and a higher proportion of sandy shores.

As explained above, bio-erosion by living organisms is also important in the breakdown of limestone rock. In sheltered places, where mechanical wave erosion is minimal, bio-erosion may be the main rock destroying process. It also gives rise to sand and in extreme cases, such as Harrington Sound, it produces a notch in the limestone. However, unlike the wave-cut notches these **bio-erosional notches** are just below low tide level, rather than in the intertidal zone. Nevertheless, like wave-cut notches, they weaken the cliff above which tumbles into the water. However, unlike the exposed cliff situation, the further breakdown of rock rubble is slow and there is no wave action producing currents to sweep the sand away. In this case the sand accumulates on the bottom, beneath the cliff, causing shallowing, and, rather than rocky shore declining it is increased. In Harrington Sound, sandy beaches are very minor features.

Summary

Once formed, rock coasts are subject to continual physical erosion which produces most of the sand found in bays. Exposed coasts such as those on the south shore erode fastest. This slowly reduces headlands and creates a straighter coastline. Coasts are also subject to erosion by animals and plants. Blue-green cyanobacteria erode the shore in the spray zone to produce a spiky rock surface called phyto-karst.

Sheltered outer shores too have only minor wave erosion and bio-erosion is important, particularly just above high tide mark. There **blue-green cyanobacteria** break down the rock surface producing a very spiky rock surface called **phyto-karst**. Sand is created in this erosion, in only small quantities, as the limestone is mostly dissolved away. Bermuda's sheltered shores tend to be mostly rocky, with only limited beaches. This is very evident along the North Shore where the only significant beaches are Shelly Bay and Tobacco Bay. These more sheltered shores along the coasts also tend to be more gently sloping than exposed ones. This is because erosion on sheltered shores is more active above high tide line than between the tide marks. This tends to lower shore level in the upper shore. The reverse is true on exposed shores where the majority of rocky shores are either steeply sloping or cliffs since erosion is more active in the lower, intertidal portion.

Chapter 2. The Open Rocky Seashore

Introduction

There is a group of features that combine to create the essential character of the rocky shores found in Bermuda. Probably the main one of these is the very small tidal range giving a very small vertical distance through which the tide travels. In Bermuda the tide rises, on the average, only 75 cm (2.5 ft) from low water to high water, a range that is typical of oceanic islands. The part of the shore between average low and high tidal levels is the **intertidal zone**. Thus, the intertidal zone on cliffs is only 75 cm in height; on sloping shores, the width of the intertidal zone depends on the slope. If the slope is very slight then the intertidal zone can be quite wide. Normally, however, the average rocky shore in Bermuda slopes quite steeply and the intertidal zone is just a few metres (yards) wide at the most. In contrast to this situation, intertidal zones on mainland shores can be very extensive because there, tidal ranges are much greater and the slope is often much less.

Summary

One of the main factors determining the character of Bermuda's rocky shores is the very small tidal range of 75 cm (2 1/2 ft)Although this is typical of oceanic islands, it is much less than on mainland shores. The soft aeolianite rock also affects the nature of the shore since it is easily eroded and supports bio-erosion.

A second moulding characteristic of Bermudian rocky shores is the nature of the rock. As explained above almost all rock at the surface of the land is **aeolianite**, which is a comparatively soft and easily eroded form of limestone. This makes our seashores vulnerable to damage in storms and more readily eroded, both physically and biologically, than those composed of harder rock. Erosion occurs from wave action and spray, from chemical by-products of living organisms and from the grazing of seashore algae by crabs and fishes. There is, however, another result of the soft limestone and this is the presence of both animals and **cyanobacteria** (formerly called Blue-green Algae) that burrow into the limestone. The commonest animal as we shall see below, burrows partially into the limestone surface and several cyanobacteria species live in the surface layers of the aeolianite. In fact, as will be explored below, the nature of the upper seashore results from the **bio-erosion** caused by one of the cyanobacteria.

Summary

Wind and waves, which determine exposure, are also important in setting the nature of the rocky shore. There are few places in the world that have as great a range of shoreline exposure as Bermuda. The south shore headlands are very exposed whereas some marine ponds have virtually no exposure at all.

Bermudian seashores in common with others in the tropics and sub-tropics, are rich in cyanobacteria. This is partly because of the presence of limestone, but also because cyanobacteria are prevalent on tropical and sub-tropical shores, whereas a variety of **lichens** occupy similar habitats in temperate and cold climates.

The biological effects of exposure to wind and waves will be discussed below, but Bermuda has few equals in the magnitude of this phenomenon. The south shore of Bermuda is not only exposed to waves and swell produced in local storms, but also from storms far to the south, even down into the Antarctic. The south shore is rarely flat calm and has no protection from large tracts of reefs such as occur to the north, west and east. As a result, the south shore can be pounded by huge waves and large ones are common. The result is a very wide (and high) zone that is inundated by sea water or spray. This **littoral zone** is very wide in contrast to the **intertidal zone**; often ten times wider or higher. The result of this is that we do find a wide littoral zone in exposed locations even though the true intertidal zone is very small. Exposure to wind and waves is reduced, compared to the south shore, on Eastern, Western and Northern coasts, but still may be considerable. This is especially true of the north shore lying south of North Lagoon. North Lagoon is wide enough that quite large waves can be generated there in northerly gales.

The range of exposure is further expanded in Bermuda by the series of inland saltwater bodies called sounds and harbours (See Project Nature, "The Ecology of Harrington Sound"), in these places large waves are rare or absent. We can however, also see rocky shores where exposure to wind and wave is virtually nil. This situation occurs in the saltwater ponds of Bermuda (See Project Nature, "Bermuda's Wetlands") some of which have partly rocky shores. Additionally in these ponds, the tidal range is also reduced, in cases to a few centimetres (an inch or so). This produces unique conditions where the intertidal and littoral zones are almost identical in extent and exceedingly small. There are few places in the world that can boast this range of intertidal conditions.

Special Biological Features of the Open Rocky Shore

The rocky seashore has been widely studied throughout the world because it shows beautiful examples of biological features and processes in a very small area. The seashore is best noted for its demonstration of the features of **vertical zonation**. This zonation is a biological response to a changing environment. Mountains are zoned as the climate changes with height, but the zones are wide and often ill defined. In the littoral zone of the sea shore, the marine climate changes so rapidly that the zones are comparatively narrow and very well defined. Such an area of rapid change is called a <u>steep environmental gradient</u>. In addition to showing zonation, the sea shore also shows very marked adaptations of the **biota** (animals and plants) to a very variable environment. Organisms must be able to withstand immersion in sea water as well as exposure to the air and the drying that brings. Their environment is alternately wet and dry. Rainy weather at low tide, in calm weather, results in the **salinity** (amount of salt in water) dropping, sometimes to near zero. Temperature too is variable and may change suddenly. Exposed to the hot sun at low tide, inhabitants of the shore can get very hot, however, this suddenly changes to much cooler seawater temperature when the tide comes in. Littoral organisms on exposed shores must be able to withstand enormous pressures in breaking waves. Many are beautifully adapted to avoid being preyed upon or grazed away.

Summary

Of all the ecosystems in the world the rocky shore shows the best example of vertical zonation or horizontal banding of communities. This results from the very different environmental conditions with increasing height above the low tide level.

Tide pools are partially to fully insulated from the variability of the open shore and will be dealt with in a separate chapter.

The Main Changing Characteristics or Variables

<u>The Tides</u>

There is no doubt that the main environmental variable on the shore is the tide.

Tides are a universal feature of the oceans. Tides are really very long waves and result from the gravitational pull of the heavenly bodies on the envelope of seawater around the Earth. In effect the gravitational force of the moon pulls a bulge of seawater towards it and causes a second bulge on the opposite side of the Earth. These bulges follow the moon around the Earth. Since the duration of the moon's orbit is 24 hrs 50 min, both the crests of the waves, which are high tide, will pass each point in the ocean at this interval. Thus the time between successive high tide times should be 12 hrs 25 min. The only ocean

Summary

Tides result from the gravitational pull of the moon and the sun. There is a high tide every 12 hrs 50 min. At 14-day intervals tides have a larger range; these are **spring tides** and small range tides called **neap tides** follow 7 days later. Tides can be predicted and their time and height is published in the newspaper.

on Earth that has tides exactly following the path of the moon is the Southern Ocean. This is because it is the only ocean that is continuous around the planet. In the other ocean basins, just as currents are modified by the land masses so are tides. Nevertheless most places have regular high tides at close to 12 hours and 25 minute intervals. Low tides occur halfway between highs. This is especially true of oceanic islands such as Bermuda.

The only other heavenly body other than the moon that has an appreciable effect on the tides is the sun. At 14-day intervals, the sun and the moon are roughly in line and their gravitational forces combine to produce tides of a larger range. Tidal range is the height difference between high and low water levels. These higher tides at fortnightly intervals are called **Spring Tides**. Seven days after spring tides the sun has negligible effect and the tidal range is at its minimum. These smaller tides are called **Neap Tides**. Since the orbits of the heavenly bodies are highly predictable, so are tides. This allows the production of tide tables for any point on Earth that predict the time and height of each tide. Tide predictions in Bermuda are published in the newspaper and also available as yearly sets looking something like a calendar. The average tidal range in oceanic localities such as Bermuda is about 75 cm (2.5 ft); this increases to about a metre (3.2 ft) on spring tides and decreases to about 50 cm (1.6 ft) on neap tides. These tides are small compared to the average for continental shores and are quite easily altered by the weather both in timing and range. Nevertheless, the tides are amazingly regular; this is very important to organisms along the shore since it is a virtual certainty that a high tide will follow a low in a reasonable time. Occasionally, large changes in the atmospheric pressure pattern around Bermuda do occur and at some of these times the tide remains low for days at a time. This can result in high mortalities in intertidal organisms.

<u>Waves a Big Modifying Factor</u>

The other factor on the shore that moves water up and down is the waves. Additionally, waves place mechanical stress on seashore creatures and they must be adapted to withstand wave action. Think about the Bermudian situation. Here tides average 75 cm or about 2.5 ft. On the south shore waves can be at least 5 m (l5 ft) high in storms. So regardless of the tide the whole shore will be alternately exposed to air and submerged in water by the waves. Clearly too, wave action can extend well above tidal action. The effect of waves is to extend the marine environment higher up the shore. In the most exposed places the littoral zone may be <u>10 times as wide</u> as in the most sheltered.

Summary

Waves modify the effect of tides by driving water and spray to higher levels. The more exposed the shore is, the more the effect. The higher the exposure on shores the higher the zones extend vertically.

<u>Tide and Wave Related Variability on the Rocky Shore</u>

The main environmental stress to exposed shoreline organisms that results from the tides and waves is desiccation or drying. Virtually all animals and plants of the open rocky shore, except at the very top, have evolved from marine ancestors. They are used to immersion in water and desiccation imposes a severe stress that these organisms must adapt to. The mechanisms of these adaptations will be explored below. Marine seashore organisms in tidal pools are insulated from this effect.

A second significant stress faced by littoral marine organisms is **salinity** variation. When animals and plants are immersed by tide or wave, they are usually in full strength seawater which around Bermuda is about 36-38 ‰ (parts per thousand of salts in the water). [For more information on seawater see Project Nature “The Open Ocean Around Bermuda”, or Project Nature “A Teaching Guide to the Biology and Geology of Bermuda”.] However, if it is pouring rain and the tide is out on a calm day, the shore salinity may drop to close to zero.

Summary

Many other environmental factors vary with tidal and wave conditions. Organisms are adapted to withstand this variability. Factors that vary greatly in comparison to the sea are; temperature, salinity, pH, oxygen and carbon dioxide levels etc.

Temperature is another major variable. When immersed, the temperature is that of the coastline water, which varies through a range of perhaps 12°C-25°C on an annual basis. However, when exposed, the range can be much greater. Air temperatures vary through at least 5°C to 30°C and high temperatures on the open shore surface are greatly increased by solar heating. Dark objects may reach at least 45°C!

Other environmental factors that vary with tide and wave action are pH (acidity), light intensity and concentrations of gases important to life, including oxygen and carbon dioxide. However, these variations are minor compared to those above.

Adaptation to Open Rocky Shore Conditions
There are three basic ways in which organisms from the sea have adapted to life on the open rocky seashore, these are physical adaptation, behavioural adaptation and physiological adaptation.

Physical Adaptation
This category involves changes in structure to allow life above low tide level. The main variables requiring extensive adaptation are desiccation and wave action. Adaptation to these often gives protection from most of the more minor variables also.

Summary
Adaptation to life on the open rocky shore are in three categories; physical, behavioural and physiological adaptation.

Physical adaptation to slow desiccation almost always involves some form of tough outer body coating. So many littoral animals have tough heavy shells that are impermeable to water. Perhaps the best examples are the snails and bivalved molluscs of the shore, but crustaceans such as the barnacle have adapted in this way too. Some of the snails can also seal the shell opening with a horny disc called the **operculum** while others fit tightly to one spot on the shore. As an extreme example, the Corroding Worm Shell (*Dendropoma annulatus*), the commonest inhabitant of most rocky open, intertidal shores has a shell that is at least half buried in the limestone of the shore; it also has an operculum. It also lives on boiler reefs (See Project Nature “Coral Reefs”) where wave pounding is extremely violent. This type of adaptation automatically confers resistance to waves and spray but in that case a very solid attachment also helps. Some animals such as the barnacles are firmly cemented to the rock while others have a large, strong, adhesive foot. Some anchor the shell rim to the rock with a secretion. Seashore crabs are adapted to resist waves by firmly hanging on with tough claws. In the case of the seaweeds physical adaptation to wave action involves a tough, flexible plant body, that can move with the water, combined with a very firm attachment often called a **holdfast**. Some shells such as the barnacles are also whitish to reflect sunlight and keep cooler, however, many intertidal animals, such as the Scorched Mussel (*Brachidontes domingensis*) are jet black. They must be physiologically adapted to very high temperatures.

Summary
Physical adaptation is seen in heavy strong shell, tenacious attachment to the rock, part burial in the rock, very strong claws and a very firm attachment, or holdfast, in shoreline seaweeds.

Behavioural adaptation
Behavioural adaptations are often easy to see. Many seashore organisms move into crevices when exposed or live there all the time. Periwinkle snails combine this behaviour with physical adaptation; Onchidella Slugs (*Onchidella floridana*), small sea slugs of the open shore are particularly highly adapted, they leave the crevice shelter in groups when conditions are right and return the same way. If threatened they can spray a foul tasting liquid. Limpets such as the Keyhole Limpet (*Fissurella barbadensis*) and Say’s False Limpet (*Siphonaria alternata*) return to a home base, to which they fit perfectly, after a foraging expedition. Scorched Mussels, Red Anemones (*Actinia bermudensis*) and Flat Rock Oysters (*Isognomon*

Summary
Behavioural adaptation to littoral life involves such things as hiding in crevices, homing to a secure place, living in depressions and rapid wave avoidance.

radiatus) settle in crevices or depressions as larvae and stay there all their adult lives. Crevices confer protection both from desiccation and wave action. Another behavioural adaptation seen in the Sally Lightfoot Crab (*Grapsus grapsus*) is the avoidance of heavy waves. As a large wave approaches, they rapidly move into shelter, as they do if a predator approaches. Mind you they can hang on in the open in some pretty vicious waves. The periwinkles of the shore, such as the Zebra Periwinkle (*Littorina ziczac*) and the Beaded Periwinkle (*Tectarius muricatus*) feed only when the exposed shore is wet, for instance at night, in light rain or in fog. At the very bottom of exposed shores, the Burrowing Rock Urchin (*Echinometra lucunter*), excavates groove-like tunnels in the rock where it lives sheltered from wave action.

Physiological Adaptation

Almost all physical and behavioural adaptations to open rocky shore life, are combined with physiological measures. Indeed for the seaweeds, physiological adaptation is the main method. Most littoral seaweeds are able to withstand extreme drying, so much so that they can become quite brittle. However, when re-wetted they take up water and resume growth with scarcely a pause. Some animals such as the Red Anemone can also lose a lot of water but not to the extent of the seaweeds. Other physiological adaptations involve resistance to very high temperatures, lowered salinity etc.

> **Summary**
> Physiological adaptation can not be seen but involves such things as resistance to extremes of littoral factors, the ability to withstand extreme water loss.

Zonation

The Causes of Zonation

As stated above vertical **zonation** results from a rapid change in the environment with a change in elevation. The main environmental factor that changes on the shore is exposure to the air. Animals and plants can occupy higher shore levels if they are adapted in some way to the conditions there. The bottom of the shore is most like the sea and inhabitants do not need a high level of adaptation to desiccation. Those with the highest level of adaptation can extend higher up the shore in some cases into levels only exposed to occasional salt spray. Because only a few species are very highly adapted to shoreline conditions, biodiversity decreases with height up the shore.

> **Summary**
> **Zonation** results from the sorting out of animals and plants according to their level of adaptation. Those marine organisms highly adapted to the effects of exposure are at the top of the shore.

The Main Features of Zonation

To understand the names given to the zones. We must understand a scientific term, namely littoral. Littoral basically refers to the zone between high and low tides, the intertidal, plus the area above that regularly wetted by waves, splash or spray.

On the shore, there is a series of defined zones, within, above and below the intertidal. You might expect zones to be defined on a physical basis but this is not so. Animals and plants on the shore are the best indication of actual conditions, so they have been used to indicate the zones. The features of rocky shore zonation have much in common on a world-wide basis and as a result, certain groups of animals and plants are used as boundary markers everywhere. This leads to some problems here since one of these groups is missing.

> **Summary**
> There are four **zones** on the shore, two wide and two narrow. The narrow ones are fringes. The zone boundaries are marked by certain animals and plants.

Figure 2.1 shows the zones for a location where wave action is minimal. Think of it as a cliff in a very sheltered bay. In this scheme, in general, narrow zones are called fringes and wider ones zones.

