CHAPTER 12

THE ECOLOGY AND RESOURCES OF THE OPEN OCEAN

12. 1. THE OCEAN: A NATURAL RESOURCE RESERVOIR

12. 1. 1. Introduction

The oceans of the world have always been important to humankind. Until recently, the oceans have been a significant barrier to most living organisms on different land masses. They have separated cultures in different parts of the world.

On the other hand, the ocean also provides a linkage between distant peoples and lands, since it provides a ready medium for transportation across the surface of the globe.

The oceans have also long been a source of food, at least for people inhabiting coastal areas. In fact, some scientists argue that early human societies probably developed in coastal areas, where many kinds of food could be easily collected from the shallow nearshore waters.

Historically, human uses of the ocean were largely limited to both transportation and food. Consider the huge size and volume of the ocean. Consider also the relatively small human populations of the past.

We can conclude that, in the past, people were only able to exploit a small part of our world's marine resources. This portion, which has always been used by humans, is limited to the shallow coastal regions or continental shelves along ocean margins.

For many centuries, most areas of the ocean remained a mystery, unknown and unexplored. In the last century, however, and especially in the last three decades of the 20th Century, there has been an explosion of scientific research.

This research is aimed at learning more about of our world's oceans. As a result, new discoveries are being made every day. Indeed, as far as the ocean is concerned, we truly live in an "age of discovery". Probably the discoveries that affect our lifestyles the most are those that result in increased knowledge about marine natural resources. A natural resource is any aspect of nature that people can use.

Humans have used the ocean for transportation for millenia.

The ocean is an important resource for food.

Fishes are a renewable ocean resource.

Of course, some resources of the ocean are well-known, and have long been used by humans. On the other hand, oceanographers are exploring the seas with better equipment and technology and are thereby uncovering new resources.

As more and more mysteries of the sea are explored, and as our understanding increases, one thing becomes clear. Our vast oceans are in many ways a reservoir of food, mineral and energy resources that offer a potential bounty for the people of the world, if managed wisely.

Food is probably the first resource that comes to mind when people think about the ocean. This is because the ocean has long been exploited for food. Oceanic food resources are **living resources**, since they include both living marine plants and animals.

Food resources are **renewable resources**, since they can generally grow back, or renew themselves. Renewable food resources of the ocean are represented by many different groups of organisms.

The most common of these are the fishes. Another common food resource are the crustaceans (shrimp and crabs). Additionally, various plants (seaweeds) of the oceans represent yet another kind of renewable resource.

Mineral resources in the ocean are both numerous and abundant. Yet, very few have been used by people. In fact, the only oceanic mineral resource with a long history of exploitation by humans is salt, which is extracted from sea water. Other mineral resources that have been more recently exploited include oil and natural gas.

Another major kind of oceanic resource is energy. The ocean is a great reservoir of energy, and this energy is present in many different forms.

For example, ocean tides, waves, and currents all contain large amounts of energy that might one day be harnessed to provide an inexhaustible supply of nonpolluting power for the earth.

While it is known that great stores of energy exist in the ocean, the main problem at this time is how to convert them into more usable forms.

Several promising methods are either in use on a small scale, or are being experimentally put to use. Until a method is devised to tap oceanic energy on a large scale, exploitation of these resources belongs to the future.

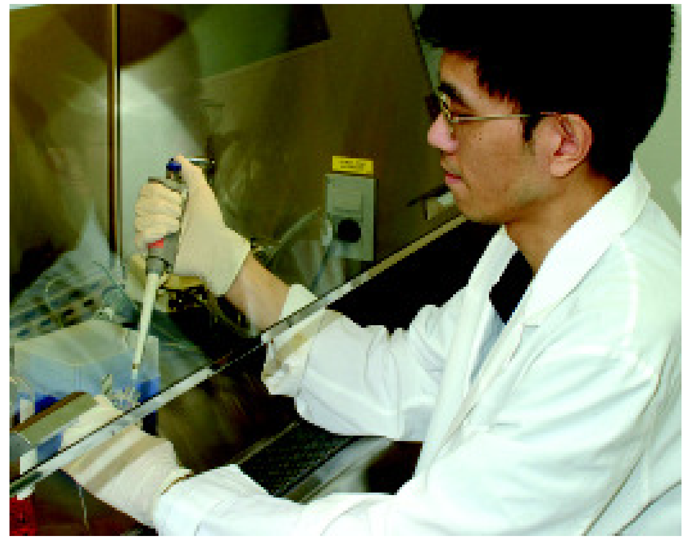
12. 1. 2. Mineral Resources

Minerals from Seawater

Salt water of the oceans contains a large amount of minerals in the form of dissolved compounds. These minerals amount to about 35 parts per thousand in sea water. This means that each cubic mile of ocean water (7 billion tons of water) contains about 24.5 million tons of minerals. These include not only common salts, but also valuable metals, such as gold, silver, uranium, copper, and zinc.

