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The Open Ocean around Bermuda

written by

Dr. Martin L. H. Thomas

Project Nature

Field Study Guides for Bermuda Habitats

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The Open Ocean around Bermuda

(Second Edition)

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Field Study Guide

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The Open Ocean around Bermuda
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Cover photograph of open ocean North of Bermuda
by Martin L. H. Thomas

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Foreword

Were it not for the ocean that embraces us, the earth would be intolerably hot by day and freezing by night. Our oceans absorb and store the sun's energy, distribute it around the world, and release it back into the atmosphere, thus making earth a viable and comfortable place to live.

Were it not for the ocean around us, Bermuda would not be that special place where warm waves surge across productive coral reefs and lap onto sparkling pink sand beaches. The ocean has brought from afar an array of life that we have come to acknowledge as our island community; with many life forms still to be discovered. The ocean surrounding Bermuda today is teeming with multitudes of creatures comprising hundreds of species yet we know so little about them. Just beyond the waves and the reefs are sea birds, marine mammals, fish, invertebrates and plants in a world that is mysterious and fascinating to explore.

There is wealth in the sea, both in food and in minerals; but true wealth lies in better utilization of the sea's resources by man. By learning about species interactions, complex food chains and dynamic exchanges of gas, minerals and water we will be better able to protect this precious resource for future generations.

Another in the excellent "Project Nature" series published by the Bermuda Zoological Society, this latest reference by Dr. Martin Thomas immerses the reader into the limitless world of the open ocean around Bermuda. Summarizing everything from oceanography to our geological formation and the abundance of life in our oceans, this publication is easy to read, comprehensive and fascinating in content and a must for every educator's book shelf.

Jennifer Gray
Head Aquarist
Bermuda Aquarium, Museum & Zoo
October 2003

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Jack Ward, Principal Curator of the Bermuda Aquarium, Museum and Zoo paved the way for the production of this volume and enthusiastically supported the work. Mary Winchell, the former Educational Coordinator is largely responsible for all the previous publications in the Project Nature series, now comprising nine field guides. Holly Holder, the present Educational Coordinator has taken over Mary Winchell's supportive role and this is the second field guide published under her leadership. Liz Nash took on the task of preparing this manuscript including setting up the text, assembling all the illustrations of species, inserting them in the text, producing and printing the end product in preparation for binding. Her dedication to this task for the past eight field guides has ensured that the final products would be easy to use, most attractive and as error free as possible.

Many people have assisted in the background field, library, proof-reading and museum work essential to a task such as this. Without their help and encouragement the guide would be much less complete and practical than it is. Grateful thanks are extended to: Anne Glasspool, Lisa Greene, Bobbi Cartwright, Judie Clee, Chris Flook, Sarah Manuel, Alan Logan, Richard Winchell, Wolfgang Sterrer, Margaret Emmott, and Penny Hill.

The illustrations of the species of plants and animals important in the ecology of the open ocean around Bermuda, were adapted, with permission, from a variety of sources including, "Marine Fauna and Flora of Bermuda" edited by W. Sterrer, "Bermuda's Marine Life" by W. Sterrer, "Bermuda's Seashore Plants and Seaweeds" by W. Sterrer and A. R. Cavaliere, and the "Identification Manual to the Pelagic Sargassum Fauna", Bermuda Biological Station for Research Special Publication No. 11, by B. Morris and D. D. Mogelburg. Others including the text figures were prepared especially for this publication by the author.

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Introduction

Bermuda is an **Oceanic Island** with vast expanses of open sea on all sides. Additionally, Bermuda is more oceanic than many islands since depths plunge to very deep values very close to the coast. Indeed, off the south shores of the islands the descent is virtually immediate. This is why Bermuda was the base for the first deep submersible tests by William Beebe and John Tee Van in the Bathysphere which took place to the south of Nonsuch Island. We will return to this historic topic later.

To live in Bermuda is almost to live on the ocean. The only thing lacking is the motion of a vessel; thank goodness for that! The main effects of the ocean are part of the way of life. As an example, the usually friendly climate of Bermuda depends almost totally on the ocean. At a similar latitude on the North American continent the annual variation in climate would be very much greater. Bermuda's two seasons, summer and winter, are expanded to include very definite spring and autumn but winter shows the greatest differences. On the continent, winter would be much more severe with frost and snow a regular, annual occurrence. This in turn affects the way of life for humans and determines what animals and plants live there. Rough weather at sea close to Bermuda affects everyone on the islands. In the case of a hurricane or other violent storm, there are no inland areas in which to seek shelter and salt spray affects everything. Life in Bermuda means being ready for anything the ocean can foster.

On the other hand, the ocean provides great opportunities for commercial and recreational fishing, boating for pleasure and marine commerce, wonderful salt-water swimming from fantastic beaches, wonderful coastal scenery and opportunities to study oceanic and sub-tropical marine life. These sorts of things have fostered a vigorous tourist trade which brings in the equivalent of almost ten times the resident human population each year. The opportunities afforded by Bermuda for marine study have led to its being a centre for marine and oceanic research carried on mainly at the Bermuda Biological Station for Research but also at the Bermuda Aquarium, Natural History Museum and Zoo. Also attracted both by the tourist trade and the ocean nature of Bermuda are commercial endeavours such as the Bermuda Underwater Exploration Institute and Dolphin Quest.

Consider the matter of ocean transport. Most people will think immediately of cruise and freighter ships that come to Bermuda all the time; however, there is another aspect of ocean transport which is less obvious until one considers it. Bermuda is a tiny island in the North Atlantic Ocean and yet the undeveloped parts are densely covered in plants and there is a wealth of birds and animals around. Most of these arrived by ocean transport one way and another. If we look at the marine life we find most of it to be remarkably similar to that of the Gulf of Mexico and the southern U. S. A. It can be correctly concluded that it has been transported to Bermuda by the ocean. The same is true of almost all the plants that grow along the coastline; even many of the more inland plants probably arose from floating seeds. One might question, however, that the bulk of creatures and plants of inland locations were brought here by the sea. A close look reveals that this is incorrect. The bulk of the inland plants has arrived as introductions by man, shipped by sea. Much more detail of this aspect is available in the Project Nature guide "Oceanic Island Ecology of Bermuda".

The plants and animals of the open ocean are highly adapted for their mode of life and are interesting in that they include some of the smallest and some of the largest animals in the world. This is less true of the plants most of which tend to be so small as to be microscopic. Animals range in size from tiny, single celled, creatures to the largest animals ever to live on Earth, the great whales. The oceanic birds are of particular interest, many being adapted to remain at sea except for breeding purposes. One of these, a medium-sized bird in the petrel family, called the Bermuda Petrel or Cahow

(*Pterodroma cahow*), is of particular interest in that it is **endemic** to Bermuda. Endemic is a word meaning that the organism referred to evolved there. In this case the Cahow breeds only on a few small islands in Bermuda, spends the vast majority of its life at sea and is in danger of **extinction**.

Although not so obvious as on the land, pollution is an ever increasing problem in the open ocean. Materials discharged from all the rivers end up in the sea; many places discharge wastes directly into the ocean and ships contribute to this. Oil has been a particular problem in the sea as it floats at the surface, fouling birds and washing up on beaches. A growing problem is plastic waste which may entangle marine life or be eaten in mistake for food only to clog up the digestive tract of the consumer. It is not uncommon for members of dwindling populations of whales to become entangled in rope; some of these die. Oceanic turtles found dead at sea and brought in to the Bermuda Aquarium for **autopsy**, have been found to have succumbed to the effects of eaten plastics. Other pollutants have more subtle effects when they are diluted in sea water. For example the banned **insecticide** DDT has been spread throughout the world in sea water, to turn up in the bodies of animals in places where it was never used, such as Antarctica.

The Project Nature field guide series has been produced to provide essential background material for school teachers to describe the characteristics of the major natural **ecosystems** of Bermuda, and to conduct field trips which give hands-on experience of these unique systems to their students. Because, in Bermuda, the historical geological background and the present geological conditions are of great importance in setting the biological scene, most of the field guides have presented considerable detail on geological topics. This approach has been expanded in the present guide to give basic oceanographic information as well. The biological material has been presented in two major categories. The first of these is the ecological characteristics of the **ecosystem** under discussion and the second consists of descriptions of all the common species of animals and plants that are present together with a picture of each. The ecology is vital to an understanding of the structure and functioning of an ecosystem. The descriptions and illustrations are equally necessary because they enable teachers and students to identify the animals and plants they are likely to find, and then link them to the ecological information. In this volume oceanographic information is not restricted to ecology but includes aspects of physical and chemical **oceanography** as well. Each field guide is essentially a self-contained document but others in the series may be useful in giving additional information on surrounding areas. Up to now all but one of the field guides have concentrated on the major ecosystems of the land, shore and coastal sea. For instance sandy shores, rocky shores, forests, wetlands, coral reefs, bays and seagrass beds and the unique Harrington Sound have been featured. These are the main systems found in Bermuda that are readily accessible and which have good, safe field study sites within them. The one departure from this plan was devoted to the more general topic of oceanic island ecology.

In the general text, technical words in **bold** are defined in the glossary at the end. In the subsequent sections bolding is used for emphasis.

Scientific names of animals and seaweeds, written in italics, are given for the first mention of any species in the text or section but not for subsequent mentions in the same section. Scientific names are included because they provide a reference to that exact species in other writings. Common names can change from place to place; indeed quite a few apply only in Bermuda. Additionally, scientific names, once you get used to them also give clues to family relationships of organisms and often are quite descriptive of some feature. For example an anemone found only in the floating masses of the oceanic seaweed called Sargasso Weed (*Sargassum* species) was formerly given the scientific name of *Anemonia sargassensis*! And of course the seaweed itself (*Sargassum*) is named for the vast body of ocean water lying to the east of Bermuda called the Sargasso Sea. A really extreme example is the scientific name for the deepwater Vampire Squid, *Vampyroteuthis infernalis*, which might be roughly translated as the Infernal Vampire Squid!

Getting out on the Ocean

All the natural systems covered in the Project Nature Field Guides before this one have been reasonably accessible with the possible exception of the coral reef. Getting out on the open sea is more difficult and expensive. Perhaps this guide will be used more for study than in the field, nevertheless actually getting out on the open sea is well worth the challenge.

The closest approach to the open sea is to the south. There the water deepens very rapidly and open ocean conditions are available quite close to land. However, the open sea is not an environment to take lightly and a boat of reasonable size, with an experienced skipper is essential. At the very least the boat should have all modern navigational equipment, a depth sounder and be equipped with full first aid and life-saving devices. If possible, it would be advisable to have somebody on board familiar with ocean sampling methods. The Bermuda Aquarium is available to give advice on vessels and guides.

Those going on an ocean field trip should take waterproof clothing and footwear and a warm sweater. It is much cooler out on the water than on land and some spray coming on to the boat is almost inevitable unless it is very calm. Those subject to seasickness should take a remedy that they know works for them, <u>prior to departure</u>. It is too late once one starts to feel sick.

The trip leader should always have a cell phone with well-charged batteries to hand. This can back up the on-board radio equipment. Everyone should have basic note-taking material. A clipboard and pencil is the best combination.

The trip will be much more interesting if some basic equipment is obtained prior to the excursion. Straightforward items can probably be borrowed from the aquarium but a few can be easily made. A **Secchi disc** to check water clarity is a good example; one can easily be made from the bottom of a white pail. Just cut out the bottom; mark it in quarters with two lines crossing the center, then paint two opposite quarters black, leaving the other two white. To lower it you will need a sturdy cord marked at meter intervals, at least 30 m long. A permanent marker readily marks cord and one can just count the marks as you haul it in. A couple of lead diving weights will help to get the disc down quickly. Another good device to have is a plankton net, it does not have to be very big, 50 or 100 cm in diameter is fine. A dip net is handy for scooping up Sargasso Weed and several buckets and a few jars are essential.

It is always advisable to have several pairs of binoculars on board with which to find and observe oceanic birds and possibly whales.

Oceanographic Background

The Ocean System

From an oceanic island the overwhelming magnitude of the ocean is more obvious than from a continental shore, but still few people are aware of how much of our planet is ocean. The interconnected parts of the oceans comprising open ocean areas, bays, gulfs, estuaries etc., together make up seven tenths of the surface of the earth. Not only are the salt-water bodies wide, they are also very deep. The deepest places in **trenches** exceed 10,000 m (32,800 ft) while the average depth of the oceans is 3,800 m or 12,400 ft (3.8 km, 2.35 miles). The volume of water in the oceans is about 1,400 million cubic kilometers. A single cubic kilometer of water is a huge amount, enough to cover Bermuda in a layer 18 m or 59 ft deep!

The part of the planet that supports life is called the **biosphere**. On land the biosphere is almost two-dimensional compared to the sea since life is mainly in a layer about 25 m deep, from the tree tops to a meter or so into the soil although birds and some insects and spiders can go a few hundred meters into the air. In the ocean life is more three-dimensional extending from the surface to the deepest locations of over 10,000 m. There is 300 times as much living space in the oceans as on land!

It is also important that all ocean areas are interconnected and so anything introduced into the ocean can theoretically appear anywhere else. This interconnection also means that seawater can and does move very long distances. Surface and deep **currents** are characteristic of the oceans. These currents and the property of water known as **heat capacity** means that sea water can absorb a great deal of energy from sunlight. Thus water may be heated, at the surface in warm climates, and then be transported in currents to cold climates. There the contained heat is slowly released, resulting in a milder climate. Thus the ocean extends the areas on earth that support abundant life. Bermuda is an excellent example of a place where the climate is greatly improved by the ocean. This topic will be explored in more detail in the section on currents. Also of importance in terrestrial climate is the fact that water vapour evaporates into the air from the surface of the sea. This humid air is the source of most of the rainfall on land areas. Rainfall is not only essential to life but also a powerful eroding agent of terrestrial rock, in turn producing the soil.

Another important fact about the oceans is that life originated there. At first it was simple but with time became more complex. With increased complexity came the ability of some bacteria and most plants to photosynthesise. **Photosynthesis** is the process by which the light energy of the sun is used, within bacterial or plant bodies, to combine carbon dioxide from the air with water to produce organic material. This organic material in turn is the food for the animal kingdom. A by-product of photosynthesis is oxygen and the oxygen produced in the oceans has provided the bulk of that in the atmosphere as well as that dissolved in water. It was the availability of oxygen from the oceans that paved the way for the evolution of higher life forms.

Despite the huge size and volume of the oceans they can and do become polluted. All material released into rivers ends up in the sea and to this burden is added that coming from densely populated coastal areas. Once in the ocean this material can be spread throughout all the oceans.

The vast volume of the oceans gives them great stability and one might consider that they could not be radically changed by climatic conditions. However, the unravelling of **pre-historic** events has shown that this is not so. Climatic changes have the ability to change the ocean drastically. During climatic cooling periods which produced the ice ages much of the water evaporated from the oceans froze on land in polar regions to produce immense ice caps or glaciers. Thus water was transferred from the oceans to the land and not returned. This led to a lowering of the level of the sea on a large scale. At the height of glaciation sea level was lowered at least 100 m or 325 ft.

The ocean system has a controlling influence on life and conditions on the planet Earth.

The Characteristics of Water

Water

Water is essential to life and found only rarely in the **solar system**. For water to remain on a planet there must be an **atmosphere**; in the absence of an atmosphere water is lost into space. All the water on Earth has originated from rocks and most was released during the cooling of the Earth's crust. New water is still released during volcanic activity; this addition is balanced by loss of water to space and the total amount of water on Earth remains almost constant. Water has many unique properties which are important to life on Earth. The range between melting and boiling points means that most water on Earth is in a liquid state. The **specific heat capacity** of water is very high which results in its ability to store large amounts of heat. This property also means that water changes temperature only slowly and is able to transport large quantities of heat in currents. Another unusual property of water is that it expands on freezing. Were it the other way around, ice would form at the bottom of water bodies. In cold climates, floating ice protects the water and organisms beneath. As with most liquids, the **density** of water depends on temperature. Density falls as temperature rises. The only exception to this is that the density of fresh water rises between 4ºC and 0ºC. This unique property of fresh water does not apply to seawater.

Sea Water

The most obvious difference between fresh water and seawater is that the latter is salty. Although the most obvious component of seawater is common salt (Sodium chloride) there are also a large number of other salts present. In order of decreasing quantity the main ones are; Magnesium Chloride, Sodium Sulphate, Calcium Chloride, Potassium Chloride, Sodium Carbonate and Potassium Bromide. Also present are most of the elements on Earth, many in very tiny quantities. Another feature of the composition of seawater is that the great majority of these chemical components are present in constant proportion to each other. Only a few constituents, for example dissolved oxygen vary greatly.

All the salts naturally present in seawater have come from the **weathering** of rocks and volcanic activity on land and in the seabed.

The total of the dissolved salts in seawater is termed its **salinity**. Salinity could be determined directly by evaporating a known quantity of water to dryness and weighing the resultant salts. If one litre (1000 ml) of seawater from around Bermuda were evaporated in this way we would be left with about 36.5 grams of salt. By convention the salinity of seawater is expressed in 'parts per thousand' which is abbreviated as ‰. Thus the surface salinity in the ocean around Bermuda is 36.5 ‰.

The salinity of seawater is very rarely measured directly. Various types of **salinometers** take advantage of the fact that salinity affects many other properties of seawater. For a fairly rough measurement, electrical conductivity may be used. The conductivity of water rises as the salt content increases. More accurate measurement is often done with an induction salinometer. These meters measure the strength of a magnetic field induced in seawater. The strength of the field varies with salinity and temperature. A convenient and reasonably accurate reading of salinity can be made using a refractometer. The refractive index of water changes with salinity and temperature, but a liquid prism incorporated in seawater refractometers corrects for the temperature and the instrument reads directly in salinity. Salinity refractometers are relatively inexpensive and very reliable; they offer the best approach to the measurement of salinity provided great accuracy is not needed. It is also possible to measure salinity with a **hydrometer**, which measures density in liquids. However, the density is also affected by temperature and correction for this factor is quite complex and hydrometers are very fragile.

Water Masses and their Characteristics

General Matters

In such a huge volume of water as the world's oceans, it is inevitable that water in different locations will show different properties. On this basis the water in the oceans can be divided into **water masses**. The properties used to define a water mass are generally temperature, salinity and density. Coastal water masses are generally lower in salinity and density than offshore ones. Tropical waters have higher temperatures, at least at the surface, than temperate and polar ones.

Temperature

Temperature changes cause differences in the properties of seawater and temperature is very important to marine life. Few organisms can live at the full range of temperatures found in the oceans.

The main factor increasing temperature in seawater is **infra-red solar radiation**. Water absorbs infra-red light very rapidly and because of this, solar heating is confined to a very thin layer of about 1 m (3 ft) at the surface of the ocean. One might think that this heated surface water would be mixed to greater depths very readily but this is not so. As water is heated it expands and its density falls. Thus, surface water in an area where it is gaining heat is lighter than the water beneath it. When large volumes of lower density water overlie cooler, higher density water they tend to stay as a warm layer on the surface. Literally the surface water floats on that underneath much like cooking oil would float on water if you tried to mix both in a glass. However, unlike the oil, waters of differing density can mix if enough energy is put into the mixing process. At the surface of the ocean, wind and wave action can provide this energy and mix the surface water with that immediately below. Not even violent storms however can mix more than the top 30-50 m (100-160 ft) of water, which is nothing compared to the 3,800 m average depth of the oceans. At the junction between surface and deeper water temperature tends to fall quite sharply. This zone of rapid temperature change is called a **thermocline**. Density increases going down through the thermocline.

Ocean seawater loses temperature by conduction into colder air as well as in the process of evaporation. Cooled water increases in density and if its density becomes higher than that underneath, it will tend to sink mixing with just sub-surface water as it does so. This happens routinely during winter. Around Bermuda this winter water does not sink to the bottom because deep waters are always colder and denser than surface ones. However in winter, a deeper surface layer extending down to about 600 m (2,000 ft) is quite well mixed. At its junction with deeper waters, a **permanent thermocline** has formed which is present the year round.

When a water mass becomes divided into layers of differing characteristics such as density and temperature it is called **stratified**. Stratification can occur on vastly different scales; in saltwater ponds it can be very well established in just a few meters of water.

At sea where the temperature distribution in a water mass needs to be measured quickly, an instrument called a **bathythermograph** is used. Like a little torpedo, it is dropped into the ocean, tethered by a thin line and draws a graph of temperature against depth on a glass slide. Another version of the same instrument is disposable; it is tethered by a thin wire to a ship where a meter graphs temperature against depth. On reaching the end of the wire, the instrument breaks free and becomes seabed garbage.

Density

Density is determined by the combination of temperature and salinity. Its main value is that it allows prediction of the behaviour of water, particularly in relation to sub-surface currents. The densest water will always be at the bottom and the lightest at the surface.

Density is almost never measured directly (see **hydrometer** above). Additionally, it is never expressed as **specific gravity** because the numbers would have many zeroes after the decimal point. Instead it is given as Sigma-t values (^{o}t). (Sigma-t = [density-1] x 1,000). Open ocean waters have sigma-ts in the range of 24-30.

Salinity

The basis of salinity was introduced above. What causes variations in salinity? Salinity is reduced by dilution with fresh water either from fresh water run-off from land or in the form of rainfall. Because of the effect of rivers along shorelines, coastal water is often reduced in salinity. Whereas oceanic waters usually have salinities of around 35‰, coastal waters of 28‰ are quite frequent and in **estuaries** where rivers meet the sea, salinities decline to close to zero. The most common cause of an increase in the salinity of seawater is evaporation of water under conditions where the humidity of the air is below 100%. In the sub-tropics evaporation usually exceeds rainfall and surface ocean water increases in salinity. This is the reason that ocean water around Bermuda has a higher salinity than the average. It would be reasonable to ask why this increase in salinity would not increase density so that surface waters could sink. In reality the effect of temperature in lowering density is much greater than the effect of salinity in increasing it!

Figure 1 shows how temperature, salinity and density vary in relation to depth in ocean waters around Bermuda.

Light in Seawater

General

Light in seawater is very important because of its importance to life. As mentioned above the process of photosynthesis, which is dependent on light energy, is the basis of organic food upon which all organisms rely. Even photosynthetic plants need organic material for life energy during the dark hours. Light is also important for visual behaviour, such as food gathering, recognition of enemies, identification of the opposite sex etc.

Penetration of Light into Water

In general light is rapidly absorbed in seawater but the depth to which it penetrates depends on the wavelength. In general 65% of all light is lost in the first 1 m (3 ft) of water. As already mentioned infra-red rays penetrate about 1 m (3 ft). At the other end of the spectrum ultra-violet frequencies are even more rapidly absorbed in just the first few centimetres (inches) of water.

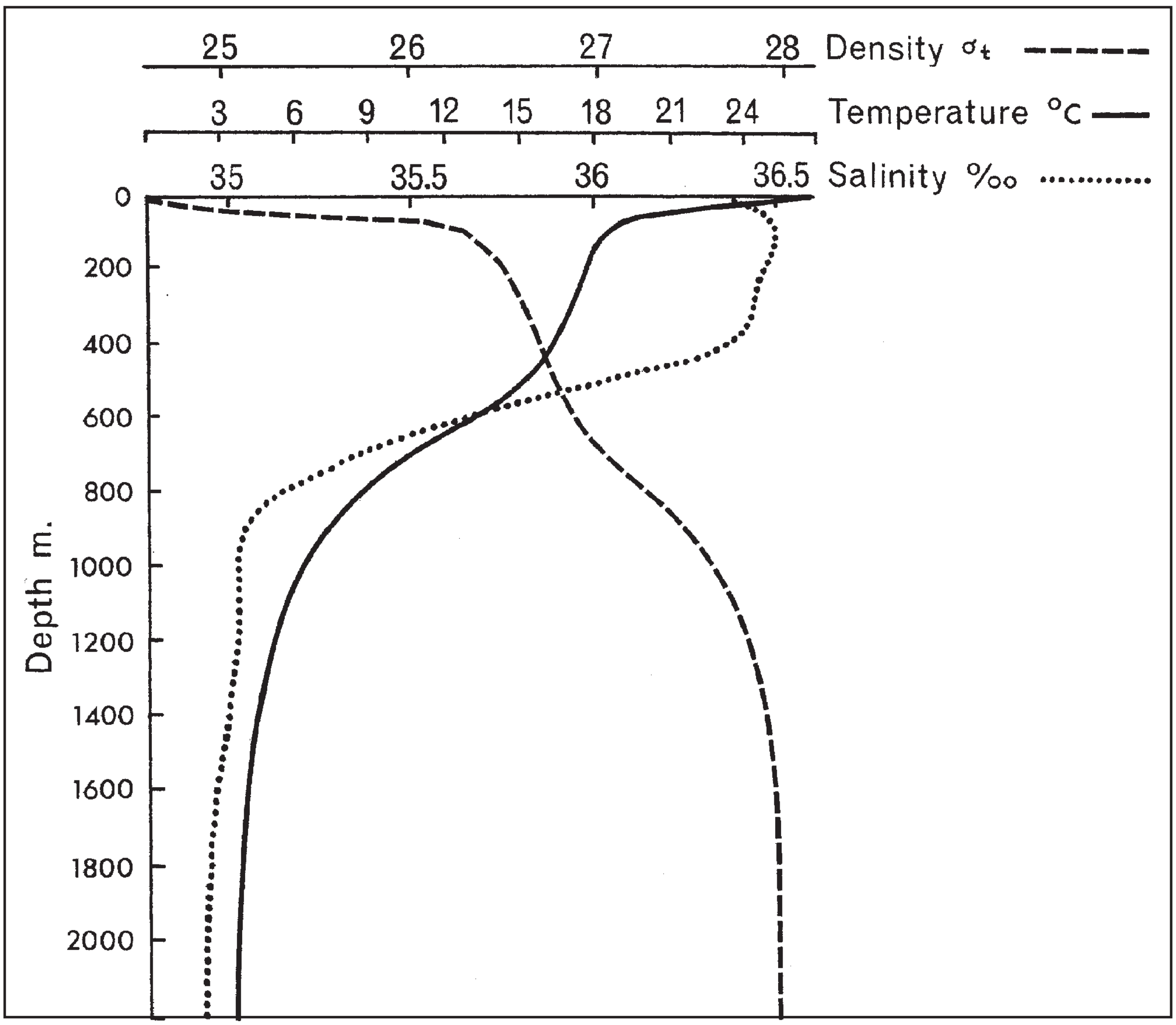


Figure 1. Temperature, salinity and density plotted in relation to depth for average ocean waters off Bermuda. At depths greater than 2,000 m (6,600 ft.) conditions are almost constant.

Visible light penetrates much further, especially blue and green wavelengths, and its penetration depends on water clarity. In the very clearest waters only 0.1% of light reaches 200 m (650 ft) but some highly adapted deep sea animals respond to very minute light levels down to a depth of 1,000 m (3,300 ft). The measurably illuminated waters of the ocean are termed the **photic zone**. Nowhere is this deeper than 200 m (650 ft), in turbid coastal waters the photic zone is often only a few metres (yards) deep.

Since photosynthesis is so important, a name has been given to the depth where the production of organic material (food) by photosynthesis balances food energy usage. This is the **compensation depth** and it coincides with the depth to which 1% of surface illumination reaches. Above the compensation depth more food is produced than is consumed and below it the opposite is the case. In ocean waters around Bermuda the compensation depth lies at about 100 m (325 ft).

The measurement of light levels in seawater can only be done accurately with sophisticated electronic **photometers,** but a good index of light penetration can be made with a **Secchi Disc** which is a weighted, white disc about 30 cm (1 ft) in diameter painted with two black quadrants alternating with white ones. The Secchi Disc is dropped on a depth-graduated rope until it can no longer be seen. This depth will be somewhat shallower than the compensation depth, but can be used as an index. A Secchi Disc is particularly useful in comparing light penetration at a series of locations from the open sea in to coastal waters.