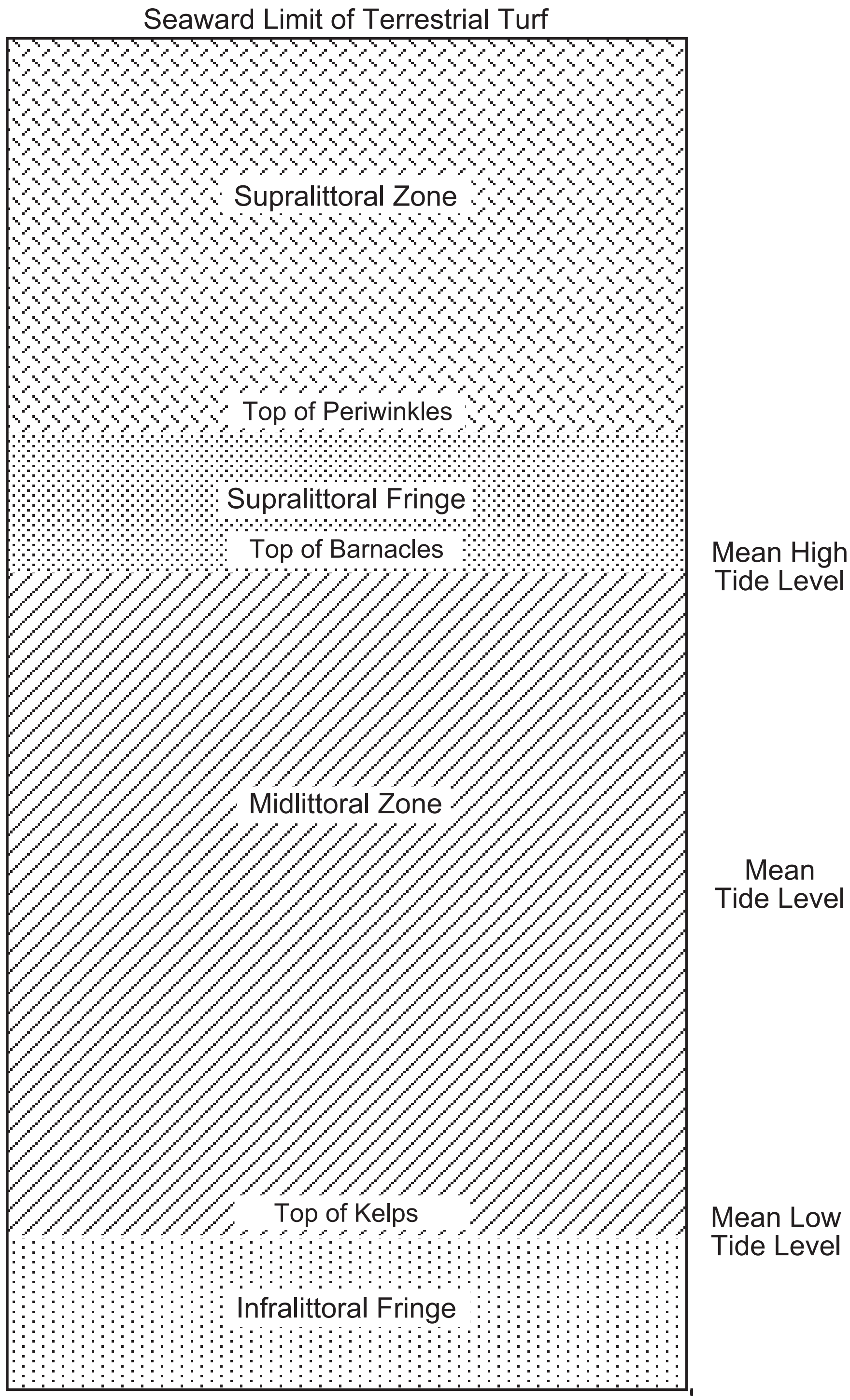


Figure 2.1 Standard world-wide rocky shore zones in relation to tidal level for a fairly sheltered location.

The Effect of Wave Action on Zonation

The basic effect of wave action in increasing the height of the marine influence on the open rocky shore has been discussed above. In terms of the zones, wave action broadens the zones. The effect is most marked in the supralittoral fringe and supralittoral zone. In a sheltered location, the midlittoral zone will rise to high tide level or about 75 cm (2.5 ft) above low tide level. In the most exposed locations, for example Stonehole Head on the South Shore, the midlittoral zone rises to about 170 cm (5.5 ft) above low tide level. However the supralittoral zone which commences at about 80 cm (2.7 ft) above low tide level in shelter, rises to at least 750 cm (24.5 ft) above low tide level in extremely exposed locations, this is about a ten-fold increase! The effect is best shown diagrammatically as in **Figure 2.2**. This diagram shows an extremely exposed location and a sheltered one. Note the extension of the supralittoral zone top to a height equivalent to ten times the tidal range.

Summary

Waves drive water higher up the shore than tides and in doing so cause a great increase in zone height particularly in the upper littoral zones.

The Zones and their Characteristic Organisms

The Infralittoral Fringe

The bottom zone, the infralittoral fringe, is the most marine and the most stable; it is a very narrow zone. It would (in the absence of waves) only be exposed to the air for a few days, on spring tides, every two weeks. This zone has great diversity, very similar to the subtidal rocky shoreline. However, it is in looking for the top of this zone that we encounter a major difficulty. Bermuda has no true kelps or oar weeds , the top of which is the internationally recognised boundary for this zone. We must use something else, on the south shore the Burrowing Rock Urchin will do. Elsewhere, in more sheltered locations, as along the north shore, the Large Tube Shell (*Serpulorbis decussatus*) is useful. Along parts of the south shore, the very large, black-and-white snail, the West Indian Top Shell (*Cittarium pica*), also marks this zone. If you see any corals on the shore they will be in the infralittoral fringe. However, due to wave action and the infrequency of spring tides this zone is normally at least partially submerged and difficult to study. In very sheltered locations it is virtually non-existent. A wide variety of just sub-tidal seaweeds are possible but the Jamaican Petticoat (*Padina jamaicensis*) is frequently present.

Summary

The lowest **zone**, the infralittoral fringe is most like the sea. Diversity is very high. The top of the zone is marked by the uppermost extent of either urchins, large tube shells or corals.

The Midlittoral Zone

The next zone is a wide one, the midlittoral zone extends from the top of the infralittoral fringe to the top of barnacles. Barnacles are crustaceans but as adults they are permanently attached to the rock. They are an excellent zone marker because they must be immersed in seawater for a reasonable amount of time every day to feed and breed. However, they are superbly adapted to intertidal life and exist as high as they can on the shore. Everywhere in the world some kind of barnacle has colonised shores to the same level, approximately the average high tide level in shelter. In Bermuda on exposed shores, the Common Barnacle (*Chthamalus angustitergum*) is characteristic; in more sheltered locations the Striped Barnacle (*Balanus amphitrite*) is almost always common.

Summary

The **midlittoral zone** is wide and is the main part of the shore totally immersed in seawater at high tide in calm weather. The top of the zone is the upper limit of barnacles and the characteristic organisms are a mat of low red seaweeds and the Corroding Worm Shell. The diversity is quite high including many snails.

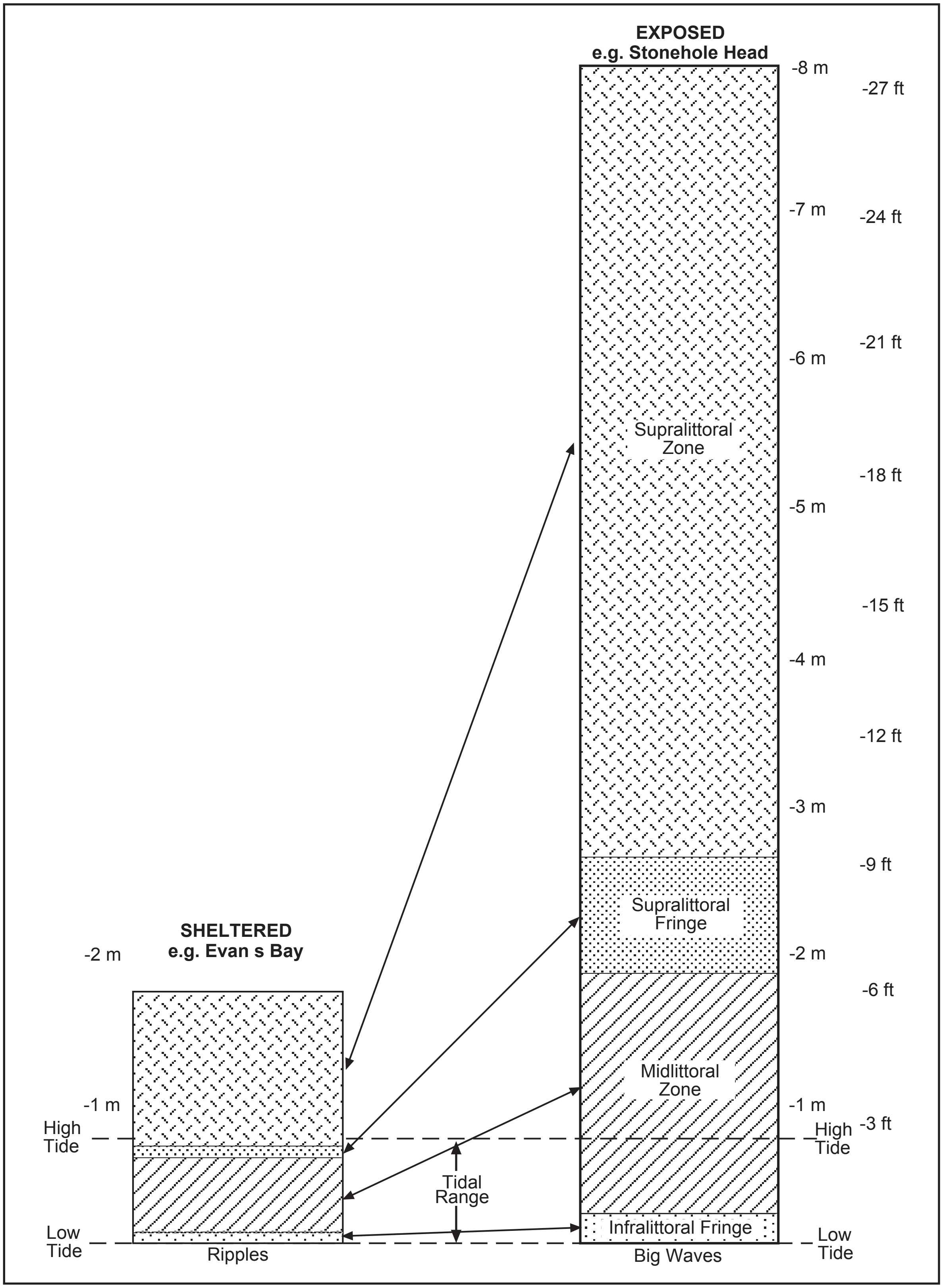


Figure 2.2 The extent of rocky shore zones compared for a sheltered and very exposed location to show zone widening in exposed situations.

This zone is one where change occurs rapidly and it is frequently subdivided into lower, mid and upper sub zones. Barnacles are characteristic of the top of the zone but do not occupy all of it. The animal most characteristic of the entire zone at a very wide range of exposures is the tiny Corroding Worm Shell. This is a snail that is, as explained above, cemented into the top of the rock. It cannot move. It relies on the waves and tides to bring it food as it is a **filter feeder** (Filter feeders obtain their food by filtering organic particles out of the water). This zone is also covered in a thin mat of seaweed consisting of several species chiefly in the group of polysiphonous red seaweeds (*Polysiphonia* and *Herposiphonia* species). Polysiphonous, simply means that under a microscope they appear to be composed of a group of tubes arranged side-by-side. Generally, they appear yellowish in colour due to bleaching by sunlight. They are eaten (grazed) as fast as they grow by a variety of animals. Frequently small patches of what, at first, appears to be oil are present as well as very small black tufts of hair-like filaments, these are both forms of the same species the Oilspot Blue-green (*Calothrix crustacea*). Also common in this zone are two limpets, the Keyhole Limpet (*Fissurella barbadensis*) and Say's False Limpet (*Siphonaria alternata*), the West Indian Chiton (*Chiton tuberculatus*) and several species of Nerita snails. The commonest of these are the Tessellated Nerite (*Nerita tessellata*) and the Variegated Nerite, (*Nerita versicolor*). The Red Anemone (*Actinia bermudensis*) retracted as a blood-red dome is sometimes very common, but usually absent. The same applies to the small black sea slug. Many other species of animals and plants occur there but less commonly.

The Supralittoral Fringe

Above the midlittoral zone lies the supralittoral fringe another narrow one. This zone is only immersed in water at spring tides in sheltered locations. Inhabitants may be exposed to the air for nearly two-week stretches in calm weather. It is the zone of the periwinkles and stops at their upper limit. There is a problem in that periwinkles are mobile shells and move with the weather, going higher when it is damp. Despite this, they are a reasonable zone indicator. In Bermuda four different periwinkles occupy this zone. Three of them are common, the Prickly Winkle (*Nodilittorina tuberculata*), the Beaded Periwinkle (*Tectarius muricatus*) and the Zebra Periwinkle (*Littorina ziczac*). In this zone, particularly in crevices protected from grazing, one should also see small patches of a small dark red, fuzzy seaweed, the Stiff Sea Moss (*Bostrychia binderi*) and the rock will be blackened by the blue-green cyanobacterium, Hofmann's Scytonema (*Scytonema hofmanni*).

Summary

The **supralittoral fringe** is a narrow zone and the main habitat of periwinkles. Their upper limit is the top of the zone. One red seaweed and black **cyanobacteria** are characteristic.

The Supralittoral Zone

Above the supralittoral fringe is the supralittoral zone, usually the widest zone of all. It is often called the <u>splash or spray zone</u>; it is only wetted by storm waves or spray. It is the least marine of the zones and unlike those below it, tends to be colonised by terrestrial plants adapted to partly marine conditions. However, marine species such as the Sally Lightfoot Crab feed here. This zone is characteristically black owing to the presence of the blue-green cyanobacterium Hofmann's Scytonema (*Scytonema hofmanni*), also seen in the supralittoral fringe. This species is the food of the Sally Lightfoot crab. Look for scrape-like grazing marks of this crab in this zone; the crab takes the cyanobacterium and a thin layer of rock. This is an example of **bio-erosion** as well as feeding. Another good example of bio-erosion is provided by Hofmann's Scytonema itself. This cyanobacterium lives partly within the rock and dissolves it away. This leaves a very rough jagged rock surface (Phyto-karst) in the supralittoral zone (see Chapter 1). Several land plants adapted to salty conditions also live in this zone. The commonest

Summary

The **supralittoral zone** can be very wide in exposed places. Few marine creatures can live in this zone as it is almost terrestrial. Its top is marked by a growth of shrubs, trees or grass. Animals and plants, other than **cyanobacteria**, are few and those that are present are highly adapted terrestrial organisms.

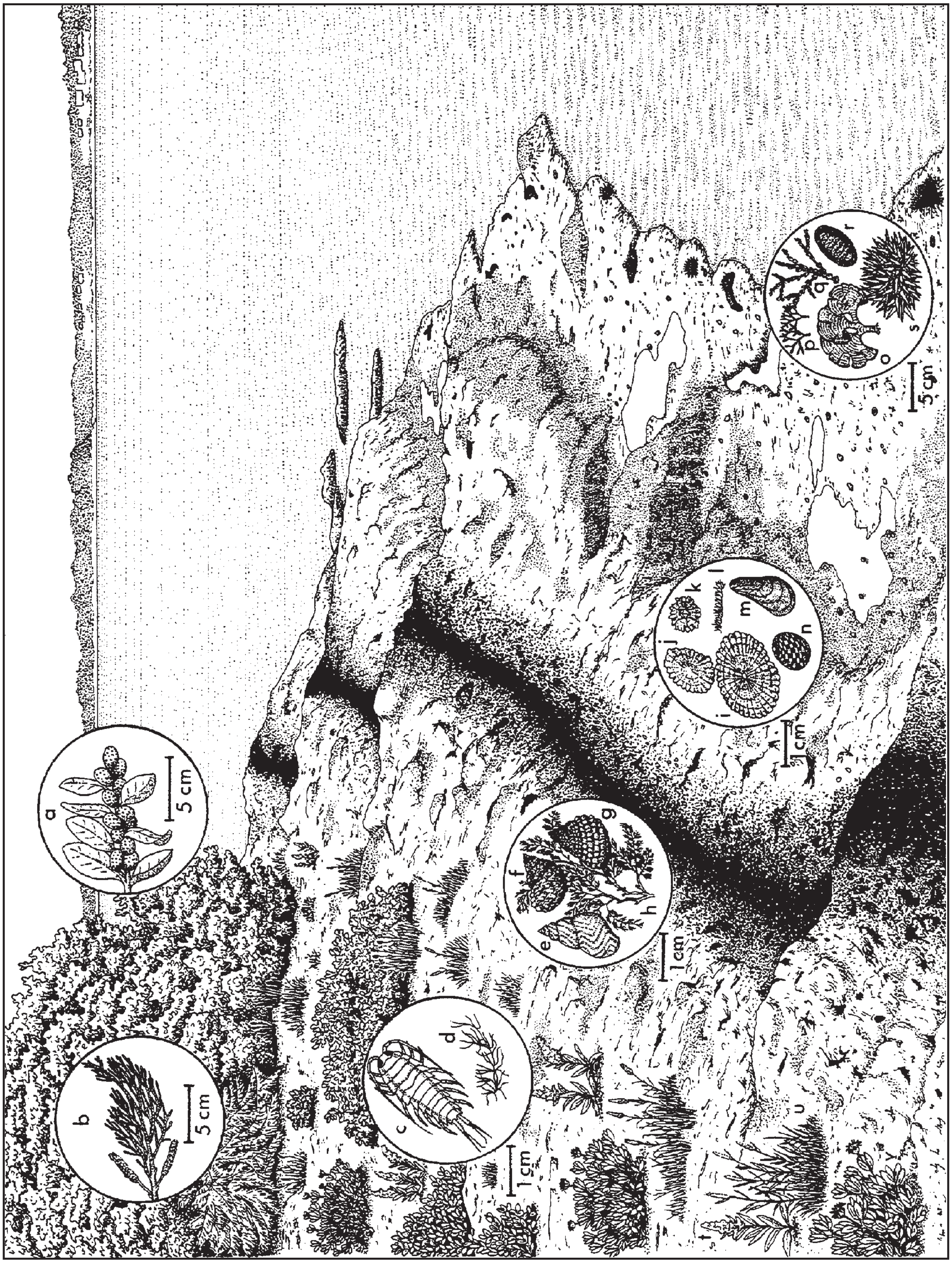

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Figure 2.3. A typical rocky shore zonation in Bermuda for a moderately sheltered sea shore. The prominent organisms for each zone are shown in insets.