The only minerals commonly extracted from sea water, however, are salt, magnesium, and bromine. The production of salt from sea water dates back many thousands of years. Today, about 29% of the world's salt comes from the ocean. The rest is mined from inland salt deposits.

Magnesium and bromine are more recent sea water products. The ocean yields some 61% of the lightweight magnesium used by people and 70% of all the bromine; bromine is used as an additive for gasoline and in medicine.



Bromine, extracted from sea water, is used as a gasoline additive and in medicine.

The other valuable minerals in ocean water seem appealing. For example, it is estimated that the oceans contain about 5 million tons of gold. This gold, however, is in such a diluted form that the cost of extracting it from the water would be more than the gold is worth.

For example, to process just 1 cubic mile of sea water for gold would require a processing plant that could handle 2.1 million gallons of water per minute, for an entire year. The energy to run such a plant would cost much more than the value of the gold.

One other resource of sea water, though not a mineral, should also be mentioned. This resource is fresh water. In some parts of the world, especially dry regions, the ocean offers a valuable, and sometimes the only, source of fresh water for drinking, agriculture, and industrial uses.

Plain ocean water, of course, cannot be used for these purposes. First, it must be processed to remove salts. This is costly in terms of energy, but for some areas with few other alternatives, it is well worth the cost.

For example, numerous **desalination** plants today produce fresh water for several Middle Eastern countries along the Red Sea, the Arabian Sea and the Persian Gulf. Desalination is also useful on some islands, where sea water is abundant but fresh water is not.

Desalination plants, such as Jubail in Saudi Arabia, produce fresh water for several Middle Eastern countries along the Red Sea, the Arabian Sea and the Persian Gulf.

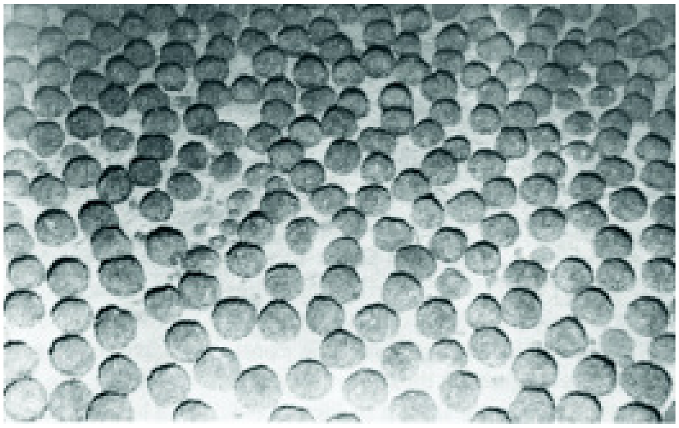
For example, on the island of Ebeye, in the Marshall Islands, a large desalination plant has been installed to provide fresh water for the many residents.

Minerals from the Ocean Floor

Minerals from the ocean bottom include those on the continental shelves and those on the deep ocean floor. On the continental shelves and other coastal areas, the most commonly mined resources are sand, gravel and shells. These are used primarily for construction materials.

The demand for these resources has grown in recent years as more roads are paved, more buildings are constructed and landfill sites get developed. The most common method of mining involves dredging the material directly from the bottom of the ocean along shallow nearshore areas.

At some locations of the continental shelves, valuable deposits of heavy metals, such as gold, tin and chromium are found. These deposits are often associated with ancient river channels that were cut across the continental shelves during periods of lower sea level. Commercially valuable deposits of phosphorite, used in making fertilizer, are also found on continental shelves.



Manganese nodules, composed of iron and manganese, are found on the ocean floor.

One of the more surprising oceanic discoveries of recent decades is the existence of large mineral deposits on the deep mid-ocean floor. The most valuable mid-ocean minerals are found in small, stonelike accretions known as **manganese nodules**.

These nodules build up as layer upon layer of mineral particles form coatings around a small central nucleus (perhaps a small volcanic rock). The nodules form very slowly and are therefore best developed in mid-ocean areas far from suffocating sediment.