Pressure in Seawater

Anyone who has **SCUBA** dived into the sea or any water for that matter will know that the pressure increases rapidly with depth. In fact pressure increases by one atmosphere for every 10 m (32 ft) of depth. This is why submersible vehicles have to be extremely strong. The bathysphere used by William Beebe in the first deep submersible dive off the south coast of Bermuda was basically a thick, very strong, steel sphere with a very thick window for viewing.

You may wonder if such high pressures as occur in the deep sea are not a barrier to life there. Basically, there is no effect of pressure on creatures at great depth since they are largely composed of water which is essentially incompressible. The only problems arise if creatures move through a great range of depths and have any gas-filled spaces in their bodies. The effect most often seen is the grotesque bloating of fish brought up in fishing gear. Fish living down to moderate depth, but not on the bottom, have a gas-filled organ called a "**swim bladder**", which enables then to be weightless in the water and thus to swim easily. They can adjust to moderate changes in depth and pressure, by either secreting more gas or absorbing it with a gas gland. However, when they are hauled abruptly to the surface in a net, they cannot accommodate quickly enough and the bladder expands as the pressure decreases, bloating the body. Bottom-living and deep sea fishes generally have no swim bladders.

Sound in the Sea

Sound is transmitted more efficiently in seawater than in air and almost three times as rapidly. It is not surprising therefore that sound is used by many sea creatures. One of the best known examples is the Great Whales but many fish also use sound to communicate or as a warning. Grunts are named for the sound they produce, as are croakers. Marine mammals use sound in navigation to judge depth and the position of underwater obstacles. This method has been adopted by man in the acoustic depth sounder or sonar and side scan sonar which can detect objects, such as wrecks, on the sea-floor.

Oxygen in Seawater

Oxygen is one of the few elements found in seawater that varies greatly in quantity. This is because oxygen is closely linked to life processes. During the process of respiration most living organisms use oxygen and give off carbon dioxide. However photosynthetic plants in lighted waters give off oxygen and take up carbon dioxide in the process of photosynthesis. The result is that in the **photic zone**, above the **compensation depth** dissolved oxygen levels rise during the day. At night oxygen levels fall at all depths. In shallow water with lots of plant life, dissolved oxygen levels in the water frequently reach the **saturation point** and bubbles of oxygen rise to the surface.

Any oxygen in deep, dark waters must have come from the surface carried in water currents. However water isolated for long periods at depth gradually declines in oxygen content which may fall to very low levels. In water masses where intense **stratification** prevents any appreciable mixing of surface and deep waters, water at the bottom may run out of oxygen completely, this is called **anoxia**. An example of a seawater body with **anoxic** water at depth is the Black Sea but this situation also develops occasionally in Bermuda in Harrington Sound (See Project Nature, "The Ecology of Harrington Sound"). Anoxic conditions are lethal to most higher animal life.

The measurement of dissolved oxygen in seawater is not easy. It can be done with sophisticated electronic instruments or by a delicate chemical titration.

Plant Nutrients in Seawater

All plants need nutrients in order to grow and reproduce. Plant nutrients are divided into macro-nutrients which are needed in appreciable quantity and micro-nutrients needed only in trace amounts. In the sea nitrates and phosphates are the two main macro-nutrients. Potassium compounds are a required macro-nutrient on land but in the sea potassium is available in very large quantity and so can be ignored. Since plant life is confined to the shallow photic zone, these nutrients are only important there. Although nutrients are added in freshwater runoff and some nitrogen is fixed at sea, the bulk of the nutrient supply is recycled within the ocean. Phytoplankton and other plants take up both nitrogen and phosphorous compounds as they grow and they return to the water when these organisms die. In most of the open ocean, especially where there is a **permanent thermocline**, these nutrients are in very low supply; they are added only very slowly and completely lost when dead plant cells drop through the thermocline. Thus they tend to build up in deeper water. In temperate climates where surface waters cool enough in winter to sink down, sub-surface waters rich in nutrients rise to replace them, this is called an **overturn**. In spring this new supply produces a rapid growth among the phytoplankton known as a **bloom**. However, in most tropical and sub-tropical waters, surface temperatures are always high and overturns do not occur. Because of this surface waters are constantly nutrient depleted and phytoplankton growth and reproduction are severely limited. This leads to the very clear waters found in such situations since there are very few organisms to impede light penetration.

Movement of Seawater

Seawater is never really still there are always currents, tides, waves etc that set it in motion at the surface. In deep water almost all locations have deep currents flowing through them. Extraordinary events such as underwater earthquakes or landslides also produce waves that may travel around the world.

Currents

There are two main types of currents in the sea these are 1) **Wind-driven Currents** and 2) **Density Currents**. Wind-driven currents, as the name suggests, are produced by the action of wind on the sea surface while density currents arise from the difference in densities of bodies of water. The topic of density in seawater was introduced above.

<u>Wind-driven Currents</u>

It stands to reason that wind blowing across water sets it in motion. What is less easy to understand is that the action of wind around the earth determines a widespread and highly predictable set of currents in each ocean basin. To a casual observer in one location, it might appear that the wind blows over the sea from almost random directions. This may be true in some places in the short-term, but in the long term the wind is fairly predictable, even in Bermuda where it is more variable than elsewhere. If we look at the whole globe, we find that in polar regions the winds are easterly, in mid latitudes they are westerly and in the tropics they are either NE or SE. These tropical winds are called the **Trade Winds** and blow virtually constantly. This is shown diagrammatically in Figure 2. If there were no continents to interfere with current flow, currents would go around the world in bands like the winds. However the continents provide barriers and cause currents to flow in huge circles around the ocean basins. These circles are called **gyres** and are shown in simplified form in Figure 3. Notice that in this diagram currents are shown as more intense on the west side of ocean basins. This is called **westerly intensification**, and is caused by the rotation of the earth.

At this point we must digress to explain a strange fact. Winds are named after the direction they come from. Currents, by contrast, are named for the direction they are going to! A west wind blows from the west, whereas a westerly current flows towards the west. This can cause confusion!

In each ocean basin, the shapes and positions of the continents cause some complications in the flow of the gyres. The situation for the North Atlantic Ocean basin, in which Bermuda lies, is shown in Figure 4. Let us look at the particular situation of Bermuda. To do this we will start with the NE Trade Winds just to the north of the equator. The trade winds are among the most predictable winds on earth, blowing constantly and strongly in a band to the north of the equator. Over the equator itself winds are generally calm and this region has been called the **Doldrums**. The names for this area and the trade wind belt hark back to the era of sail. Trading ships could rely on the trade winds for a passage from E to W, but straying into the doldrums meant days of being becalmed. In the North Atlantic, the trade winds produce the **North Equatorial Current**, which flows ever more strongly as it moves west. Much of this water enters the Gulf of Mexico where its further progress is dammed by South America, Central America and the southern USA. The only exit is the comparatively narrow Straits of Florida. As a result the water mounds up in the Gulf of Mexico so that the surface is 1 m (3 ft) higher than in the ocean. This may seem slight but an immense volume of water is involved and it flows out to the N under the influence of gravity to produce one of the largest and strongest currents in the world. To get an idea of the size of the Gulf Stream consider that the flow of all the rivers in the world combined is about 1 million cubic metres per second, the flow in the Gulf Stream is about 25 million cubic metres per second!

The Gulf Stream flows NE up the eastern seaboard of the USA passing to the west of Bermuda. As it goes it broadens, slows and curls of water peel off the sides mixing with other water. These curls are also called **gyres** and many of them impinge on Bermuda bringing warm water and organisms from the south. To the north of Bermuda, between here and Canada, the current turns east under the influence of the westerly winds and crosses the Atlantic Ocean. On the other side most turns south as the **Canary Current** which re-joins the North Equatorial Drift to complete the gyre.

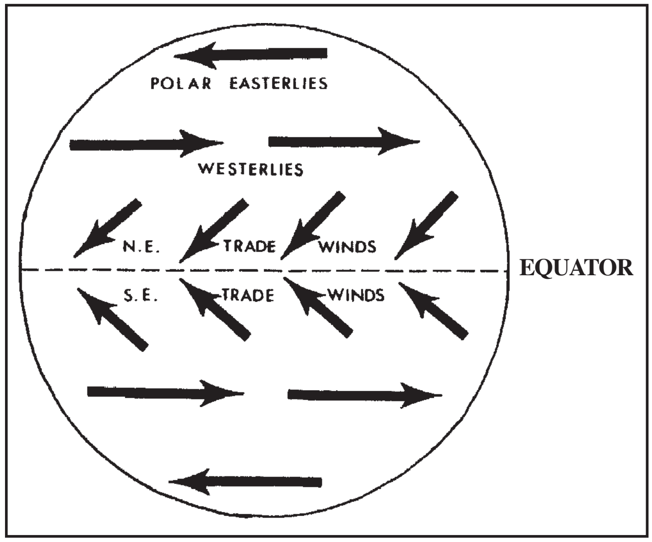


Figure 2. General wind patterns at the Earth's surface.

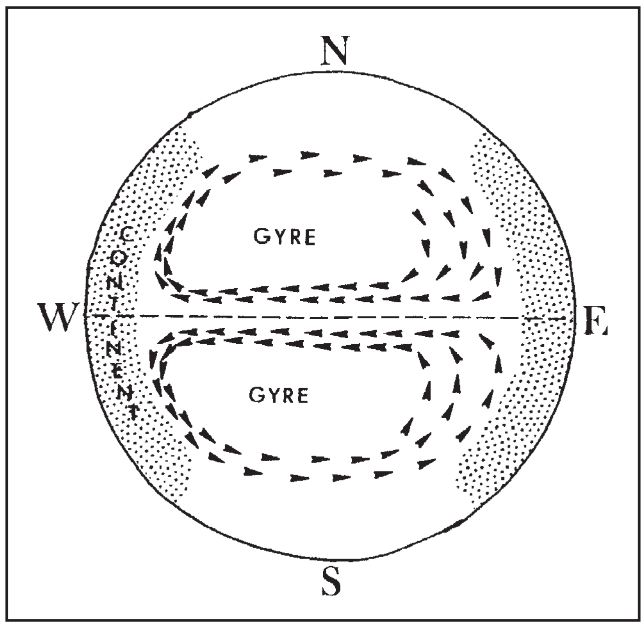


Figure 3. Generalised current patterns for ocean basins.

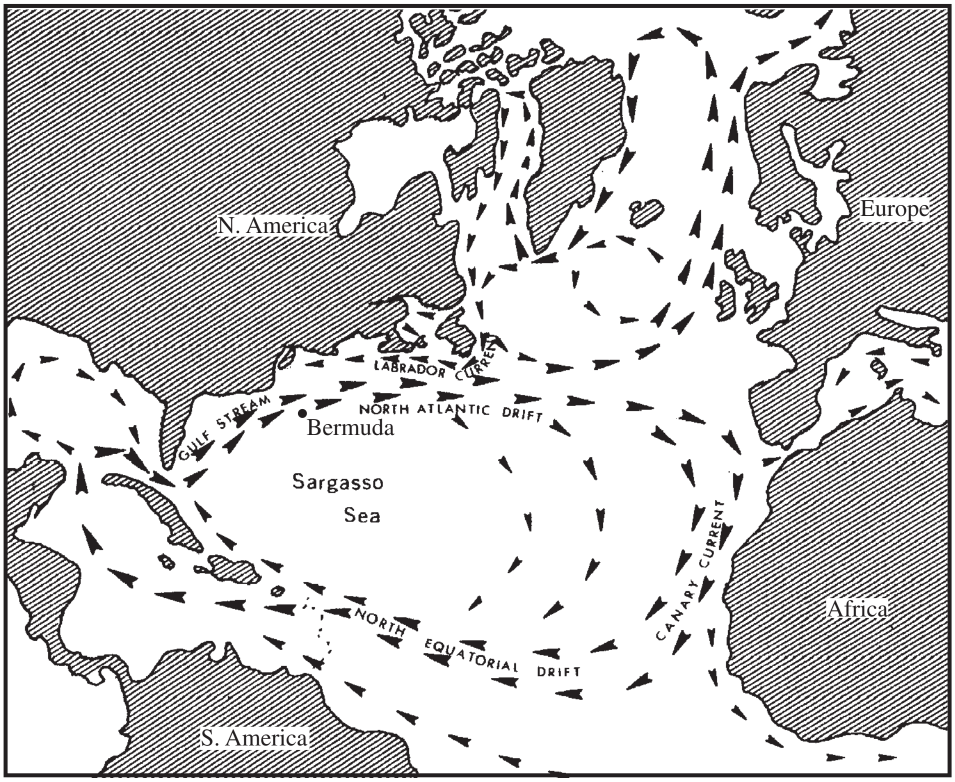


Figure 4. Surface currents in the North Atlantic.

Some water also flows north past the west coast of the British Isles and proceeds into the Arctic as shown in Figure 4. The effect of the Gulf Stream on the climate and biology of Bermuda is great and the amount of water is so large that a similar but reduced effect is felt in W Ireland and W Scotland.

Density Currents

Density currents are much more complex than wind-driven currents and most occur beneath the surface where they can't be seen. Density currents mainly arise when the density of a water mass increases due to cooling at the surface, which causes it to sink. This happens on a very large scale in both the Arctic and Antarctic. In the North Atlantic, the surface current that passes the British Isles and Scandinavia steadily cools as it proceeds through the Arctic Ocean to turn S again down the E coast of Greenland. In an area to the south of Greenland it has finally become denser than all the water around it and it sinks to 2,000-2,500 m (6,600-8,000 ft) to proceed all the way south to the Antarctic as a huge deep current. It cannot sink to the bottom because the deeper layers are occupied by even denser water produced in the Antarctic. This is an excellent example of how water masses of differing densities both produce currents and sort themselves out according to their densities. Although density currents mostly arise from surface cooling they can also be initiated where surface salinity rises due to high evaporation.

These deep density currents pass Bermuda but have no effect at the surface. They do however provide the explanation of why the deep water here is so cold as shown in Figure 1.

Tides

Tides are a universal feature of the oceans and small ones even occur in large freshwater lakes. 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 this bulge follows the moon around the earth. Since the duration of the moon's orbit is 24 h 50 min, the crest of the wave which is high tide will pass each point at this interval. High tides are actually half this time apart, at 12 h 25 min, because the net gravitational forces also produce a second bulge opposite the first on the other side of the world. The only ocean 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 were modified by the land masses so are tides. Nevertheless most places have regular tides at close to12 h 25 min intervals.

The only other heavenly body 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 tidal range is at its minimum and 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 easily altered by the weather both in timing and range.

Waves

Like surface currents, waves result from the force of the wind on the surface of the water. The higher the wind velocity the higher the waves. Small waves are closer together than large. The distance between wave crests is called the **wavelength** and the vertical height difference from trough to crest is the **wave height**. As height increases so does wavelength. Strong winds blowing over a large area of ocean for a considerable time can produce very large waves. These waves can travel over the surface of the ocean far beyond their point of origin. Such waves, produced by distant winds are called **swell**. Swell from storms far to the south is a frequent feature of Bermuda's south shore beaches.

When waves or swell move into shallow water their motion is affected. At a depth of half the wavelength the waves steepen and shorten and with further shallowing the wave breaks. Figure 5 shows the stages in breaking waves. Breaking waves impinge on the shore with great energy and can do considerable damage. When waves meet an irregular coastline they tend to straighten it by eroding headlands away and depositing sediment in bays. This process is very evident along Bermuda's south shore and is shown diagrammatically in Figure 6. Figure 7 shows the erosional effect of waves on rocky and sandy shores. The **wave cut notch** typical of rocky shores with soft rock is very well shown on south shore headlands in Bermuda. Figure 7 also shows how sandy shores are affected by waves, these features too can be seen on the south shore, but they vary considerably with the intensity of wave action. Observation of the shore after a moderate storm will show these typical features. The position of the **berm** should coincide with high tide level. During local storms such as hurricanes wave action can remove huge quantities of sand, break up rocks and damage wharves etc.

Wave action is very important to intertidal life (See Project Nature Guides to the Rocky Coast and Sandy Shore).

Tidal Waves or Tsunami

These are very long wavelength waves caused by earthquakes, underwater volcanoes and

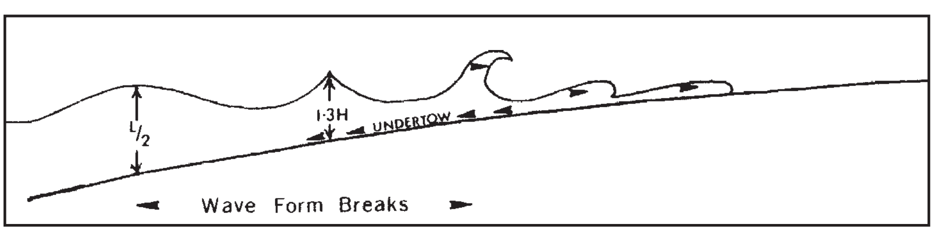


Figure 5. Stages in wave breaking. L = Wave Length H = Wave Height.

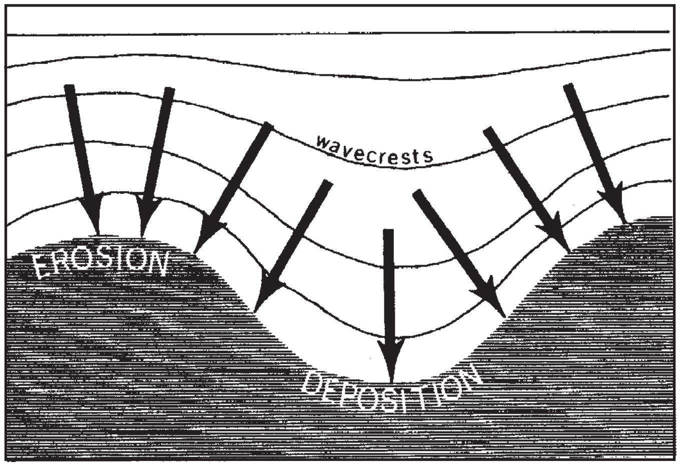


Figure 6. Shoreline wave action. The distance between the arrows shows wave intensity.

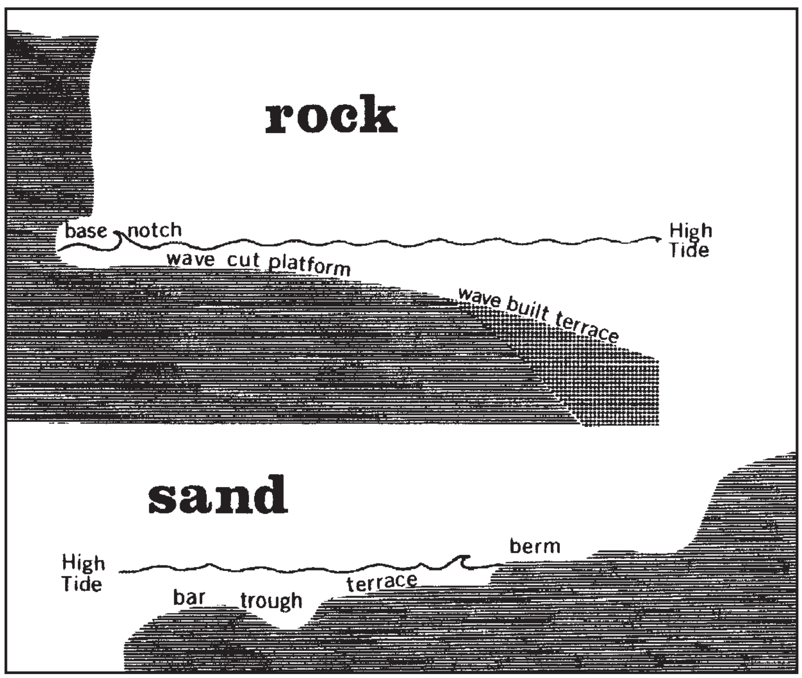


Figure 7. Wave-cut profiles of rocky and sandy shores.

landslides. The term "tidal wave" is very confusing as they have nothing whatever to do with tides. Tsunami, the Japanese word for such waves is a better term. Tsunami always have a long wavelength, often many kilometres (miles), but their height is very variable. At sea, because the wave is so long, these waves are scarcely noticeable to ships. However, when they impinge on shores, those with a large wave height often cause catastrophic damage. Some of the worst shoreline disasters have been the result of tsunami.

Internal Waves

Where there is a well-defined **thermocline** (see water masses above) at an appreciable depth in the ocean, huge waves can develop there. Such waves have no surface effect but may affect both oceanic life and submersible vehicles.

Geological Background

The Development of Ocean Basins

The world's oceans did not always look as they do today. Millions of years ago there was one large continent and the rest of the surface was ocean. All this changed in the process of **plate tectonics** whereby large sections of the Earth's crust moved under the influence of convection currents in the molten magma. Thus the original continent split into several pieces which migrated to various locations on the Earth's surface. Where crustal plates spread apart molten magma rose close to the surface or the sea bed creating **rift** or **spreading zones** and **ocean ridges**. Naturally as some plates spread apart others ground together and one plate generally bent down below the other. These plate meeting areas are characterised by mountain ridges on land and/or deep trenches in the oceans, these are **subduction zones**.

Ocean edges that are not subduction zones show a characteristic shape. The shoreline usually slopes down gradually to about 200 m (650 ft) in depth forming a **continental shelf** which in places is very wide. Both the European and North American Atlantic coasts have wide coastal plains. Continental shelves are the sites of the world's most intensive fisheries. Beyond the shelf is the **continental slope**, sloping more steeply than the shelf, but still gently to about 4,000 m (13,000 ft) in depth. At this point the slope gives way to the very flat **abyssal plain** with depths varying between 4,000-5,000 m (13,000-16,500 ft). Where **trenches** are present, the plain slopes relatively steeply into waters up to 10,000 m (33,000 ft). Trenches are generally long and fairly narrow. Islands within the ocean basins, such as Bermuda, that have arisen through volcanic activity, lack the continental shelf and slope and depths plunge to the abyssal plain relatively close to shore.

Life beyond the continental shelf depths is very diverse but sparse. The waters are dark and cold and food is in very short supply. Oxygen and most of the food at these depths must have originated in surface waters and been transported in density currents. Some food in the form of dead organisms does sink down to the ocean floor even at great depths

The Atlantic Ocean is of particular interest to Bermudians. The Atlantic was formed from the action of a spreading zone creating a mid-ocean ridge down the center. So the American Continent and the European and African Continents were once joined and have moved steadily apart as material came to the surface along the ridge. The American Plate that includes Bermuda also contains the American continents. There is a subduction zone down the west coast of the continents where the American Plate collides with the Pacific Plate. That area is marked by mountain building and earthquake activity. There are no deep ocean trenches in the Atlantic Ocean but they are characteristic of the edges of the Pacific Ocean. As the Atlantic Ocean gets slowly larger, the Pacific shrinks.

The Origin of the Bermuda Islands

According to the most widely accepted theory, Bermuda had its origins on the Mid Atlantic Ridge of the Atlantic Ocean about 110 million years ago. This puts Bermuda in the sub-group of oceanic islands called **ridge islands**. Sometimes islands are produced in ocean situations where crustal plates collide, these are called **island arcs** because they often occur in arc shaped groups. Along the Mid Atlantic Ridge, molten magma from within the earth rises to the surface and hardens to form the plates. This is a continuous process and as a result the two plates move slowly apart at about 4 cm/yr. Together with the spreading, come frequent small tremors, some earthquakes and the creation of a variety of volcanoes. One of these erupting 110 million years ago, later became the Bermuda islands. It is theorised that the volcano appeared just to the west of the ridge and produced a large sea mount which rose close-to or above the surface. This volcano, which has been called Mount Bermuda, then moved slowly away from the ridge, covering 750 miles or 1,200 km during 60-80 million years without further volcanic activity, it then went through a second phase of eruption. At this time Mount Bermuda was enlarged to form the Bermuda

Seamount, consisting of three volcanic peaks the Bermuda Pedestal, the Challenger Bank and the Plantagenet or Argus Bank. If Bermuda had arisen solely as a result of a volcanic eruption away from the Mid Atlantic Ridge, it would be a **hot spot island** rather than a ridge island. Some recent theories suggest that Bermuda is indeed a hot spot island and therefore not as old as originally thought. More research may sort out these conflicting ideas.

The group of peaks rises sharply about 4,000 m or 13,000 ft from the seabed but the Bermuda Pedestal is the only one currently above sea level. The Bermuda Seamount has moved a further 500 miles or 800 km away from the Mid Atlantic Ridge in the last 30 million years or so to lie where it is today. Luckily, volcanic activity is a thing of the past for the Bermuda Seamount as it lies low in a stable area of the Earth's crust. However, occasional earthquakes still occur as weaknesses in the underlying rock give way under the stress of the spreading process. The last significant earthquake, centered 370 km southwest of Bermuda occurred on March 24, 1978 and measured 5.8 on the Richter scale!

At first the island which became Bermuda would have been a volcanic island and the rock would have been hard, black **basalt** resulting from the volcanic eruptions. A good model of very early Bermuda can be seen in the island of Surtsey lying off the south coast of Iceland. Iceland itself is on the Mid Atlantic Ridge and volcanic activity there is virtually constant. One large eruption in the recent past, produced Surtsey, a new island consisting of dark volcanic rock. At first, as in the case of Bermuda, Surtsey had no life but as soon as the rock cooled, animals and plants started to colonise this new habitat. However, Surtsey is far to the north of Bermuda in cool waters and coral reefs will never develop there. In the case of Bermuda, the remains of the original volcanic island are now well below the island surface which consists of light coloured, alkaline limestone rocks and soils which have resulted from the biological activity of seaweeds and marine animals such as corals. These animals and plants extract calcium carbonate or limestone from seawater and incorporate it into their structure as a hard skeleton. After the death of these organisms, this skeletal limestone is eroded away by physical or biological action to produce light-coloured calcareous sand. In time this sand may move onshore, form dunes and they in turn may become a rock called **aeolianite** which is alkaline and also pale in colour. Thus the surface rocks of today are very different from the original dark coloured and acidic basalt.

Marine Sediments

Sediment Types

In general, the bottoms of the oceans are covered in sediment. Rock does appear, for example along mid-ocean ridges, but its occurrence is comparatively uncommon. Sediment is produced in two main ways. The main one is the erosion of rock. Eroded material enters the sea in rivers, shoreline run off and as a result of coastal erosion. Continental shelves are typically floored with material of these origins. A second main source of sediment is the skeletal remains of minute **planktonic** animals and plants in the sea. These skeletal materials are either calcium carbonate (limestone) or silica dioxide (glass) in nature. The former form huge tracts of **carbonaceous ooze** and the latter deposits of **siliceous** or **diatomaceous ooze**. **Diatoms** as explained below are single-celled planktonic plants that have characteristic, clear, glass-like silica skeletons. These oozes have developed over millions of years and are very extensive on the abyssal plain. In tropical shallow waters, sediments of biological origin are also produced from the skeletal material of marine animals such as corals and limy marine plants. Such sediments are mainly sands and coarse muds of much larger particle size than the oozes of the abyss. (See Project Nature "Sheltered Bays and Seagrass Beds" and "Coral Reefs of Bermuda".)

Sedimentation

Once sediment is produced it tends to fall to the sea bed. This is called **sedimentation**. The rate of sedimentation is directly proportional to particle size and density. Thus sedimentation is rapid in sand and slow in mud. If water carrying sediment is in motion, then **sediment sorting** will take place with coarse sediments being deposited at relatively fast current velocity and fine muds only in comparatively still conditions. Places with frequent wave action, such as the south shore of Bermuda, or constant high current velocity, such as Flatts Inlet, are characterised by coarse sands. Locations with negligible wave action and very slow currents, for example Coot Pond on the north shore, or Sinky Bay on the south shore, are characterised by muddy sediments. All deep ocean areas are characterised by fine muds, clays and oozes. Another factor that affects sediment mobility is **sediment consolidation**. In places of very varying current velocity, sediments may be constantly deposited and then re-suspended. Fine sediments when first deposited trap large amounts of water within them. As they sit, this water is slowly expelled, consolidating the sediment. Consolidated sediment is firmer and denser than that which was deposited. Consolidated sediments can only be moved by a much higher current velocity than that in which they were deposited. Because of this they become more stable with time and tend to stay put.