Key to Figure 2.3

a Buttonwood
b Tamarisk
c Wharf Louse
d Hoffman's Scytonema
e Zigzag Periwinkle
f Prickly Winkle
g Beaded Periwinkle
h Stiff Sea Moss
i Keyhole Limpet
j Say's False Limpet
k Common Barnacle
l Low Siphonweed
m Scorched Mussel
n Tessellated Nerite
o Jamaican Petticoat
p Pointed Needleweed
q Laurence's Tufted Weed
r West Indian Chiton
s Burrowing Rock Urchin
t Seaside Goldenrod
u Seashore Rush Grass
v Sea Oxeye

is Coast Spurge, (*Euphorbia mesembrianthemifolia*) but the Sea Oxeye (*Borrichia arborescens*) is frequent as is the Seaside Goldenrod (*Solidago sempervirens*). In moderately sheltered locations such as the north shore, the Tamarisk (*Tamarix gallica*) frequently spreads out over this zone, although it is rooted higher up. If any grass is present it will be the Seashore Rush Grass (*Sporobolus virginicus*). However, the zone has very low diversity and low abundance of larger organisms, an unusual combination, reflecting ultra-hard conditions for life. This zone ends where a turf of land grasses or herbs begins. Almost all soil entering this zone is washed away in storms leaving the bare rock.

A typical example of intertidal zonation in Bermuda together with the main indicator species and other common inhabitants is shown in **Figure 2.3**.

Grazing on the Open Rocky Shore

It has been emphasised above that the low quantity and small size of seaweeds on the rocky shores of Bermuda is the result of heavy grazing by a great variety of organisms both vertebrate and invertebrate. Most of this grazing occurs when the tide is high, but the process is also active on damp days and nights at all stages of the tide.

<u>Vertebrate Grazers</u>

The vertebrate grazers are mainly fish and they have to be immersed in water to feed, because of this, they affect mainly the intertidal zone. They tend not to venture into breaking waves as some of the invertebrates do. The main group of fishes that graze along rock shores are the Parrotfishes. Parrotfishes are a diverse group in Bermuda with at least 10 common species. Of these, the Blue Parrotfish (*Scarus coeruleus*), the Midnight Parrotfish (*Scarus coelestinus*), The Princess Parrotfish (*Scarus taeniopterus*), the Queen Parrotfish (*Scarus vetula*), the Rainbow Parrotfish (*Scarus guacamaia*), the Redband Parrotfish (*Sparisoma aurofrenatum*), the Redtail Parrotfish (*Sparisoma crysopterum*), the Stoplight Parrotfish (*Sparisoma viride*) and the Striped Parrotfish (*Scarus croicensis*) all feed along rocky shores at times, at some stage of their life history. They feed by scraping away the algae along with some of the rock with their strong, parrot-like mouths. They are important bioeroders and sediment producers. Evidence of Parrotfish feeding on rocky shores can often be seen as numerous double, parallel, straight scrape marks about 1 cm (1/2 in) long.

The other group of fishes often seen feeding along rocky shores even in heavy wave action are the Surgeonfishes consisting of the Blue Tang (*Acanthurus coeruleus*), the Doctorfish (*Acanthurus chirurgus*) and the Ocean Surgeonfish (*Acanthurus bahianus*). This group of fishes tend to feed more selectively than the Parrotfishes, nipping off exposed parts of intertidal animals. They leave no obvious grazing marks.

Summary

Grazing is a very active process on the open rocky shore. Most grazing takes place at high tide through the action of Parrotfish and Surgeonfish. Grazing also results from the feeding activities of littoral snails, slugs, chitons and crabs.

<u>Invertebrate Grazers</u>

There are many invertebrate grazers on rocky shores including sea urchins, crabs, chitons and snails. Some of these graze to very high levels compared to the fish. That with the widest grazing zone of all is probably the Sally Lightfoot crab. This crab is common on all moderately exposed shores and will graze well above the water as long as the shore is damp. One of its favourite foods is the blue-green cyanobacterium Hofmann's Scytonema. It tends to leave wavy lines of numerous short graze marks. Most of the other invertebrate grazers feed in specific zones. In the infralittoral fringe of exposed shores the Burrowing Rock Urchin grazes within its elongate, trough-like burrow, keeping it virtually seaweed free. Slightly higher, the West Indian Chiton (*Chiton tuberculatus*) grazes on the algal mat and on some southern shores the West Indian Top Shell (*Cittarium pica*) also grazes in this zone. The main midlittoral zone grazers are the three Nerita species detailed above and in the supralittoral fringe the Periwinkles of the three species mentioned earlier, graze. In damp weather they may extend their feeding well into the supralittoral fringe. They tend to leave very convoluted trails of tiny scrape marks. Several other species of snails and slugs may also graze but are not common.

Predation on the Open Rocky Shore
Grazers as described above are principally **herbivores**, or animals that eat plants, however, grazing tends to be a rather indiscriminate process and undoubtedly some animal material is consumed too. In fact the Surgeonfish group although grazers are almost pure carnivores.

Summary
Predation activity is quite low on rocky shores, but, one snail and some birds are important.

The other carnivores that visit the littoral zone are almost all visitors, rather than residents, however, the rather rare snail, the Rusty Whelk (*Thais rustica*) is a resident predator that eats barnacles periwinkles and other snails. It get a around the problem of the thick tough shells by boring a hole, through which it sucks out its prey. At low tide a few terrestrial birds such as the Great Kiskadee (*Pitangus sulphuratus*) and the Yellow-crowned Night Heron (*Nyctanassa violacea*) are often seen foraging on rocky shores. What they actually eat there is not known. At high tide the shore is open to predatory fishes, but the tough shells and crevice-hiding habits are quite effective protection.

Chapter 3. Tide Pools or Rock Pools

Introduction
Pools formed in depressions in the rocky littoral zone are variously called tide pools, tidal pools or rock pools. None of these names is fully accurate since the pools are not necessarily in the intertidal zone but rather in the littoral zone. They can exist as high on the shore as sea water can reach under normal circumstances. The term 'rock pools', does not show their dependence on the sea.

Tidal pools are much more stable than the open, well-drained shore because they retain water and therefore the great difficulties imposed by **desiccation** are normally avoided. Tidal pools are also by their very nature depressions in the rock and this gives protection from wave action particularly if pools are fairly deep. However, do not assume that all tidal pools are easy places to live; like the open shore, they have a gradient of environmental stress which increases with height on the shore.

Those pools in the intertidal portion of the littoral zone are the most stable and as a consequence they show high biodiversity. Those up to the level of high neap tide level, are usually filled with new sea water on every tide. Although higher examples, in calm weather, may heat up somewhat when exposed to the sun, or dilute somewhat in torrential rain, they are essentially like a piece of the infralittoral fringe with a few added sub-tidal inhabitants. Pools above the high neap tide level are much more variable. In calm weather, they range from having sea water addition at about 8 day intervals to having such addition every 14 days. Pools in the latter category, lie up to the level of high spring tide level.

Summary

Tide or rock pools form in depressions in the rocky shore. They retain water as the tide goes out and are much more stable than the open shore as desiccation is not a factor. Intertidal pools are the most stable and have high biodiversity. Higher pools are less stable and very high ones support little life.

Of course there are many pools above the intertidal zone but they can only receive water from waves or in splash or spray, or the odd unusual tide. These are the most variable pools of all. On exposed coastlines, such as the south shore of Bermuda lower examples may get pretty regular splash or spray additions. However, in calm spells they are isolated and small ones may even dry up. Higher up, pools may go for weeks or even months without fresh seawater addition. Such pools are the most unstable of all and tend to be hyper-saline (higher in salinity than the sea) most of the time, which means they are saltier than the sea. In intense prolonged rain, however, they may totally fill with freshwater. The range of salinities is therefore from close to 0‰ to that of saturated salt solution. They also tend to get very hot in summer and cool in winter. Such variability makes them very difficult habitats for living organisms and only a few very tough examples are found there.

Below, tidal pools will be treated in three categories, high, mid-level and low.

Tidal Pool Fauna and Flora

<u>High Tidal Pools</u>
Very high pools are almost devoid of organisms as conditions are too variable to support life, however, if anything is present, it will probably be one of the very diverse group of **cyanobacteria** found in Bermuda.

A little further down, where some splash and/or spray comes at reasonably regular intervals, the pools often support large populations of the False Cerith (*Batillaria minima*), a small dark, elongate snail also common on some sheltered shores and inlets. Frequently present at the water line there may be Say's False Limpet (*Siphonaria alternata*) which graze down into the pools, and onto surrounding rocks when they are wet. If any seaweeds are present they are likely to be filamentous in nature. The commonest one in these pools is the Green Cushionweed (*Cladophoropsis membranacea*) which may form mats in sheltered pools and tufts in exposed ones. Sometimes tubular green seaweeds the Smooth Sea Intestine (*Enteromorpha lingulata*) may occur in quiet pools along with Thin Sea Lettuce (*Monostroma oxyspermum*) and Common Sea Lettuce (*Ulva lactuca*) both of which form thin bright green fronds. These green seaweeds are very tolerant of the addition of freshwater to pools.

Summary
High tidal pools support few species. Cyanobacteria only occupy the highest but somewhat lower ones often have green seaweeds, and possibly some limpets and snails.

<u>Mid level Pools</u>
These pools show a striking resemblance to the midlittoral zone but organisms can exist in them at higher levels than they do on the open shore. Deeper ones through which water drains often have large populations of Say's False Limpet with a few Keyhole Limpets (*Fissurella barbadensis*) and numerous Corroding Worm Shells. Among the fish, the Blenny known as the Molly Miller (*Scartella cristata*) is common in many pools while the Notchtongue Goby (*Bathygobius curacao*) inhabits others and tiny, very charming Sergeant Majors (*Abudefduf saxatilis*) are sometimes observed. The Bleeding Tooth Nerite (*Nerita peloronta*) can sometimes be seen in deeper, shaded pools even though it is quite rare and has been subject to collection. The Red Anemone (*Actinia bermudensis*) is also present in some pools as is the Scorched Mussel (*Brachidontes domingensis*). Seaweeds in these mid-level pools are typically encrusting coralline species of red seaweeds (Crustose Coralline Algae) which form extensive light pink, hard layers on the rock and on mollusc shells. There may also be patches of a blood-red encrusting species as yet unidentified.

Summary
Mid level pools show many similarities to the shore around them. Several fish species frequent these pools as do snails such as the nerites. Other inhabitants include anemones and Scorched Mussels. Sheets of pink crustose algae are common.

<u>Low Level Pools</u>
The lowest pools show the highest biodiversity of all the pools and may include a few just subtidal corals such as the Golf Ball Coral (*Favia fragum*), the Rose Coral (*Isophyllia sinuosa*) and the Lesser Starlet Coral (*Siderastrea radians*). Two of the nerite snails, the Tessellated Nerite (*Nerita tessellata*) and the Variegated Nerite (*Nerita versicolor*) often occur in large clusters at the pool edges. The The Dwarf Cerith or Horn Shell (*Cerithium lutosum*) is often common on the bottom and dead shells of this species may be occupied by the Tricolor Hermit Crab (*Clibanarius tricolor*). On more sheltered shores the Large Tube Shell (*Serpulorbis decussatus*) may be found attached to the pool bottom, its empty tubes may be occupied by the endemic Verrill's Hermit Crab (*Calcinus verrilli*). The fish mentioned above are also present.

The seaweeds of these lower pools can be quite varied but as they are heavily grazed at high tide most examples are small or chewed off. Pointed Needleweed (*Amphiroa fragilissima*) is quite common as is Laurence's Tufted Weed (*Laurencia papillosa*). The Banded Threadweed (*Ceramium byssoideum*) occurs from time to time. As with mid level pools Crustose Coralline Algae (Several species) are commonly encrusting the rocky bottom in a thin, hard sheet.

Summary
Tidal pools near to the bottom of the shore support very similar inhabitants to the sea just below low tide level. As a consequence biodiversity is very high.

Chapter 4. Coastal Cliffs

Introduction

At first glance one might think that cliffs, being highly inaccessible, would be a habitat of negligible importance in the overall ecology of Bermuda. However, a moment's reflection shows that this is not true. The very inaccessibility of cliffs is important since birds can find nesting sites there which predators from the land cannot reach. Additionally, very steep rather than sheer cliffs, although more accessible, are unsuitable for development as building sites and difficult to walk along. Because of this, they are a refuge for endemic and native plants. Indeed Abbotts Cliff, in Harrington Sound, is a park and a treasure trove of endemic and native plants. It is targeted for the removal of invasive and introduced species and may become a nature reserve. One other point in favour of sheer cliffs is that they show off geological features wonderfully well and in many places show unique fossil deposits.

Summary

Although cliffs are very inaccessible they are an important habitat particularly for nesting White-tailed Tropic Birds. Less sheer cliffs support many endemic and native plants. Cliffs also display key geological features.

The Sheer Rock Habitat

Animal Habitats

Sheer cliffs may descend either into seawater or down to land. Those going into seawater support an array of marine life close to water level. The littoral area of cliffs show all the features described for rocky shores above. If cliffs descend into water that is below low tide level, they support a huge diversity of marine life. Walsingham Pond and Harrington Sound have such cliffs and the diversity of life on them is amazingly high as described in Project Nature "Bermuda's Wetlands".

Cliffs above the water present natural nesting sites for several birds. Before the arrival of man in Bermuda, the main occupant of holes and crevices on the cliffs, was the White-tailed Tropic Bird or Longtail (*Phaethon lepturus*). These nesting sites were very secure until man arrived, but man introduced rats, cats and Pigeons or Rock Doves (*Columba livia*). The predators raided the nests taking eggs and/or fledglings and the Pigeons competed for nest sites. These pressures on the breeding of Longtail or White-tailed Tropic Birds resulted in the decline of the population. To alleviate this situation the Bermuda Audubon Society has encouraged the use of artificial nesting cavities made of concrete. These look like, and have been dubbed, igloos, since they are hemispherical in shape. They are quite successful. Cliffs also support colonies of Honey Bees (*Apis mellifera*), which have escaped from captivity.

Summary

Underwater cliffs support a huge diversity of life in Harrington Sound and Walsingham Pond. Above water cliffs are the nest sites of White-tailed Tropic Birds some of which have been claimed by Rock Doves, reducing the reproductive success of the White-tailed Tropic Birds or Longtails.

Plant Habitats

Sheer coastal cliffs above high tide level offer only limited habitats for plants, nevertheless, some do grow there. Probably the most frequent stunted trees are Buttonwoods (*Conocarpus erectus*) which can survive in very windswept locations with virtually no soil. Also quite frequent are small Casuarina or Whispering Pines (*Casuarina equisetifolia*) an introduced species which can

Summary

The plant life of cliffs includes several hardy species which gain a hold on ledges and in crevices. Buttonwood in its stunted form is common as are small Casuarinas. Coast Spurge is quite common as is Seaside Goldenrod.

take hold on small ledges. In addition one might find the odd specimen of Coast Spurge (*Euphorbia mesembrianthemifolia*), Seaside Goldenrod (*Solidago sempervirens*) and more commonly Sea Oxeye (*Borrichia arborescens*) which can extend an amazing distance down cliffs. Occasionally, one finds specimens of the Iodine Bush (*Mallotonia gnaphalodes*), the Tassel Plant (*Suriana maritima*) and Coast Sophora (*Sophora tomentosa*) at the very top of cliffs.

Steep Rocks and the Life They Support

Most steep rock surfaces are on the coast, since inland ones that once existed have become grown over and the rock lies under a layer of soil. These have mainly become forested over time and their inhabitants are described in Project Nature, “The Bermuda Forests”.

Along exposed rocky coasts, there are often considerable expanses of almost bare rock, where any soil that accumulates is likely to get swept away in violent storms. The soil in these places is confined to cavities and crevices and there a sparse flora of very tough plants ekes out an existence. These areas are part of the supralittoral fringe and were described above. The only inhabitant of the surface of the bare rock is Hofmann’s Scytonema (*Scytonema hofmanni*), a very tough blue green cyanobacterium. The characteristic flowering plant is the Coast Spurge, but Seaside Goldenrod and Sea Oxeye are frequently present and Spanish Bayonet (*Yucca aloifolia*) and Prickly Pear (*Opuntia stricta*) are occasional inhabitants. Almost no animals reside on these rocky slopes but Sally Lightfoot crabs (*Grapsus grapsus*) may venture up from the sea under wet conditions and Land Crabs (*Gecarcinus lateralis*) and Bermuda Skinks (*Eumeces longirostris*) may come down from above. Additionally a variety of insects from the land can be seen there.

Summary

Steep bare rock slopes along the coast are a harsh **habitat** but support blue-green cyanobacteria and a few hardy plants such as Coast Spurge. Sally Lightfoot crabs feed on these slopes when they are wetted by salt spray.

Steep rocky coasts that are not quite cliffs can support an amazing variety of life including many rare and endangered species. The sheer difficulty of access has provided some protection for these species although invasive introduced species do occur there too. Abbotts Cliff in Harrington Sound is the best example of this habitat and in the future it will have the invasive plants removed and probably become a nature reserve.