Manganese nodules are rich in a number of valuable minerals, primarily copper, nickel, and cobalt, as well as manganese and iron.

While manganese nodules are potentially valuable, they are not currently being mined on a commercial scale. The main reason is because the technology for such deep water mining has not yet been perfected.

Several experimental mining methods are now being tested, and the future will undoubtedly see large scale mid-ocean mining projects get underway.

12. 1. 3. Energy Resources

Energy Beneath the Ocean Floor
The most exploited mineral resources from beneath the ocean floor are oil and natural gas. Oil and natural gas have been drilled from far beneath continental shelves for several decades. Today they are the most valuable resources being taken from the ocean.

Oil and natural gas are removed through wells drilled from offshore platforms. Many wells can be drilled from a single platform. The well shafts are slanted, so that just one platform can extract oil and gas from a large area.

Drilling platforms are used to exploit the ocean's resources.

Some of the major locations of offshore oil and gas fields include the continental shelf areas of Alaska, Mexico, the North Sea, and the Arabian Gulf. Offshore oil and gas production requires very careful management and many safety precautions. This is because of potential accidents and oil spills that might pollute the ocean.

Other Energy Sources: e.g. Ocean Tides
Besides oil and gas, the ocean contains immense amounts of energy in many other forms. This energy is potentially the most valuable resource the ocean may have to offer. This is because ocean energy is renewable, largely non-polluting and almost inexhaustible.

One type of energy which the ocean possesses is found in tides, the daily movement of the oceans caused by the gravitational attraction of the moon and the sun. Several sites, in France and Russia, for example, are today producing small but locally significant amounts of electricity from tidal power.

However, in order to produce electricity from tides, it is necessary to have a large tidal range. This is the difference in sea level between high and low tide.

In fact, with current technology, a minimum tidal range of 15 feet is required. This severely limits the use of tidal energy since most areas, including our own, have tidal ranges of only 5 feet or less.

A few places, however, have a much higher range. The largest range is 45 feet, in the Bay of Fundy, Canada.

The largest tidal range is 45 feet, in the Bay of Fundy, Canada.

Tapping the Ocean's Thermal Energy Resources
Other potential energy resources of the oceans are found in the vast **solar energy** that is absorbed by the oceans. When solar energy enters ocean waters, it is largely converted into heat.

The ocean is thus a huge reservoir of **thermal energy**. This pool of thermal energy has a strong effect on world climates, actually warming up large areas of the earth. This is why in high latitudes, land areas adjacent to oceans always have milder, warmer climates than areas farther inland.

Besides moderating climates, ocean thermal energy has other potential uses. One of the most promising is a proven method of producing electricity from the temperature differences in the ocean.

Most solar energy is absorbed in only the top layers of the ocean. Thus, while surface waters may be quite warm, deeper waters remain much colder. This is especially true in tropical regions of the earth. It is possible to produce electricity through this heat difference.

Under controlled conditions, warm surface waters and cold deep waters can be piped and used to control certain chemical compounds causing these to evaporate and to condense when exposed to these two contrasting water temperatures. This process can drive a turbine that will produce electricity.

In this way, two experimental projects known as OTEC (Ocean Thermal Energy Conversion) have produced electrical power from the waters off Hawaii for many years now. Locally, Lau Lau Bay, on the east coast of Saipan, has been noted as a possible site for future OTEC energy production.

OTEC offers a clean, renewable source of energy.

Wave Energy
Another type of energy resource is found in ocean waves. These contain a tremendous amount of energy. For example, it is estimated that 10 kilowatts of power are released in just a 1 meter length of a 1.8 meter (5 foot) high wave.

Thus, the amount of energy released daily along a single area of coast is enormous. Small amounts of wave energy are now used to power warning devices on navigational buoys. But the real challenge is how to tap wave energy on a larger scale.

12. 2. OPEN OCEAN ECOLOGY

12. 2. 1. Physical Properties of Sea Water

Seawater has many unique physical properties.

Introduction

To discuss the ecology of the ocean, it is necessary to review some physical properties of seawater. Seawater requires a large amount of heat energy to change phase, or to change temperature. In other words, seawater has high **heat of vaporization,** high **heat of freezing** and high **specific heat**.

These properties mean that organisms living in the ocean are in an environment where temperatures do not change as much as temperatures often do in land environments.