Another physical attribute of sediments that is of great importance to life therein is **sediment permeability**. Permeability refers to the amount of open, water-filled spaces among sediment grains. It can also be measured as the rate at which water can move through the sediment. This property can be made clearer with examples. Consider a coarse sand deposited in constant high water velocity, it will lack smaller sediment particles, be very permeable and have lots of water-filled voids. In a second example, varying current velocity has resulted in a sediment of very mixed particle size. In this sediment the voids between large particles are filled with small particles, permeability is poor and spaces are few and far between. Permeability is also low in sediments of constant, tiny particle size. Permeable sediments are often colonised by communities of tiny animals called the **interstitial fauna**. For descriptions of some of these animals refer to the Project Nature Field Guide "The Sandy Shore."

Gravity and water movement combine to move sediment into low spots both on land and in the sea, and at the same time to reduce the grain size. Thus bays and most coastal waters were naturally floored by sediments. The finest of these sediments, called muds, clays or oozes, most readily suspended in water, have finished up in the quietest and most sheltered environments, for example, the deep sea floor. Examples in Bermuda include the innermost part of Hamilton Harbour at the Foot of Crow Lane, Sinky Bay on the south shore, Coot Pond on the North Shore and the inner part of Tucker's Town Bay in Castle Harbour. The coarser sands on the other hand are characteristic of areas with consistent wave and/or water current activity. Thus coarser sands tend to be found just offshore and where tidal currents are vigorous. In these locations, in common with wind exposed sand on land, the sand tends to form underwater structures rather like dunes. These are often called **sand waves** or **sand ridges**. They are usually much lower in height than sand dunes on land. Sand waves, like dunes, are often mobile moving slowly with the current. However, in many places they become colonised by seagrasses which fix them in place. A good example of this are the seagrass beds off Fort St Catharines on the east end of Bermuda. Very nice mobile sand waves may be seen in Flatts Inlet.

Life in the Oceans

The Main Groups of Marine Life

Introduction

Life in the ocean has been classified into several main groups depending on their environment and mode of life. Organisms living up in the water off the bottom are called **pelagic** and those living on the bottom are referred to as **benthos**.

The most abundant and widespread pelagic forms of life in the ocean are the **plankton.** They are divided into two sub-groups, the **phytoplankton** or plant plankton and the **zooplankton** or animal plankton. Plankton are generally small or minute and if they have any swimming ability it is weak. Most just float in the water. If they can swim, they can not do it strongly enough to swim against ocean currents except for short bursts. A few larger, weakly swimming creatures, such as jellyfish, are still plankton.

A very special group of the plankton are the **neuston** which drift right at the surface. We will return to this group as they are particularly important around Bermuda.

Pelagic animals that can swim strongly in the water above the bottom comprise the **nekton**. The nekton includes a huge diversity of organisms from great whales, through many fish, squids and others.

The benthos also includes a huge variety of organisms. Benthos are divided into those that live in burrows, the **infauna** and those that live on the surface of the sediment, the **epibiota**.
In shallow water the epibiota includes both animals and plants. In deep water all the benthos is animal.

Phytoplankton

The phytoplankton are the floating plant life of the ocean. By far the majority are single-celled plants from a wide variety of plant groups. Several are from the **cyanobacteria** or **blue-green algae** which were formerly classified as plants. A few are multicellular. The phytoplankton are the main photosynthesisers in the ocean and are at the base of many food chains. Virtually all phytoplankton live in the photic zone although a few can survive in deep waters for long periods.

The most abundant group of phytoplankton are the **diatoms**. These tiny, single celled plants have no means of movement and are suspended in the water. The characteristic feature of the diatoms is that they form a very thin perforated, capsule or **frustule** of silicon dioxide which is crystal clear. The frustule is composed of two halves one of which slides over the other forming a box-like structure. Each species has a characteristic frustule shape. Reproduction is usually by division. There are two basic shapes of diatom, one like a very shallow cylinder called **centrate** and the other elongate or **pennate**. Figure 8 shows examples of both these types of diatom as well as the division of a centrate one. When they die, the frustules of diatoms which are delicate but resistant to fragmentation, slowly sink to the seabed. Where they are the main phytoplankton in deep sea areas, these remains form silicious or **diatomaceous oozes**. Not all diatoms are pelagic; there are a great many benthic forms and not infrequently, these may form colonies that resemble true seaweeds. These deposits are used commercially as abrasives and insecticides.

The second most important group among the phytoplankton are the **dinoflagellates**.. Many of these are armoured by chitin plates which form a characteristic skeleton. Others are naked. Whichever form they are in, there are usually two whip like **flagellae**, one in a groove around the body and one trailing. Both beat constantly, the one spinning the body and the other driving it forward. Thus these organisms can swim

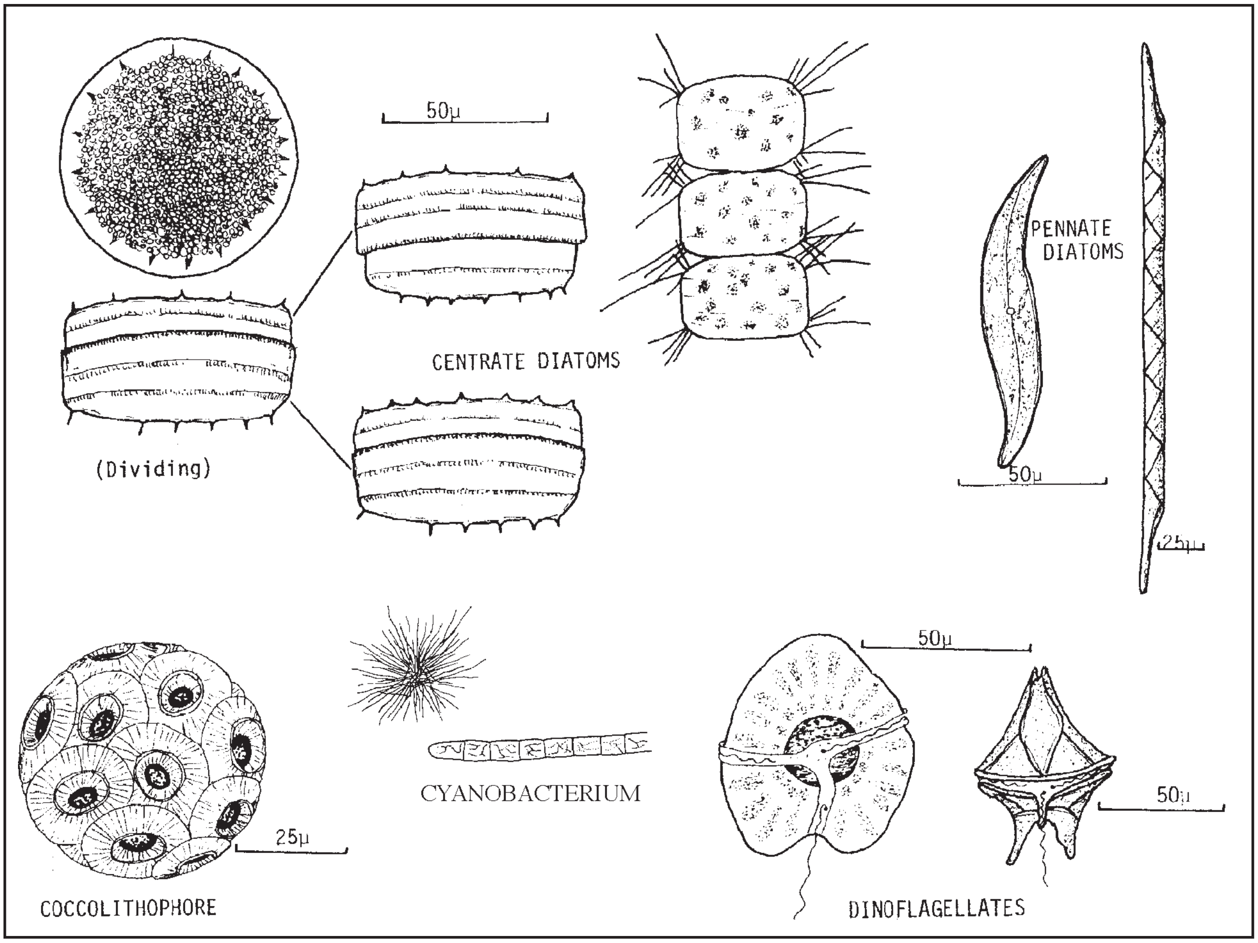


Figure 8. Representative phytoplankton. A micron (μ) is a thousandth of a mm.

weakly and use this to maintain their place in the surface waters. An armoured and a naked one are illustrated in figure 8. The dinoflagellates are a very diverse group and not all are pigmented. Some species are **bioluminescent**, meaning they can produce light, and may flash or glow in surface waters. If you are swimming at night and the water lights up as you disturb it, ten to one it is a caused by a dinoflagellate. Other dinoflagellates are quite poisonous and may cause fish kills and **paralytic shellfish poisoning**. Some are quite brightly coloured and may give the water a characteristic tint. One reddish one, also poisonous, is called '**red tide**'. Most members of this group are good food for a variety of organisms in the sea.

Another member of the phytoplankton that can contribute to deep sea oozes are the **coccolithophores**. These are small organisms with a single flagellum, the exterior of which is protected with a series of disc-like plates of calcium carbonate. In places they are common enough to give the sea a milky appearance. Some of the deep sea calcareous oozes are composed entirely of coccolithophore plates and are termed **coccolithophore oozes**.

Phytoplankton belonging to the cyanobacteria are worth a mention because they are able to fix dissolved nitrogen into nitrogen compounds. Nitrates are required by plankton, as discussed above, and are often in poor supply in the ocean. Some members of this group are quite common in warmer oceans and some use gas bubbles to buoy themselves up in the water.

Cyanobacteria may be abundant enough to colour the water and some water bodies are named because of this. One example is the Red Sea and another the Azure Sea also called the Gulf of California.

Zooplankton

Zooplankton are a very diverse group with almost all of the phyla in the animal kingdom represented. There are two main groups of the zooplankton, the **holoplankton** or permanent plankton and the **meroplankton**, the seasonal or temporary plankton. The latter are larval or juvenile stages of nekton and benthos. An example of the meroplankton would be the larva of the Bermuda Lobster (*Panulirus argus*). Most zooplankton are virtually colourless, which makes them very difficult to see in the water. This is an adaptation to avoid being eaten by predators.

Among the zooplankton is a wide range of protozoa some of which are very numerous. One of the best known groups are the **foraminifera**. The red sands of the south shore of Bermuda are coloured by the skeletons of a benthic member of this group. However, there are lots of pelagic examples too. Each individual consists of several chambers of calcium carbonate forming a **test**, pierced with holes from which protrude the **pseudopodia** which collect phytoplankton and organic particles as food. In places the tests of foraminifera are numerous to form a calcareous ooze called **foraminiferan ooze**. An example is shown in Figure 9. A small but interesting group of zooplankton are the **acantharians**; these unique members of the zooplankton have a skeleton of strontium sulphate which consists of 20 regularly arranged spines. Another large group of protozoa are the **radiolarians**; radiolaria have a skeleton of silica rods (Fig. 9). Feeding in a similar way to the foraminifera they too are numerous enough that the skeletal material forms an ooze called **radiolarian ooze**. Many other small protozoa, such as the **ciliates** are also included in the zooplankton.

Examples of the jellyfish group (**Coelenterates**) that are common in the plankton are many; these range from the small larval **medusas** of benthic forms such as hydroids and anemones to large jellyfish which may have trailing tentacles 10 m (30 ft) long. A typical medusa is shown in figure 9. An interesting subgroup from this general group is the **siphonophores** which are really colonies of animals each individual having a specialised function. The Portuguese Man-of-War (*Physalia physalis*) is one of these but it is a member of the neuston. Other smaller species are common in the plankton. The **Comb Jellies** (**Ctenophores**), a totally marine group, closely resemble the jellyfish group but have a generally round body which has bands of beating cillia to propel it. Its shape has given rise to the name of Sea Gooseberries; one is shown in Figure 9.

Another group of animals only found in the zooplankton are the **Arrow Worms** or **Chaetognaths**. This is a very widespread group with low **species diversity**. They resemble small, perfectly clear fish; they can dart rapidly to catch prey but are generally weak swimmers.

The most diverse and abundant group of animals in the zooplankton are the **crustaceans**: the planktonic crustacea are the single largest group of protein producers in the world. They are very important food for a wide variety of fish. Many benthic crustaceans such as crabs, lobsters and shrimps have meroplanktonic larvae, but the vast bulk of the planktonic crustaceans are holoplanktonic creatures called **Copepods,** a group with over 6,000 species. A typical copepod such as is shown in Figure 9 looks like a small grain of rice with two long antennae and a number of shorter legs. Both legs and antennae are used in swimming but like other zooplankton they are relatively weak swimmers. Copepods are one group which demonstrate the behaviour of **diurnal vertical migration**. This typically involves their feeding near the surface by night and descending to deeper water by day. Such behaviour has been shown to minimise predation and to diversify their diet. The second-most important group of planktonic crustacea are the **Euphausid Shrimps** or **Krill**, an example of which is depicted in Figure 9. As plankton go these are large creatures up to several cm (an inch or so) long; they are abundant in southern waters but widely distributed. They are very important food for many of the great whales and also for seabirds including penguins. An average Blue Whale consumes about three tons of krill per day!

There is a wide variety of other zooplankton such as the meroplanktonic larvae of starfish and sea urchins but one particularly interesting group are the **Salps**. As shown in Figure 9 they resemble miniature, transparent barrels which

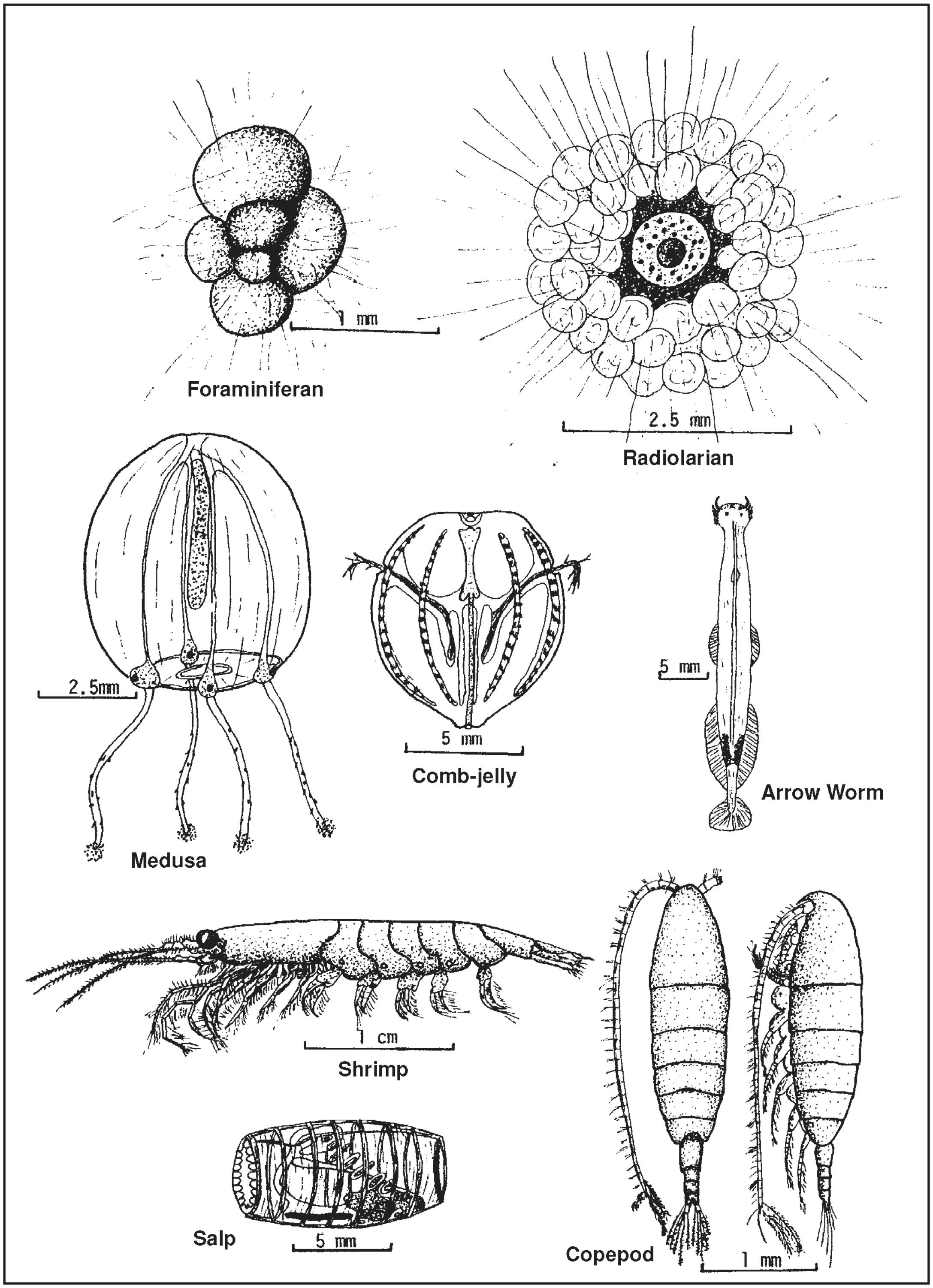


Figure 9. Representative zooplankton.

move slowly through the water by a form of jet propulsion aided by a series of one-way valves in the body.

Neuston

The neuston are a very specialised group of animals and plants which live in association with the surface of the sea. Members of this group are not infrequently washed ashore in large numbers in Bermuda. One member of the is group the Portuguese Man-of-War has already been mentioned. It is a siphonophore colony in which one individual forms a sail at the top and others below form a group of feeding individuals. As all Bermudians know, this is a very poisonous creature. In the same group, but more benign, is the By-the-Wind Sailor (*Velella velella*) which also has a sail but is much smaller than the Portuguese Man-of-War. In both these examples the sail enables them to feed over a very large area of water but does not consume the energy that swimming does. Also washed ashore with the By-the-Wind Sailors is a snail, the Common Purple Sea Snail (*Janthina janthina*) that travels the sea surface on a raft of hardened bubbles that it produces. It is a predator on By-the-Wind Sailor which it intercepts by collision!

<u>The Sargassum Weed Community</u>

One very special group of neuston forms the **Sargassum weed patch** or sargasso weed community, very common in the oceans around Bermuda. The oceanic species of sargassum are brown seaweeds that unlike most members of that group, do not live attached to the bottom. Rather they drift at the surface of the ocean buoyed up by gas-filled bladders. Other sargassum species live attached to the bottom in shallow water and one, the Bermuda Sargasso Weed, *Sargassum bermudae*, is **endemic** to Bermuda. There are two common species of floating sargassum: these are *Sargassum fluitans* and *Sargassum natans*. Both are described and illustrated later in this guide. Each sargassum plant forms a roughly spherical mass about15 cm (6 in) in diameter. However, plants become entangled and may form huge rafts 100's of metres (yards) long. Sargassum rafts provide food for a wide variety of organisms but perhaps more important provide cover and shelter in an environment generally lacking these attributes. Some of the animals living in association with the sargassum are only found in that situation; in other words they are endemic to the sargassum community, and have evolved there. A larger group is found both in sargassum clumps and elsewhere, for instance in shallow coastal environments. Some of the sargassum fauna is very highly adapted to that environment, so much so that they are exceedingly difficult to spot as they have become camouflaged in both shape and colour to look like sargassum itself! Around Bermuda, sargassum can be readily collected with a dip net as clumps pass by a boat. For study purposes, sargassum collected in this way should be immediately placed in a pail of fresh seawater, as some of the inhabitants are very delicate. Many of the inhabitants are extremely difficult to see but non-attached ones may be brought into the open by shaking bunches of sargassum over a white pail of seawater. Many others are firmly attached to the weed and many are tiny. A good microscope is needed to study them. Sargasso weed that is washed ashore is useless for study except to see the dried remains of some of the attached creatures.

The most common animals found in association with the sargassum rafts are **hydroids**. At least 11 different species are common and many others are uncommon or rare. Hydroids are small, generally colonial animals related to the jellyfish. Colonies most commonly consist of a branching, stem-like structure from which arise numerous **polyps** consisting of a ring of tentacles round the mouth. They are commonly found attached to rocks and seaweeds in shallow water, however, one species, *Halecium nanum* is almost never found except on sargasso weed. Like many of the sargasso weed associates this is a tiny species, the colony only reaching 3 mm (1/8 in) high. The common species are illustrated later in this guide. A binocular microscope is needed to identify them. Closely related to the hydroids and jellyfish are the **sea anemones**. One member of this group is characteristic of the sargassum clumps and commonly found there; this is the Dark Star Anemone, *Pseudactinia melanaster*, which also occurs along rocky shores.

If you happen to have the opportunity to look at open-sea sargassum with a good microscope, you might find a very interesting little **flatworm,** *Acerotisa notulata* that is very common there.

This tiny animal is only 1 mm (1/20 in) long. It has a pair of dark eyes and all the internal organisms are clearly visible through the transparent body. Another member of this group that grows to 10 mm (3/8 in) and is called by the daunting name of *Gnescioceros sargassicola*, is also very common. More elongated than the former species, it has two tiny tentacles which contain several eyes each. It is milky clear with brown camouflaging spots.

In the sea the commonest worms are the **polychaetes**, characterised by their bristles, and several of these are commonly found in the sargassum patches. Some of these like Dumeril's Ragworm *(Platynereis dumerilii)* are also common in shoreline situations. Perhaps more typical of the weed environment are the tiny Coiled Tube Worms (*Spirorbis formosus*), which can be recognised by the tiny (1.5 mm, 1/15 in) coiled, white tube in which they live.

After the hydroids, the **crustacea** show the most species diversity among the sargassum clumps. A group of tiny crustaceans having much in common with the planktonic copepods described above, but adapted to live in association with the bottom or on seaweeds or attached animals, are common among the sargasso weed fronds. A typical one of these is called *Macrochiron sargassi* which is only 1 mm (1/20 in) long and colourless. In comparison to its planktonic counterparts the antennae are much shorter. The barnacles are also crustaceans but the adults are always attached and most have protective plates around the body. The Sargasso Barnacle (*Lepas pectinata*) is one of the 'goose barnacles' group found often attached to floating objects in the ocean. These barnacles have a fleshy stalk which attaches them. In the Sargasso Barnacle this stalk is short and the whole animal less than 2 cm (3/4 in) long. A third crustacean common on sargassum weed is the very small and aptly named *Carpias bermudensis* only 2 mm 1/10 in) long; it is flattened from top to bottom, whereas some other small relatives are flattened from side to side. Two are found commonly in sargassum weed clumps and one of them, *Biancolina* occurs nowhere but among sargassum. The caprellids are very highly adapted crustaceans with very slender bodies and grasping legs. They typically live attached to seaweeds or bottom-dwelling animals and are usually well camouflaged; one called *Hemiaegina minuta* is common in the sargasso weed. As its scientific name suggests it is small reaching only 4 mm (1/8 in) long. Among the higher crustaceans several shrimps are common, typical of these is *Leander tenuicornis* also found commonly in seagrass beds. Its yellowish-brown colour with darker brown patches is good camouflage. It reaches 5 cm (2 in) long. The most typical crab of the sargassum clumps is the Sargassum Crab (*Planes minutus*) which has also been found on oceanic turtles. Despite its scientific name it is not minute but may reach 2 cm (7/8 in) long! This is large compared to much of the weed clump fauna.

The **sea-spiders** are a curious group of marine animals which bear a superficial resemblance to true spiders. They are generally small with tiny bodies and long clinging legs. The Sargassum Sea-spider (*Anoplodactylus petiolatus*) is very common and reaches about 4 mm (1/5 in) long.

The **mollusca** which include the snails, slugs and clams as well as octopuses and squids, have a few representatives living in the weed rafts. The only common snail is the Brown Sargassum Snail (*Litiopa melanostoma*), growing to about 5 mm (1/5 in). The shell is very light in weight, thin and smooth and may sometimes be found in large numbers washed up on the beach. Two sea slugs (nudibranchs) are common among the weed tangles. The Sargassum Nudibranch (*Scyllaea pelagica*), grows to about 5 cm (2 in) long, the species is brown in colour and has flaps on the body which resemble the seaweed. A very tiny cousin is the Pygmy Doto (*Doto pygmaea*) only 3 mm (1/8 in) long, also well camouflaged.

Bryozoa or Moss Animals are often mistaken for plants. Like the hydroids they are mostly colonial and may grow as a sheet on rocks or seaweeds or have an upright plant-like form. The one found abundantly on sargassum plants (*Membranipora tuberculata*) forms lacy layers over the stems, bladders and fronds. Although typical of sargassum it is also found on other brown seaweeds.

To conclude this account of the animals associated with the sargassum rafts, two fascinating fish that live there must be mentioned. The first of these is a small angler fish, the Sargassum Fish (*Histrio histrio*) which may attain 15 cm (6 in) long, but is commonly much smaller. It is well camouflaged in colour and in that the fins resemble sargassum fronds. Although many of the angler fish use an artificial fishing lure on a rod attached to the top of the head, to attract their prey, this one stalks fish and crustaceans among the weed clumps. The second fish resident in the sargassum is the Pugnose Pipefish (*Syngnathus pelagicus*) a very slender, eel-like fish, closely related to the seahorses, reaching 12 cm (4 3/4 in) long. Like the Sargasso Fish this one hunts among the weed clumps. When sargasso weed is washed ashore, as it often is, the Sargassum Pipefish may take up residence in shoreline weed beds or seagrass meadows.

Nekton

Most nekton are fish, but squids, crustaceans, reptiles and mammals are all represented.

Fish

Fish living close to the bottom but not on it are called **demersal** rather than pelagic. The true pelagic fish live and feed up in the water above the bottom. Another way in which the fish are subdivided is into the **bony fish** and **cartilaginous fish**. The bony fish are those with hard bony skeletons and the majority of fish are in this group. Common bony fish around Bermuda would include the Wahoo (*Acanthocybium solandri*), the Yellowfin Tuna (*Thunus albacares*) and the Blue Marlin (*Makaira nigricans*) as well as the bulk of inshore fishes such as the Sergeant Major (*Abudefduf saxatilis*) and the Bermuda Bream (*Diplodus bermudensis*). The cartilaginous fishes include the sharks, skates and rays. Local examples are the Bermuda Dusky Shark (*Carcharhinus galapagensis*), the Whale Shark (*Rhincodon typus*) and the Spotted Eagle Ray (*Aetobatus narinari*). Among these only the Spotted Eagle Ray is demersal. the remainder being truly pelagic. Most of the big fisheries in the world are for bony fish, some of which occur in huge numbers, an example would be the Herring (*Clupea harengus*) caught on both sides of the temperate North Atlantic. The most numerous bony fish are plankton eaters; an example of this group in Bermuda would be the several small, silvery fishes known as 'fry'. Fishes such as the sharks and tuna are predators at the other end of the food chain which never occur in huge schools.