Questions

1) What is zonation? ______________________________

2) What is the difference between the intertidal zone and the littoral zone? ______________________________

3) Name the four rocky littoral zones starting at the bottom.

   A) ______________ B) ______________

   C) ______________ D) ______________

4) What is Phyto-karst? ______________________________

5) Name the group of animals recognised throughout the world, which defines the top of the midlittoral zone. ______________________________

6) Which zone are periwinkles characteristic of? ______________________________

7) Since oarweeds are absent in Bermuda, how do we find the top of the infralittoral fringe? ______________________________

8) What biological process results in the very low turf of seaweeds in the intertidal zone? ______________________________

9) Name two groups of fishes that graze on the shore at high tide.

   A) ______________ B) ______________

10) Give an example of a physical adaptation to littoral life. ______________________________

11) Give an example of a behavioural adaptation to littoral life. ______________________________

12) Give an example of a physiological adaptation to littoral life. ______________________________

13) Name one snail that grazes in the midlittoral zone. ______________________________

14) What is an example of an animal that acts as a rocky shore predator? ______________________________

15) Why is wave action critical in setting the heights of the littoral zones? ______________________________

16) What is the most critical variable that results from the rise and fall of the tides? ______________________________

17) Why do tidal pools contain animals at higher shore levels than they are found on the open shore? ______________________________

18) Corals might be found in one intertidal habitat. Which would that be?

____

19) Name two places on the rocky shore where you might find the Red Anemone.

A) ____________________ B) ____________________

20) Which two types of tidal pool might support crustose coralline seaweeds?

A) ____________________ B) ____________________

21) What is one way that cliffs are created? ____________________

22) Why are cliffs more common on the south than the north shore? ________________

23) What is the difference between a wave-cut notch and a bio-erosional notch?

____

24) In what inland salt-water body can you find a bio-erosional notch? __________

25) What are the common names of two birds that nest in cliff holes?

A) ____________________ B) ____________________

26) What are some of the factors that threaten nesting success in the White-tailed Tropic Bird? ____________________________________

____

27) What are the names of two plants that you might find on cliffs or steep rocky shores?

A) ____________________ B) ____________________

28) What is the name of the rock that composes cliffs in Bermuda? ________________

29) Name two animals, other than birds, that you might find on cliffs or steep rocky shores?

A) ____________________ B) ____________________

List of Species Mentioned and/or Illustrated in this Guide

Key to Habitat Codes

B	= Lagoons, Bays and Coastal Waters	OC	= Open Coastal
C	= Coral Reefs	R	= Rocky Shores
SD	= Sand Dunes	F	= Forest
SP	= Saltwater Ponds	U	= Urban Environments
M	= Mangrove Swamps and Salt Marshes	W	= Wasteland, Open Spaces, Wayside

Note: Common names are listed in the first column except where there is no accepted common name, in these cases the scientific name is used. For each group of organisms, the common names are in alphabetical order. The habitat codes defined in the key before the list show where the organisms are commonly found. The illustrations following this list are in the same order as the list and are also accompanied by habitat codes.

Common Name	Scientific Name	Taxonomy	Habitat Code
Hofmann's Scytonema	Scytonema hofmanni	Blue-green Cyanobacteria	R
Oil-spot Blue-green	Calothrix crustacea	Blue-green Cyanobacteria	R
Common Sea Lettuce	Ulva lactuca	Seaweeds - Green Algae	B, R
Green Cushionweed	Cladophoropsis membranacea	Seaweeds - Green Algae	B, M
Smooth Sea Intestine	Entermorpha lingulata	Seaweeds - Green Algae	R
Strap Sea Lettuce	Ulva fasciata	Seaweeds - Green Algae	B
Thin Sea Lettuce	Monostroma oxyspermum	Seaweeds - Green Algae	R
Jamaican Petticoat	Padina jamaicensis	Seaweeds - Brown Algae	B
Banded Threadweed	Ceramium byssoideum	Seaweeds - Red Algae	B, C
Crustose Coralline Algae	Lithothamnion spp., Lithophyllum spp.	Seaweeds - Red Algae	B, C
Laurence's Tufted Weed	Laurencia papillosa	Seaweeds - Red Algae	B
Low Siphonweed	Herposiphonia secunda	Seaweeds - Red Algae	R
Pointed Needleweed	Amphiroa fragilissima	Seaweeds - Red Algae	B, C
Stiff Sea Moss	Bostrychia binderi	Seaweeds - Red Algae	R
Seashore Rush Grass	Sporobolus virginicus	Grasses	OC, R
Coast Spurge	Euphorbia mesembrianthemifolia	Herbaceous Flowering Plants	R
Prickly Pear	Opuntia stricta	Herbaceous Flowering Plants	OC, W
Sea Oxeye	Borrichia aborescens	Herbaceous Flowering Plants	OC
Seaside Goldenrod	Solidago sempervirens	Herbaceous Flowering Plants	OC
Spanish Bayonet	Yucca aloifolia	Herbaceous Flowering Plants	OC, SD, W
Coast Sophora	Sophora tomentosa	Shrubs	R
Iodine Bush	Mallotonia gnaphalodes	Shrubs	OC, SD
Tassel Plant	Suriana maritima	Shrubs	OC, SD
Buttonwood	Conocarpus erectus	Trees	M, OC
Casuarina, Australian Whistling Pine or Whispering Pine	Casuarina equisetifolia	Trees	F, OC, W
Tamarisk	Tamarix gallica	Trees	F, OC
Golf Ball Coral	Favia fragum	Corals	B, C
Lesser Starlet Coral	Siderastrea radians	Corals	C, SP
Red Anemone	Actinia bermudensis	Anemones	R
Honey Bees	Apis melifera	Insects - Bees	U, W

Common Barnacle	Chthamalus angustitergum	Crustacea - Barnacles	C
Striped Barnacle	Balanus amphitrite	Crustacea - Barnacles	R
Tricolor Hermit Crab	Clibanarius tricolor	Crustacea - Hermit Crabs	R
Verrill's Hermit Crab	Calcinus verrilli	Crustacea - Hermit Crabs	C
Land Crab or Red Land Crab	Gecarcinus lateralis	Crustacea - Crabs	OC
Sally Lightfoot Crab	Grapsus grapsus	Crustacea - Crabs	R
Wharf Louse	Ligia baudiniana	Crustacea - Isopods	R
West Indian Chiton	Chiton tuberculatus	Chitons	R
Keyhole Limpet	Fissurella barbadensis	Gastropoda - Limpets	R
Say's False Limpet	Siphonaria alternata	Gastropoda - Limpets	R
Onchidella Slug	Onchidella floridana	Gastropoda - Sea Slugs	R
Beaded Periwinkle	Tectarius muricatus	Gastropoda - Snails	R
Bleeding Tooth Nerite	Nerita peloronta	Gastropoda - Snails	R
Corroding Worm Shell	Dendropoma annulatus	Gastropoda - Snails	C, R
Dwarf Cerith or Horn Shell	Cerithium lutosum	Gastropoda - Snails	B
False Cerith	Batillaria minima	Gastropoda - Snails	B, M
Large Tube Shell	Serpulorbis decussatus	Gastropoda - Snails	R
Prickly Winkle	Nodilittorina tuberculata	Gastropoda - Snails	R
Rusty Whelk or Rustic Rock Shell	Thais rustica	Gastropoda - Snails	R
Tessellated Nerite	Nerita tessellata	Gastropoda - Snails	R
Variegated Nerite	Nerita versicolor	Gastropoda - Snails	R
West Indian Top Shell	Cittarium pica	Gastropoda - Snails	R
Zebra Periwinkle	Littorina ziczac	Gastropoda - Snails	R
Black Date Mussel	Lithophaga nigra	Clams and Mussels	B, C
Flat Rock Oyster	Isognomon radiatus	Clams and Mussels	R
Scorched Mussel	Brachidontes domingensis	Clams and Mussels	R
Burrowing Rock Urchin	Echinometra lucunter	Echinoderms - Sea Urchins	C, R
Sergeant Major or Cow Polly	Abudefduf saxatilis	Fish - Damselfishes	B, C
Molly Miller	Scartella cristata	Fish - Blennies	R, SP
Notchtongue Goby	Bathygobius curacao	Fish - Gobies	R, SP
Blue Tang	Acanthurus coeruleus	Fish - Surgeonfishes	B, C
Doctorfish	Acanthurus chirurgus	Fish - Surgeonfishes	B, C
Ocean Surgeonfish	Acanthurus bahianus	Fish - Surgeonfishes	B, C
Blue Parrotfish	Scarus coeruleus	Fish - Parrotfishes	B, C
Midnight Parrotfish	Scarus coelestinus	Fish - Parrotfishes	B, C
Princess Parrotfish	Scarus taeniopterus	Fish - Parrotfishes	B, C
Queen Parrotfish	Scarus vetula	Fish - Parrotfishes	B, C
Rainbow Parrotfish	Scarus guacamaia	Fish - Parrotfishes	B, C
Redband Parrotfish	Sparisoma aurofrenatum	Fish - Parrotfishes	B, C
Redtail Parrotfish	Sparisoma crysopterum	Fish - Parrotfishes	B, C
Stoplight Parrotfish	Sparisoma viride	Fish - Parrotfishes	B, C
Striped Parrotfish	Scarus croicensis	Fish - Parrotfishes	B, C
Bermuda Skink	Eumeces longirostris	Lizards	F, OC
Pigeon or Rock Dove	Columba livia	Birds - Doves	F, R, U, W
Great Kiskadee	Pitangus sulphuratus	Birds - Flycatchers	F, U, W
Yellow-crowned Night Heron	Nyctanassa violacea	Birds - Herons	F, M, SP
White-tailed Tropic Bird	Phaethon lepturus	Birds - Tropic Birds	B, CL, O

Species Illustrations and Descriptions

Blue-green Cyanobacteria

Hofmann's Scytonema
Scytonema hofmanni
This species is very important in sediment formation but is not seen on sandy bottoms. It forms the black zone at the top of rocky shores and is characterised by a spiky surface to the rock. Spikes up to 12 cm (5 in) high. **Native**.

R

Oilspot Blue-green
Calothrix crustacea
This blue-green cyanobacterium of just above high tide mark and the upper intertidal may appear in at least two forms. The first is just like a jet-black heavy oil spot, the second a fuzzy, very small black mound up to about 4 mm (3/16 in) high. **Native**.

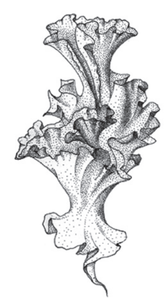
R

Seaweeds

Green Algae

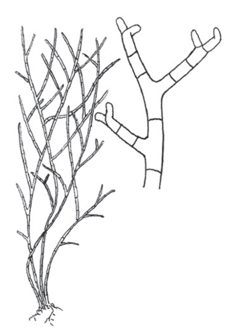
Common Sea Lettuce
Ulva lactuca
This bright green seaweed consists of one or a group of very thin sheets. The length is commonly up to about 10 cm (4 in) although in very calm, nutrient-rich locations it can be much larger. On the rocky sore it stays small and is found in damp hollows and tidal pools. **Native.**

B, R

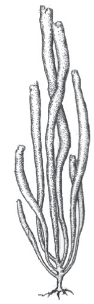


Green Cushionweed
Cladophoropsis membranacea
This is a very tiny, usually only 1 cm (1/3 in) high filamentous green seaweed that grows as a mat on the bottom among seagrasses, or out in the open. All that can be seen are the bright green tips of the filaments protruding from a soft layer of sediment. The bottom is usually slightly raised where it occurs. **Native**.

B

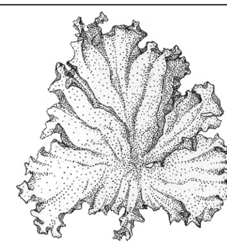


Smooth Sea Intestine R
Enteromorpha lingulata
this small bright green seaweed grows to about 6 cm (2 1/2 in) high. Although this is difficult to see, each branch of the seaweed is really a tube, only obvious if a bubble is trapped. This plant is found in tidal pools and near to low tide level. **Native.**



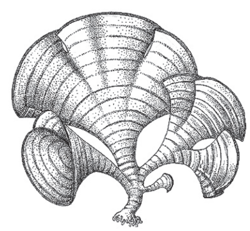
Strap Sea Lettuce R
Ulva fasciata
A soft, flat green seaweed often found on the roof of the notch. The elongated blades may divide and reach about 15 cm (6 in). **Native.**

Thin Sea Lettuce B, R
Monostroma oxyspermum
This alga consists of a very thin film of dark green tissue up to 10 cm (4 in) across. Delicate and easily torn it is a plant of very sheltered saltwater locations such as the ponds. **Native.**



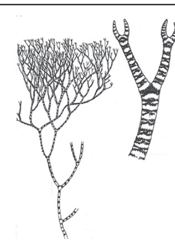
Brown Algae

Jamaican Petticoat B
Padina jamaicensis
This is a brown, fan shaped seaweed about 10-15 cm (4-6 in) high. The fan is generally banded with lighter zones reflecting the light calcification present. Widely common. **Native**.

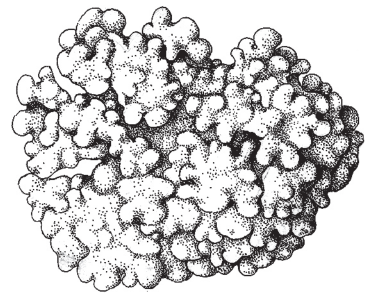


Red Algae

Banded Threadweed B, C
Ceramium byssoideum
A small red, threadlike seaweed, generally looking like pink turf or small clumps. Microscopically, the characteristic red-banded appearance shows up. Grows to 10 cm (4 in) high. **Native**.

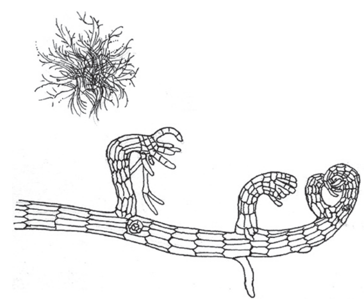


Crustose Coralline Algae **B, C**
Lithothamnion spp., *Lithophyllum* spp.
These algae are the main rock-builders of the coral and algal-vermetid reefs. They form smooth to knobby sheets of pale pink, rock hard algae. However, they may be hidden by a thin overgrowth of turf-like red seaweeds. These species can create very large expanses of growth and all are highly resistant to both wave action and heavy grazing. Very variable in size, commonly to 30 cm (1 ft) across. **Native.**

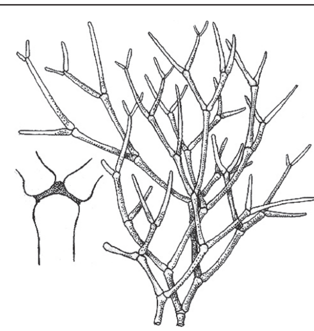


Laurence's Tufted Weed **B**
Laurencia papillosa
This is one of a group of Laurence's Weeds that grow as small tufts about 10 cm (4 in) tall. The greenish stems divide repeatedly but have characteristic knobby ends with a red tip. These plants are quite common on reefs protected from violent wave action. **Native.**

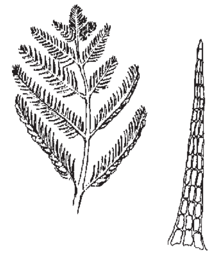
Low Siphonweed **R**
Herposiphonia secunda
As the common name suggests, this is a small seaweed. It is typical of wave-washed rocky shores and boiler reefs. It appears as a low reddish-yellow fuzz that is frequently grazed down to resemble velvet. Never more than 2 cm (3/4 in) high, it is usually only a few mm (1/10 in) tall. **Native**.



Pointed Needleweed **B, C**
Amphiroa fragilissima
This common alga is heavily calcified with calcium carbonate and a light pink in colour. The hard, thread-like branches divide repeatedly and evenly. In quiet areas it may form bush-like growths 15 cm (9 in) high, but on reefs it is usually part of the low turf dominated by Siphonweeds. **Native.**



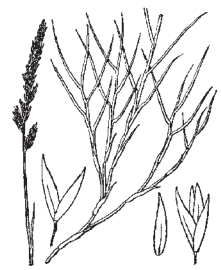
Stiff Sea Moss
Bostrychia binderi
A generally purple to black red alga that may bleach to yellowish in intense sunlight. Generally only about 2 cm (3/4 in) high this seaweed is commonly found in small depressions in the upper intertidal zone. **Native**.