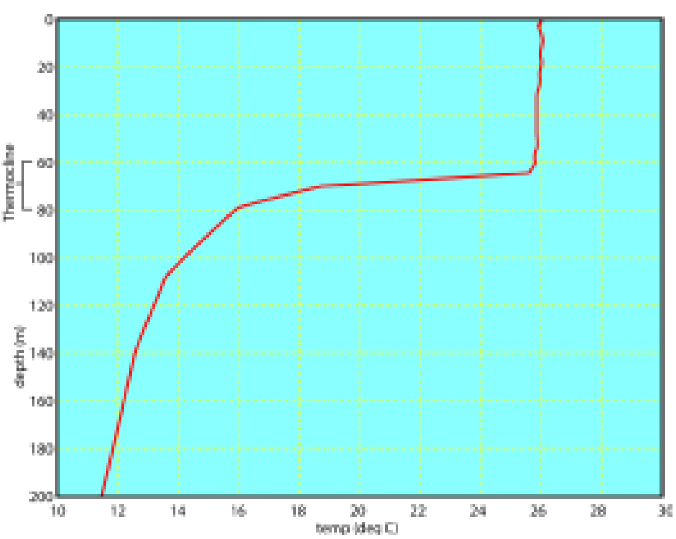
Seawater also has high **density**, which means that it sinks below fresh water and gives an uplifting force, or **buoyancy**, to organisms that float or swim in the oceans. Due to attractions between water molecules, seawater also has a “skin” at the surface due to **surface tension** that helps small organisms to stay at the surface.

Viscosity

Organisms attempting to swim in water, however, find it much more difficult to move through water than through air. This is because water, including seawater has a high **viscosity**.

Viscosity can be thought of as how easily an object can move through the liquid or gas. It is obviously much more difficult to move an object through seawater than through air. Thus, seawater has a higher viscosity than air.

Other physical properties of seawater are important to organisms in the oceans.



A region of rapid temperature change, or thermocline, exists and separates warm surface waters from the colder, deeper waters.

Temperature Layers

The density of sea water depends on both its salinity and its temperature. Cold, salty water has a higher density than water that is warmer, or has a lower salinity.

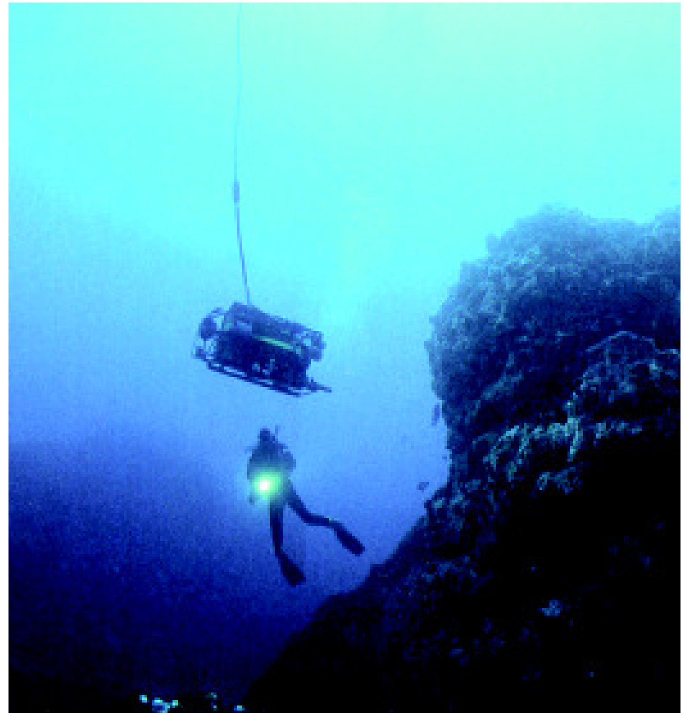
The sinking of cold, salty water makes layers of seawater in the oceans; these layers do not always mix easily. The production of different layers of ocean waters is called **stratification**.

Stratification of ocean waters can be important for determining where different organisms can live in the oceans and where nutrients are found. One special characteristic of the tropical oceans, including those near Micronesia, is a permanent stratification throughout the year.

A region of rapid temperature change, or **thermocline**, exists and separates warm surface waters from the colder, deeper waters of the oceans. This thermocline continues year round. It prevents surface waters from mixing with the deep layers.