Turtles

The most familiar turtle around Bermuda is the Green Turtle (*Chelonia mydas*). As with the other marine turtles, the Green Turtle undertakes long oceanic migrations but the bulk of its life is spent in shallow waters where it feeds principally on seagrasses. Those seen in Bermuda have migrated from the south and may then stay around Bermuda for at least 13 years before they start to migrate back toward their breeding beaches. Those seen around Bermuda measure 40-76 cm (16-30 in) long but at full size may reach 122 cm (48 in) and weigh 295 kg (650 lb). They do not mature until they are about 30 years old. At the time of colonisation, Green Turtles bred on Bermuda beaches in large numbers, however, they were heavily exploited and soon ceased to breed here. The second-most common sea turtle seen around Bermuda is the Loggerhead Turtle (*Caretta caretta*), a medium sized turtle reaching 1 m (3 ft) long. It still nests on Bermuda at infrequent intervals and in very small numbers. It has a wider diet than the Green Turtle, taking a wide variety of animal and plant life, but does most of its feeding in relatively shallow waters. The third most common turtle is the Hawksbill Turtle. It is just a bit smaller than the Loggerhead, reaching 80 cm (2 ft 8 in) long. It is a more colourful turtle than the others, the back being boldly marked in black, brown, amber and olive-green. The mouth has a characteristic shape rather like a hawk's beak. Their diet is rather like that of the Loggerhead but lower in plant material and again they feed in fairly shallow waters. The one turtle that is truly oceanic except at breeding season is the Leatherback Turtle (*Dermochelys coriacea*), a huge turtle reaching 1.8 m (6 ft) in length and a weight of 600 kg (1,300 lb)! Unlike the other turtles it does not have a bony shell, but rather is covered in a thick, leathery skin with five prominent longitudinal ridges. Specimens are occasionally brought ashore in Bermuda, but it is rarely seen. Its diet consists almost solely of jellyfish but they also consume floating plastic, which may kill them.

Birds

Bermuda's own endemic oceanic bird is the Cahow (*Pterodroma cahow*). Cahows had been thought to have been extinct for 300 years when Cushman and Mowbray discovered 7 breeding pairs in 1951. The recovery of the population to the present level of just below 100 pairs has been slow but steady under the devoted stewardship of David Wingate, Bermuda Conservation Officer until 2000. The first breakthrough was the idea of artificial breeding burrows, followed by successful control of competition for nest space. No more than 8 young per year were raised until 1960; the increase after that was slow partly due to the presence of DDT in the food chain, and its effect of causing fragile, thin-shelled eggs. However, by 1972 when 17 chicks were raised by 26 pairs of parents, the recovery seemed assured. There was a slight setback in the winter of 1986-87 when a rare, over-wintering, Snowy Owl (*Nyctea scandiaca*) took 5 non-breeding adults. In 1988-89, 45 pairs raised about 30 young; in 1999-2000, 53 pairs raised 25 chicks.

The Cahow is certainly the most famous of Bermuda birds and at the same time the least observed! Like all the Gadfly Petrels, the Cahow is a truly oceanic bird. It remains on the open ocean except for the breeding season, which extends from late October to early June. Even during this breeding period a great deal of time is spent at sea. The first breeding individuals arrive in Bermuda in late October to early November. Since their approach to, and activities on, land is totally nocturnal, they are rarely seen except by their human custodians.

Breeding is confined to several small islands off Castle Harbour and Coopers Island. All these islands are protected refuges. Visitors to the breeding sites are discouraged as the population is still very small and fragile! Courtship is aerial and a noisy affair: it was perhaps these sounds that gave Bermuda its early reputation as the "Island of Devils". The nests, which are merely a scrape in the ground, are now all situated in artificial burrows about 4 feet (1.3 m) in length, constructed of concrete with a wooden baffle part-way down the tunnel to exclude White-tailed Tropicbirds or Longtails (*Phaethon lepturus*), as they are locally known. Formerly, the birds probably nested all over the Bermuda Islands in burrows in the forest. The first eggs are laid in early January, one per female, and are incubated by the female parent for 51-53 days. The young are fed in the burrow, by the female, for about another 12 weeks, until they are full grown by late May or early June.

The feeding in itself, is a marvel of nature. The food does not consist of local species but rather, small squid found in the Gulf Stream hundreds of km (miles) to the west of Bermuda. Because of this, it takes a parent a full day to get a meal for the single chick. The squid, swallowed at capture, is regurgitated when the parent returns. When the chicks are fully grown, they are abandoned by their parents. They emerge from the burrow, have a few practice wing stretchings and take-offs for a few nights and then fly off, not to return for many years when they are sexually mature. Long-term plans for the Cahow include a return to breeding on Nonsuch Island, and perhaps carefully protected main-island sites. The Cahow is still one of the rarest birds in the world and is even more rarely seen!

There are also a number of oceanic birds, which tend to stay off-shore. Some of these can be seen with powerful binoculars, or a telescope, as they fly by on migration or while feeding. This group includes, Cory's Shearwater (*Calonectris diomedea*), the Greater Shearwater (*Puffinus gravis*), the Sooty Shearwater (*Puffinus griseus*), the Manx Shearwater (*Puffinus puffinus*) and the two Petrels, Wilson's Storm Petrel (*Oceanites oceanicus*) and Leach's Storm Petrel (*Oceanodroma leucorhoa*).

<u>Mammals</u>

The Whales are certainly one of the best known groups within the nekton even though they are neither numerous or common. Some of the whales are plankton eaters especially where krill abound but others include smaller fish in their diet. An example of a whale seen close to Bermuda is the Humpback Whale (*Megaptera novaeangliae*). Whales in this general group are called baleen whales and they capture their small prey by filtering huge volumes of water through a set of whalebone (baleen) plates in their mouths. Another whale in this same group seen in this area is the Minke Whale (*Balaenoptera acutorostrata*). These huge whales therefore feed just like the smaller plankton feeding fishes such as the Herring. The Sperm Whale (*Physeter macrocephalus*) on the other hand is a hunting predator that feeds on large deepwater squid. Other marine mammals include the Dolphins and Seals.

Squids
Some of the more interesting and bizarre of the nekton are the giant deep sea squids. These huge creatures are rarely seen by humans but are the normal food of Sperm Whales. Sperm Whales can dive to great depths and find their prey in almost total darkness. The imprints of squid suckers are often clear on Sperm Whale skins and the beak-like feeding mechanisms of giant squids have been found in Sperm Whale stomachs. There are several other species of squid occasionally seen at sea such as the Orange-back Squid (*Ommastrephes pteropus*); little is known about their habits and ecology. In some places, for example off the coast of Newfoundland, Canada small open sea squids are numerous enough to be the base of an important fishery.

Also included in the nekton are a few large shrimp-like crustaceans, however, few of these are seen near to the surface.

Deep-sea Nekton
The ecosystem of the deep sea is a difficult one to study; life there is very sparse but also very diverse. Studies of the fauna of the deep sea starting with those off Bermuda by William Beebe have shown several interesting features, which differentiate deep sea life from that closer to the surface. The effect of diminishing light levels with depth is clearly shown at depths where light is dim— the so-called twilight zone. Their adaptations such as very large eyes and deep, flat silvery bodies are seen, as is the appearance of light producing organs. Often the eyes point up whereas the light producing organs point down. The Hatchet Fishes typified by *Sternoptyx diaphana* show these features clearly, whereas the Lantern Fish, which may ascend to the surface at night, are less adapted but still have large eyes and light producing organs. Figure 10 shows a typical Hatchet fish and a fairly common Lantern Fish (*Myctophum nitidulum*). The adaptations shown in these small fishes enable them both to catch prey and avoid detection by predators; the light organs are probably used to attract mates at breeding times.

As depth increases and light is totally gone, the trend is to black or dark-red colouration, combined with tiny eyes and very large mouths. These abyssal creatures hunt by senses other than sight and need to be able to consume prey almost as big as themselves. This is because life is so sparse that meals become very infrequent. Another radical adaptation found in the Angler Fish is the presence of tiny males, parasitic on females. This eliminates searching for a mate in total darkness where the next individual of the species may be kilometres (miles) away. Three highly-adapted nektonic fish from mid-depth dark waters are shown in Figure 11.

Benthos
The vast majority of the animal benthos are **invertebrates**; they are very diverse in anatomy and behaviour and found in all

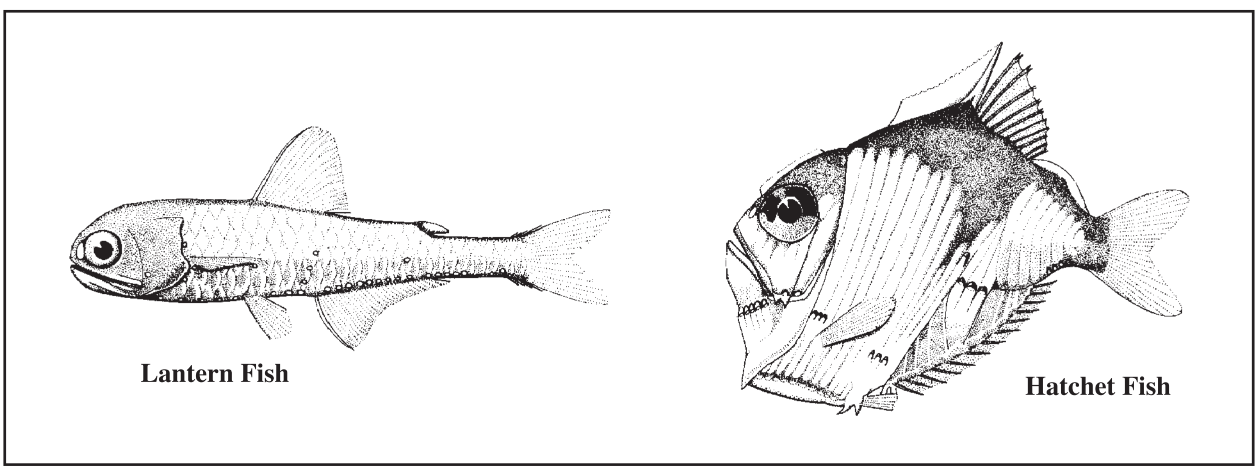


Figure 10. Typical Lantern Fish and Hatchet Fish

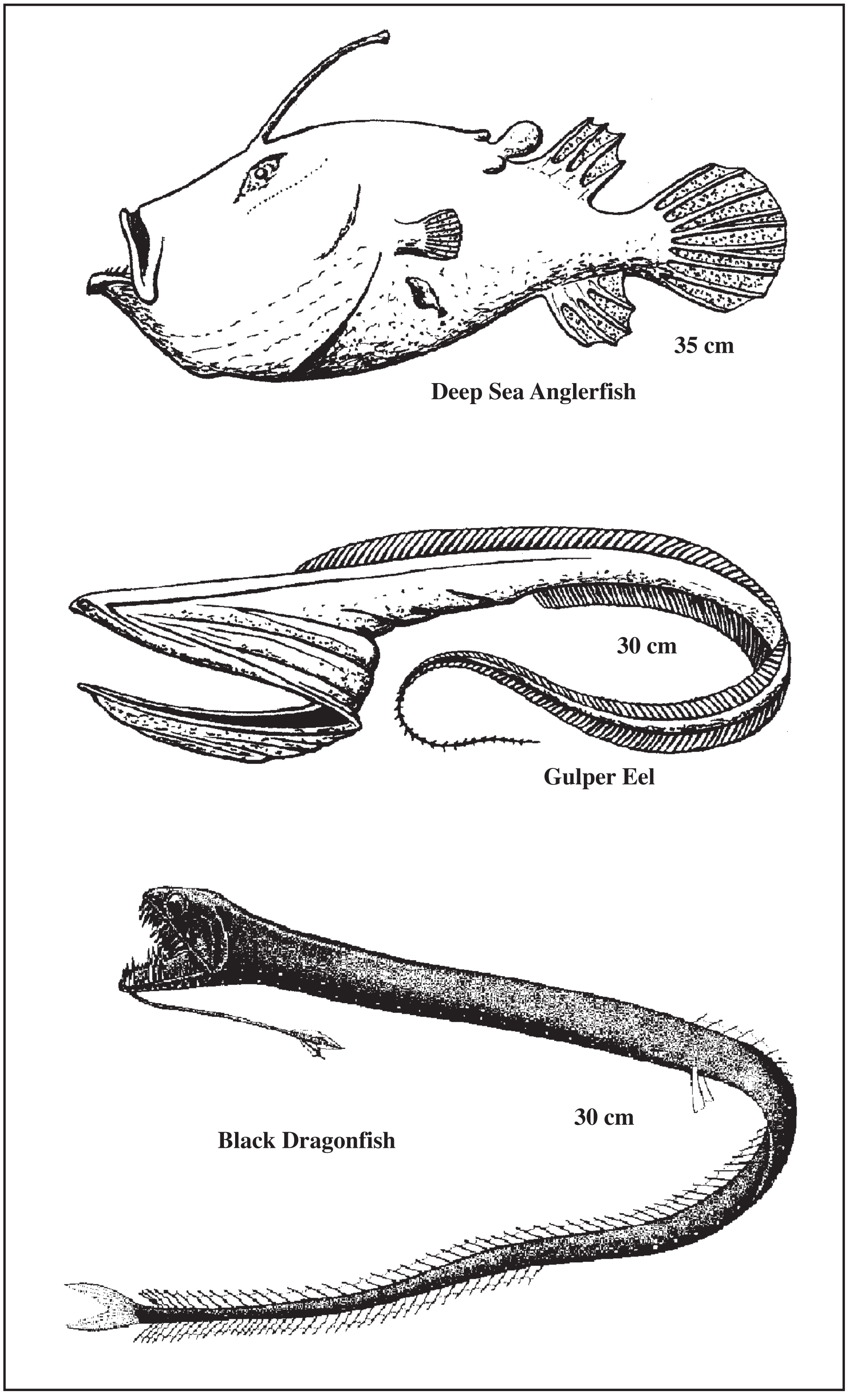


Figure 11. Deep Sea Anglerfish with parasitic male on side,
Gulper Eel with huge mouth and expandable stomach
and Black Dragonfish with large mouth and sharp teeth.

marine environments. Biodiversity in this group increases with depth in the ocean whereas abundance decreases. The main groups of animals found in the benthos are sponges, corals and their relatives, worms, clams, snails, chitons, crabs, lobsters, shrimps, barnacles, starfish, sea urchins and sand dollars. There are also a few fish which never leave the bottom.

The benthos of waters from the outer reefs into shoreline bays is covered in two other Project Nature guides. These are "Coral Reefs of Bermuda" and "Sheltered Bays and Seagrass Beds of Bermuda". In waters deeper than those described in those two volumes, the benthos is difficult to study and rarely seen. Just a few examples are highlighted here. The corals of deeper waters are generally the **soft corals**, these lack the limestone skeleton and have very long **polyps**. One of these, the Dandelion Coral (*Nidalia occidentalis*) is shown in Figure 12. Lobsters and crabs from deeper waters tend to have long slender legs and antennae. The Long-armed Spiny Lobster (*Justitia longimanus*) from very deep reefs and the Galatheoid crab *Munida simplex* from deeper soft bottoms are shown in figure 12. There are a wide variety of deep sea snails, one of those found at mid depths around Bermuda, Lightbourn's Murex (*Pterynotus lightbourni*) is named after the Bermudian collector Jack Lightbourn. It is illustrated in Figure 12. Also shown in Figure 12 is the Oval Corbula (*Varicorbula operculata*), a clam, from sand at moderate depths. An example of a fish from quite deep locations is the Longsnout Scorpion Fish (*Pontinus castor*) (Fig. 12). Fishes from even deeper often have very elongated fins, almost like legs, to keep them above the very soft mud.

Food Chains in the Open Ocean

Food chains show the feeding relationships among groups of organisms. At the base of the food chain are the photosynthetic plants. In the sea these sea these are pigmented members of the blue-green cyanobacteria and the phytoplankton, the seaweeds and the seagrasses. These organisms are called the **primary producers** because they use the sun's energy to synthesise organic compounds from carbon dioxide. All the higher levels of the

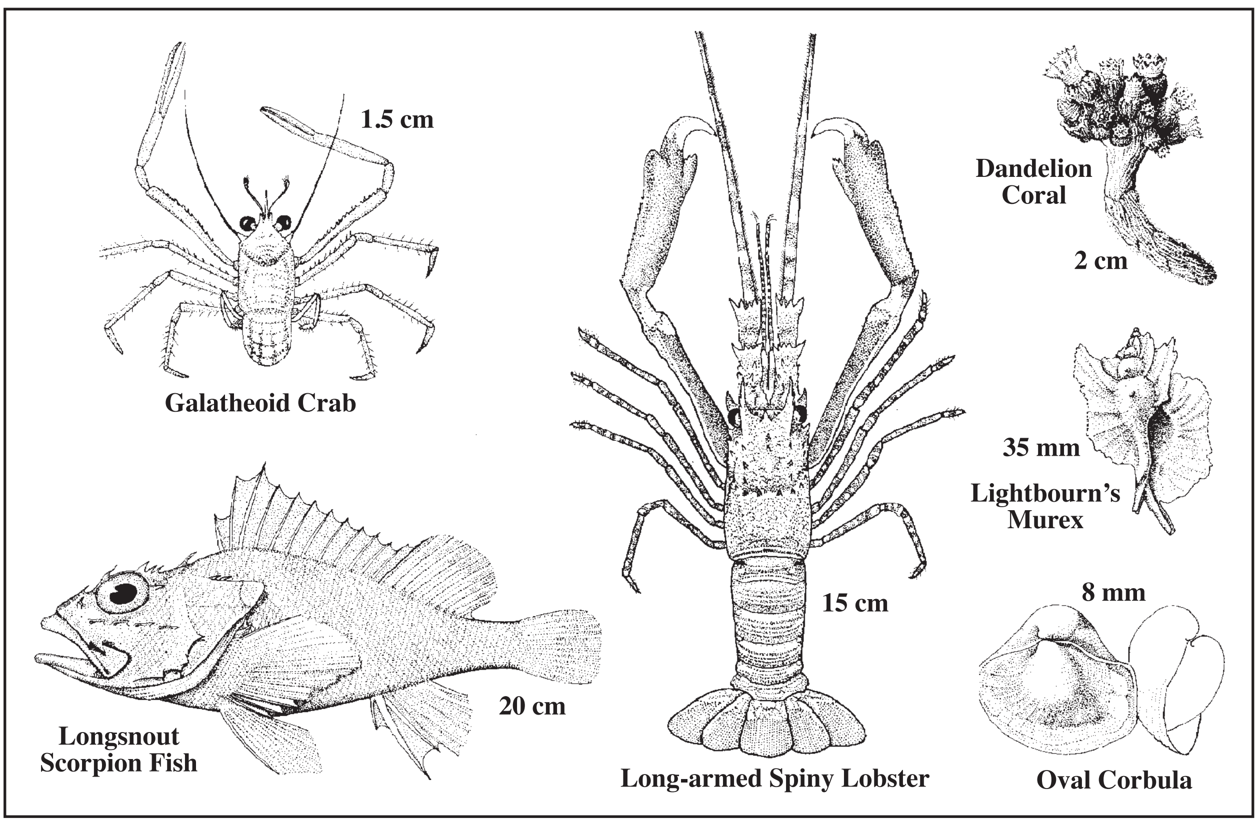


Figure 12. Examples of deepwater benthos

food chain are **consumers**. Consumers that eat plant material are **herbivores** and those that eat animals are **carnivores**. The food (chemical) energy fixed by the primary producers flows through the food chain from the primary producers to the **top carnivores**, which form the end of the food chain. This process is called **energy flow**. Each step of the food chain is called a **trophic level**. When energy flows from a lower to a higher trophic level about 90% is lost between each level. In terms of weight this would mean that for 100 g of plant material eaten by a herbivore only 10 g would appear as increased weight of the herbivore. The remainder is lost in respiration. If in turn the herbivore were eaten by a carnivore only 1 g would pass on. This may seem like just technical jargon but it has very practical implications. In plain terms it means that a huge mass of primary producers is needed to support the higher trophic levels. Additionally it shows that as we progress through the food chain, the quantity of organisms rapidly declines. At the level of the top carnivore the quantity of organisms will be very small.

On land, a typical food chain would have three links. A couple of examples are grass→rabbit→wolf; there is lots of grass, a fair quantity of rabbits but very few wolves. In another case we might see, plant seeds →mice→hawk. In the sea everything is on a much larger scale and the typical food chains are longer. Oceanic food chains often have five links. Primary producers, herbivores and three levels of carnivore. Here is a typical example, phytoplan kton→zooplankton→small fish→medium→sized fish→shark. To return to the numbers involved it would require 10,000 g of phytoplankton to support 1 g of shark! No wonder we rarely see sharks! One might logically think that it would take an inconceivable amount of phytoplankton to support a great whale. If we look at the feeding relationships, however, we see that this is not so. The great whales eat krill or small fish, the krill eat phytoplankton; the food chain is therefore phytoplankton→zooplankton→krill→whale. So the whalebone whales exploit the fact that a great deal more food is available if they feed lower down the trophic levels. The largest of the sharks, for example the Whale Shark have made the same feeding adaptation as the great whales. To return to the ocean around Bermuda we have already seen that the amount of phytoplankton is quite small, thus the amount of top carnivore is very small indeed. We might cruise all day in the open sea before we saw a Marlin or Tuna which are local examples of carnivores at or near the top of the food chain. On the other hand we might spot half a dozen oceanic birds such as the Storm Petrel which feed lower down the food chain.

The other difference between the land and sea is that on land the primary producers tend to be large but in the ocean the main primary producers are very small. It is therefore more difficult to see the whole oceanic food chain. Fortunately around Bermuda we have a readily understood example in the sargassum clumps. There the primary producer is the sargassum weed, herbivores are small crustaceans, and carnivores are the worms, sea slugs etc leading to fish such as the Sargasso Fish. Top carnivores in this case would be roving fish such as Marlin.

Plants and Animals Important in the Open Sea around Bermuda

List of Species Mentioned and/or Illustrated in this Guide

Key to Habitat Codes

B	**=**	**Lagoons, Bays and Coastal Waters**	**O**	**=**	**Open Ocean**
C	**=**	**Coral Reefs**	**S**	**=**	**Sandy Shores**
CL	**=**	**Cliffs and Steep Rocky Coasts**	**SG**	**=**	**Seagrass Beds**
FW	**=**	**Freshwater Habitats**			

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 show where the organisms are commonly found. The illustrations following the list are in the same order as the list and are also accompanied by habitat codes.

Common Name	Scientific Name	Taxonomy	Habitat Code
Trichodesmium thiebautii	Trichodesmium thiebautii	Plant Plankton - Blue-green Cyanobacteria	O
Cerataulina bergonii	Cerataulina bergonii	Plant Plankton - Diatoms	O
Chaetoceros glaudazii	Chaetoceros glaudazii	Plant Plankton - Diatoms	O
Guinardia flaccida	Guinardia flaccida	Plant Plankton - Diatoms	O
Hemiaulus hauckii	Hemiaulus hauckii	Plant Plankton - Diatoms	O
Leptocylindrus danicus	Leptocylindrus danicus	Plant Plankton - Diatoms	O
Rhizosolenia shrubsoleii	Rhizosolenia shrubsoleii	Plant Plankton - Diatoms	O
Thalassonema nitzschoides	Thalassonema nitzschoides	Plant Plankton - Diatoms	O
Anoplosolenia brasiliensis	Anoplosolenia brasiliensis	Plant Plankton - Coccolithophores	O
Discosphaera tubifera	Discosphaera tubifera	Plant Plankton - Coccolithophores	O
Emiliana huxleyi	Emiliana huxleyi	Plant Plankton - Coccolithophores	O
Ceratium furca	Ceratium furca	Plant Plankton - Dinoflagellates	O
Ceratium fusus	Ceratium fusus	Plant Plankton - Dinoflagellates	O
Gonyaulax polygramma	Gonyaulax polygramma	Plant Plankton - Dinoflagellates	B, O
Gyrodinium spirale	Gyrodinium spirale	Plant Plankton - Dinoflagellates	B, O
Peridinium brochii	Peridinium brochii	Plant Plankton - Dinoflagellates	O
Prorocentrum gracile	Prorocentrum gracile	Plant Plankton - Dinoflagellates	B, O
Pyrocystis noctiluca	Pyrocystis noctiluca	Plant Plankton - Dinoflagellates	O
Globigerinoides ruber	Globigerinoides ruber	Animal Plankton - Foraminifera	O
Globorotalia truncatulinoides	Globorotalia truncatulinoides	Animal Plankton - Foraminifera	O
Hastigerina pelagica	Hastigerina pelagica	Animal Plankton - Foraminifera	O
Orbulina universa	Orbulina universa	Animal Plankton - Foraminifera	O
Amphilonche elongata	Amphilonche elongata	Animal Plankton - Acantharia	O
Lithoptera tetraptera	Lithoptera tetraptera	Animal Plankton - Acantharia	O
Coelodendrum ramosissimum	Coelodendrum ramosissimum	Animal Plankton - Radiolaria	O
Hexalonche amphisiphon	Hexalonche amphisiphon	Animal Plankton - Radiolaria	O
Sphaerozoum punctatum	Sphaerozoum punctatum	Animal Plankton - Radiolaria	O
Thalassolampe maxima	Thalassolampe maxima	Animal Plankton - Radiolaria	O
Tintinnopsis campanula	Tintinnopsis campanula	Animal Plankton - Ciliata	O
Abylopsis eschscholtzi	Abylopsis eschscholtzi	Animal Plankton - Cnidaria	O
Agalma okeni	Agalma okeni	Animal Plankton - Cnidaria	O
Aglaura hemistoma	Aglaura hemistoma	Animal Plankton - Cnidaria	O
Chelophyes appendiculata	Chelophyes appendiculata	Animal Plankton - Cnidaria	O
Cytaeis tetrastyla	Cytaeis tetrastyla	Animal Plankton - Cnidaria	O
Eudoxoides mitra	Eudoxoides mitra	Animal Plankton - Cnidaria	O
Liriope tetraphylla	Liriope tetraphylla	Animal Plankton - Cnidaria	O