R

Grasses

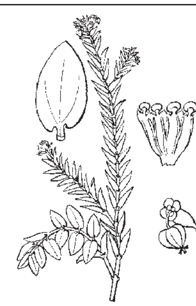
Seashore Rush Grass
Sporobolus virginicus
This is a fairly low trailing grass of partly salty places. The stems are stout, firm and scaly rising above the soil. The narrow 4 mm (1/8 in) wide leaves are numerous, and their basal sheaths overlap. About 40 cm (15 in) high. **Native.**



OC, R

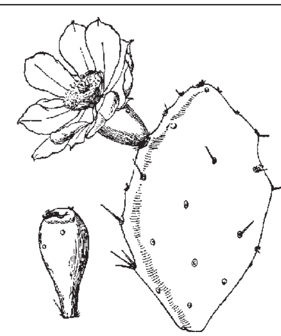
Herbaceous Flowering Plants

Coast Spurge
Euphorbia mesembrianthemifolia
This plant of the supra-littoral fringe of the rocky coast grows along the rock surface or is found in small depressions. The leaves are small and arranged along the sides of the stem. The flowers are minute and yellowish. 1-3 cm (1/2-1 1/2 in) high. **Native.**



R

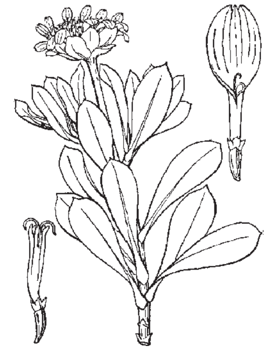
Prickly Pear
Opuntia stricta
This cactus with oval pads can hardly be mistaken for anything else. The pads up to 12 cm (5 in) long form bushes or clumps up to 1 m (3 ft) high. The spines are stout and sharp and the flowers a showy yellow. The pear-like fruits are a magenta-red when mature and very tasty. **Native.**



OC, W

OC

Sea Oxeye
Borrichia arborescens
Also native, the sea oxeye is a shrubby herb seen very commonly along Bermuda's rocky shoreline. It is variable in height, sometimes growing low to the ground and sometimes reaching 1.5 m (4 ft) or so in height. The colour of its leaves can also vary between grey and green, often on the same plant. It bears single, yellow, daisy-like flowers at the top of the stem, throughout most of the year. **Native.**

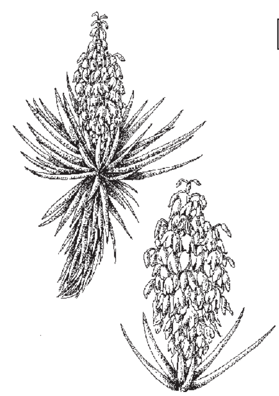


OC

Seaside Goldenrod
Solidago sempervirens
This herbaceous plant has an exceedingly wide geographic distribution and occupies a wide range of habitats. The stem is stout with the long leaves closely arranged around the stem. The stem is crowned by a long flower head with very numerous, small yellow flowers, each daisy-like in appearance. Flowers in summer and autumn. About 70-100 cm (2-3 ft) high. **Native.**

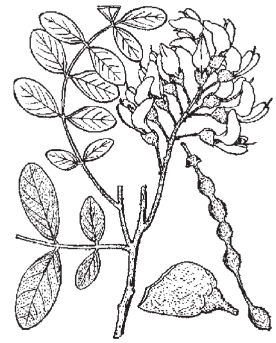
OC, SD, W

Spanish Bayonet
Yucca aloifolia
Easily recognizable by its long, needle-like leaves, this is a plant seen very commonly along the south shore of Bermuda. It has very thick, fleshy leaves often with serrations along the edges. The flowers are white, growing on spikes of about 70 cm (2 ft) in length which appear from spring to autumn. These flowers are pollinated by night-flying moths. When not in flower the plant grows to 3m (10 ft). **Native**.



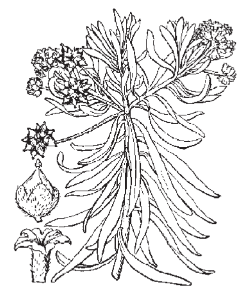
Shrubs

Coast Sophora
Sophora tomentosa
A tall shrub with a woody stem, the sophora has leathery leaves covered with downy hairs and forming pairs along the stem. The flowers, which occur from summer to spring, are most often yellow, sometimes white or even purple and similar to those of the pea family. They form pods rather like peapods after flowering. 90 cm to 2.7 m (2.5-9 ft) in high. **Native**.



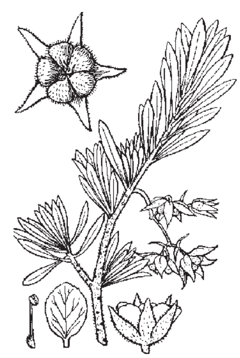
R

Iodine Bush
Mallotonia gnaphalodes
A low-growing native shrub, the bay lavender has numerous long fleshy leaves which are covered in downy hair. The flowers which grow up through the centre of the leaf cluster are white and bell-shaped, appearing from spring to autumn. To 90 cm (3 ft) high. **Native.**



OC, SD

Tassel Plant
Suriana maritima
A shrub of sandy coasts often growing in dense thickets. It has clustered leaves and varies in height from the low-growing to fairly tall. The leaves are soft in texture and covered with fine, silky hairs. The yellow flowers, appearing mostly from spring to autumn, are protected by "tassel-like" leafy clusters giving the plant its name. 1.5-2 m (4-6 ft) high. **Native**



OC, SD

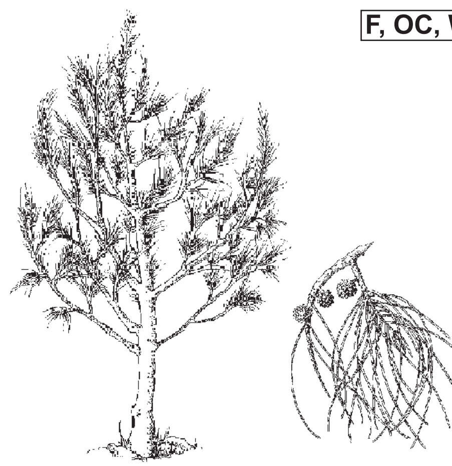
Trees

Buttonwood
Conocarpus erectus
A tree which does not live up to its "erectus" name since some specimens in exposed places are sprawling or even ground hugging. A tree of very varied height. Sometimes considered a mangrove, it is common as the rear tree of mangrove swamps or forming fringing stands along sheltered coasts. The leaves are oval, fairly broad and leathery and have two little keels on either side of the leaf stalk. The flowers are white fuzz-balls and the fruit small cone-like structures, turning red when mature. Height from a few cm (in) to 6.5 m (20 ft). **Native.**

M, OC

Casuarina, Australian Whistling Pine or **Whispering Pine**
Casuarina equisetifolia
Casuarina is a shallow rooted tree. It resembles a conifer but the "pine needles" are segmented branchlets about 1 cm.(3/8 in) long with tiny leaf scales appearing at the segments. The branchlets appear in sprays. There are separate male and female flowers. The female flowers produce a prickly cone with tiny winged seeds. This fast growing tree was planted in large numbers during the 1940s, following the Bermuda Cedar blight. Grows from 10-25 m (30 to 80 ft) high. **Introduced.**

F, OC, W

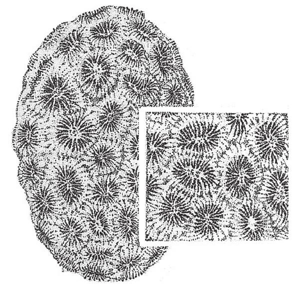


Tamarisk
Tamarix gallica
A small tough tree or large shrub, typical of windswept shorelines and very common along the North shore. It is also found bordering ponds and scattered in other habitats. The branches are arching and the leaves small and scale-like. The attractive pink flowers appear in sprays. It is often called "spruce". Up to about 5 m (15 ft) high. **Introduced**.

F, OC

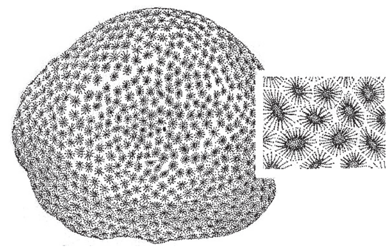
Corals

Golf Ball Coral
Favia fragum
While this coral is not very common it is easy to spot, because in this case the common name is very descriptive. The coral colony takes the form of a ball like structure 2.5-5 cm (1-2 in) across. It has comparatively large polyps and may be found on reef flanks or shallow cavities. **Native**.



B, C

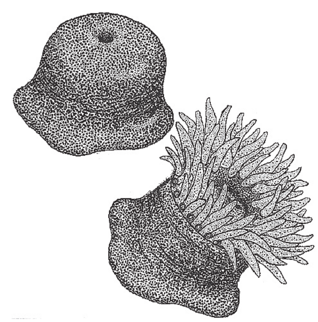
Lesser Starlet Coral
Siderastrea radians
The Lesser Starlet Coral is smaller than the Massive Starlet Coral and lives in shallower water. It may even be seen on rock surfaces in Walsingham Pond. Usually 20 cm (8 in) across. **Native**.



C, SP

Anemones

Red Anemone
Actinia bermudensis
Anemone with a low dark red to brownish column and more highly coloured tentacles. When the tide is out it is always contracted to a red hemisphere. It is found in crevices in the midlittoral zone of exposed rocky shores and under stones intertidally. Base up to 4 cm (1 3/4 in). **Native**.

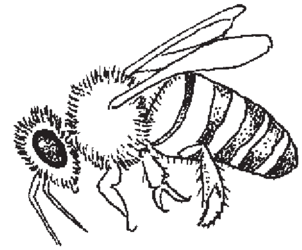


R

Insects

Bees

Honey Bee
Apis mellifera
There are approximately 500 colonies of bees kept on Bermuda. In addition there are many wild hives in such places as hollow trees and vents in buildings. There are three castes in a hive: one queen and small number of drones (males) and as many as 80,000 workers (sterile females). 1.5 cm (1/2 in) long. **Introduced**.



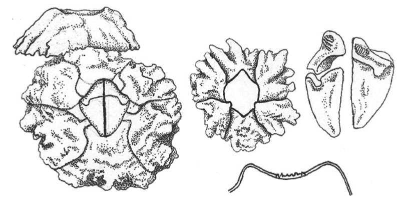
U, W

Crustacea

Barnacles

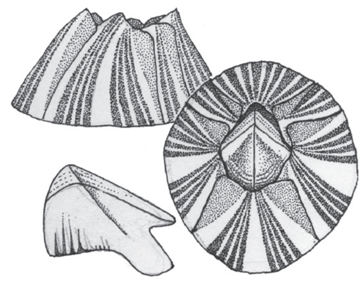
C

Common Barnacle
Chthamalus angustitergum
This barnacle is a dull white in colour. There are six plates in the conical shell. This is the common species of exposed shores and is often abundant. Its upper limit marks the top of the midlittoral zone. Up to 1 cm (3/8 in) across. **Native**.



R

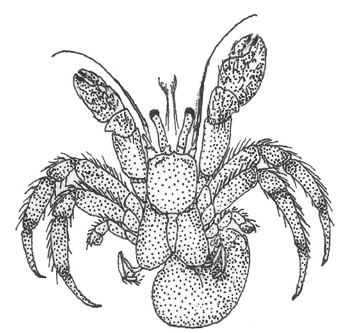
Striped Barnacle
Balanus amphitrite
This barnacle, common on rocky shores occurs at near to high tide level. It is conical with stripes running up the sides of the cone. The opening at the top can be closed with four plates. Up to about 1 cm (3/8 in) in diameter but usually much smaller. **Native.**



Hermit Crabs

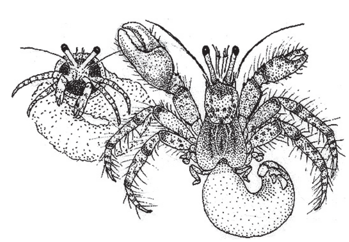
R

Tricolor Hermit Crab
Clibanarius tricolor
This crab can be found in the shallow water of tide pools, protecting its soft abdomen by living inside a borrowed shell abandoned by its former tenant. Its large claws are uneven, the left one being larger than the right. The eye stalks are blue and the base of the antennae is orange. Segments of the legs are coloured variously orange, blue, white and yellow. To 1 cm (1/2 in). **Native**.



C

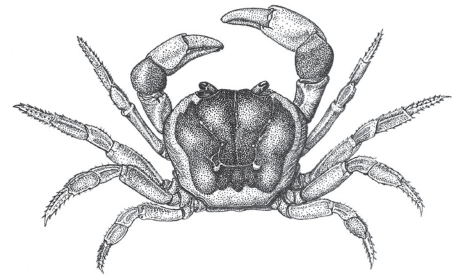
Verrill's Hermit Crab
Calcinus verrilli
This is another of the very few marine species **endemic** to Bermuda. It is a curious small hermit crab that has taken up a mode of life similar to the tube snails (*Vermetidae*). Indeed it lives in abandoned tube shells and is very common on the Boiler Reefs and Bioconstructional Lips. A maximum of 2 cm (3/4 in) long, These crabs are very colourful being bright purple with red spots. **Native**.



Crabs

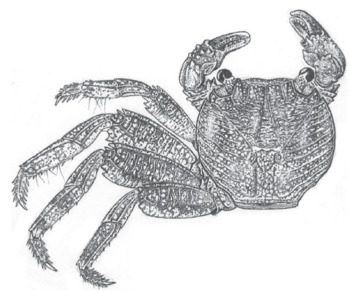
OC

Land Crab or **Red Land Crab**
Gecarcinus lateralis
The most common land crab in Bermuda, this species inhabits burrows in the treed and grassy areas of the shoreline. The carapace is oval in shape, wider rather than long. It is coloured dark, reddish brown. The chelipeds are red or purple and are large and unequal in the male. The legs are paler and narrow at the tips, making them unsuitable for swimming. To 4.5 cm.
Native.



R

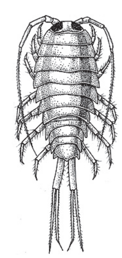
Sally Lightfoot Crab
Grapsus grapsus
This shore crab with a nearly circular carapace (shell) is found throughout the intertidal and supralittoral zones on very exposed rocky shores and cliffs. Its colour varies but its carapace and legs are dark reddish brown with pale blue markings. It feeds on the algal turf and blue-green cyanobacteria. It is aptly named for its quickness as it escapes a crashing wave or curious human. To 12 cm (4 1/2 in) across.
Native.



Isopods

R

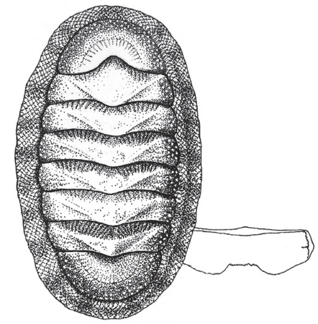
Wharf Louse
Ligia baudiniana
A very active, dark grey, flattened crustacean about 2 cm (3/4 in) long, very common along sheltered shores and around ponds, just above the water-line. It hides rapidly when disturbed.
Native.



Chitons

R

West Indian Chiton
Chiton tuberculatus
This West Indian Chiton has an oval greenish segmented shell. The central area of each shell segment is smooth, while the edge is broad and rough with bands of green and black. Found only at the very bottom of the intertidal zone on moderately to highly exposed shores. It can reach 7.5 cm (3 1/2 in) in length. **Native.**

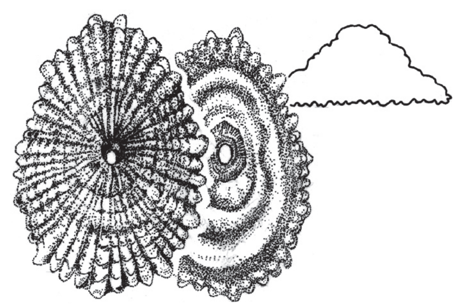


Gastropoda

Limpets

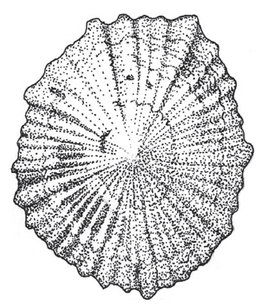
R

Keyhole Limpet
Fissurella barbadensis
This species has a conical shell of variable shape with a round or oval hole on the top, circled with pink. The shell is coloured cream, greyish white or olive green, with ribs highlighted in brown. It is common intertidally, grazing on algae and always finding its way back to its "home" place on the rock before the tide subsides. To 25 mm (1 in) long. **Native.**



R

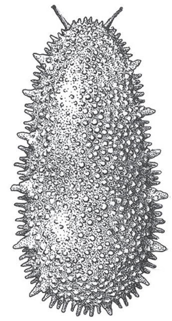
Say's False Limpet
Siphonaria alternata
This air-breathing limpet has a flattened conical shell with no opening at the top. Brownish in colour with stripes or patches. The interior is glossy tan, brown or cream. Its homing ability is exceptional. Found in tide pools or around the high tide mark. To 20 mm (3/4 in). Very common. **Native**.



Sea Slugs

R

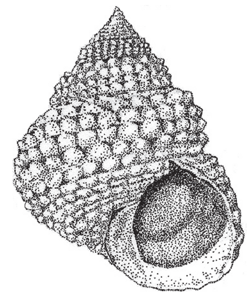
Onchidella Slug
Onchidella floridana
This is a tough little slug of the open shore. The body is an elongated oval up to 25 mm (1 in) long, coloured from dark green in some to almost black in others. The top surface is velvety in texture. It is generally hidden in crevices but emerges under damp conditions to graze on the rock surface. **Native**.



Snails

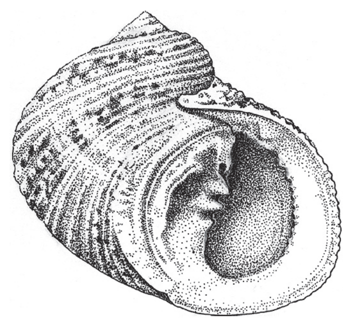
R

Beaded Periwinkle
Tectarius muricatus
This large periwinkle species is coloured grey on the outside and dark brown on the inside. The spirals are covered with evenly spaced knobs. This species occupies a zone slightly higher up the shore than the other periwinkles. To 2.5 cm (1 in). **Native**.



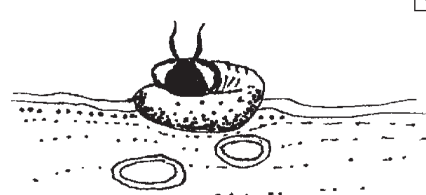
R

Bleeding Tooth Nerite
Nerita peloronta
This is one of the nerites which have a rounded, thick-shell. The colour is basically pale yellow, there are orange, red, purple or black markings. A blood-red mark on the two teeth-like formations called denticles on the shell's inner lip gives it its name. It is found in the midlittoral where there is moderate wave action. Formerly common, now rare. To 4 cm. (1 3/4 in). **Native.**



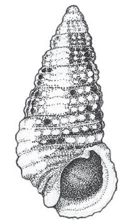
C, R

Corroding Worm Shell
Dendropoma annulatus
This tiny member of the worm shell family is the most abundant animal of the exposed midlittoral zone but is rarely noticed. The shell is mostly buried in the rock and the 1 mm (1/25 in) black opening is all that can be clearly seen. Feeds on suspended detritus. **Native.**



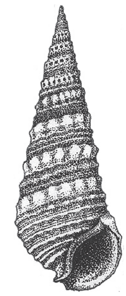
B

Dwarf Cerith or **Horn Shell**
Cerithium lutosum
This species can be confused with the False Horn Shell but it is stockier, less pointed and dark brown in colour. To 1.2 cm. It is found under rocks and in tide pools. **Native**.