Increased Pressure with Depth

Many people enjoy snorkeling and SCUBA diving in the Pacific islands. These divers know how pressure changes can affect ears and lungs. The high density of seawater produces very rapid pressure changes; every 10-meter (33 feet) increase of ocean depth results in a pressure increase of 1 atmosphere. Organisms that live deep in the oceans must be adapted to high surrounding water pressure. Whales and other deep divers must also adapt to rapid pressure changes.



Light cannot easily penetrate into the oceans.

Dissolved Oxygen
Even the amount of oxygen available to organisms depends upon physical properties of seawater. Water that is cold or has low salinity will dissolve more oxygen than water that is warm or has high salinity. Fish and other organisms in warm, salty lagoons at low tide must have special adaptations to survive in water with little oxygen.

Osmotic Balance
The salinity of seawater is also important for organisms when their body fluids are of different salinity than the surrounding water. **Osmosis**, or the movement of water molecules across a cell membrane, can bring too much water into organisms or remove too much water from them.

Many organisms that live in the oceans have special glands to remove salt or have other adaptations to prevent problems due to osmosis.

Light and Sound in the Sea
Light and sound are affected by seawater. Light cannot easily penetrate into the oceans, and the wavelengths that make up sunlight penetrate to different depths in the ocean. Red and orange wavelengths (colors) will only penetrate a short distance into the sea, while green and blue can penetrate more deeply.

Some organisms that perform photosynthesis will only be found at certain depths. This is because the wavelength they require cannot penetrate more deeply.

While light does not penetrate well into seawater, sound does travel very well in the ocean, about 4.5 times faster in water than in air. Some marine organisms, especially whales and dolphins, use sound for communication, navigation and finding food.

Special ocean regions where sound travels easily over long distances, called Sound Fixing And Ranging (SOFAR) channels, are used by naval forces for communication. They may be used by whales as well.

12. 2. 2. Ocean Environments

Because there are many different environments in the ocean, scientists have developed a system for classifying and describing "zones" that have special features (see figure 12.1). This system allows people to compare the different zones and to examine the physical and biological features that are special in each one.

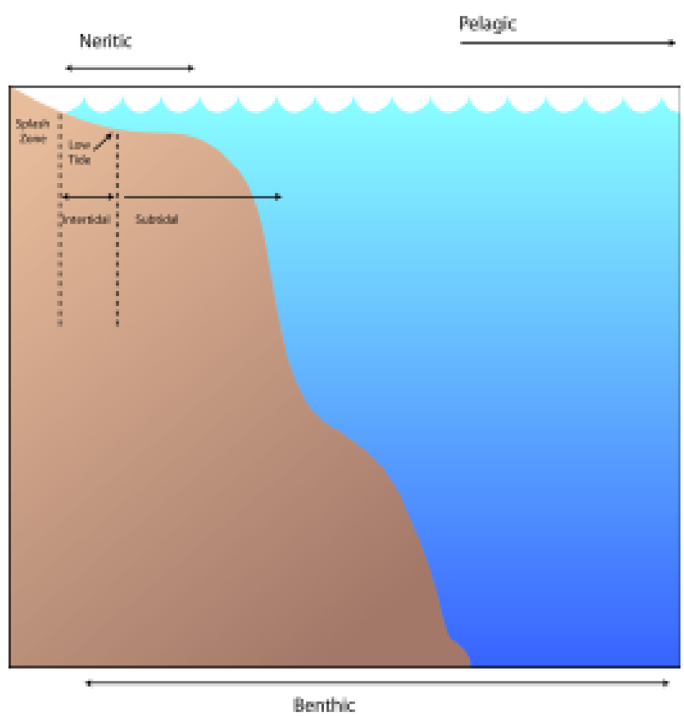
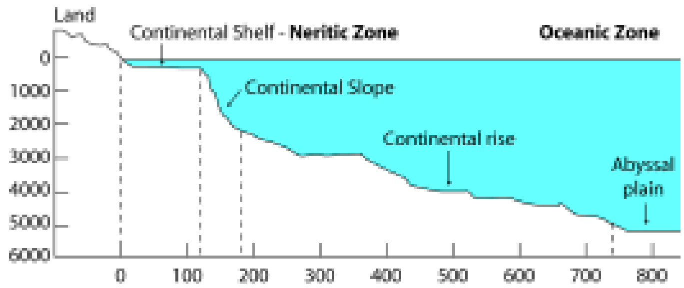