Pelagia noctiluca	Pelagia noctiluca	Animal Plankton - Cnidaria	O
Rhopalonema velatum	Rhopalonema velatum	Animal Plankton - Cnidaria	O
Beroe ovata	Beroe ovata	Animal Plankton - Ctenophora	O
Sea Gooseberry	Pleurobrachia pileus	Animal Plankton - Ctenophora	O
Anchialina typica	Anchialina typica	Animal Plankton - Crustacea	O
Brachyscelus crusculum	Brachyscelus crusculum	Animal Plankton - Crustacea	O
Candacia ethiopica	Candacia ethiopica	Animal Plankton - Crustacea	O
Centropages violaceus	Centropages violaceus	Animal Plankton - Crustacea	O
Clausocalanus furcatus	Clausocalanus furcatus	Animal Plankton - Crustacea	O
Common Krill	Euphausia brevis	Animal Plankton - Crustacea	O
Conchoecia spinirostris	Conchoecia spinirostris	Animal Plankton - Crustacea	O
Copilia mirabilis	Copilia mirabilis	Animal Plankton - Crustacea	O
Corycaeus speciosus	Corycaeus speciosus	Animal Plankton - Crustacea	O
Evadne spinifera	Evadne spinifera	Animal Plankton - Crustacea	O
Evadne tergestina	Evadne tergestina	Animal Plankton - Crustacea	B
Farranula rostrata	Farranula rostrata	Animal Plankton - Crustacea	O
Hyperia bengalensis	Hyperia bengalensis	Animal Plankton - Crustacea	O
Oithona plumifera	Oithona plumifera	Animal Plankton - Crustacea	O
Oncaea venusta	Oncaea venusta	Animal Plankton - Crustacea	O
Pontella atlantica	Pontella atlantica	Animal Plankton - Crustacea	O
Sapphirina auronitens	Sapphirina auronitens	Animal Plankton - Crustacea	O
Siriella thompsoni	Siriella thompsoni	Animal Plankton - Crustacea	O
Stylocheiron carinatum	Stylocheiron carinatum	Animal Plankton - Crustacea	O
Thysanoëssa gregaria	Thysanoëssa gregaria	Animal Plankton - Crustacea	O
Cavolinia gibbosa	Cavolinia gibbosa	Animal Plankton - Mollusca	O
Clio pyramidata	Clio pyramidata	Animal Plankton - Mollusca	O
Diacria trispinosa	Diacria trispinosa	Animal Plankton - Mollusca	O
Limacina inflata	Limacina inflata	Animal Plankton - Mollusca	O
Styliola subula	Styliola subula	Animal Plankton - Mollusca	O
Sagitta bipunctata	Sagitta bipunctata	Animal Plankton - Chaetognatha	O
Sagitta minima	Sagitta minima	Animal Plankton - Chaetognatha	O
Sagitta serratodentata	Sagitta serratodentata	Animal Plankton - Chaetognatha	O
Doliolum denticulatum	Doliolum denticulatum	Animal Plankton - Thaliacea	O
Iasis zonaria	Iasis zonaria	Animal Plankton - Thaliacea	O
Oikopleura longicauda	Oikopleura longicauda	Animal Plankton - Thaliacea	O
Pyrosoma atlanticum	Pyrosoma atlanticum	Animal Plankton - Thaliacea	O
Salpa fusiformis	Salpa fusiformis	Animal Plankton - Thaliacea	O
Common Sargasso Weed or Common Gulfweed	Sargassum natans	Sargassum Community - Plants	O
Sargasso Weed or Broad-toothed Gulfweed	Sargassum fluitans	Sargassum Community - Plants	O
Aglaophenia latecarinata	Aglaophenia latecarinata	Sargassum Community - Cnidaria	O
Clytia cylindrica	Clytia cylindrica	Sargassum Community - Cnidaria	O
Clytia noliformis	Clytia noliformis	Sargassum Community - Cnidaria	O
Dark Star Anemone	Pseudactinia melanaster	Sargassum Community - Cnidaria	B, C, O
Dynamena quadridentata	Dynamena quadridentata	Sargassum Community - Cnidaria	O
Halecium nanum	Halecium nanum	Sargassum Community - Cnidaria	O
Obelia dichotoma	Obelia dichotoma	Sargassum Community - Cnidaria	B, O
Obelia hyalina	Obelia hyalina	Sargassum Community - Cnidaria	O
Plumularia margaretta	Plumularia margaretta	Sargassum Community - Cnidaria	O
Plumularia setaceoides	Plumularia setaceoides	Sargassum Community - Cnidaria	O
Plumularia strictocarpa	Plumularia strictocarpa	Sargassum Community - Cnidaria	O
Sertularia inflata	Sertularia inflata	Sargassum Community - Cnidaria	O
Sertularia meyeri	Sertularia meyeri	Sargassum Community - Cnidaria	O
Zanclea costata	Zanclea costata	Sargassum Community - Cnidaria	O
Acerotisa notulata	Acerotisa notulata	Sargassum Community - Flatworms	O
Gnescioceros sargassicola	Gnescioceros sargassicola	Sargassum Community - Flatworms	O
Dumeril's Ragworm	Platynereis dumerilii	Sargassum Community - Polychaete Worms	B, O

Coiled Tube Worm	Spirorbis formosus	Sargassum Community - Polychaete Worms	B, O, R, SG
Amonardia phyllopus	Amonardia phyllopus	Sargassum Community - Crustacea	O
Biancolina sp.	Biancolina sp.	Sargassum Community - Crustacea	O
Carpias bermudensis	Carpias bermudensis	Sargassum Community - Crustacea	O
Dactylopodia tisboides	Dactylopodia tisboides	Sargassum Community - Crustacea	O
Harpacticus gurneyi	Harpacticus gurneyi	Sargassum Community - Crustacea	O
Hemiaegina minuta	Hemiaegina minuta	Sargassum Community - Crustacea	O
Hippolyte coerulescens	Hippolyte coerulescens	Sargassum Community - Crustacea	O
Latreutes fucorum	Latreutes fucorum	Sargassum Community - Crustacea	O
Leander tenuicornis	Leander tenuicornis	Sargassum Community - Crustacea	O
Macrochiron sargassi	Macrochiron sargassi	Sargassum Community - Crustacea	O
Paralaophonte congenera	Paralaophonte congenera	Sargassum Community - Crustacea	O
Sargasso Barnacle	Lepas pectinata	Sargassum Community - Crustacea	O
Sargassum Crab	Planes minutus	Sargassum Community - Crustacea	O
Sargassum Swimming Crab	Portunus sayi	Sargassum Community - Crustacea	O
Scutellidium longicauda	Scutellidium longicauda	Sargassum Community - Crustacea	O
Sunampithoë pelagica	Sunampithoë pelagica	Sargassum Community - Crustacea	O
Endeis spinosa	Endeis spinosa	Sargassum Community - Pycnogonida	O
Sargassum Sea-spider	Anoplodactylus petiolatus	Sargassum Community – Pycnogonida	O
Brown Sargassum Snail	Litiopa melanostoma	Sargassum Community - Mollusca	O
Pygmy Doto	Doto pygmaea	Sargassum Community - Mollusca	O
Sargassum Nudibranch	Scyllaea pelagica	Sargassum Community - Mollusca	O
Membranipora tuberculata	Membranipora tuberculata	Sargassum Community- Bryozoa	O
Pugnose Pipefish	Syngnathus pelagicus	Sargassum Community - Fishes	B, O
Sargassum Fish	Histrio histrio	Sargassum Community - Fishes	O
By-the-wind Sailor	Velella velella	Jellyfishes	O
Porpita	Porpita porpita	Jellyfishes	O
Portuguese Man-of-War	Physalia physalis	Jellyfishes	O
Ocean Skater	Halobates micans	Insects - Bugs	O
Common Goose Barnacle	Lepas anatifera	Crustacea - Barnacles	O
Blue Glaucus	Glaucus atlanticus	Gastropoda - Sea Slugs	O
Common Purple Sea Snail	Janthina janthina	Gastropoda - Snails	O
Common Paper Nautilus	Argonauta argo	Squids and Octopuses - Squids	O
Onykia caribbaea	Onykia caribbaea	Squids and Octopuses - Squids	O
Orange-back Squid	Ommastrephes pteropus	Squids and Octopuses - Squids	O
Rams Horn Shell	Spirula spirula	Squids and Octopuses - Squids	O
Vampire Squid	Vampyroteuthis infernalis	Squids and Octopuses - Squids	O
Blue Shark	Prionace glauca	Fish - Sharks	O
Dusky Shark	Carcharhinus galapagensis	Fish - Sharks	O
Scalloped Hammerhead	Sphyrna lewini	Fish - Sharks	O
Short-finned Mako	Isurus oxyrinchus	Fish - Sharks	O
Whale Shark	Rhincodon typus	Fish - Sharks	O
Spotted Eagle Ray	Aetobatus narinari	Fish - Rays	B, O
American Eel	Anguilla rostrata	Fish - Eels	FW, O
Bristle Mouth	Gonostoma elongatum	Fish - Lantern Fishes	O
Cocca Lantern-fish	Gonichthys coccoi	Fish - Lantern Fishes	O
Hatchet Fish	Sternoptyx diaphana	Fish - Lantern Fishes	O
Lantern Fish	Myctophum nitidulum	Fish - Lantern Fishes	O
Black Dragonfish	Idiacanthus fasciola	Fish - Gulper Eels	O
Fourwing Flying Fish	Hirundichtys affinis	Fish - Flying Fishes	O
Spotfin Flying Fish	Cypselurus furcatus	Fish - Flying Fishes	O
Sharksucker or Remora	Echeneis naucrates	Fish - Remoras	B, O
Greater Amberjack	Seriola dumerili	Fish - Jacks and Pompanos	O
Horse-eye Jack	Caranx latus	Fish - Jacks and Pompanos	B, O
Mackerel Scad	Decapterus macarellus	Fish - Jacks and Pompanos	O
Rainbow Runner	Elagatis bipinnulatus	Fish - Jacks and Pompanos	B, O
Dolphin Fish	Coryphaena hippurus	Fish - Dolphinfishes	O
Bermuda Bream	Diplodus bermudensis	Fish - Chubs and Breams	B

Sergeant Major or Cow Polly	Abudefduf saxatilis	Fish - Damselfishes	B, C
Great Barracuda	Sphyraena barracuda	Fish - Barracudas	B, C, O
Blackfin Tuna	Thunnus atlanticus	Fish - Tunas	O
Little Tunny or Mackerel	Euthynnus alletteratus	Fish - Tunas	O
Wahoo	Acanthocybium solandri	Fish - Tunas	O
Yellowfin Tuna	Thunnus albacares	Fish - Tunas	O
Tapioca Fish	Ruvettus pretiosus	Fish - Oilfishes	O
Blue Marlin	Makaira nigricans	Fish - Billfishes	O
White Marlin	Tetrapturus albidus	Fish - Billfishes	O
Man-of-war Fish	Nomeus gronovii	Fish - Man-of-war Fishes	O
Slender Mola	Ranzania laevis	Fish - Sunfishes	O
Atlantic Ridley Turtle	Lepidochelys kempi	Turtles and Terrapins - Turtles	B, O,
Green Turtle	Chelonia mydas	Turtles and Terrapins - Turtles	B, O, SG
Hawksbill Turtle	Eretmochelys imbricata	Turtles and Terrapins - Turtles	B, O
Leatherback Turtle	Dermochelys coriacea	Turtles and Terrapins - Turtles	O
Loggerhead Turtle	Caretta caretta	Turtles and Terrapins - Turtles	B, C, O, SG
Cahow or Bermuda Petrel	Pterodroma cahow	Birds - Petrels and Shearwaters	O, OC
Cory's Shearwater	Calonectris diomedea	Birds - Petrels and Shearwaters	O
Greater Shearwater	Puffinus gravis	Birds - Petrels and Shearwaters	O
Leach's Storm Petrel	Oceanodroma leucorhoa	Birds - Petrels and Shearwaters	O
Manx Shearwater	Puffinus puffinus	Birds - Petrels and Shearwaters	O
Sooty Shearwater	Puffinus griseus	Birds - Petrels and Shearwaters	O
Wilson's Storm Petrel	Oceanites oceanicus	Birds - Petrels and Shearwaters	O
White-tailed Tropic Bird or Longtail	Phaethon lepturus	Birds - Tropic Birds	B, CL, O
Common Dolphin	Delphinus delphis	Marine Mammals - Dolphins	O
Cuvier's Beaked Whale	Ziphius cavirostris	Marine Mammals - Whales	O
Humpback Whale	Megaptera novaeangliae	Marine Mammals - Whales	O
Minke Whale	Balaenoptera acutorostrata	Marine Mammals - Whales	O
Pilot Whale or Pothead	Globicephala melaena	Marine Mammals - Whales	O
Sperm Whale	Physeter macrocephalus	Marine Mammals - Whales	O

Species Illustrations and Descriptions

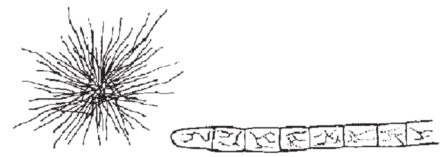
Plant Plankton

Note: Plant Plankton are very small and can only be collected with special equipment and they are very delicate. A high-powered microscope is needed for identification. There are no common names. Sizes in metric units only. A μm is one thousandth of a mm.

Blue-green Cyanobacteria (Blue-green algae)

Trichodesmium thiebautii
This cyanobacterium is a major component of the phytoplankton around Bermuda. It occurs as a ball of radiating filaments, reddish-brown to yellowish in colour and up to about 3 mm in diameter. **Native.**

O

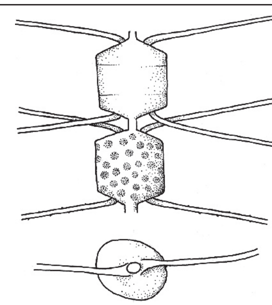


Diatoms (Plant protozoa with a silica skeleton)

Cerataulina bergonii
This species is very common both in inshore and offshore waters forming chains that are often twisted in appearance. The individual cells are quite large, about 25-50 μm in diameter. **Native.**

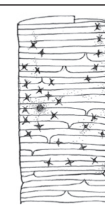
O

Chaetoceros glaudazii
This species is typically oceanic but sometimes extremely common near to shore. The squarish cells each have four long hair-like structures and are united into chains by a narrow connection giving a string-of-beads like appearance. The cells are each 15-20 μm wide and 30-35 μm long. **Native.**



O

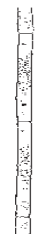
Guinardia flaccida
This diatom common in oceanic plankton has broad cells linked end-to-end in chains. The cell diameter is about 30-50 μm and the chain length up to 0.1 mm. **Native.**



O

Hemiaulus hauckii
This offshore diatom has elongated cells with two long extensions at each end. Cells form chains by joining at the extension ends. The cells are 15-18 μm in diameter and three times this in length. **Native.**

Leptocylindrus danicus
This species has very narrow, elongated cells, linked end-to-end in chains. The cell diameter is only 6-11 μm and the chain length up to 0.12 mm. Common in nearshore and oceanic plankton. **Native.**

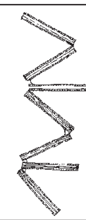


O

Rhizosolenia shrubsoleii
A very widely distributed species most common in inshore plankton. It usually occurs as single cells of very characteristic shape, but may form short chains. The cells are about 15 μm in diameter and up to 0.5 mm long. **Native.**

O

Thalassonema nitzschoides
The cells are rectangular in shape and form chains with zigzag and star-shaped parts. The narrow cells are 2-5 by 30-90 μm. A common species around Bermuda. **Native.**



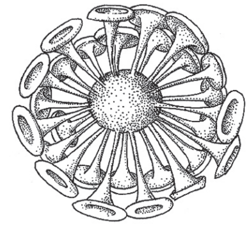
O

Coccolithophores (Plant protozoa with calcareous plates)

Anoplosolenia brasiliensis
The cell is extremely elongated being 70-110 μm long and 4-7 μm in width and tapers from the middle to both ends. This is one of the coccolithophores and is covered in tiny, elongated calcareous plates. Common inshore and in the ocean. **Native.**

O

Discosphaera tubifera
This very interesting coccolithophore is common offshore. Projecting from the cell 10 μm in diameter are numerous trumpet shaped processes each about 10 μm in length. A winter member of the plankton. **Native.**



O

Emiliana huxleyi
A typical spherical coccolithophore 5-12 μm in diameter. The tiny plates or coccoliths covering the cell are elliptical in shape. Very common in winter. **Native.**

O

Dinoflagellates (Plant protozoa with flagellae)

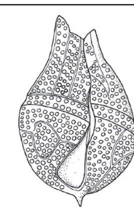
Ceratium furca
This species is common in both shallow and deep water and is widely distributed. The 210-280 μm long cell has a very distinctive shape with one long horn on top and two shorter ones below. **Native.**

O

Ceratium fusus
Common in all situations at sea, this tall, narrow dinoflagellate is distinguished by its two long horns, one sticking up and the other down. The long cell is about 300-500 μm in length. **Native.**

O

Gonyaulax polygramma
Armoured by plates on the outside and having two distinct grooves one longitudinal and one transverse, housing the flagellae. About 60 μm in diameter. Greenish-brown. Common. **Native.**

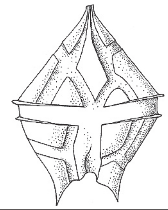


B, O

Gyrodinium spirale
Has an elongated cell shape with longitudinal marks. One of the two flagellae is in a spiral groove, the other in a longitudinal one. About 80 μm long. Greenish-brown. **Native**.

B, O

Peridinium brochii
This species has a triangular top and a hemispherical bottom part with two horns. The armour plates are strongly sculptured. About 80 μm long. Present all year long. **Native.**

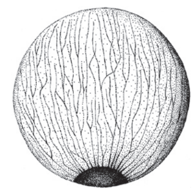


O

Prorocentrum gracile
Flattened from side to side and armoured with two plates. Has one flagellum at one end. About 50 μm long. Greenish. **Native.**

B, O

Pyrocystis noctiluca
Although not very common, this species is well known for its ability to produce light. Noctiluca means night light. The shape is spherical and up to 1 mm across. **Native.**



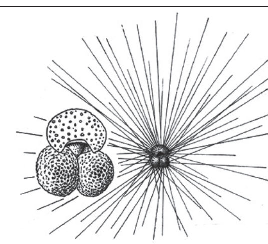
O

Animal Plankton

Note: Zooplankton, although larger than phytoplankton are generally quite small**.** A compound or stereo microscope is needed for identification, depending on the size of the specimens. Sizes are given in metric units only.

Foraminifera (Protozoa with a calcareous skeleton)

Globigerinoides ruber
A common open ocean species. The calcareous, central test is multi-chambered and about 0.6 mm in diameter. Numerous, long, calcareous spines project radially out from the test to bring the diameter to 5 mm or so. **Native.**

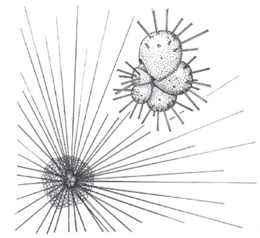


O

Globorotalia truncatulinoides
This foraminiferan is very common in the open ocean. The calcareous test is rather snail-like in shape and 0.8 mm in length. **Native**.

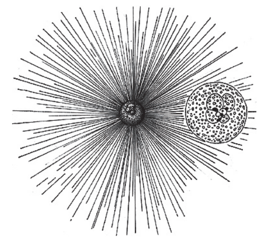
O

Hastigerina pelagica
The test of this large species has numerous chambers and is about 1.2 mm in diameter. Outside the test is a layer of bubbly protoplasm through which project the numerous, calcareous spines. The total diameter is about 2 cm. **Native**.



O

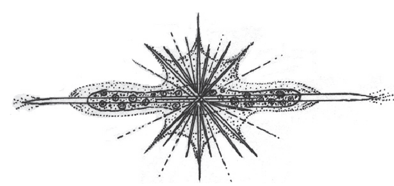
Orbulina universa
As its name suggests this species is common and widespread in the oceans. The spherical test is about 1 mm in diameter and from it project numerous fine, calcareous spines which bring the total diameter to about 5 mm. **Native**.



Acantharia (Protozoa with strontium sulphate skeleton)

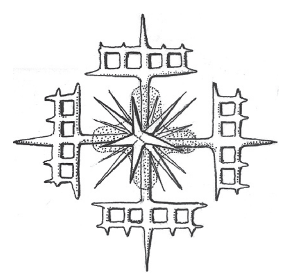
O

Amphilonche elongata
This species has two of the 20 spines much longer than the others and emerging from the center opposite to one another and giving the organism an elongated appearance reaching 0.6 mm long. Found in the near-surface depths. **Native**.



O

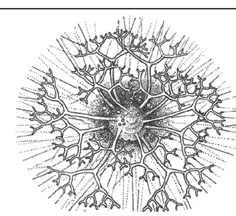
Lithoptera tetraptera
This species is unmistakable if seen in collections from near to the surface. The distinguishing feature is the presence of four, larger spines arranged in a circle each having a crossbar with four squares. The other simple spines are shorter. The diameter is about 0.5 mm. **Native**.



Radiolaria (Protozoa with silica skeletons)

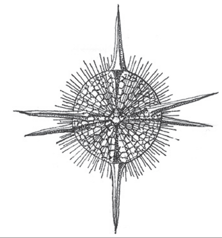
O

Coelodendrum ramosissimum
This species is a striking member of the group having long, evenly branched spicules arising from the small central capsule about 1.5 mm in diameter. **Native**.



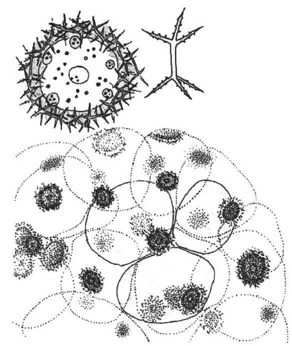
O

Hexalonche amphisiphon
This species is a typical radiolarian having a clear, spherical shell from which project six large spines and numerous small ones. Found at depths to about 100 m (300 ft). About 0.45 mm in diameter. **Native**.



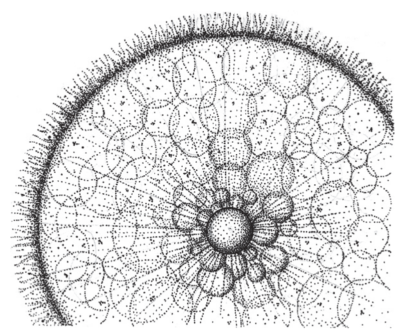
O

Sphaerozoum punctatum
This interesting radiolarian is a colony the tiny individuals of which are embedded in a gelatinous ball about 3 mm in diameter. The ball is covered by a layer of spicules having needle-like projections armed with short spines. Another interesting feature of this species is that the central ball containing the individuals also has **zooxanthellae**. These are members of the phytoplankton living in a symbiotic relationship with this member of the zooplankton. Common near to the surface of the ocean. **Native**.



O

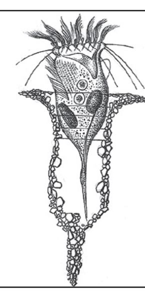
Thalassolampe maxima
As the second of the scientific names suggests, this is a large species for this general group of zooplankton, in fact it is the largest known radiolarian. The body appears as a sphere up to 12 mm (1/2 in) in diameter covered in a transparent membrane, minutely hairy on the outside. Unlike most radiolarians, there are no spicules. Common near to the surface of the ocean. **Native**.



Ciliata (Ciliated protozoa)

O

Tintinnopsis campanula
This species has a loosely fitting shell, shaped like a wine-glass with no foot, composed of irregular grains which the protozoon produces. The emerging part of the organism has a prominent crown of long cilia. Very widespread in surface waters. About 0.15 mm long. **Native**.

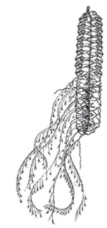


Cnidaria (Hydroids, jellyfish, etc)

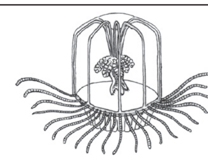
Abylopsis eschscholtzi
A most peculiar-looking species up to 7 mm long consisting of two box-like parts, one above the other. **Native**.

O

Agalma okeni
The elongated body measures up to 15 mm and contains many specialised individuals. The species is almost totally transparent and hard to spot. It is common offshore from the surface to 200 m (650 ft) deep. **Native**.

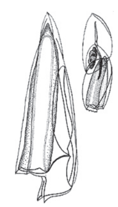


Aglaura hemistoma
A small medusa about 6 mm across. It is shaped like a thimble with numerous tentacles. **Native**.



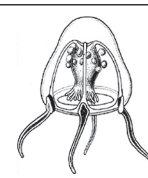
O

Chelophyes appendiculata
About 15 mm long this species has a pointed top and skirt-like bottom. It is very common and aggregates at the surface on moonlit nights off Bermuda. **Native**.



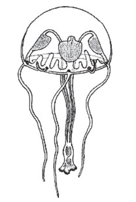
O

Cytaeis tetrastyla
A small medusa about 6 mm across which is quite common. There are four tentacles below a bell-shaped body. **Native**.



Eudoxoides mitra
About 15 mm long this species has a narrow pyramidal top with serrated ridges running longitudinally. The species ranges from the ocean surface to a depth of about 1,300 m (4,500 ft). **Native**.

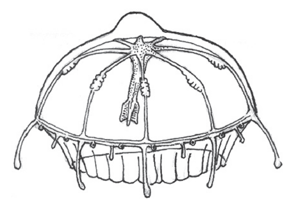
Liriope tetraphylla
One of the larger medusas being up to 24 mm across. It has a hemispherical body with four long tentacles. It is very common in oceanic surface waters. **Native**.



O

Pelagia noctiluca
A jellyfish up to about 10 cm across with a lightly spotted inverted bowl shaped top and eight long tentacles. Sometimes this oceanic species drifts inshore in large numbers. **Native**.

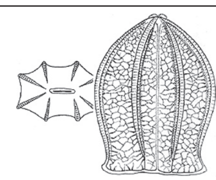
Rhopalonema velatum
Up to about 10 mm across, this species is quite common. There is a shallow bell-shaped body with 8 longer club-shaped tentacles and many smaller ones. **Native**.



O

Ctenophora (Comb Jellies)

Beroe ovata
A large comb-jelly up to 50 cm across. The body is bell shaped. It feeds on other ctenophores. **Native**.



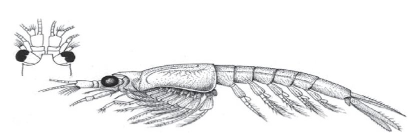
O

Sea Gooseberry
Pleurobrachia pileus
This is a very widespread species which brings to mind the common name of sea gooseberry. The body is almost spherical with longitudinal ciliated bands. There are two long tentacles. Body up to 20 mm in diameter. **Native.**

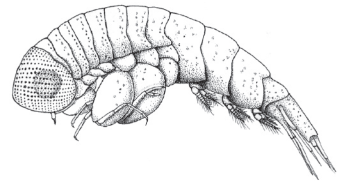
O

Crustacea (Copepods, shrimps, crabs etc)

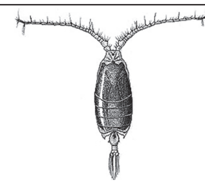
Anchialina typica
About 9 mm long, this shrimp is very similar to the preceding one and like it can be collected using a light. **Native**.



Brachyscelus crusculum
Quite a large amphipod up to about 20 mm long, this species has very large compound eyes which cover the entire side of the head.

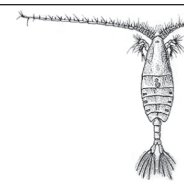


Candacia ethiopica
Measuring about 2.5 mm in length this species is an unusual pale chocolate-brown in colour. **Native**.



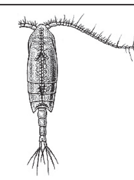
O

Centropages violaceus
About 2.5 mm long is pale violet in colour; this crustacean is found in near-surface oceanic water. **Native**.



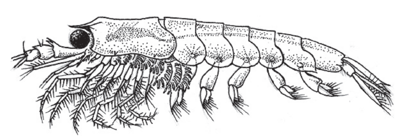
O

Clausocalanus furcatus
This is a typical calanoid crustacean of near-surface oceanic waters. The virtually clear body is about 1.2 mm long. **Native**.



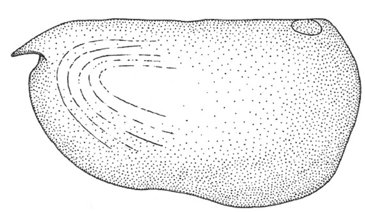
O

Common Krill
Euphausia brevis
This is the commonest of the krill found in the ocean around Bermuda. It ranges from the surface to 300 m in depth and reaches 10 mm in length. **Native.**



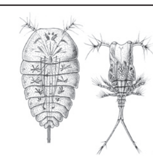
O

Conchoecia spinirostris
The body of this species is enclosed in a bivalved shell about 1.2 mm long. The front of the shell has a short, sharp projection. The body is hidden within the shell. Common near to the surface. **Native**.

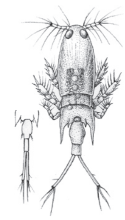


O

Copilia mirabilis
The 5 mm long oval shaped body has short antennae. Found near to the surface of the ocean. **Native**.

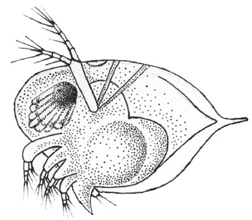


Corycaeus speciosus
The shape of this 1.9 mm long crustacean is quite unusual. The narrow body has three large legs protruding from each side. The antennae are short. **Native**.



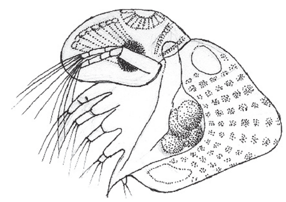
O

Evadne spinifera
This is a small species with a body about 0.7 mm long with a large, prominent eye. The shell is colourless, thin and simple, covering the hind end and finishing in a short spine. Found in surface waters of the Sargasso Sea. **Native**.



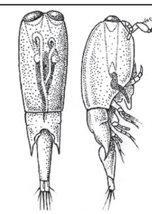
B

Evadne tergestina
Very similar to the species above except that the hind end of the shell is rounded and the head is more clearly set off from the body. About 0.7 mm in length. **Native**.