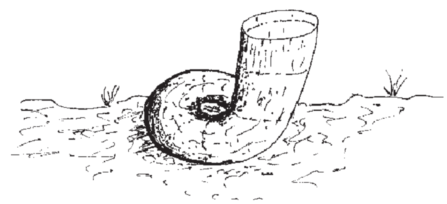
B, M

False Cerith
Batillaria minima
These little shells often occur in almost countless profusion on sheltered shores, particularly where there is both rock and sediment. Reaching only 15 mm (5/8 in) in length, the shell is very tall and slender with numerous whorls of ridges and small bumps. **Native**.



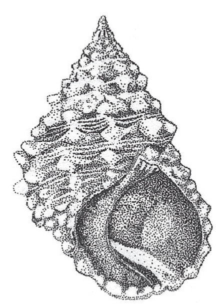
R

Large Tube Shell
Serpulorbis decussatus
This is the largest tube shell in Bermuda with an opening up to 7 mm (1/4 in) in diameter. The rim of the shell is exceedingly sharp and can puncture even stout footwear. The shell is white but the snail within comes in either white or red colour phases. There is no operculum. Usually, the shell is cemented to the rock, but sometimes the shells are cemented to each other in huge numbers to form Vermetid (Worm Shell) Reefs. **Native**.

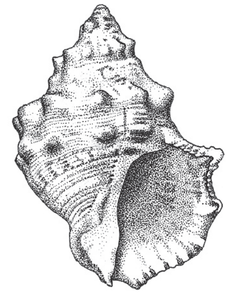


R

Prickly Winkle
Nodilittorina tuberculata
This species has a grey-brown conical shell covered with spiralled rows of pointed knobs. Found on exposed rocky shores in a narrow band at the top of the midlittoral zone, often in depressions or crevices. This is by far the commonest of the intertidal periwinkles. From 1.2-2 cm (1/2-3/4 in) in size. **Native**.



Rusty Whelk or **Rustic Rock Shell**
Thais rustica
A thick-shelled species with large whorls and a wide oval aperture marked with long denticles on the inner lip and a prominent groove at the front. It is grey with bands of brown and purple. A carnivore, it is rare, found intertidally feeding on barnacles and mussels. To 3.5 cm (1.5 in) long. **Native**.

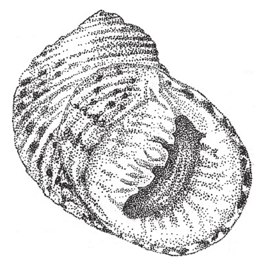


R

Tessellated Nerite
Nerita tessellata
This species has a spotted black and white shell with spiralling grooves. Some are black. Found in large numbers with other nerite species along the rocky north and south shores, they prefer areas of moderate wave action and feed on algae and seek shelter at low tide. To 2 cm (3/4 in). **Native**.

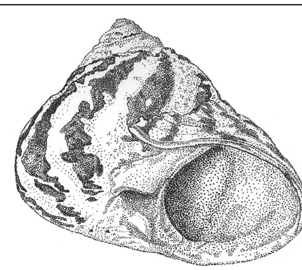
R

Variegated Nerite
Nerita versicolor
A species shaped like the other nerites above and coloured greyish-white with markings of red and black. The inner lip is yellow with four denticles. Found in the mid-littoral zone with other nerites. To 25 mm (1 in). **Native**.



R

West Indian Top Shell
Cittarium pica
This is the largest Bermudian marine snail. It has a checkered black and white shell and may reach at least 10 cm (4 in) across. Extirpated then recently re-introduced and now doing well. Up to 12 cm (5 in) in diameter. **Native**.



R

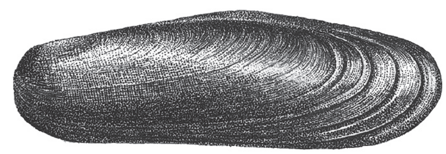
Zebra Periwinkle
Littorina ziczac
The shell is oval-shaped, greyish-white in colour with irregular oblique purplish brown stripes. Found on exposed rocky shores in a narrow band at the top of the mid-littoral zone. To 2 cm (3/4 in). **Native**.

R

Clams and Mussels

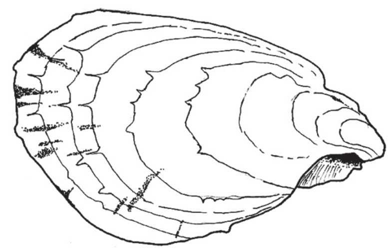
Black Date Mussel
Lithophaga nigra
This is a species which can only be seen as an oval hole showing at the mouth of the burrow in the limestone. The mussel looks very like a large date pit, with ridges on the larger end of the shell. Up to 4 cm (1 1/2 in) long these shells can be present in very large numbers. To enlarge the burrow as they grow they both dissolve the limestone and scrape it away. They are filter feeders. **Native**.

B, C



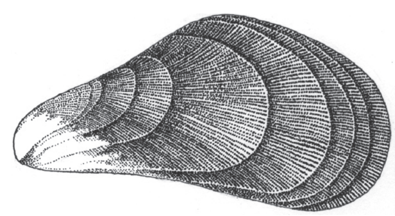
Flat Rock Oyster
Isognomon radiatus
This sea shell is found in small groups in crevices on intertidal rocky shores. The shells are very flat, brownish black and about 5 cm (2 in) long. They are firmly attached to the rock by strong threads and can stand very rough conditions. **Native.**

R



Scorched Mussel
Brachidontes domingensis
A small mussel of the mid-littoral zone. The shell is elongated, black and ribbed. Attached to the rock by byssal threads. Often clustered in cracks and crevices. 1 cm (3/8 in) long. **Native**.

R

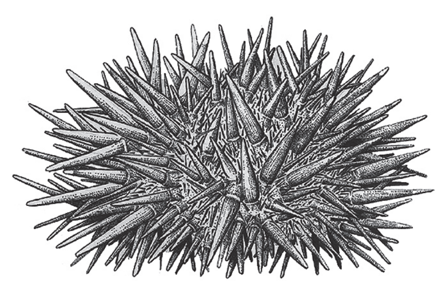


Echinoderms

Sea Urchins

Burrowing Rock Urchin
Echinometra lucunter
This deep purple urchin with short, conical spines is up to about 8 cm (3 in) long and has a somewhat ovoid body, when viewed from above. They are found occupying elongate, shallow burrows in the surface limestone of Boiler Reefs and Bioconstructional Lips. They do not leave these burrows and feed on the algae growing within them. The burrows are vigorously defended. These animals occupy one of the harshest reef environments in Bermuda. **Native**.

C, R

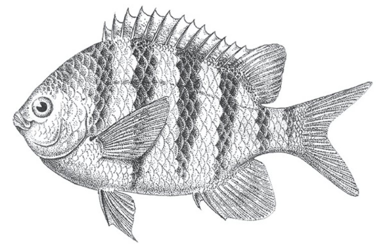


Fish

Damselfishes

B, C

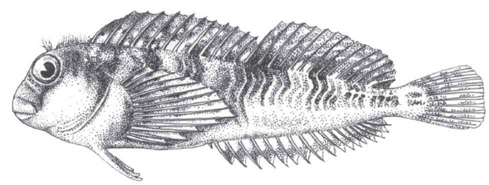
Sergeant Major or **Cow Polly**
Abudefduf saxatilis
The Sergeant Major is one of the damselfishes, and is strikingly coloured with a blue head, and with vertical dark bars on a yellow background along its back, grading to light blue beneath. It is a very active small fish, up to 15 cm (6 in) long. **Native**.



Blennies

R, SP

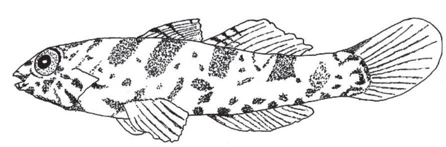
Molly Miller
Scartella cristata
The Molly Miller is a member of a group of small fishes known as blennies. These fish are some of the real characters of the fish world. The Molly Miller reaches only 10 cm (4 in) when fully grown. It lives on the bottom in shallow water along rocky shores and in rock pools. The eyes are far-forward and very large. On the top of the head are a series of short, hair-like bristles that extend back to the start of the dorsal fin. The colour is a vey dark green with brown bars on the back. **Native**.



Gobies

R, SP

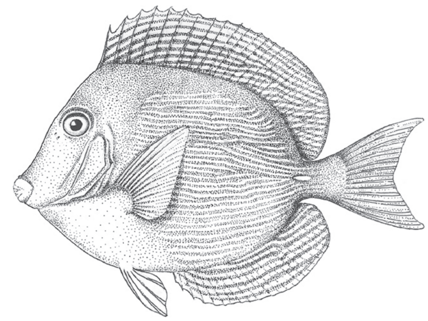
Notchtongue Goby
Bathygobius curacao
This small fish, one of the gobies, can grow up to 15 cm (6 in) long but those found in small tide pools are always very much smaller. There are two distinct dorsal fins, a characteristic which distinguishes this fish from the blennies found in the same habitat. The colour is brown with darker blotches on the sides and several dark brown bands on the top. Older fish move from pools to shallow water and seagrass beds. **Native**.



Surgeonfishes

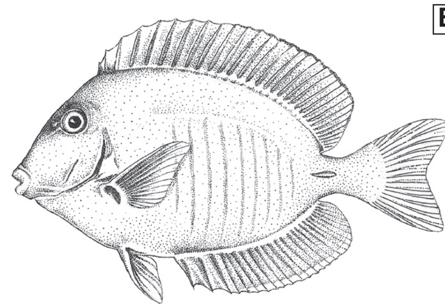
Blue Tang
Acanthurus coeruleus
These fish are deep in the body and are a brilliant blue. They reach a maximum size of 38 cm (15 in) and have very sharp ridges, resembling the edge of a scalpel, at the base of the tail. The striking, brilliant blue of the adult Blue Tang is all the more remarkable when we learn that the juveniles are coloured a brilliant yellow with faint, darker longitudinal lines. This fish has the same razor-sharp ridges at the base of the tail as the Ocean Surgeonfish. **Native**.

B, C



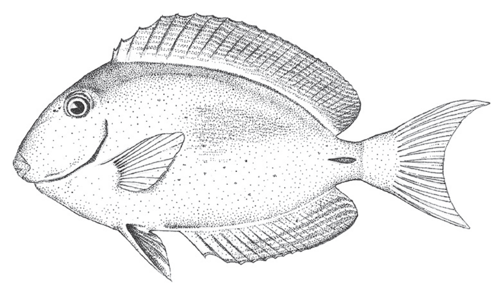
Doctorfish
Acanthurus chirurgus
This is a typical member of the surgeonfish family, having a large eye set high on the head and a small mouth below a long, sloping forehead. The colour is blue and may be dark or light but the distinctive feature is a set of vertical darker bars on the body, which may be difficult to see. Up to 30 cm (1 ft) long. **Native.**

B, C



Ocean Surgeonfish
Acanthurus bahianus
The Ocean Surgeonfish like the Blue Tang (above) is a member of the surgeonfish family. The fish are deep in the body, and the Surgeonfish varies from a dull brown colour to a pale grey. It reaches a maximum size of 38 cm (15 in) and has very sharp ridges, resembling the edge of a scalpel, at the base of the tail. These razor-sharp features give the group their name, and are something to beware of if you get the chance to handle one. **Native**

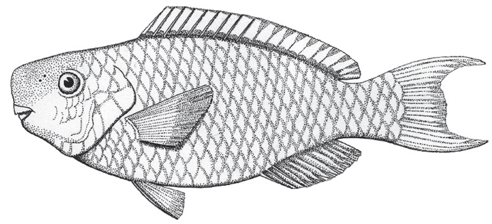
B, C



Parrotfishes

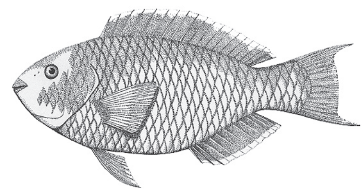
B, C

Blue Parrotfish
Scarus coeruleus
The Parrotfishes are quite distinctive with their blunt heads, stocky bodies and indented tails. The Blue Parrotfish, up to 1 m (3 ft) long, is a fairly uniform medium blue, whether immature or adult. They are important algal grazers on the reef, but also penetrate into mangrove swamps at high tide and are in larger ponds. **Native.**



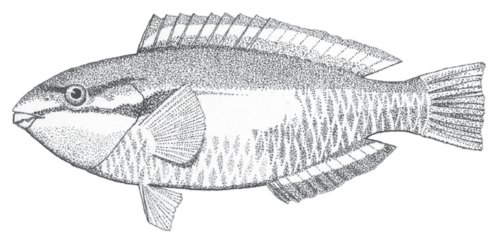
B, C

Midnight Parrotfish
Scarus coelestinus
Midnight Parrotfish are all navy blue with bright blue markings on the head and grow to about 1 m (3 ft). **Native**.



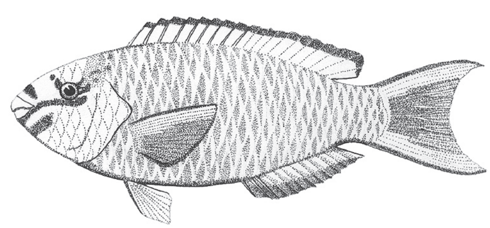
B, C

Princess Parrotfish
Scarus taeniopterus
The primary colour phase shows three, longitudinal dark brown stripes on the upper half of the body. The terminal male has a red top to the head and a pinkish bottom with two narrow blue-green stripes. The body is bluish-green and orange with a broad pale yellow stripe on the upper front. The tail is blue with bright orange upper and lower edges. Length to 35 cm (13 in). **Native**.



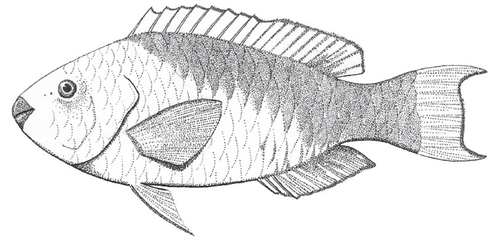
B, C

Queen Parrotfish
Scarus vetula
The primary colour phase is grey to dark red-purple-brown with a broad white stripe on the lower part of the body. The terminal males are a bluish-green with scales bordered in red. The head has alternating bands of blue-green and orange. This fish can reach 55 cm (1 3/4 ft). **Native**.



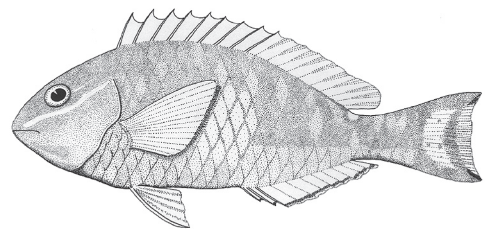
Rainbow Parrotfish
Scarus guacamaia
This is one of the largest of the parrotfish, growing to a length of 1 m (3 ft). It lives in a variety of habitats from the rocky coast to the outer reefs. This parrotfish has green scales rimmed with orange and orange fins with a streak of green and a blue edge. Adults are more deeply coloured than juveniles but colours in both sexes are the same. **Native**.

B, C



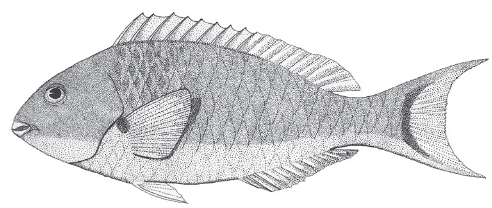
Redband Parrotfish
Sparisoma aurofrenatum
The primary colour phase is greenish-brown or mottled brown with a touch of blue. Along the lower side this changes to a pale mottled red. In the terminal male the body is orange to green-blue and has a diagonal pale orange stripe from the mouth to the top of the gill cover. There is an orange spot behind the gill cover and a white one at the end of the caudal fin. A small parrotfish reaching 30 cm (1 ft). **Native**.

B, C



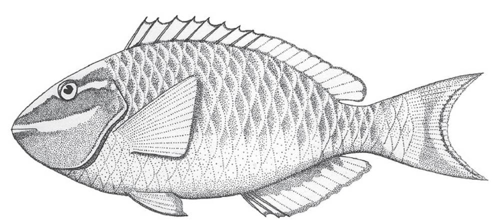
Redtail Parrotfish
Sparisoma crysopterum
This Parrotfish has a distinctive crescent-shaped mark on the tail. The primary colour phase is olive-green on the back, a mottled reddish colour on the sides and with a pale belly. Terminal males are green with brown-bordered scales. On the sides the body is blue-green becoming clear blue lower down. The fins are all reddish. One of the smaller parrotfish reaching about 35 cm (13 in). **Native**.

B, C



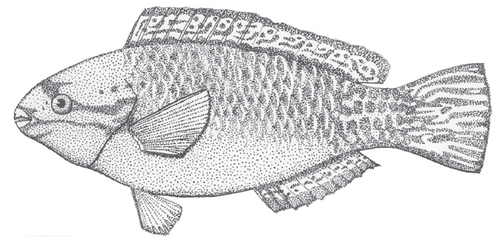
Stoplight Parrotfish
Sparisoma viride
In the initial color phase all fish are red-green above and bright red below with red fins. The terminal colour phase of mature males is mainly green. There are three diagonal orange bands on the head. The fins are yellow and blue. This species is commonly about 40 cm (15 in) long. **Native**.

B, C



B, C

Striped Parrotfish
Scarus croicensis
The primary phase shows three broad, dark brown stripes running the length of the body. The lowest stripe is lighter in colour. The body is whitish with a yellow snout. The terminal male has a pink lower head and chest. The top of the head is orange and a green-blue stripe runs through the centre. The body is blue-green and orange with a central pink stripe on the forward half. Fins are blue and orange. Grows to about 35 cm (13 in). **Native**.



Lizards

F, OC

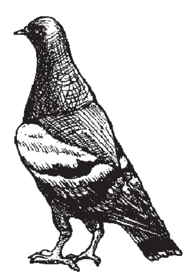
Bermuda Skink
Eumeces longirostris
This is the only non-introduced lizard in Bermuda. It is now endangered being reduced to a few small populations mostly along the south shore. This is a small, rather stiff lizard with short legs and clawed feet. Blunt-nosed and dark greyish-brown except for mature adults which have a reddish throat. Length 15-20 cm (6-8 in). **Endemic.**

Birds

Doves

F, R, U, W

Pigeon or **Rock Dove**
Columba livia
Introduced in the 1600s but remained rare until 1977 when the population exploded. This bird is variable in colour due to captive breeding but grey is the commonest colour. The Rock dove is about the size of a crow. They nest in a variety of places including holes in cliffs where they compete with the White-tailed Tropic Bird. About 25 cm (10 in) long. **Introduced**.



Flycatchers

Great Kiskadee
Pitangus sulphuratus
This is a large, basically yellow flycatcher with a black and white striped head and a raucous call. It is 27 cm (10 1/2 in) long and has a broad black beak. The back is browner than the underparts. **Introduced** to control lizards.

F, U, W

Herons

Yellow-crowned Night Heron
Nyctanassa violacea
A rather small heron. The adult is slate-grey with a black head capped with a yellowish crown and plumes. The beak is black and the legs yellow to orange. Has become very common after its introduction in 1976-8. Eats mainly land crabs. 56-69 cm (22-27 in) long. **Introduced**.

F, M, SP

Tropic Birds

White-tailed Tropic Bird or **Longtail**
Phaethon lepturus
The Longtail or White-tailed Tropic Bird is a summer breeder in Bermuda. It nests in holes in the cliffs and suffers competition from Rock Doves and predation from rats. The distinctive feature of this bird is the extremely long and graceful tail feathers. The wingspan is about 90 cm (3 ft). **Native.**

B, CL, O

Field Trips

Field Trip # 1 to an Exposed Rocky Shore

Preparation
Read the appropriate sections of this field guide. Find out from the newspaper the time of low tide. To find the time of low tide in advance, tide tables are available from the Bermuda Biological Station for Research. This field trip must be done within an hour, before or after low tide, and when the sea is relatively calm. Nothing can be achieved by going out when large waves are crashing on the shore. Limit the area to be studied from where terrestrial vegetation starts at the top to the waterline.

Dress
No special clothing is needed but shoes should be sturdy and have good non-slip soles. If it is sunny, those prone to sunburn should apply a sun screen with a high SPF.

Equipment
Clipboard, pencil and several sheets of good paper. A 30 m (100 ft) survey tape. A few pairs of binoculars for the group.

Suggested Location
For best results it is best to pick a fairly exposed area so that the littoral zone is wide. Additionally, work is facilitated if the shore has a fairly low slope, without abrupt drop-offs or bumps. If the weather is fairly calm and there is not a surge, the south shore offers some good sites. Possible locations are John Smith's Bay, Spittal Pond and Devonshire Bay Park. If the south shore is unsuitable, there are lots of potential sites along the north shore. Possible study sites are the Tobacco Bay area, the Ferry Point Park area, Coney Island Park, Penhurst Park and Spanish Point Park.

Observations

1) <u>General appearance of the shore</u>
   From a spot where the whole shore is visible, look for evidence of zonation. Look for general colour changes such as are shown in Figure 2.3. Make a sketch of the shore from the waterline to where trees, grass or other land vegetation starts. Put an approximate distance along the bottom of your diagram. (Lay a measuring tape down the shore.)

2) The zone indicators
Look for the organisms that are characteristic zone markers as follows.

   A) Top of periwinkles.
   B) Top of barnacles.
   C) Top of Rock Urchins, Chitons, West Indian Top Shells, Corals or anything not normally exposed to the air, whichever is present. Put an arrow on your sketch, above, showing about where each was found.

3) Diversity of life
Go slowly down the shore from the top to the bottom and try to find two places where there are the most different species. Don't get confused between abundance and diversity. A place with a whole lot of one kind of organism does not count. Put two stars on your sketch, above, to show where these are.

4) Abundance of life
Repeat what you just did and look for the one place where there is the greatest number of individuals, regardless of how many different kinds there are. This is a tricky one. Don't get mislead by size. Look very closely at the surface of the rock for small organisms, such as tiny seaweeds or very small animals such as the Corroding Worm Shell (Illustrated in the identification section of this book). Put a small circle, filled in black, on the sketch to show where this is.

5) Structural Adaptations to life on the shore
Pick three different animals (A, B and C) that you have found on the shore, identify them and look at them carefully. Make a small drawing of each. Then describe how you think it is adapted to life on the shore. Hint: Look at shape, shell strength, good attachment etc.

A)

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B)

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C)

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6) General Observations

A) Watch out for birds, both on the shore and at sea. List them.

B) Look just above the shore and describe the kind of vegetation there.

C) Look for evidence of pollution in the form of trash, oil patches etc. List what you found.

Field Trip # 2 to a Sheltered Rocky Shore

Preparation

Read the appropriate sections of this field guide. Find out from the newspaper the time of low tide. To find the time of low tide in advance, tide tables are available from the Bermuda Biological Station for Research. This field trip must be done within an hour, before or after low tide, and when the sea is relatively calm. Nothing can be achieved by going out when waves are crashing on the shore. Limit the area to be studied from where terrestrial vegetation starts at the top to the waterline.

Dress

No special clothing is needed but shoes should be sturdy and have good non-slip soles. If it is sunny, those prone to sunburn should apply a sun-screen with a high SPF.

Equipment

Clipboard, pencil and several sheets of good paper. A 30 m (100 ft) survey tape. A few pairs of binoculars for the group.

Suggested Location

Work is greatly facilitated if the shore has a fairly low slope, without abrupt drop-offs or bumps. This simplifies the situation and gives a good big area for study. To get a sheltered study site, the best locations are in sheltered bays, sounds or harbours. Great Sound has some good locations in the Ireland Island to Somerset areas. Castle Harbour has suitable sites in the Blue Hole area. St. Georges Harbour has reasonable sites in Mullet Bay and Whale Bone Bay has many possible locations.

Observations

1) General appearance of the shore

   From a spot where the whole shore is visible, look for evidence of zonation. Look for general colour changes such as are shown in Figure 2.3. Make a sketch of the shore from the waterline to where trees, grass or other land vegetation starts. Put an approximate distance along the bottom of your diagram. (Lay a measuring tape down the shore.)

Sketch of shore

2) The zone indicators
Look for the organisms that are characteristic zone markers as follows.

A) Top of periwinkles.
B) Top of barnacles.
C) Top of Large Tube Shells, Brown Seaweeds, Corals or anything not normally exposed to the air, whichever is present. Put an arrow on your sketch, above, showing about where each was found.

3) Diversity of life
Go slowly down the shore from the top to the bottom and try to find two places where there are the most different species. Don't get confused between abundance and diversity. A place with a whole lot of one kind of organism does not count. Put two stars on your sketch, above, to show where these are.

4) Abundance of life
Repeat what you just did and look for the one place where there is the greatest number of individuals, regardless of how many different kinds there are. This is a tricky one. Don't get mislead by size. Look very closely at the surface of the rock for small organisms, such as tiny seaweeds or very small animals such as the Corroding Worm Shell (Illustrated in the identification section of this book). Put a small circle, filled in black, on the sketch to show where this is.

5) Structural Adaptations to life on the shore
Pick three different animals that you have found on the shore, identify them and look at them carefully. Make a small drawing of each. Then describe how you think it is adapted to life on the shore. Hint: Look at shape, shell strength, good attachment etc.

A) ______________________________
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B) ______________________________
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C) ______________________________
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6) General Observations

A) Watch out for birds, both on the shore and at sea. List them.

B) Look just above the shore and describe the kind of vegetation there.

C) Look for evidence of pollution in the form of trash, oil patches etc. List what you found.

Field Trip # 3 to a Tidal Pool Location

Preparation

Read the appropriate sections of this field guide. Find out from the newspaper the time of low tide. To find the time of low tide in advance, tide tables are available from the Bermuda Biological Station for Research. This field trip must be done within an hour, before or after low tide, and when the sea is relatively calm. Nothing can be achieved by going out when large waves are crashing on the shore. Limit the area to be studied from where terrestrial vegetation starts at the top to the waterline.

Dress

No special clothing is needed but shoes should be sturdy and have good non-slip soles. If it is sunny, those prone to sunburn should apply a sun-screen with a high SPF.

Equipment

Clipboard, pencil and several sheets of good paper. A few metre sticks, long rulers or short survey tape. A few pairs of binoculars for the group.

Suggested Location

For best results it is best to pick a fairly exposed area with a moderate slope so that the shore is wide. Naturally, tidal or rock pools must be present and of a reasonable size. Those over two metres (6 ft) long are too large. As a rough guide pools of about 1 m (3 ft) in the largest dimension are best. Those running the field trip should scout out a suitable location in advance. Probably, the south shore offers the best locations. Just west of John Smith's Bay is good as is the point on the western boundary of Devonshire Bay.

Groups

This field trip will be more successful if fairly small groups of students are assigned each to a different pool in the same area. This will allow a comparison of results to show differences between pools at different heights and of differing sizes.

Observations

1) <u>General appearance of the shore</u>
   Before picking pools to examine, look at the shore as a whole and make a sketch showing the locations of various pools. This will be more meaningful if the shore is divided into its zones as described in the foregoing field trips. Try to put the zone boundaries on your sketch. Particularly important are the top of the midlittoral zone (top of barnacles) and the top of the supralittoral fringe (top of periwinkles).

2) <u>Picking a Pool</u>
   Groups of no more than five students should pick suitable pools as outlined above. Each group must decide whether the pool they choose is a low level (bottom ¼ of the shore), mid level (middle ½ of the shore), or upper level (upper ¼ of the shore, above any seaweeds). Record pool level by ticking the correct box.

   Lower ☐ Mid ☐ Upper ☐

Draw a simple sketch map of the pool as seen from directly above. Reasonable accuracy will help in this, take particular notice to record the pool outline clearly. Use metre sticks or a tape to get approximate dimensions for length and width and add these to your sketch map.

3) Pool Depth
Using a metre stick or ruler find the deepest point in the pool, note its depth and indicate its approximate location on the sketch above by a star (*). Maximum depth __________ cm.

4) Pool Inhabitants
Now look carefully at what you have living in the pool. First look for seaweeds, remember that some of these seaweeds may be encrusting (forming a thin layer on the surface of the rock). Identify any seaweeds that you can, from your own knowledge, from advice from the teacher, or by using the identification section at the end of this guide. First note the colour of the seaweeds. Red algae will be some shade of red or pink but may be bleached quite pale. Brown seaweeds are some shade of brown but may have white areas. Green seaweeds are normally bright green, but in pools they may be quite faded. Fill in the following table for pool seaweeds. Estimate how many different kinds of seaweed are in your pool. This is seaweed biodiversity. Also estimate the total number of seaweed specimens there are in the pool, this is seaweed abundance. Fill numbers in for these values below the table.

Rock Pool Seaweeds

Seaweed name if known (if unknown use a different letter for each. (A, B etc.)	Seaweed Colour (Bright red, dull red, pink etc.)	Seaweed Form (encrusting, threadlike, leaf-like etc.)	Abundant, common, rare, (one only) Clumped or evenly spread

Seaweed biodiversity ____________________ Total seaweed abundance _____________________

Continue the examination of pool inhabitants by looking for pool animals. Again try to identify any that you can but at any rate try to place animals in their appropriate group. (Sponges, Anemones, Worms, Barnacles, Crabs, Hermit Crabs, Sea Slugs, Snails, Clams, Fish) Again estimate biodiversity and abundance as you did for seaweeds. Fill in the following table.

Rock Pool Animals

Animal name if known (if unknown use a different letter for each. (A, B etc.)	Animal Group (sponges, barnacles, clams, fish, etc.)	Habit (attached to rock, crawling, swimming etc.)	Abundant, common, rare (one only) Clumped or evenly spread

Animal biodiversity _____________________ Total animal abundance _____________________

5) General Observations
In the following space write your observations on the general nature of the shore where your pool is located. Does it face N,S,E, or W? Is it steep or gently sloping? Is it rough or smooth? Did you see any birds, if so list them. Did you notice pollution of any kind? If you did say what type of pollution it was and where it was observed. Did the pollution appear to be harming seashore life?

Field Trip # 4 to Cliff and Steep Rock Locations

Preparation
Read the appropriate sections of this field guide. By their very nature cliffs are a very hazardous environment to man. This field trip must therefore be confined to observation of cliffs rather than hands-on study.

Dress
No special clothing is needed but shoes should be sturdy and have good non-slip soles. If it is sunny, those prone to sunburn should apply a sun-screen with a high SPF.

Equipment
Clipboard, pencil and several sheets of good paper. A few pairs of binoculars for the group.

Suggested Locations
Cliff locations are often difficult of access, but where there is a will there is a way. If a good boat is available, it is possible to look at a great variety of cliffs and steep rocky shores in one trip. Harrington Sound is an obvious choice. Cliffs are everywhere there and Abbott's Cliff, one of the best in Bermuda is at the NE end. Additionally there is a good White-tailed Tropic Bird nesting site on Rabbit Island. If you would like to go to an outer shore cliff, then St. David's Head is a great location and lots of steep rocky coastline occurs in that area too. If a land approach is desired, several coastal Parks are possible. There are fine cliffs in the eastward part of Astwood Park as there are towards the west end of South Shore Park. There is also a nice cliff with good access at Windsor Beach in Tuckers Town but permission is required to take groups there.

Observations

1) <u>The Cliff Habitat</u>
From anywhere where you can get a good view of a whole cliff, draw a sketch of the cliff face, showing the geological structures, ledges, holes and where vegetation occurs, if present. Estimate the height of the cliff and add that information to your diagram. If you see White-tailed Tropic Birds going into holes put an arrow on your diagram showing the location.

Sketch of a cliff face

2) Cliff Dwelling Animals and Plants
Look carefully at the cliff from a distance (binoculars will help) and up close. Identify as many animals and plants as you can see and note their habitats (e.g. Open Cliff Face, Ledge, Crevice, Hole, etc.). List your information below.

A) Identity ______________________ Habitat ______________________

B) Identity ______________________ Habitat ______________________

C) Identity ______________________ Habitat ______________________

D) Identity ______________________ Habitat ______________________

E) Identity ______________________ Habitat ______________________

F) Identity ______________________ Habitat ______________________

G) Identity ______________________ Habitat ______________________

H) Identity ______________________ Habitat ______________________

3) Details of one Cliff Dweller
Choose one of the animals or plants that you have listed above. State its identity. Draw a sketch of it showing as much detail as you can. State how it is adapted to live on a cliff face.

Sketch of a cliff dwelling animal or plant

A) Identity ______________________ Animal ☐ or Plant ☐

B) Observations on its adaptation to the cliff environment.

Appendix

Field Trip # 5 Advanced Zonation Mapping for Senior Students

Introduction
This method of mapping zonation is based on the technique of 'horizon levelling' which is based on the fact that a horizontal line from a near sea level object to the horizon, is virtually perfectly level. The sea shore is virtually the only location where this method of mapping zonation can be used. In the simplest case, the equipment is very inexpensive and simple. However, the method requires concentration and an understanding of basic levelling in order to avoid mistakes. For this technique to work at its best, the horizon must be visible at all points from low tide level to the top of the supralittoral zone. It will not work in a channel between the mainland and an island and is more difficult but not impossible where the shore is not a steady slope to the sea. In practice, minor undulations in the surface are best ignored as they do not affect zonation. A significant bump or drop, however, must be mapped as zonation may well change there. Rock pools are a complication that is best avoided. You will only need a belt 1 m (3 ft) wide down the shore. It is easy to find such places that are devoid of pools or have significant rises. However, once you practice the method you will realise that it is, with care, adaptable to all complications. One advantage of this method is its extreme accuracy. Measurements can be taken to 1 mm but often accuracy to the nearest centimetre will suffice.

The method is a superb way of comparing zonation patterns at a variety of locations with differing degrees of exposure. The south shore presents the most exposed locations but is frequently too rough to make a survey possible, even in calm weather. If a south shore location is planned always have a fallback location in mind if you have to abort the very exposed place.

Preparation
Read the introduction to this field trip and study the figures for this technique as well as Figure 2.3, which shows a suitable location. Also look at the illustrations of species found on the shore, concentrating on ones that might be used as zone boundary indicators. For example, periwinkles, barnacles, and infra-littoral fringe organisms. Make sure that you go as close to low tide time as possible, say one hour before. It is best to go on a low spring tide. Consult tide tables in the paper or published elsewhere to ascertain this. If you don't understand tides read that section of this field guide.

Dress
The main thing is to wear good footwear that has an excellent grip on smooth, possibly slippery, surfaces and at the same time is sturdy enough to resist penetration by small spikes of rock.

Equipment
The basic equipment consists of four metre sticks and a metric surveying tape. It is also essential to have a clipboard, pencils and prepared table for the results, such as is shown below. Some fluorescent tape and masonry (concrete) nails are needed to mark each reference location. A hammer is handy to drive nails and you will need a waterproof black marker to write on the tape.

Suggested location
As explained in the introduction to this field trip, suitable locations are those with a steady slope to the sea and an unobstructed view of the horizon. Do not choose very sheltered locations as the zonation there will be so compressed that accuracy to 1 mm would be essential.

<u>Observations</u>

FIELD OBSERVATIONS. (The method is summarised in Figure A.1)

1) Size of team. A team approach is essential and the minimum is three persons, two to hold metre sticks in place and take sightings and a third to record the results. More than five per team can be a detriment to success.

2) Pick location. Decide the general location before starting the field trip. Once on the spot pick a site where a 1m wide belt free of pools and obstructions can be seen down the shore. This is called a belt transect.