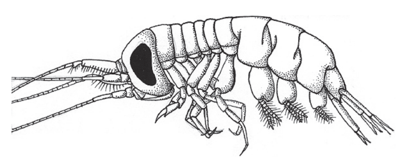
O

Farranula rostrata
This species of surface water oceanic situations is small, only 0.7 mm long. The body is blunt at the front with two large eyes. The antennae are not visible from above. **Native**.



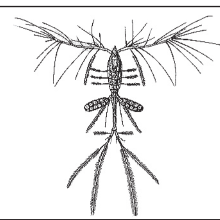
O

Hyperia bengalensis
This planktonic amphipod crustacean is flattened from side-to-side and characterised by the presence of two very large, dark eyes. Commonly about 6 mm long this crustacean is common in offshore waters. **Native**.

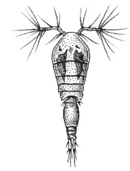


O

Oithona plumifera
This is an unmistakable species characterised by very long, feathery spines on the antennae, body and tail. Up to 1.2 mm long this oceanic species is found close to the surface. **Native**.

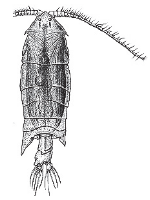


Oncaea venusta
The body is only 1 mm long and much broader at the front than elsewhere. The antennae are comparatively short. **Native**.



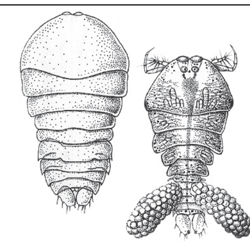
O

Pontella atlantica
Pontella is comparatively large for this group of planktonic crustacea, measuring up to 5.5 mm long. A pale, clear blue in colour it occurs in offshore surface waters. **Native**.



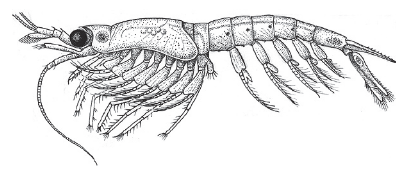
O

Sapphirina auronitens
The body in this species about 2 mm in length is very chunky and the antennae are tiny. Unlike most zooplankton the body is coloured and iridescent. An oceanic species typical of near-surface waters**. Native**.



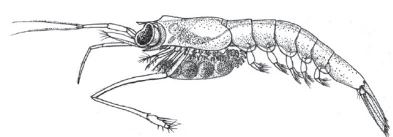
O

Siriella thompsoni
This is a mysid shrimp which can be collected at the ocean surface at night using a light. Measuring about 10 mm long. Colourless. **Native**.

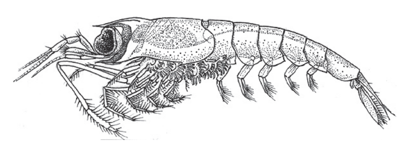


O

Stylocheiron carinatum
Ranging from oceanic surface waters to 200 m in depth, this 12 mm long krill is colourless and common. **Native**.



Thysanoëssa gregaria
This krill may reach 12 mm in length and is characterised by bright red colour on the back and sides. Found from the surface to 200 m deep. **Native**.

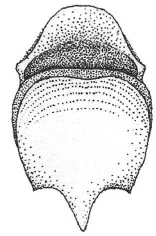


O

Mollusca (Snails and Clams)

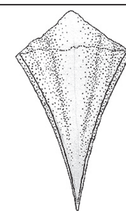
O

Cavolinia gibbosa
Of all the sea butterflies this one has the most globose shell which is up to 10 mm long. There are three weak points at the hind end, one central and two lateral. The colour is a light brown. Common worldwide. **Native**.



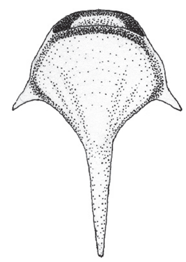
O

Clio pyramidata
One of the larger sea butterflies with a shell up to 21 mm in length. The shape is conical with incurved sides. The colour is often pale red. Common worldwide**. Native**.



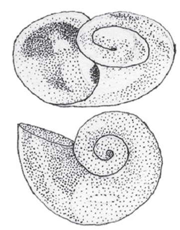
O

Diacria trispinosa
This species has a very distinctive shell shape, having three horns, one large one at the hind end and two smaller ones on each side hence the scientific name 'trispinosa'. The colour may be either brown or clear. Common worldwide**.** 20 mm long. **Native**.



O

Limacina inflata
This general group of snails is called the 'sea butterflies' This species has a coiled shell up to 1.5 mm wide. In life, lobes of the foot extend from the shell opening, like butterfly wings, and serve in locomotion in the water. **Native**.



O

Styliola subula
This sea butterfly has a relatively simple, conical shell about 10 mm in length and of a delicate rose colour. Very common worldwide. **Native**.

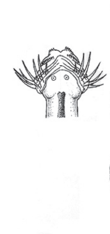
Chaetognatha (Arrow Worms)

O

Sagitta bipunctata
This is a fairly large arrow worm reaching18 mm (3/4 in). It is very similar to the species above and found in the top 200 m (600 ft) of water. **Native**.

O

Sagitta minima
Almost transparent with a fairly rigid body. Length about 10 mm (1/3 in). Like the other arrow worms this species can dart rapidly, for a short distance to capture prey. Common in the top 300 m (1,000 ft) of water. **Native**.



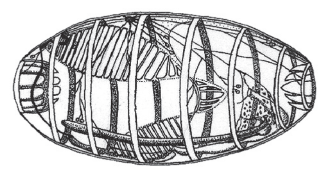
O

Sagitta serratodentata
Very similar to the species described above but reaching 13 mm (1/2 in) long and having more prominent fins and tail. One of the commonest offshore arrow worms. **Native**.

Thaliaceans (Salps etc.)

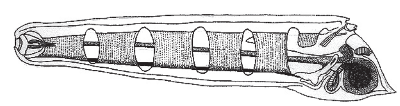
O

Doliolum denticulatum
This species and its near relatives resemble a barrel in shape. They move with the long axis of the barrel horizontal in the water. Very transparent. About 4 mm in length. Common at all times. **Native**.



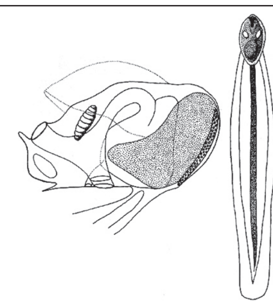
O

Iasis zonaria
An elongated species that is abundant offshore at all times of the year. The length is up to 50 mm. **Native**.



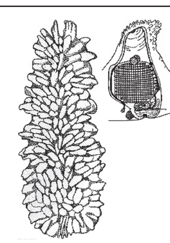
O

Oikopleura longicauda
This is a common member of a group called the Larvacea. The individual resembles a tiny tadpole. However, it lives in a complex 'house', 4 mm or so long, which it secretes and propels through the water. The house can be abandoned very quickly and a new one built. Very common offshore close to the surface. **Native**.

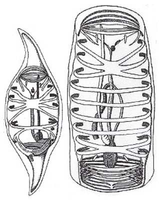


O

Pyrosoma atlanticum
This is a colonial member of the zooplankton. The individuals are small and the colony of hundreds of individuals is up to 50 cm long. Occurring from the surface to a depth of 200 m the colonies are often in large groups. **Native**.



Salpa fusiformis
The body may be either blunt or sharp-ended depending on the stage of the life history. Extremely common in offshore surface waters especially in winter. 25 mm long. **Native**.



O

Sargassum Community

Plants (Brown algae)

Common Sargasso Weed or **Common Gulfweed**
Sargassum natans
The dominant seaweed in the sargassum rafts. Common throughout the year at sea and washed up on shore. Each plant may be up to 50 cm (20 in) long and consists of many branches with elongated, coarsely serrated leaves and numerous bladders each bearing a terminal spine. **Native**.

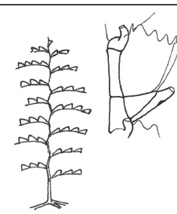
O

Sargasso Weed or **Broad-toothed Gulfweed**
Sargassum fluitans
Almost exactly like the species above except that the bladders have no spine. Fairly common. Each plant is up to 50 cm (20 in) across. **Native**.

O

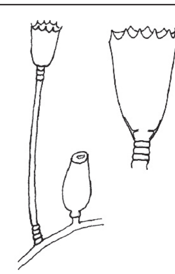
Cnidaria (Hydroids, jellyfish, etc)

Aglaophenia latecarinata
The vertical branches of this hydroid, which are about 20 mm (3/4 in) high, branch very regularly and alternately on opposite sides of the stalk. Very common. **Native**.



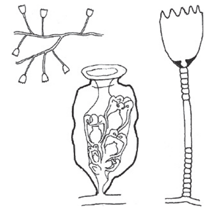
O

Clytia cylindrica
The individuals of the colony arise from a threadlike base attached to the sargassum. Each individual occupies a cup-like protective structure with rounded, marginal teeth on top of a stalk Each individual is only 7 mm (1/4 in) tall. Common. **Native**.



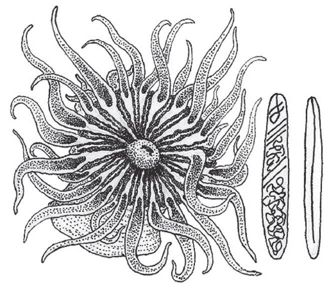
O

Clytia noliformis
Rather similar to the species above but much smaller, the individuals being only 2 mm (1/12 in) tall. The edge of the protective cup has closely set marginal teeth. Common. **Native.**



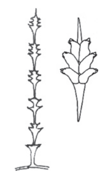
O

Dark Star Anemone
Pseudactinia melanaster
This is the only sea anemone commonly found on sargassum. It has 32 tentacles and is about 10 mm (3/8 in) in diameter. The colour of the body is fawn to reddish-brown, while the top disk has a star-shaped pattern of dark and light stripes radiating from the center. Very common. **Native**.



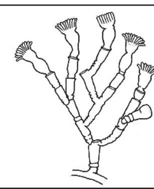
B, C, O

Dynamena quadridentata
The stocky branches with individuals closely spaced in groups of 1-6 individuals are about 10 mm (3/8 in) tall. Very common. **Native**.



O

Halecium nanum
This is another small hydroid with the vertical stalks of the colony only 3 mm (1/8 in) high. The stalks branch irregularly. Common. **Native**.

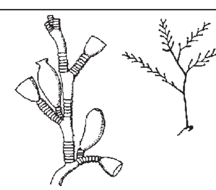


O

Obelia dichotoma
In this rather feathery species, the individuals of the colony are quite closely set together on vertical stalks arising from a connecting structure on the sargassum. The vertical branches are about 10 mm (3/8 in) tall. Common. **Native**.

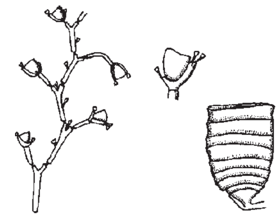
B, O

Obelia hyalina
Closely related to the above species but much larger, the upright stalks, which may branch, reaching 25 mm (1 in) tall. Common. **Native**.



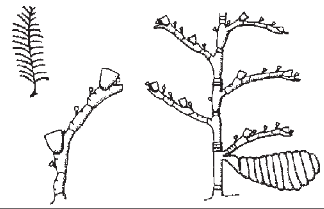
O

Plumularia margaretta
As the scientific name suggests these hydroids are plume-like or feather-like, branching very regularly from the central stalk, with a single individual on each branch. Branches 15 mm (5/8 in) high. Common. **Native**.



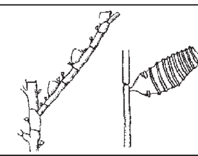
O

Plumularia setaceoides
Rather similar to the above species except that there are several individuals per branch and the branches reach 25 mm (1 in) high. Common. **Native**.



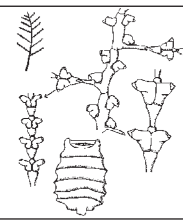
O

Plumularia strictocarpa
A quite large species in which the branches reach 50 mm (2 in) long. Common. **Native**.



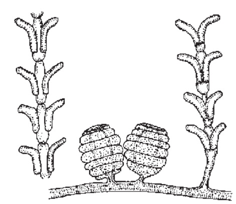
O

Sertularia inflata
The upright stalks up to about 50 mm (2 in) high have the individuals alternating on the central stalk but opposite on the short side branches. The side branches alternate. Common. **Native**.



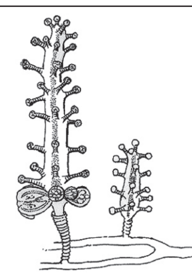
O

Sertularia meyeri
This is a small, delicate species with the branches only about 12 mm (7/8 in) high. The uprights do not branch and the individuals are arranged oppositely. Common. **Native**.



O

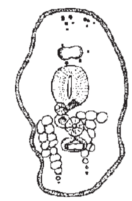
Zanclea costata
The whole colony of this minute hydroid is small and takes the form of a branching, threadlike base, attached to the sargassum. From this base arise the individuals which are only 1.5 mm (1/16 in) tall bearing a few short tentacles. Very common**.** **Native**.



O

Flatworms

Acerotisa notulata
A tiny, colourless little flatworm 1 mm (1/32 in) long crawling on sargassum. There are two groups of tiny eyes at the front end. Common. **Native**.



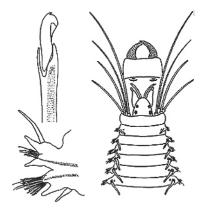
O

Gnescioceros sargassicola
A milky coloured flatworm with faint brown spots, reaching 10 mm (3/8 in) long. The body is broadest at the front then tapers steadily back. Common. **Native**.

O

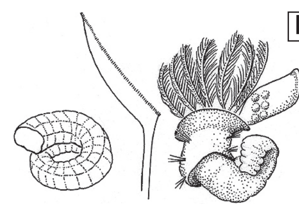
Polychaete Worms (Spiny marine worms)

Dumeril's Ragworm
Platynereis dumerilii
This worm growing to 60 mm (2 3/8 in) long forms transparent, weak tubes on the sargassum. There are up to 90 segments. Very common. **Native**.



B, O

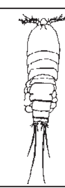
Coiled Tube Worm
Spirorbis formosus
This worm makes very distinctive small, anti-clockwise-coiled, white tubes about 3 mm (1/8 in) across on the surface of the sargassum. Very common. **Native**.



B, O, R, SG

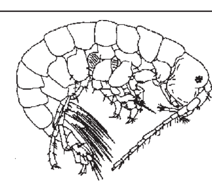
Crustacea (Copepods, shrimp, crabs etc.)

Amonardia phyllopus
This copepod has a body about 0.3 mm long broad at the front, tapering to the back. It has a large, single red eye. Common. **Native**.



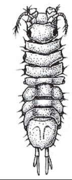
O

Biancolina sp.
Another small amphipod crustacean reaching only 2 mm long. The body is very slender. Common. **Native**.



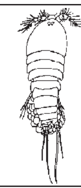
O

Carpias bermudensis
A tiny flat isopod crustacean, 2 mm (1/16 in) long, whitish-brown in colour with darker spots. Common. **Native**



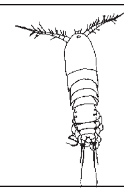
O

Dactylopodia tisboides
In this species about 0.5 mm long the body tapers steadily and is of a reddish-brown colour. Common. **Native**.



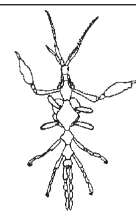
O

Harpacticus gurneyi
A copepod with a steadily tapered body about 0.5 mm long. It is coloured a light reddish orange. Common. **Native**.



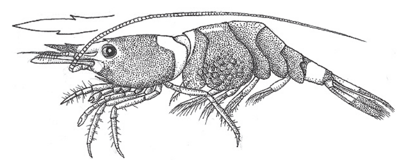
O

Hemiaegina minuta
As suggested by the name, this is a tiny shrimp only 4 mm (3/16 in) long. The antennae and legs are all very long and the body slender. Common. **Native**.



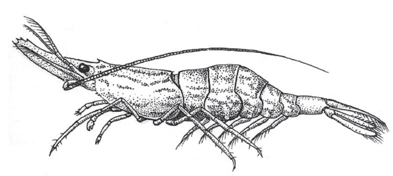
O

Hippolyte coerulescens
A shrimp about 30 mm (1 1/4 in) long. The body is banded in brownish-yellow so that it is well camouflaged among the sargassum. Common. **Native**.



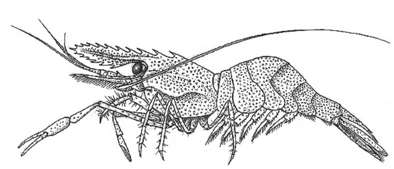
O

Latreutes fucorum
This shrimp is about 20 mm (3/4 in) long. The body is coloured brownish-yellow with white areas and it blends in well with the colour of sargassum. Very common. **Native**.



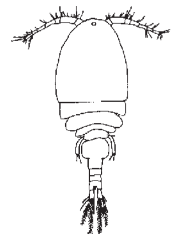
O

Leander tenuicornis
A shrimp reaching 50 mm (2 in) long having a strongly serrated spine between the eyes. The body is yellowish-brown with numerous, small darker brown spots. Very common. **Native**.



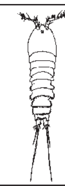
O

Macrochiron sargassi
This is a small copepod crustacean only about 1 mm (1/32 in) long, lacking colour or whitish. Front part of body much broader than the rear. Moves over the surface of the sargassum. Common. **Native**.



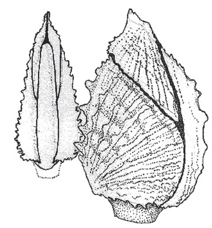
O

Paralaophonte congenera
This copepod has a tapered body, widening slightly 2/3 of the way back. 0.6 mm long. Common. **Native**.



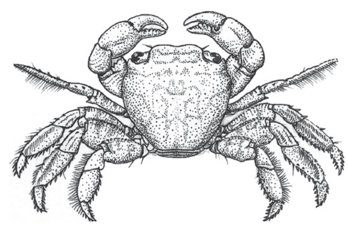
O

Sargasso Barnacle
Lepas pectinata
This is the most common Goose Barnacle found on sargassum. The stalk is very short. The plates on the body are very grooved and often spiny. The total length is about 20 mm (3/4 in). Common. **Native**.



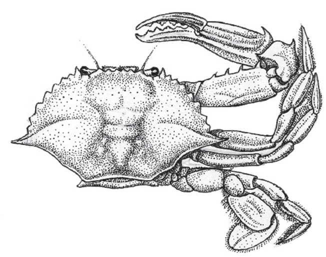
O

Sargassum Crab
Planes minutus
This species is a small crab up to 20 mm (3/4 in) long. The shell is about as broad as it is long. The colour is yellowish-brown. Very common. **Native**.



O

Sargassum Swimming Crab
Portunus sayi
This crab about 25 mm (1 in) across is characterised by its broad hind limbs which are modified for swimming. In colour it may be brown or purplish-brown with olive-green or brown shading and orange markings on the front claws. Common. **Native**.



O

Scutellidium longicauda
A small copepod about 0.7 mm in length, has a body which is broad and rounded at the front and very narrow at the rear. Common. **Native**.

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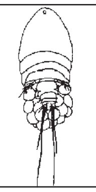
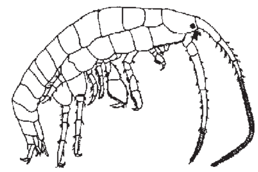


O

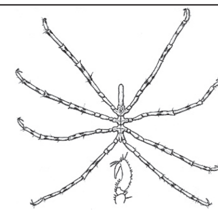
Sunampithoë pelagica
A small amphipod crustacean, flattened from side-to-side and reaching 4 mm (3/16 in) long. Common. **Native**.



O

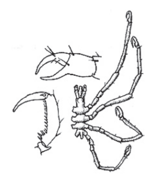
Pycnogonida (Sea Spiders)

Endeis spinosa
This sea spider up to 30 mm (1 1/4 in) long has extremely long, slender legs and a slender body about half the length of the legs. It is greenish in colour. Common. **Native.**



O

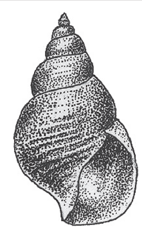
Sargassum Sea-spider
Anoplodactylus petiolatus
A small sea spider reaching only 4 mm (1/8 in) long. The body is short and stocky but the legs are very long and slender. Very common. **Native**.



O

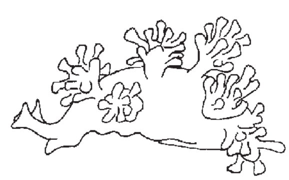
Mollusca (Snails, Clams and Slugs)

Brown Sargassum Snail
Litiopa melanostoma
This small snail about 5 mm (3/16 in) long is coloured yellowish-brown to dark brown. The shell is light and thin and has about 9 whorls. Very common. **Native**.



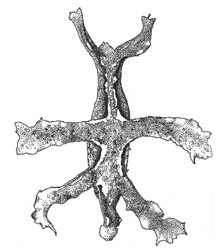
O

Pygmy Doto
Doto pygmaea
A tiny sea slug about 3 mm 1/8 in) long. There are several knobby processes on the back, the colour is dark brown. Common. **Native**.



O

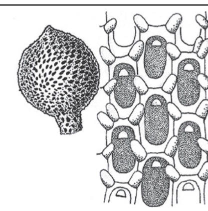
Sargassum Nudibranch
Scyllaea pelagica
This large sea slug about 50 mm (2 in) long has a very characteristic shape the body is thickest in the middle and has three long, leaf like processes on each side. The colour is a translucent olive-brown to orange-brown. It blends in well with the sargassum. Common. **Native**.



O

Bryozoa (Moss Animals)

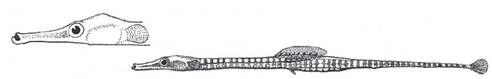
Membranipora tuberculata
This colonial animal forms a thin, encrusting, lacy sheet over the surface of the sargassum and its bladders. Colour is a pastel brown. Very common. **Native**.



O

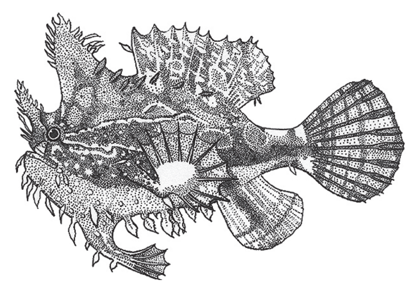
Fishes

Pugnose Pipefish
Syngnathus pelagicus
A very slender fish up to about 12 cm (4 3/4 in) in length. The fins are small and the anal fin is absent. The colour is highly variable but is generally some combination of light and dark brown rings around the body. Common. **Native**.



B, O

Sargassum Fish
Histrio histrio
A member of the Frogfish family this chunky fish up to 15 cm (6 in) long fish is beautifully camouflaged to blend in to the sargassum. The colour is a mottled mix of brown, tan and yellow and the fins and protrusions on the body resemble sargassum leaves. Common. **Native**.

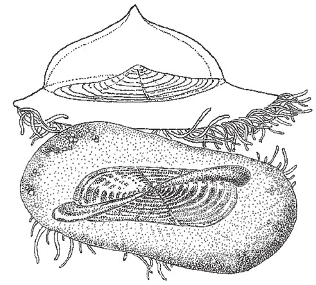


O

Jellyfishes

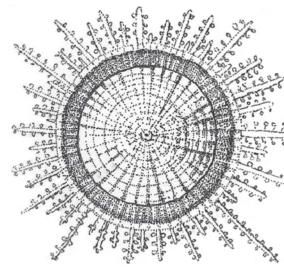
O

By-the-wind Sailor
Velella velella
A common species found floating at the surface and equipped with a triangular sail that propels it through the water. This cnidarian may occur in enormous numbers and be driven onshore in storms. The colourless float is about 10 cm (4 in) long. **Native**.



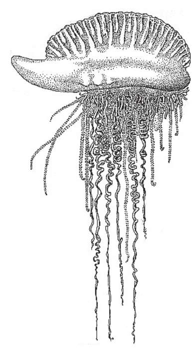
O

Porpita
Porpita porpita
Porpita has a circular float within which are gas-filled chambers that keep it at the sea surface. Unlike the previous species there is no sail and it is much less common and smaller. About 3 cm (1 1/2 in) in diameter. **Native**.



O

Portuguese Man-of-War
Physalia physalis
This large and very well-known member of the neuston is actually a colony and is highly poisonous. The top of the colony consists of a large purple, gas filled float, up to 20 cm (8 in) long, with a pleated sail. Many tentacles which may be meters long dangle beneath and serve to catch prey. They contain the poisonous nematocysts. **Native**.

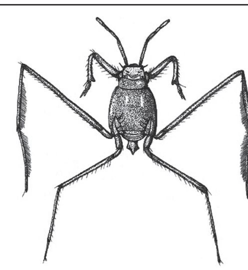


Insects

Bugs

O

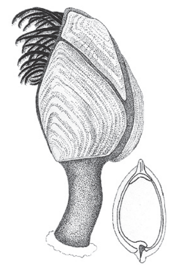
Ocean Skater
Halobates micans
This very unusual insect can stand on the surface of the ocean where it catches zooplankton, small fish etc. as they rise to the surface. It is about 5 mm (3/16 in) across. **Native**.



Crustacea

Barnacles

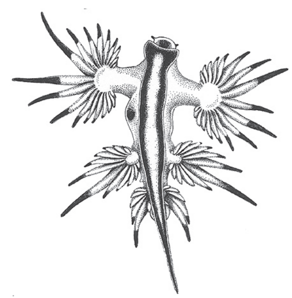
Common Goose Barnacle O
Lepas anatifera
This barnacle is commonly found attached to objects such as wood or bottles floating at the surface. It grows up to at least 50 mm (2 in) long and has a stout stalk and a body encased in four calcareous plates. **Native**.



Gastropoda

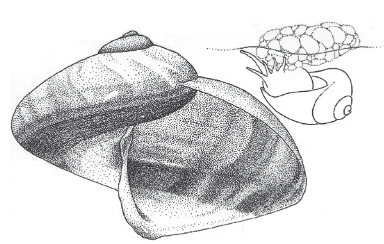
Sea Slugs

Blue Glaucus O
Glaucus atlanticus
This is really a planktonic sea slug but it swallows air to keep it right at the surface, where it feeds on floating cnidarians. The Blue Glaucus is a very strikingly beautiful species being a bright blue in colour and up to 50 mm (2 in) in length. Three or four fan-shaped projections extend from each side of the body. **Native**.



Snails

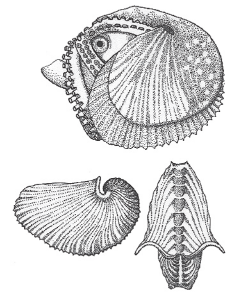
Common Purple Sea Snail O
Janthina janthina
These specialised snails which feed on By-the-wind Sailors float at the surface of the sea on a raft made of bubbles which the snail produces. The very fragile shell is a beautiful purple in colour and up to 35 mm (1 1/2 in) long. **Native**.



Squids and Octopusus

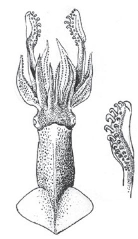
Squids

Common Paper Nautilus
Argonauta argo
This is really an octopus with a thin, slightly coiled shell. The female reaches 30 cm (12 in) in length but the shell-less male is only 1.5 cm (1/2 in). The very ridged shells are sometimes washed ashore. This species lives close to the surface but is not commonly seen. **Native**.



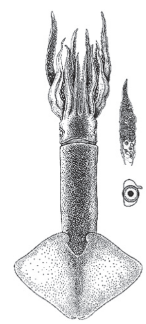
O

Onykia caribaea
This is a small, typical oceanic squid which lives close to the surface and is often found under sargassum rafts. The colour is a deep, iridescent blue and the body length is up to 7 cm (3 in). Common. **Native**.



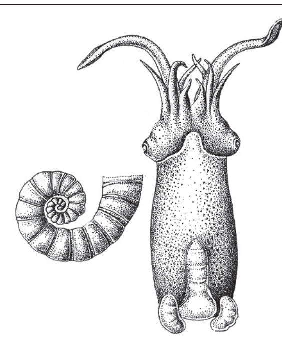
O

Orange-back Squid
Ommastrephes pteropus
The Orange-back Squid is a medium-sized one with a body length up to 40 cm (16 in). This squid lives in the upper few hundred m (<1,000 ft) of water and is a strong swimmer. It often congregates, at night, at the surface around lighted vessels. The colour is a striking deep red or maroon. Common. **Native**.



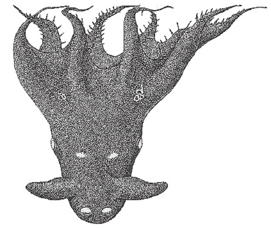
O

Rams Horn Shell
Spirula spirula
This species is rarely seen alive but is common and the shells of dead specimens, up to 2.5 cm (1 in) are often washed up on beaches. The squid which lives in the shell is about 7 cm (2 3/4 in) long . There are two long tentacles and eight short ones. Comes up to 100 m (300 ft) depth by night but is deeper by day. **Native**.



O

Vampire Squid
Vampyroteuthis infernalis
This black squid with red eyes rarely comes closer than 300 m (1,000 ft) to the surface. It has eight quite short tentacles. The body is up to 28 cm (11 in) long. Uncommon. **Native**.

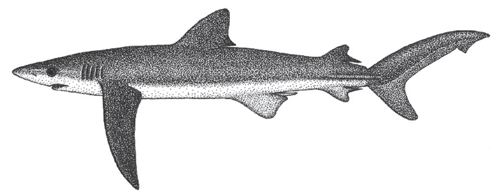


O

Fish

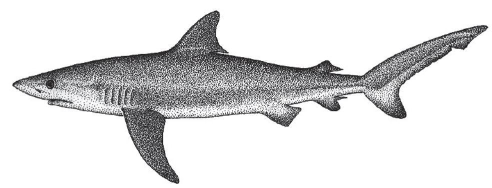
Sharks

Blue Shark
Prionace glauca
This 3.8 m (12 ft) shark sticks to the open ocean where it feeds on fish and squid. It is dark-blue on the back, bright blue on the sides and white below. Sport fishermen take this species. Uncommon. **Native**.



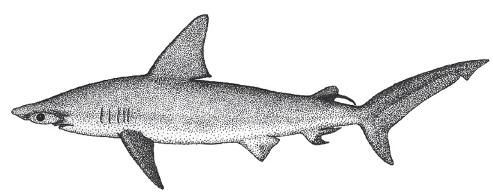
O

Dusky Shark
Carcharhinus galapagensis
This smallish shark may be found in both oceanic and near shore environments. It reaches a length of 3.7 m (11 ft). It is dark-grey above and virtually white below. This shark is caught on hook and line and by long-lining. Uncommon. **Native**.



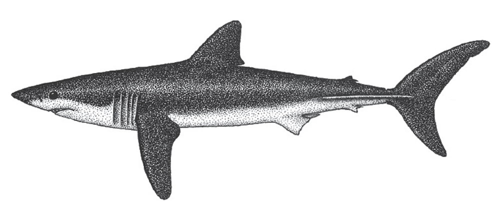
O

Scalloped Hammerhead
Sphyrna lewini
As its common name suggests this shark has a hammer-shaped head. It is grey above shading to whitish below and grows up to 4.2 m (14 ft). An entirely oceanic shark, it feeds on fish, squid and krill. Uncommon. **Native**.



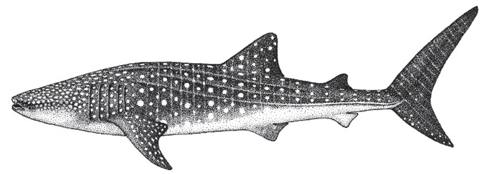
O

Short-finned Mako
Isurus oxyrinchus
This oceanic shark is a dark blue-grey on the back, grey on the sides and whitish beneath; it reaches a length of 4 m (12 ft). It feeds on fish and squid and is occasionally caught on hook and line. Not common. **Native**.



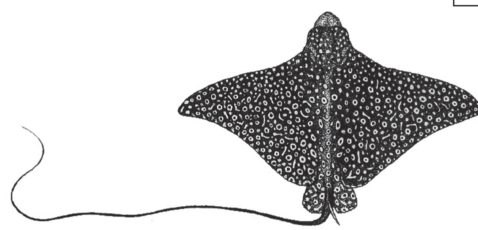
O

Whale Shark O
Rhincodon typus
The largest of the sharks reaching 12 m (38 ft), the Whale Shark is a filter feeder feeding on small fish, krill etc. It is a slow swimmer and totally harmless. The body is chocolate-brown above and yellowish below. There are white spots on the back, sides and fins. Uncommon. **Native**.



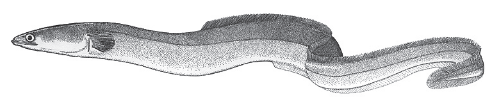
Rays

Spotted Eagle Ray B, O
Aetobatus narinari
This ray, common over sandy bottoms where it hunts its shellfish prey, is unmistakable. Up to 1.5 m (4 1/2 ft) across, but commonly smaller, The Spotted Eagle Ray has a very wide flat body and a long tail. The back is dark-grey and covered with light spots with a dark centre. **Native.**



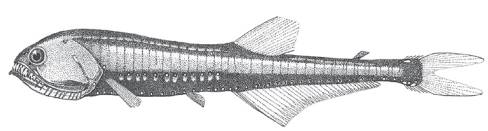
Eels

American Eel FW, O
Anguilla rostrata
The American Eel, up to 1.5 m (4.5 ft) in length is an oceanic spawner. It lays its eggs in the Sargasso Sea and the larvae travel in ocean currents until they are ready to swim ashore. Spawning has never been observed but newly laid eggs have been taken in nets. Found in saltwater ponds only. **Native**.



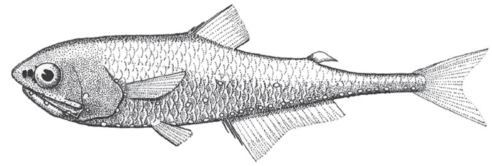
Lantern Fishes

Bristle Mouth O
Gonostoma elongatum
This dark-brown to black fish may ascend to 700 m (2,300 ft) by night but goes very deep during the day. It has a large head with many sharp teeth. It feeds on zooplankton and reaches a length of 27 cm (11 in). Common. **Native**.



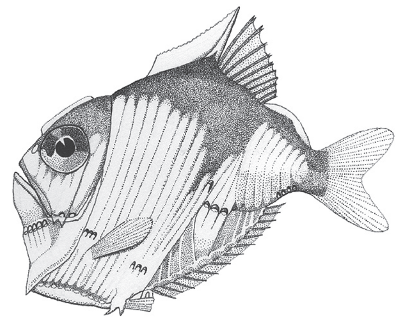
O

Cocco Lantern-fish
Gonichthys coccoi
One of the lantern fishes this species swims deeply by day but comes to the surface at night to feed on zooplankton. It has a row of **photophores** on the rear bottom side. About 10 cm (4 in) long. Blackish above, silver to golden below. Common. **Native**.



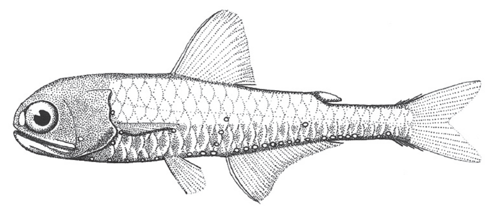
O

Hatchet Fish
Sternoptyx diaphana
Hatchet Fish have a body flattened from side-to-side and are silvery except for a dark line along the back. The eyes are very large and the photophores very well developed. Although it ascends to the surface at night it goes down to 2,000 m (6,500 ft) by day! Up to 4.5 cm (1 3/4 in) long. Common. **Native**.



O

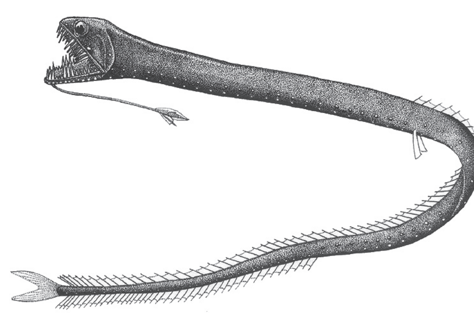
Lantern Fish
Myctophum nitidulum
A Lantern Fish found at the surface at night and down to 850 m (2,700 ft) by day. The length is about 10 cm (4 in) and it has photophores on the sides and bottom. Silvery-black above and silver below. Common. **Native**.



Gulper Eels

O

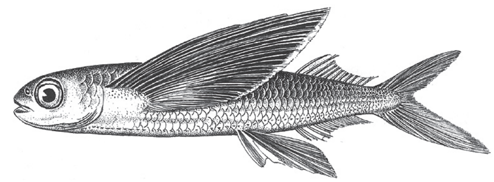
Black Dragonfish
Idiacanthus fasciola
Females are much larger than the males and may reach 30 cm (12 in). This is an elongated, eel-like fish with a large head bearing a prominent barbel on the chin. Black in colour. Although it ascends to the surface at night it goes down to 2,000 m (6,500 ft) by day! Fairly common. **Native**.



Flying Fishes

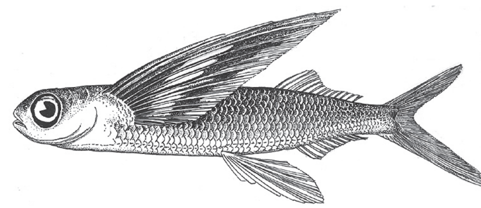
O

Fourwing Flying Fish
Hirundichthys affinis
A flying fish of the open ocean that sometimes comes inshore. The juveniles are quite different and have much enlarged pelvic fins as well as the pectoral fins. Silvery-grey in colour and reaching a length of 25 cm (10 in). Common. **Native**.



O

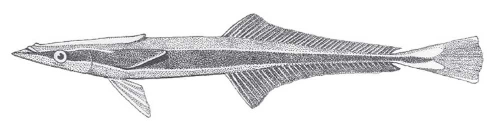
Spotfin Flying Fish
Cypselurus furcatus
The flying fishes have much enlarged pectoral fins which can act like wings and enable the fish to glide for considerable distances. This species grows to 30 cm (1 ft) in length and is a silvery-grey. Common. **Native**.



Remoras

B, O

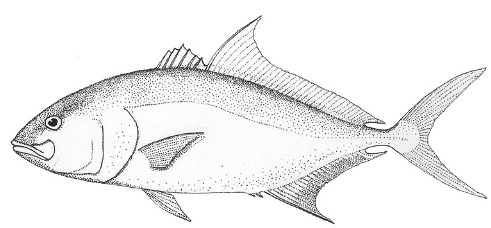
Sharksucker or **Remora**
Echeneis naucrates
This is a very slim fish up to 1 m (3 ft) long, with its dorsal fin modified to form an elaborate sucker on top of the head. While, as their name suggests, this sucker can be used to attach to sharks or rays, many Remoras swim freely around. They have been known to attach to many other things, including underwater cameras and even human swimmers! **Native**.



Jacks and Pompanos

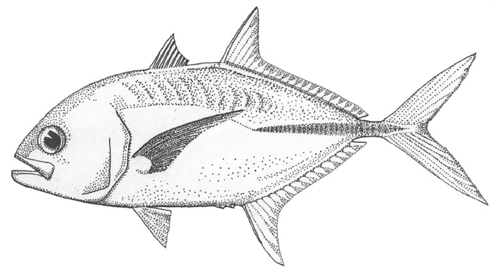
O

Greater Amberjack
Seriola dumerili
The Greater Amberjack is a large fish reaching 200 cm (6.5 ft) long. It is an important sport-fishery fish. The tail is deeply forked and the body is brownish above and silvery-white on the belly. Common. **Native**.



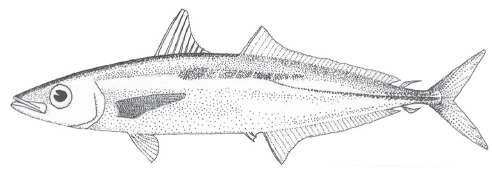
B, O

Horse-eye Jack
Caranx latus
The Jacks are silvery-blue or silvery-green fishes with a fairly deep body and a deeply forked tail. In the Horse-eye Jack, the tail is yellow and there is a black spot on the edge of the gill cover. The body is dark blue-grey on top and silver below. Feeds mainly on small fish. Length to 100 cm (3.3 ft) but those in the sound are usually half this. **Native**.



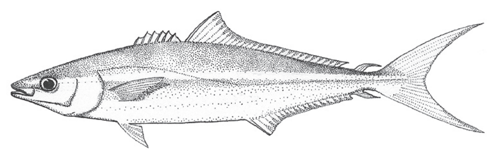
O

Mackerel Scad
Decapterus macarellus
This is a slender mackerel-like fish up to 40 cm (45 in) long. It is deep blue on the back and silvery beneath. There is a narrow golden stripe on the side. An offshore fish found in 20-200 m (60-650 ft) of water. Common. **Native**.



B. O

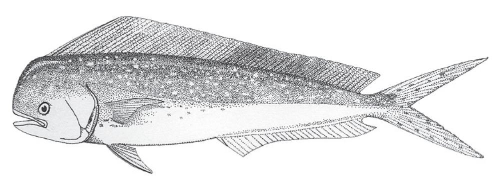
Rainbow Runner
Elagatis bipinnulatus
This fish is occasionally seen nearshore but is usually well out to sea. Growing to 130 cm (50 in) long. The tail is very deeply forked and the colour is a bluish-green above with two blue stripes on each side separated by a yellow band. Common. **Native**.



Dolphinfishes

O

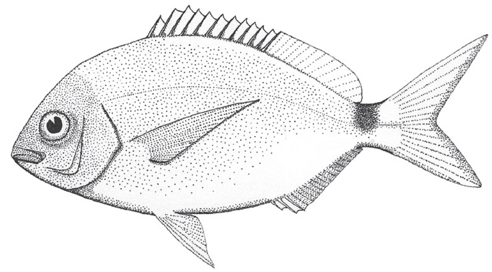
Dolphin Fish
Coryphaena hippurus
A much prized game fish that reaches 200 cm (6.5 ft) in length and a weight of 40 kg (100 lb). Its characteristic feature is the large, blunt head with small eyes. The colour is a brilliant blue with patches of yellow and gold. Common. **Native**.



Chubs and Breams

B

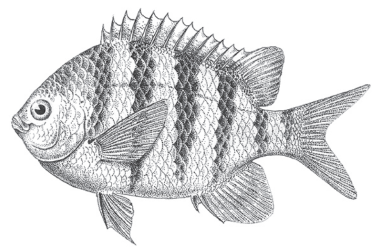
Bermuda Bream
Diplodus bermudensis
The Bermuda Bream is similar to but smaller than the Bermuda Chub growing to 40 cm (16 in). Bermuda Bream have relatively small heads and eyes, and are a dull silvery-grey in colour. The Bermuda Bream and the Bermuda Chub are easily told apart by the presence on the Bermuda Bream of a large dark spot, just above the base of the tail. **Endemic.**



Damselfishes

B, C

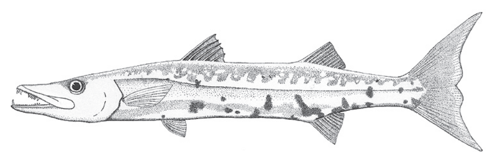
Sergeant Major or **Cow Polly**
Abudefduf saxatilis
The Sergeant Major is one of the damselfishes, and is strikingly coloured with a blue head, and with vertical dark bars on a yellow background along its back, grading to light blue beneath. It is a very active small fish, up to 15 cm (6 in) long. **Native**.



Barracudas

B, C, O

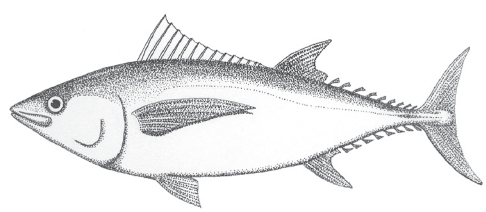
Great Barracuda
Sphyraena barracuda
Juveniles, up to about 45 cm (18 in) in length, are very frequent in the bays. Adults up to at least 1 m (3 ft) long may be seen on the reefs. This elongate fish is best recognised by the very large mouth with needle-sharp teeth, and elongated silvery body with dark markings. **Native**.



Tunas

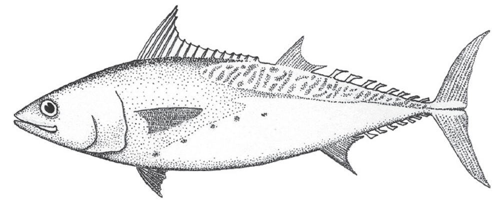
O

Blackfin Tuna
Thunnus atlanticus
A typical tuna reaching 95 cm (3 ft) in length. There are 7-9 finlets top and bottom before the smoothly forked tail. The back is dark blue which changes through dark gold to silvery-white on the belly. Quite common. **Native**.



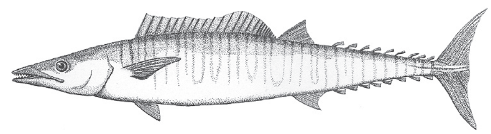
O

Little Tunny or **Mackerel**
Euthynnus alletteratus
Although it is fairly small, 50 cm (3 ft), this is a prized game fish. It has a moderately deep body, slightly forked deep tail and 7 finlets before the tail on top and bottom. The back is dark blue with a complex pattern of stripes. Quite common. **Native**.



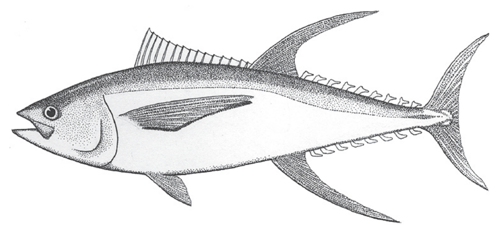
O

Wahoo
Acanthocybium solandri
A game fish reaching almost 2 m (6 ft) with a very long body and a deep, slightly forked tail. There are 7-10 finlets before the tail on both top and bottom. Dark bluish-black grading down to silvery with numerous irregular dark blue vertical bars. Quite common. **Native**.



O

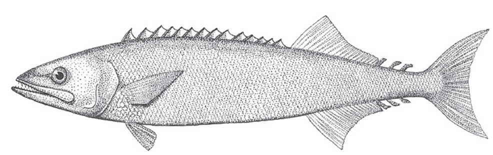
Yellowfin Tuna
Thunnus albacares
This oceanic fish is most commonly seen over offshore banks and drop-offs. It is a typical tuna with a moderately deep, muscular body. The colour is a shining dark blue on the back, grading through yellow on the sides to a gleaming white underside. In large specimens the second dorsal and anal fins are very long. The non-paired dorsal and ventral fins are bright yellow, hence its common name. Grows to about 2 m (7 ft) long. Widely used as human food. **Native**.



Oilfishes

O

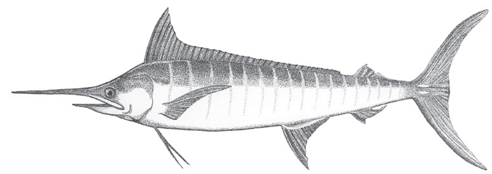
Tapioca Fish
Ruvettus pretiosus
A slender oceanic fish usually found from about 75-200 m (200-650 ft) deep, but occasionally at the surface on dark nights. The fish is a uniform dull brown and the most distinctive feature is the low front dorsal fin with 13-15 stout spines. Grows to 250 cm (10 ft) long. Not eaten by man because this results in severe digestive upset. **Native**.



Billfishes

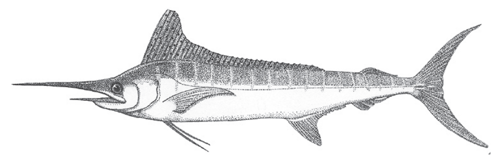
O

Blue Marlin
Makaira nigricans
A very large, heavy fish reaching 400 cm (13 ft) in length. The body is dark blue on top and silvery-white underneath. There are about 15 pale blue vertical bars on the sides. The upper jaw is a long, sword-like projection. It eats fish, squid and crustaceans. Quite common. **Native**.



O

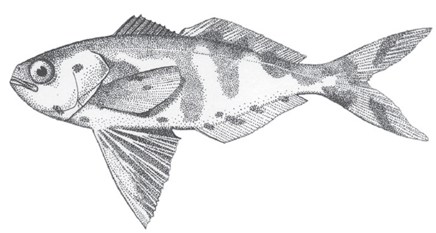
White Marlin
Tetrapturus albidus
A prized game fish reaching 200 cm (6 1/2 ft) long. The back is humped near to the front and there is a tall lobe of the top fin in the same location. The upper jaw is prolonged into a sword-like projection. Dark blue above, silvery beneath. Quite common. **Native**.



Man-of-war Fishes

O

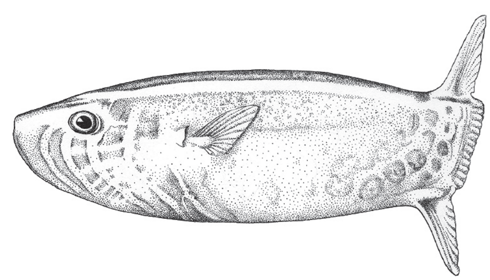
Man-of-war Fish
Nomeus gronovii
This fish lives among the tentacles of the Portuguese Man-of-war. Growing up to 20 cm (8 in), it has two pairs of large, paired fins at the front. The body colour is a blue shade in patches or bars. Not often seen. **Native**.



Sunfishes

O

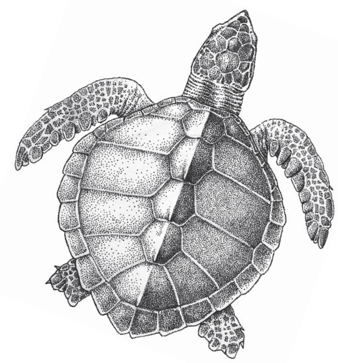
Slender Mola
Ranzania laevis
This is a member of the sunfish group that have very limited swimming abilities, drifting close to the surface of the open ocean. The body is very deep and chunky and the tail is reduced to a fringe. Grows to 60 cm (2 ft). The back is a bright, deep purple. The sides are ornamented with green lines and the underside is white. Not often seen. **Native**.



Turtles and Terrapins

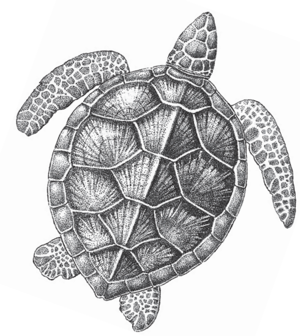
Turtles

Atlantic Ridley Turtle
Lepidochelys kempi
This is the smallest of the sea turtles not exceeding 75 cm (2 1/4 ft) in length. The shell on the back is grey to olive green. The distinguishing feature is that the central row of plates in the shell on the back are much smaller than other shelled turtles. This species breeds only on one beach in Mexico and is on the verge of extinction. Very rare. **Native.**



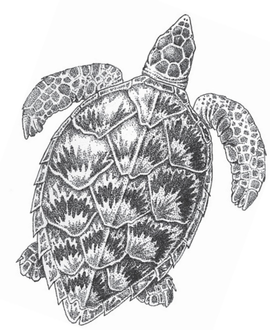
B, O

Green Turtle
Chelonia mydas
The Green Turtle is the commonest of the marine turtles seen in Bermuda and used to breed here. Up to at least 1 m (3 ft) long, they may be any shade of colour between dull, dark green and virtually black. The adults feed on sea-grasses and seaweeds and the occasional sessile invertebrate. Always present in Walsingham Pond and occasionally seen in others. **Native**.



B, O, SG

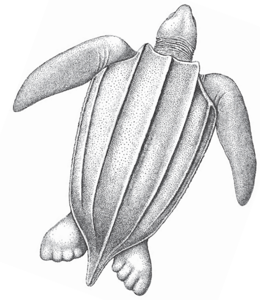
Hawksbill Turtle
Eretmochelys imbricata
This turtle reaches a length of 95 cm (3 ft). The shell on the back has an attractive pattern with streaks of black, brown, amber and olive green. The head is distinctive as the jaws form a hawksbill-like shape which gives the turtle its name. Although it is most commonly seen near to coasts it makes oceanic migrations. Uncommon**. Native.**



B, O

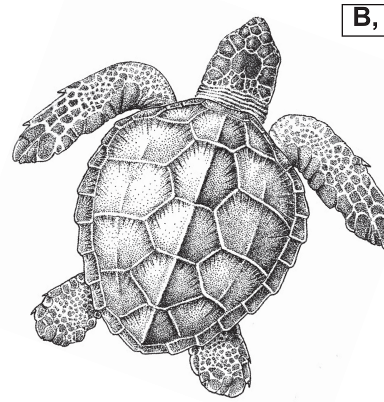
O

Leatherback Turtle
Dermochelys coriacea
This turtle is unusual in that it does not have bony plates forming a shell but rather is covered with a thick leathery skin. On the back there are seven longitudinal keels and the colour is black. A very large turtle reaching 180 cm (5 1/2 ft). Feeds on jellyfish. Uncommon**. Native.**



B, C, O, SG

Loggerhead Turtle
Caretta caretta
Several species of turtle may be occasionally observed crossing Bermuda's reefs, but the Loggerhead is the one that tends to feed there, as they have a broad diet which includes animals and plants growing on the reefs. This turtle can be quite large reaching about 115 cm (4 ft) in length but those seen around Bermuda are usually less than half this size. The colour is reddish brown above and lightish yellow below. **Native.**

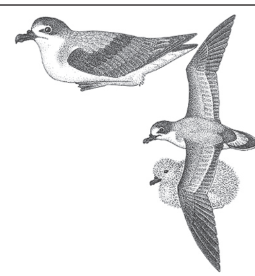


Birds

Petrels and Shearwaters

O, OC

Cahow or **Bermuda Petrel**
Pterodroma cahow
This bird is endemic to Bermuda where it breeds on islands in the southeast. Most of its life is spent at sea where it feeds on near-surface plankton. This bird is rarely, if ever, observed over the ocean. 38 cm (15 in) long. **Endemic**.



O

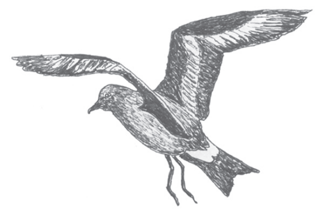
Cory's Shearwater
Calonectris diomedea
This is the largest of the shearwaters seen in the vicinity of Bermuda, reaching a length of 53 cm (21 in). It has a dark grey head top which blends gradually to white on the throat. A wide ranging bird of the open Atlantic Ocean. Occasional. **Native**.