3) Mark transect limits. A) Find the top of the supralittoral zone and mark it with fluorescent tape tied round a masonry nail. Mark this point A. B) Find the bottom of the transect which may be just submerged and drive a second nail-marker in there. Both these markers should be in the centre of the 1m belt transect.

4) Pick reference points. Working down the mid-line of the transect from the top, look for places where there is a change in gradient. For example where the slope steepens or flattens out. There is no need to put markers within an area that has a flat surface and even slope, but, if such occurrences are long, intermediate points will simplify the procedure.

   At each point drive in a marker nail with fluorescent tag. Mark them sequentially B below A, C below B etc.

5) Survey the line. For each pair of points, two measurements must be taken.

   a) The vertical drop in cm or mm;
   b) The horizontal distance between markers.

   A) Vertical drop
   As explained above, the method depends on the fact that a line from any point on shore to the horizon will be precisely horizontal. Therefore, in theory if you could place your eye at the rock surface at the higher point and then sight past a vertically-held metre stick at the lower point, the height at which your line of sight passes the metre stick (0 at the bottom) will be the vertical drop increment. In practise this cannot be done, so we take advantage of a simple geometric situation.

   i) Place one metre stick at the upper point and another at the lower point. Both vertical. The upper point stick, MUST HAVE 0 AT THE TOP.

   ii) Sight to the horizon so that the top of the lower metre stick and the horizon coincide (Refer to **Figure A1**). In practice it is easy to make a marker of your thumb nail and slide it down the upper stick until this marker, the top of the lower metre stick and the horizon are all in line. Read off the vertical drop on the upper metre stick. Note: Look at the situation and estimate the drop and compare it to the result. If the drop is 15.6 cm this is what you must read on the upper metre stick. If you read 84.4 cm instead, your upper metre stick is the right way up instead of upside down. A little thought prevents errors.

   iii) If you are working from A to B, You will be measuring the height increment at A for B so enter the result as the height increment at B. The attached table has the A results all pre-entered as 0 this is correct.

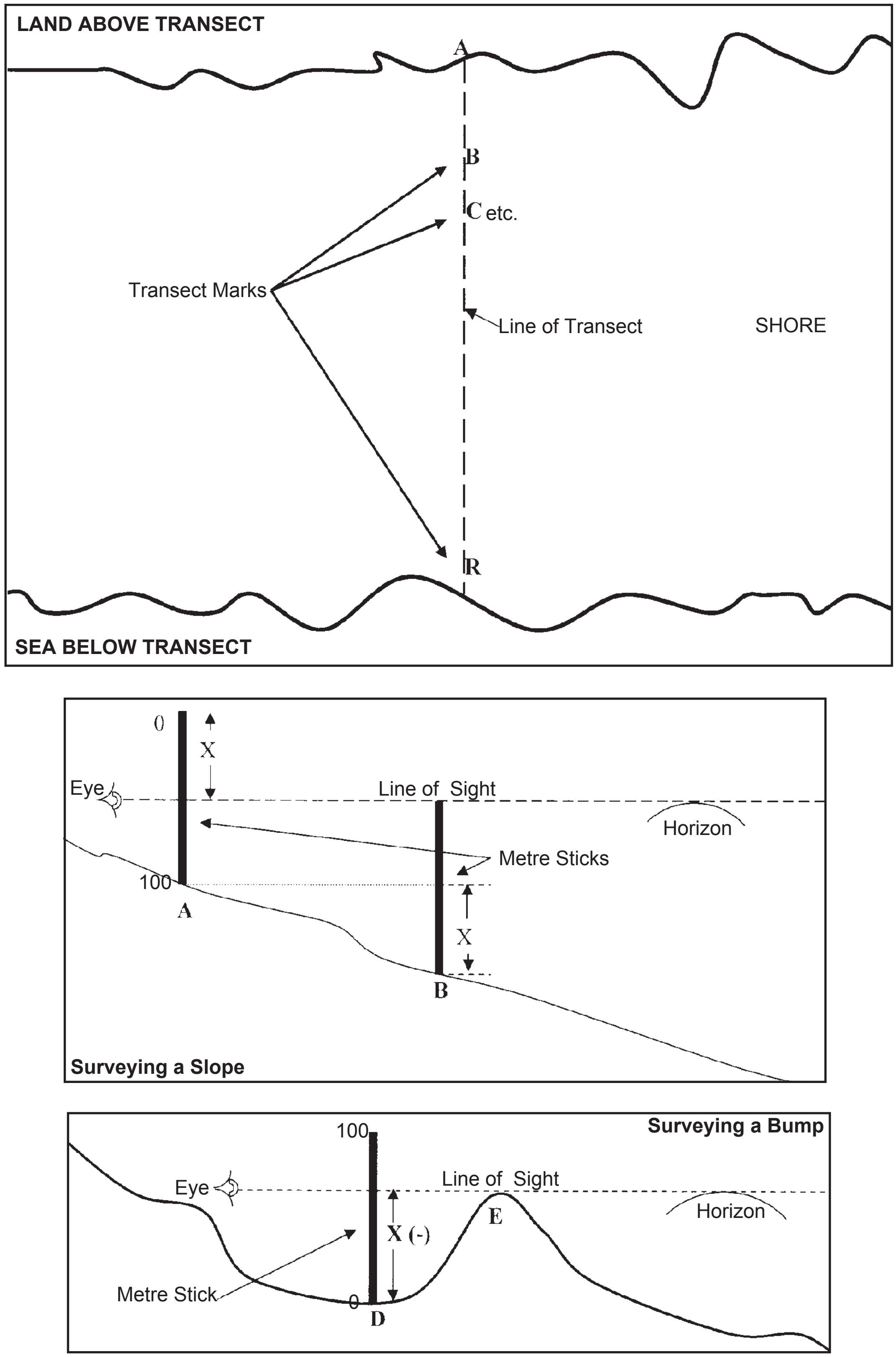

Figure A.1. Summary of advanced rocky shore zonation transect method.

B) Horizontal distance

i) Stretch a tape horizontally between the two vertical metre sticks and measure the distance to the nearest cm. The result is the incremental distance between the two points. A small deviation from horizontality at this point is allowable as all it will affect is the shape of your transect when you reproduce it on paper. It will cause no height error and we will only use height to show zonation. If the vertical metre sticks are less than a metre apart, it may be easier to use a metre stick to get the distance between the vertical sticks.

C) Record the results on a table drawn up like Table A-1. There are 5 columns.

1) Point [A, B, C, etc.], 2) Height Increment mm or cm,
3) Total height drop mm or cm, 4) Distance Increment cm or m,
5) Total distance cm or m. Fill in columns 1, 2 and 4 as you go leaving 3 and 5 blank.

D) Repeat the procedure from point to point until you reach the bottom point. If you have to wait a short while for the tide to drop, you can start on the next stage of the survey.

Note: The above method assumes that there is a <u>drop</u> between each successive point. If there is a rise, determine its height and record it as a negative in column 2). Usually, since such features are small on Bermudian shores, height rise can be simply measured with a single metre stick, with zero at the bottom, at the first point and sighting from this stick so that the top of the rise, the horizon and your marker on the metre stick are in line. More complex situations require some thought but can be overcome using the same method.

Sometimes a drop may exceed 100 cm, if so simply add a second metre stick on top of the first at the lower point. Be sure to add 100 cm or 1000 mm to your reading.

E) Error finding method. To ensure any errors can be corrected when you get back with your data, draw a fairly accurate sketch profile more or less to scale, marking on it all your reference points. Be especially careful to show changes in slope.

6) Make observations on the distribution of species. The simplest approach is to find the upper and lower limit of each species present, within the 1m belt transect. Measure each as the horizontal distance from the limit to the nearest reference point. Record as cm seaward or cm landward. This alone, when plotted up will give accurate zonation data. If you wish you can add such observations as point of maximum abundance etc. Enter this information on a table such as A-2.

7) Before leaving, remove all markers and anything else littering the shore.

LABORATORY OR WORKSHOP ANALYSIS

Fill out the two remaining columns of Table A-1. Add each successive height increment to the total above to get a total drop for each point. Negative figures are subtracted.

1) Do the same for the distance results.

2) On as large a piece of graph paper as you can find, plot total height for each point on the vertical axis and total distance for each point on the horizontal axis. Note that the two axes do not have to be to the same scale. It is often best if the vertical axis is exaggerated. This will change the shape of the profile (foreshorten it) but will not affect vertical zonation results.

3) Clearly show each point as an X and label it with its point marker (A, B, C etc). The result, if error free is an accurate cross sectional profile of the shore. Compare it to the sketch profile. If there are obvious differences look for the error.

4) Find the location on the transect on paper of the upper and lower limits of each species. Just put a short bar across the transect line at each of the lower and upper limits. Coloured pencils are best for this as there may not be room to label each species. Just use a colour key. (E.g. Red= Keyhole Limpet, etc). If species extend above or below the transect just note that. You will only have one colour bar in this case.

5) Switch to a vertical interpretation of the results. To do this put a vertical, appropriately coloured bar virtually anywhere on the vacant parts of the graph, so that its top is at the level of the upper limit and its bottom is at the level of the lower. If organisms extend above or blow the limits of the survey, put an arrow head on the appropriate end of the bar to show this.

6) Remember the organisms you will use as zone markers and find the top of each zone. The bottom will be the top of the lower zone. Show these as a column to the side of the profile, with a different colour for each zone.

7) Add the vertical limits of each species in cm or mm to your table of species observations. Note: If you wish for slightly more realism you can also plot heights as above the lowest point, using the same increment addition method as described above.

8) Label the profile as to location, time of survey etc. Other surveys in other locations can be compared to this one.

9)

Table A-1. Physical Field Transect Survey Results

Location ______________________

Time and Date ______________________

Team Members ______________________

Units of height mm ☐ cm ☐ Units of distance cm ☐ m ☐

Point	Height drop increment	Total Height Drop	Distance Increment	Total Distance	Total height from base
A	0	0	0	0	
B					
C					
D					
E					
F					
G					
H					
I					
J					
K					
L					
M					
N					
O					
P					
Q					
R					
S					
T					
U					
V					
W					
X					
Y					
Z					0

Estimate exposure Very High ☐ High ☐ Medium ☐
Low ☐ Very Low ☐ Extremely Low ☐

Glossary

Aeolinite	Limestone rock form by the natural cementation of grains of wind-blown calcareous sand.
Algae	Photosynthetic, plant-like organisms generally found growing in aquatic or damp locations.
Algal Mat	A cohesive layer of algae of one or more species.
Basalt	Hard, dark volcanic rock, originating from the magma.
Bio-deposition	The formation of rock living organisms. Coral reefs are examples of bio-deposition.
Biodiversity	The number of different species of biota in a natural system such as an ecosystem or community.
Bio-erosion	The removal of rock by biological organisms.
Bio-erosional Notch	A notch cut under water into limestone by the action of organisms.
Biodiversity	In its simplest form the number of different species present at a location. More complex measures of diversity also incorporate relative abundance or biomass.
Biota	This word is used when all types of organism in a biological system are being included.
Blue-green algae	More properly called blue-green cyanobacteria. Pigmented bacteria that can photosynthesise. Common among tropical phytoplankton.
Blue-green cyanobacteria	See blue-green algae above.
Collision junctions	Areas in the Earth's crust where tectonic plates collide and one slides beneath the other.
Continental drift	The movement of continents over time caused by plate tectonics.
Coralline algae	Another expression for crustose calcareous algae.
Crust	The layer of solid rock lying above the molten magma.
Crustose calcareous algae	Red algae (Rhodophyta) growing in a sheet like form on the substrate that incorporate calcium carbonate into their tissues and lay down a layer of limestone. They are very important reef builders.
Crustose coralline algae	Another expression for crustose calcareous algae.

Cyanobacteria	See blue-green algae.
Desiccation	Drying.
Dunes	Hills of sand created by the wind.
Ecology	The scientific study of natural history.
Ecosystem	A large area of habitats and associated organisms that have many features in common. For example, the tropical rain forest or the open ocean.
Erosion	The break-down of rock to sediment or the movement of sediment by physical, chemical or biological means.
Extirpated Species	A species which has been wiped out of a discrete part of its range.
Filter feeders	Animals that obtain their food by filtering organic particles or organisms out of water.
Grazing	The cropping of vegetation by herbivorous animals.
Habitat	A small area of an ecosystem or environment. The characteristic living space of a species.
Herbivores	Animals that eat primary producers (plants).
Holdfast	Root-like structure serving to anchor algae. Does not act as a true root.
Hot spot island	Islands that originate when a volcano forms from liquid magma that erupts through a small area of the sea bed.
Interstitial fauna	Small animals living in the spaces between grains of sediment.
Intertidal Zone	The zone around water bodies that is regularly covered and uncovered by the tides.
Lichens	A symbiotic group of associations between algae and fungi which are accorded specific status and which are very hardy.
Limestone	A rock made up principally of Calcium carbonate.
Littoral Zone	The zone around water bodies that is subject to wetting by tides, splash or spray.
Magma	Molten rock under the Earth's crust, circulating in vast convection cells.
Mid Atlantic Ridge	The spreading zone down the centre of the Atlantic Ocean.
Midlittoral Zone	The main, broad zone on the rocky seashore that in sheltered locations lies roughly between the high and low tide marks, but rises higher in exposed locations. The top of this zone is marked by barnacles.

Mobile Dunes	Sand dunes that move steadily downwind.
Neap Tides	Tides of smaller range occurring every two weeks.
Operculum	A lid-like disc used to close the shell opening of some snails and worms.
Phyto-karst	The characteristic jagged surface texture of upper seashore rocks caused by bio-erosion by blue-green cyanobacteria.
Plate tectonics	The study of the structure and movement of crustal plates.
Pleistocene Epoch	The last epoch which was characterised by the development of huge ice caps at the north and south ends of the earth.
Predatory	Using animals as food.
Ridge islands	Islands that originate along mid-ocean ridges, for example Bermuda.
Rift Valley	The gully-like centre of an ocean ridge or a spreading junction on land.
Salinity	The quantity of salts per unit volume of water.
Species	The basic unit in scientific classification applied to organisms that are genetically and physically similar. They can interbreed naturally and produce viable offspring.
Species diversity	The number of different species in an area.
Sliding junctions	Zones in the Earth's crust where two tectonic plates slide against each other.
Spreading junctions	Zones on the surface of the Earth where molten magma rises to the surface. There is a spreading zone at the centre of ocean ridges.
Spreading zones	Zones on the surface of the Earth where molten magma rises to the surface. There is a spreading zone at the centre of ocean ridges.
Spring Tides	Tides of large tidal range that occur at 14 day intervals.
Supralittoral Fringe	A narrow zone on the seashore lying immediately above the midlittoral zone, characterised by the presence of periwinkles.
Tectonic plates	Large rock plates on the surface of the Earth which move under the influence of convection cells in the molten magma beneath.
Terrestrial Systems	Natural systems where the water table lies significantly below the surface of the ground
Tidal Current	A current in water resulting from the rise and fall of the tides. Tidal currents usually reverse with the tides.

Tidal range	The vertical height between high tide level and low tide level.
Tides	The regular and predictable rise and fall of sea level resulting principally from the gravitational pull of the moon.
Tsunamis	Very large ocean waves caused by massive deformations of the Earth's crust at a collision junction.
Vertical Zonation	The establishment of distinctly different horizontal bands of organisms along an environmental gradient.
Wave-cut notch	A horizontal shoreline notch in rock resulting from wave action.
Zonation	Regular horizontal banding of communities within an ecosytem in response to changing environmental conditions.

Reading Material

Benchly P. And J. Gradnohl. 1995. **Ocean Planet: Writings and Images of the Sea.** Abrams, Times Mirror Magazine and Smithsonian Institution. 192p.

Britton, Nathaniel Lord. 1918, **Flora of Bermuda**, Charles Scribner's Sons, New York. 585 p.

Cousteau J. Y. and F. Dumas. 1953. **The Silent World**. Harper Bros., N.Y. 266p

Hayward, Stuart, Gomez, Vicki and Wolfgang Sterrer. [Eds.], 1982. **Bermuda's Delicate Balance: People and the Environment**. The Bermuda National Trust. 402p.

Phillips-Watlington, Christine. 1996. **Bermuda's Botanical Wonderland: A Field Guide**. Macmillan Education Ltd., 128p

Rowe, Mark P. 1998. **An Explanation of the Geology of Bermuda**. Bermuda Government, Ministry of the Environment, 30p

Sterrer, Wolfgang E. 1986. **Marine Fauna and Flora of Bermuda**. Wiley Interscience Publication, 742p.

Sterrer, Wolfgang E. 1992. **Bermuda's Marine Life**. Bermuda Natural History Museum and Bermuda Zoological Society, 307p.

Sterrer, Wolfgang E. and A. Ralph Cavaliere. 1998. **Bermuda's Seashore Plants and Seaweeds**. Bermuda Natural History Museum and Bermuda Zoological Society, 269p.

Taylor, W. R., 1960. **Marine Algae of the Eastern Tropical and Subtropical Coasts of the Americas**, University of Michigan Press, Michigan. 823 pp.

Thomas, Martin. L. H. and Alan Logan. 1991. **A Guide to the Ecology of Shoreline and Shallow-water Marine Communities of Bermuda**. Bermuda Biological Station for Research Special Publication Number 30. Wm. C. Brown Publishers, Dubuque, Iowa, U.S.A., 345p.

Thomas, Martin. L. H. 1998. **Marine and Island Ecology of Bermuda**. Bermuda Aquarium, Natural History Museum and Zoo, Bermuda Zoological Society and Friends of the Bermuda Aquarium, 148p.

Thomas, Martin L.H. 2003. **Marine Ecology of Harrington Sound Bermuda**. Scientific Reports of the Bermuda Aquarium, Natural History Museum and Zoo, 49p.

Thomas, Martin L. H. 2004. The **Natural History of Bermuda**. Bermuda Zoological Society, 256p.

2 Halves Publishing. 1997. **Sporty Little Field Guide to Bermuda for the Curious and Confused**. Two Halves Publishing, Bermuda, 48p.

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