O

Greater Shearwater
Puffinus gravis
Despite its common name this bird is smaller than the Cory's Shearwater described above, reaching 48 cm (19 in). This species has a dark cap on the head which changes abruptly to white below. The white of the lower head extends as a band over the back of the neck. Occasional. **Native.**

O

Leach's Storm Petrel
Oceanodroma leucorhoa
A small bird reaching 20 cm (8 in). A very dark brownish-black in colour except for a white band on top of the tail at the base. Has a very erratic manner of flight. Occurs in both the open Atlantic and Pacific Oceans. Occasional. **Native.**



O

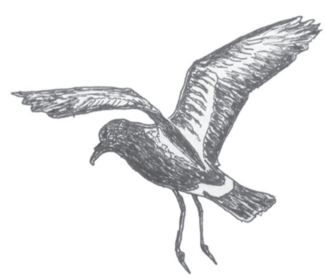
Manx Shearwater
Puffinus puffinus
This is the smallest of the shearwaters seen on the open sea around Bermuda. The length is 33 cm (13 in). A boldly black and white bird, black on the back and top of the head and white beneath except for the wing-tips. Occasional. **Native.**

O

Sooty Shearwater
Puffinus griseus
The common name is quite descriptive as the bird is almost entirely dark coloured everywhere, the only lighter patches being on the underside of the wings. A medium-sized shearwater reaching 43 cm (17 in). Occasional. **Native.**

O

Wilson's Storm Petrel
Oceanites oceanicus
This is a very tiny bird only 18 cm (7 in) in length. It flies like a swallow and often patters its feet on the surface. It is sooty-black in colour except for a white band at the top base of the tail, feet yellow. One of the most abundant birds in the world. Occasional. **Native.**



Tropic Birds

B, CL, O

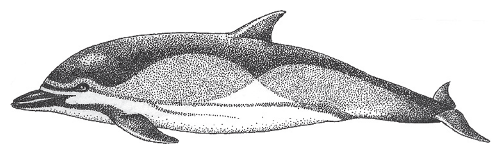
White-tailed Tropic Bird or **Longtail**
Phaethon lepturus
The Longtail or White-tailed Tropic Bird is a summer breeder in Bermuda. It nests in holes in the cliffs and suffers competition from Rock Doves and predation from rats. The distinctive feature of this bird is the extremely long and graceful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

Marine Mammals

Dolphins

O

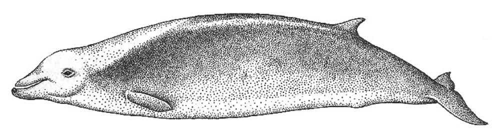
Common Dolphin
Delphinus delphis
This is a small dolphin reaching about 2 m (6 ft) long. The body is almost black on the back, the sides are grey and ochre and the bottom white. The grey and ochre side markings curve so that there is a white triangle below the dorsal fin. Usually seen in small groups well offshore. Occasional. **Native.**



Whales

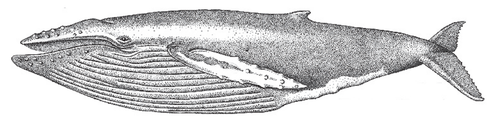
O

Cuvier's Beaked Whale
Ziphius cavirostris
A small whale of about 8 m (25 ft) in length. It has a relatively small head and short flippers and fins. Occasional. **Native.**



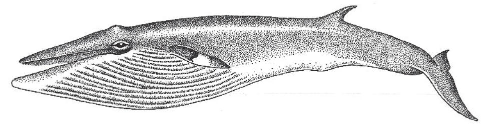
O

Humpback Whale
Megaptera novaeangliae
This filter-feeding whale may reach 19 m (62 ft) long and has a very deep body. The distinguishing features are the long flippers which are very pale in colour. The head and flippers have irregular protuberences. Individuals can be identified by colour markings and protruberances. Regular visitor in northerly migration. **Native.**



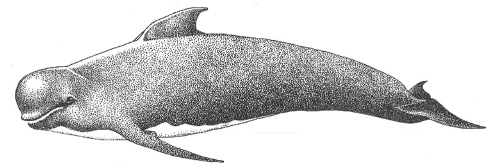
O

Minke Whale
Balaenoptera acutorostrata
The distinguishing feature of this mid-sized whale is the wide, pure-white band across the middle of the flipper. This whale reaches about 11 m (33 ft) long and is a filter feeder utilising krill and other larger zooplankton. This whale will come close to a boat. Occasional. **Native.**



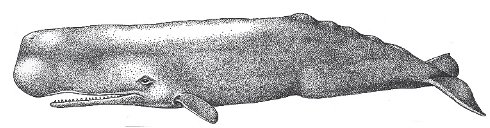
O

Pilot Whale or **Pothead**
Globicephala melaena
A very large dolphin reaching 6.5 m (20 ft) in length. The characterising feature is the very globose head. The flippers are long and pointed. When seen, this species is in herds of 100 or more. Occasional. **Native.**



O

Sperm Whale
Physeter macrocephalus
This is the largest of the whales seen around Bermuda as it may reach 19 m (62 ft). The characteristic feature is the massive head which may be 1/3 the length of the body. The lower jaw is long and toothed and the eye small. The front of the body is almost square. A hunting whale that dives very deeply to secure its prey of large squid. Occasional. **Native.**



Field Trips and Laboratory Exercises

General Field Trip

Introduction
In Project Nature Field Guides we usually give specific locations for several field trips. When looking at the open ocean it does not really matter where you go around Bermuda. Just head a km (1/2 mile) or more beyond the reefs and you are there. It often pays to cruise around for a while as some of the things you would like to see may be quite scattered. For example patches of sargassum may be everywhere or quite sparse. At any rate try to find sargassum and stop among it. In the open sea, one does not normally anchor as it is too deep, just drifting in the chosen locality is best. Note that a drifting boat will show much more motion than when underway and this may bring on seasickness quite quickly. If any students are prone to seasickness, appropriate medication should be taken before the start of the field trip.

At certain times of the year, whales or seabirds may be commoner in specific locations. The group leader can enquire at the aquarium ahead of time to see what and at what locations sightings would be most likely. For example Humpback Whales are usually seen in March or April on their migration north. Shearwaters may be seen off the island from time to time or in migration. However, they will probably not approach the boat and good binoculars are needed to get a good view. Wilson's Storm Petrels may come close to the boat and can sometimes be attracted by throwing food overboard.

The Boat
Field Trips to the open ocean with young students must be very carefully planned and safety must always be at the forefront of preparations. Since a boat must be used it should be chosen carefully. Critical factors are its capacity in terms of passengers, its seaworthiness, its safety features and the experience and knowledge of the captain or operator. Although any good boat will be equipped with ship-to-shore radio, a cell phone should be carried in case a call to shore is needed. With this in mind, vessels run by the Bermuda Biological Station for Research or by the Bermuda Aquarium, Museum and Zoo offer advantages as they are used to this type of work and have knowledgeable employees as a back up. They also have some specialised equipment such as dip nets, plankton nets, depth sounders and secchi discs, which are almost essential to get the most out of a field trip

The weather is also critical and winter is best avoided.

If it is possible it is a good idea to take along an assistant who is familiar with shipboard practices and the equipment and techniques that are to be used. The vessel may supply such a person in some cases. Whoever the assistant is, make sure they go over the field trip in advance.

Clothing
At any season good waterproof and wind-proof clothing is a good idea; foot-wear should be selected that will get a good grip on the wet deck of a boat. A good healthy snack and plenty to drink should be carried.

Preparation
Before the field trip the material presented in "Project Nature, The Open Ocean around Bermuda", should be gone over in detail that suits the age group of the students involved. This material is certainly more suited to more senior students, but all ages can get something out of it.

Equipment
The equipment needs can be divided into two groups: firstly the items the group should take and secondly those items that should be on the boat.

A) Group material:

1) A notebook or clip-board and good, heavy paper and an HB pencil. Pencils are better in damp situations than pens.

2) Several wide-mouthed plastic jars are essential, the bigger the better.

3) A plastic ruler graduated in cm.

4) The largest, long-handled, fine mesh dip net that you have or can borrow. Two if possible.

5) Some plastic bags of various sizes.

6) A pair of tweezers.

7) Binoculars. One pair each is ideal otherwise one pair per every two students.

8) An unbreakable water thermometer.

9) A metre stick.

10) Several plastic pails

11) Some waterproof card for labels. (Some card is laminated and will come apart, try a sample in water before the trip). (Labels are always placed inside bottles or bags)

12) At least one copy of the "Project Nature Guide to The Open Ocean around Bermuda".

13) If you have, or can borrow a refractometer type of salinometer, take it along.

B) Boat material

1) A Secchi disc. (This can be either white or in black and white quadrants). If it is not weighted, a good heavy weight such as a SCUBA divers belt weight is needed to help it drop straight and quickly. The line tied to the disc should be marked in m and be 50 m or more in length. Alternatively a 50 m surveying tape can be used.

2) A phytoplankton net, preferably 1 m in diameter at the mouth, but 50 cm would do. Phytoplankton nets are of very fine mesh, somewhere around 60-100 μ mesh opening. The end of the net should be a plastic bottle which can be unscrewed and poured into a plastic bottle.

3) A zooplankton net, 50-100 cm at the mouth. These nets are coarser than the phytoplankton nets and designed to let the phytoplankton through while retaining the zooplankton. A 0.5 mm mesh size is satisfactory. If such a net is unavailable some zooplankton can be collected in a finer net.

4) A depth sounder to determine the depth at the sampling location(s).

5) A gaff-hook to retrieve floating objects.

6) Long-handled fine-mesh dip nets if not brought by the group.

Procedure

A) Departure and along the way

1) Check with the captain and board the vessel when he is ready for you.

2) Get the captain to go over safety and behaviour rules and point out all the safety equipment.

3) Sail to a chosen sampling location. This may take an hour or more, depending on starting location and chosen sampling site.

4) Some time en-route can be taken to go over what will be done, and who will do it at the sampling location.

5) On the way look out for a) birds, b) whales or dolphins, c) sargassum rafts, d) floating garbage or oil, e) Portuguese Men-of-War, By-the-Sea Sailors or other neuston, f) anything else of interest. Students should make notes of all that they see.

6) Watch for changes in the weather or sea state. Get the wind direction and speed from the captain.

7) The group leader should brief the captain on the objectives of the trip, preferred sampling location, equipment to be used etc. However, remember that the captain has the right to use another location if it is safer or to abort the trip in the case of bad weather or medical problems.

B) On site (station)

1) Make sure everyone knows what is being done and who is doing it.

2) Estimate wave height and direction and wavelength. These parameters can be difficult to measure. Wave height can be done with a metre stick if you are careful and thoughtful. Remember that the boat is going up and down too! Get the captain to give you the boat length and use it for wavelength (crest to crest). Make sure you do not mix imperial and metric measures. Things to think about here

are; i) Is there just one set of waves coming from one direction? ii) If so are the waves coming down wind (wind driven). iii) If the wave situation is complex try to sort out at least two kinds. One should be wind-driven and smaller, the other swell and larger. If there is swell, where does it seem to be coming from? Think about the possible origin of the swell. Note your findings and ideas.

3) Take the water temperature in a bucket filled from the sea. Compare it to air temperature taken in the shade. Try to explain the difference. Think about the heat capacity of water and the season!

4) Keep a look out for oceanic birds and whales.

5) Scoop up a dip net full of sargassum and tip it into a bucket of fresh sea water. See what you can observe of the seaweed itself, things attached to it and things living among it.

6) Scoop up another batch of weed and holding it in your hands, shake it vigorously over a second bucket. This should dislodge some of the inhabitants, some of which can be quite surprising! These things were probably in the other lot of weed too, but probably were not seen. Why is this so? Think about camouflage and behaviour. Check the bottom of the net.

7) Repeat steps 5 and 6 to make sure you have a good sample.

8) Identify all that you can. Students might like to sketch some of the organisms that you found.

9) Drop the Secchi disc and note the depth at which it can no longer be seen. What living or non-living things in the water column will limit the depth at which the disc can be seen.

10) Note the water depth from the depth sounder. The captain will be able to show you how it works and how to read the depth.

11) Note your position with relation to Bermuda. The captain can help with this too.

12) If you are going to have a laboratory to follow the field trip take a good large bottle of clean seawater and cap it.

13) If you are going to have a laboratory to follow the field trip, put covers on the buckets if you have them. If the buckets have no covers get rid of half the water by straining it out through a dip net.

14) If you have a salinometer, check the salinity of the water, demonstrate the instrument and note the result. (Note: The best source for salinometers at a reasonable price are aquaculture supply companies)

C) In the general location of the sampling location.

1) Get the captain to go as slowly as possible and get him or some knowledgeable person to use the phytoplankton net. It will be streamed 20m or so astern while tied to the vessel. It is imperative that the vessel go very slowly and this will probably entail putting the vessel in and out of gear to keep the speed down. 5 minutes is a good tow time. At the end of the sampling period haul back the net and wash the material stuck to the mesh down into the bottle. A seawater hose at low pressure, directed onto the outside of the net will help in this. Transfer the catch into a plastic jar. Label it, cap it and pass it round for inspection.

2) Repeat the procedure outlined above with the zooplankton net. This net can be towed considerably faster as the water passes through it more easily. Remember at this point that a sample taken at night would be richer. It would also be better to drag the net at a greater depth than the phytoplankton one. Weights or a special hydroplane, called a depressor, can be used to accomplish this.

3) If the samples are to be taken back for laboratory examination, put the bottles in a cool shady place, or the 'fridge, if there is one. On return to school or laboratory, either examine the catch immediately or refrigerate it overnight and look at it as soon as possible on the next day. If you are just going to look at the catch on the boat, do so carefully, noting what you can see, and then return it to the sea. Note that phytoplankton is mostly invisible to the naked eye and will show up as cloudiness in the bottle.

4) Cruise around for half an hour or so keeping a good lookout. Note sightings of any organisms or pollution.

5) Head home.

D) When fairly close to shore.

1) Have the boat stop.

2) Repeat the Secchi disc observation.

3) Repeat wave height and length readings.

4) Try to explain differences in results.

Laboratory Work

Plankton

A) Equipment

1) Eye droppers.

2) Microscope slides.

3) Cover glasses.

4) Mounted needles.

5) Petri dishes.

6) Compound microscopes.

7) Stereo microscopes.

8) As many copies of “Project Nature, The Open Ocean around Bermuda” as possible.

B) Procedure

1) Put out the samples.

2) Students can get samples of either zooplankton or phytoplankton with the eye droppers.

3) For <u>phytoplankton</u> put a few drops of water on a slide and apply a cover glass, examine under a compound microscope. Adjusting the lighting will help to make the organisms visible. Identify from the illustrations in “Project Nature, The Open Ocean around Bermuda”. List those identified and draw several.

4) For <u>zooplankton</u> put a dropper-full in a petri dish of clean seawater. Examine under a stereo-microscope. Remember the animals are clear or nearly so. Careful observation is needed. Additionally they may still be alive and swimming. Identify from the illustrations in “Project Nature, The Open Ocean around Bermuda”. List those identified and draw several.

Sargassum Organisms

A) Equipment

1) Forceps.

2) Eye droppers.

3) Petri dishes.

4) Stereo microscopes.

5) As many copies of “Project Nature, The Open Ocean around Bermuda” as possible.

B) Procedure

1) Using the eye or a stereo-microscope as appropriate identify as many swimming or free-living organisms as possible. For the microscope use an eye dropper to get a sample. Some organisms may be quite small so suck up a sample from the bottom of the bucket. Identify from the illustrations in “Project Nature, The Open Ocean around Bermuda”. List those identified and draw several.

2) Break off a piece of sargassum and examine it using the stereo microscope. Look for attached organisms as well as those that crawl about clinging to the plant.

3) Look carefully at all the sargassum. Can you find both species? Sketch a piece of each pointing out the distinguishing characteristic.

Glossary

Abyssal plain	The very flat part of the ocean bed lying from the foot of the continental slope to the edge of the trenches. Mostly about 5000 m (16000 ft) deep.
Acantharians	These unique members of the zooplankton have a skeleton of strontium sulphate which consists of 20 regularly arranged spines.
Aeolianite	Limestone rock form by the natural cementation of grains of wind-blown calcareous sand.
Anoxia	A lack of oxygen.
Anoxic	A lack of oxygen in a system.
Arrow Worms	Members of the phylum Chaetognatha**.** Colourless, fish-like, invertebrate, predatory, zooplankton.
Atmosphere	The mantle of gasses surrounding a planet. The atmosphere of the Earth is principally nitrogen with water vapour, carbon dioxide and oxygen.
Basalt	Hard, dark volcanic rock, originating from the magma.
Bathythermograph	An oceanographic instrument which is lowered from a ship into the ocean where it graphs temperature against depth.
Benthos	All the **biota** living on or in the bottom of bodies of water.
Berm	A ridge of sand on land. Commonly found at the high tide level on sandy beaches.
Bioluminescent	An organism which can produce light.
Biodiversity	The number of different species of **biota** in a natural system such as an ecosystem or community.
Biosphere	The part of the planet that supports living organisms**.** It extends from deep trenches to a few hundred metres into the air.
Biota	This word is used when all types of organism in a biological system are being included.
Bloom	A dramatic increase in the quantity of plankton.
Blue-green algae	More properly called blue-green cyanobacteria. Pigmented bacteria that can photosynthesise. Common among tropical phytoplankton.

Bony fish	Fish that have a skeleton made of bone.
Bryozoa	A phylum of colonial, invertebrate animals. The individuals of the colony are small and the colony may be bushy or sheet-like.
Canary Current	A surface (wind driven) ocean current which passes south along the North African coast.
Carnivores	Animals that eat either herbivores or other carnivores but not plant material.
Cartilaginous fish	Fish that have a skeleton made of gristly cartilage.
Centrate	A term applied to diatoms that are shaped like a short cylinder.
Chaetognaths	Members of the phylum Chaetognatha**.** Colourless, fish-like, invertebrate, predatory zooplankton.
Ciliates	Protozoa found in all moist environments on Earth. The single cell is covered with a layer of small cilia which beat to cause movement.
Cnidarians	The cnidarians always have a body shaped like a **polyp** or a **medusa** and they always have specialised stinging cells called nematocysts.
Coccolithophore oozes	Very fine oceanic sediments consisting mainly of the tests of coccolithophores.
Coccolithophores	Members of the phytoplankton that have the cell armoured with tiny calcareous plates.
Coelenterates	The animal phylum that includes the jellyfish, corals, hydroids, siphonophores and sea anemones. Coelenterates typically have tentacles for feeding and a simple tube-like body.
Comb Jellies	Members of the phylum Ctenophora. Often called sea-gooseberries. They have a gelatinous body on which cilia are arranged in rows for locomotion.
Compensation depth	The depth in water at which, on the average, the energy fixed in photosynthesis balances that used in respiration.
Consumers	All organisms that get their energy by consuming other organisms or their dead remains.
Continental slope	The slope in the sea bed from the outer edge of the continental shelf into the abyss.
Continental shelf	The relatively shallow, coastal, sea bed extending to about 300 m in depth.

Copepods	The most abundant and important crustacean zooplankton. Most are herbivourous and resemble a small grain of rice with numerous legs.
Crustacea	Members of the phylum Arthropoda, containing crabs, lobsters, shrimps, copepods, barnacles etc.
Ctenophores	Members of the phylum Ctenophora. Often called sea-gooseberries. They have a gelatinous body on which cilia are arranged in rows for locomotion.
Currents	Directional movements of water. Examples are surface currents and deep currents.
Cyanobacteria	Pigmented bacteria that can photosynthesise. Common among tropical phytoplankton.
Demersal	Living in association with the bottom.
Density	Weight per unit volume.
Density Currents	Water currents that arise due to differences in density of water masses. Typically, water-cooled at the surface (with a rise in density) sinks to deeper levels and then proceeds horizontally.
Diatomaceous ooze	Fine oceanic ooze principally consisting of the siliceous tests of planktonic diatoms.
Diatoms	Single-celled plants with a silica frustule. The dominant plant group in the phytoplankton.
Dinoflagellates	Single-celled organisms many of which are phytoplankton. Most have two flagellae, one trailing and one in a groove around the cell.
Diurnal vertical migration	A daily migration pattern common in zooplankton in which individuals swim up to the surface at dusk and return to deeper water at dawn.
Doldrums	A part of the Atlantic Ocean centred on the equator which is usually virtually windless.
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.
Endemic species	Species that have evolved to be a new species in a specific area. They may subsequently spread to other areas.
Energy flow	The flow of energy along a food chain, starting with the primary producers and ending with the top carnivore.

Epibiota	All the organisms, both animal and plant, living on the surface of the sea bed.
Estuaries	Where rivers meet the sea. Estuaries show intermediate characteristics between marine and fresh water conditions.
Euphausid Shrimps	Often called Krill. Planktonic shrimps that are comparatively large for zooplankton. A very important food source for many marine animals including great whales.
Flagella	Tiny whip-like hairs used in locomotion by single-celled organisms.
Flatworm	Members of the phylum Platyhelminthes. There are both free-living and parasitic examples.
Food chains	The feeding relationships between trophic groups in an ecological unit such as an ecosystem or community, arranged to begin with the primary producers and proceeding through herbivores to carnivores.
Foraminifera	Single-celled protozoa in the amoeba group having a chambered calcareous exoskeleton. Common in the plankton.
Foraminiferan ooze	A fine deep sea ooze made up of the calcareous skeletons of foraminifera.
Frustule	The box-like silica exoskeleton of diatoms.
Gulf Stream	The very large ocean current originating in the Gulf of Mexico, passing through the Straits of Florida and proceeding northeast up the eastern seaboard of North America.
Gyre	A surface current travelling in a roughly circular path.
Herbivores	Animals that eat primary producers (plants).
Holoplankton	Plankton
Hot spot islands	Islands that originate when a volcano forms from liquid magma that erupts through a small area of the sea bed.
Hydroids	Members of the phylum coelenterata. Most hydroids are colonial and consist of numerous, small, anemone-like polyps connected together by a branching stalk. Most have a distinctive exoskeleton of tubes and cups.
Hydrometer	An instrument to measure the specific gravity of liquids.
Infauna	Organisms living buried in sediment at the bottom of water bodies.

Infra-red solar radiation	Energy received from the sun in the form of heat.
Insecticide	A substance used to kill insects. Some synthetic insecticides are quite persistent in the environment.
Interstitial fauna	Small animals living in the spaces between grains of sediment.
Invertebrates	Animals without backbones.
Island arcs	Groups of islands formed along the collision zones of tectonic plates.
Krill	Planktonic shrimps that are comparatively large for zooplankton. A very important food source for many marine animals including great whales.
Magma	Molten rock under the Earth's crust, circulating in vast convection cells.
Medusas	The planktonic members of the phylum coelenterata. They may be either holoplanktonic or meroplanktonic. Typically of jellyfish-like form they range in size from very tiny to very large.
Mollusca	The phylum of invertebrate animals containing the snails, clams, squids, slugs and octopuses.
Neap Tides	Tides of smaller range occurring every two weeks.
Nekton	The strongly swimming animals living in water.
Neuston	Pelagic animals associated with the water surface.
North Equatorial Current	The wind-driven current flowing from east to west north of the equator driven by the northeast trade winds.
Ocean ridges	Spreading zones in the ocean floor where tectonic plates move apart. Characterised by frequent earthquakes and occasional volcanoes.
Oceanic	In the ocean.
Oceanic Island	An island in the ocean, well away from a continent.
Oceanography	The study of the oceans.
Overturn	A term used to describe the event in which surface and deeper waters mix in a water body.
Paralytic shellfish poisoning	Poisoning resulting from the consumption of shellfish which have eaten toxic phytoplankton.

Pennate	A group of diatoms in which the silica frustule is elongated.
Permanent thermocline	A thermocline is horizontal layer in the ocean where temperature, and hence density, changes relatively rapidly with depth. A permanent thermocline is one that is always present, regardless of season, forming a barrier to the mixture of surface and deeper waters.
Photic zone	The lighted upper zone of the sea. Its depth depends on water clarity and the amount of plankton. Off Bermuda it can be very deep.
Photometer	An instrument to measure light intensity.
Photophores	Light producing organs
Photosynthesis	The synthesis of organic compounds from inorganic substances using the energy of sunlight, carried out by pigmented plants.
Phytoplankton	Plant plankton.
Plankton	The usually very small animals and plants of the open ocean that have no or very limited swimming abilities.
Planktonic	Belonging to the plankton.
Plate tectonics	The study of the structure and movement of crustal plates.
Polychaetes	Marine members of the phylum annellida. Worms with many bristles.
Polyps	The bodies of coelenterate animals characterised by a circle of tentacles.
Pre-historic	Before history recorded by man.
Primary producers	Plants that obtain their energy supplies through the process of photosynthesis.
Pseudopodia	Elongate streamers of protoplasm produced by members of the amoeba group of protozoa.
Radiolarian ooze	A fine deep-sea ooze principally composed of the silica remains of radiolarians.
Radiolarians	Marine protozoan zooplankton with a skeleton consisting mainly of silica rods.

Red tide	A water mass coloured red by the presence of numerous red-coloured dinoflagelates. These organisms are often toxic and may lead to paralytic shellfish poisoning.
Ridge islands	Islands that originate along mid-ocean ridges, for example Bermuda.
Rift	The gully-like centre of an ocean ridge.
Salinity	The quantity of salts per unit volume of water.
Salinometers	Instruments used to measure salinity.
Salps	Advanced invertebrate zooplankton from the phylum urochordata. Many are barrel-shaped.
Sand ridges	Wave like formations on the surface of sandy areas in either land or aquatic situations.
Sand waves	Underwater features in sandy sediments where the surface of the sand forms wave- like ridges.
Sargassum weed patch	A patch of the floating brown seaweed sargassum or sargasso weed.
Saturation point	The point at which a liquid can absorb no more of a dissolved substance.
Scientific names	Names composed of a mixture of Greek and Latin used to describe organisms. There are two names; the first is the genus and the second the species.
SCUBA	Self-contained underwater breathing apparatus.
Sea anemones	Animals in the phylum coelenterata, living attached to the bottom and lacking skeletal structures. They have a soft, cylindrical body and a ring of tentacles.
Sea-spiders	Marine animals in the class pycnogonida. They are spider-like but usually with 10 legs.
Seamount	A mountain in the ocean resulting from an undersea volcano. Some come above the surface.
Secchi disc	A flat white disc with two black quadrants which is lowered into the water to give an estimate of light penetration and water clarity.
Sediment permeability	This refers to the amount of open space within a sediment it can also be measured by the rate at which water can move through a sediment.

Sediment consolidation	A process taking place in fine sediments such as mud, which, in time, results in a lower trapped water content, higher density and increased physical stability.
Sediment sorting	The sorting out of different particle size sediments from a mixture in a situation of decreasing current velocity.
Sedimentation	The process in which sediment suspended in the water is deposited on the bottom.
Siliceous	Made of silica or glass.
Siphonophores	Colonial animals in the phylum coelenterata that form complex colonies in which the individuals perform different functions, such as swimming, feeding or defence.
Solar system	The sun and the planets around it.
Species diversity	The number of different species in an area.
Specific gravity	Weight per unit volume.
Specific heat capacity	The amount of heat required to raise 1 gram of water 1ºC.
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.
Stratified	Horizontally layered.
Subduction zones	Zones where tectonic plates collide and one plate descends under the other.
Swell	Ocean waves that have originated from wind action at a distant location.
Swim bladder	A gas filled bladder found in shallow-water bony fishes that gives them neutral buoyancy.
Test	A skeletal structure found in several types of protozoa. It may be of calcium carbonate or silica in structure.
Thermocline	The vertical location in a water body where the temperature changes rapidly.
Tidal range	The vertical height between high tide level and low tide level.
Top carnivores	The top of a food chain. A top carnivore has no predators.

Trade Winds	Winds that blow virtually constantly in areas just to the north and south of the equator. In the North Atlantic Ocean these are the NE Trade Winds.
Trenches	Elongated troughs in the sea bed that form the deepest places in the oceans.
Trophic level	A feeding level in a food chain. For example primary producers and carnivores.
Water masses	Large bodies of water with fairly uniform characteristics.
Wave height	The vertical height between wave crests and troughs.
Wave cut notch	A horizontal shoreline notch in rock resulting from wave action.
Wavelength	The horizontal distance between wave crests.
Weathering	Erosion resulting from the action of weather.
Westerly intensification	A phenomenon seen in surface currents where they are more intense against eastern shores. This is a result of the rotation of the Earth.
Wind-driven Currents	Surface currents that arise from the action of wind.
Zooplankton	Animal plankton.
Zoooxanthellae	Members of the phytoplankton which live inside animals in a symbiotic relationship. They are found in many corals and several zooplankton species.

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