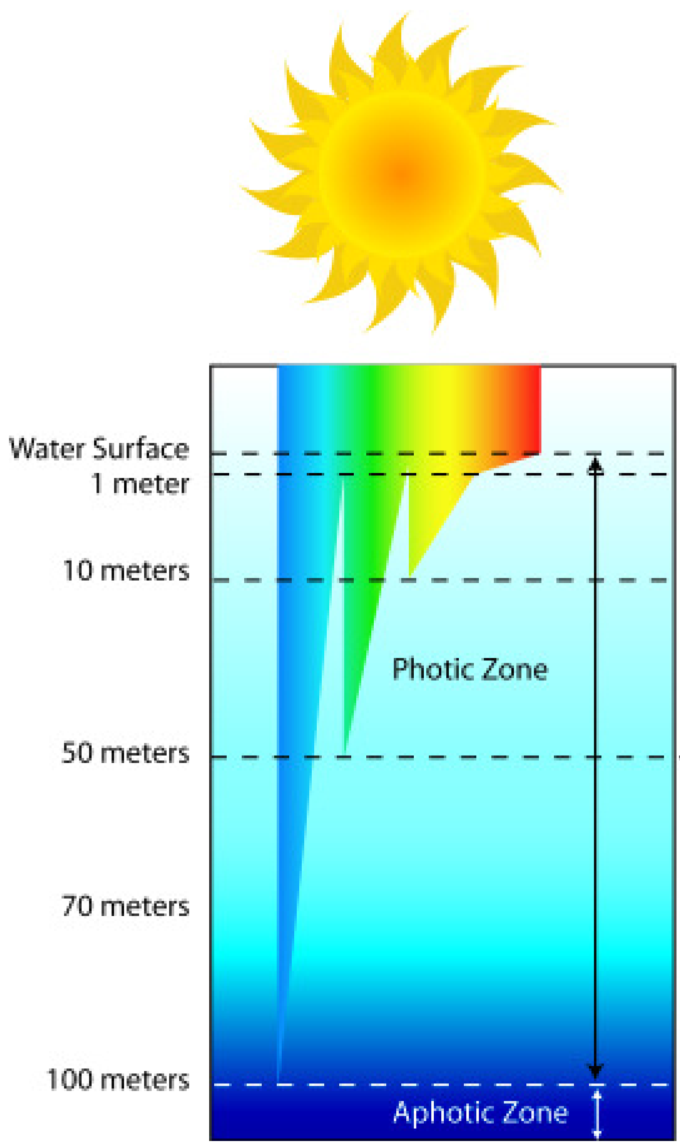
Figure 12.1 The basic ocean "zones."

Ocean zones can first be described as **benthic**, where organisms are attached to, or burrowing in, the bottom sediment, or **pelagic**, where organisms float or swim in ocean water.

The **littoral**, or **intertidal**, zone is the region between the lowest and the highest tides. Many environments are within or next to littoral zones. These include some that we will examine in more



Pelagic zones include the neritic, which is the shallow ocean sometimes found above a "continental shelf", and the deeper water oceanic.



In the photic zone, there is enough light for photosynthesis. The absorption of light by water varies with wavelength and depth. In the aphotic zone, there is not enough light for photosynthesis.

detail, such as mangrove environments, the coastal strand, and the coral reef.

Benthic zones include the **sublittoral**, which is below the littoral and is not covered and uncovered by the tides. Various zones that are at different depths on the ocean floor are the **bathyal**, **abyssal** and **hadal** zones.

Because the Marianas Trench and other deep regions are near the Marianas Islands, special environments and unique organisms can be found in some benthic environments nearby.

Pelagic zones include the **neritic**, which is shallow ocean that is sometimes above a "continental shelf". The **oceanic** zone is the deep ocean, usually where water is more than 200 meters (660 feet) deep.

Epipelagic, **mesopelagic**, **bathypelagic**, **abyssopelagic**, and **hadalpelagic** describe other oceanic zones of different depths. Even though all pelagic organisms must swim or float in ocean water, many of them are adapted to only zones of certain depths.

Other important terms used to describe zones in the oceans are **photic** and **aphotic.** These terms are especially important because they refer to the depth that light can penetrate into the sea.

In the photic zone, there is enough light for photosynthesis. In the aphotic zone, not enough light energy penetrates for photosynthesis to occur. Food chains in the aphotic zone must obtain their food energy from some other source.

Each zone has a different combination of environmental factors. These environmental factors include intensity of sunlight, amount of current and wave action, pressure, tidal exposure, temperature changes, salinity changes, pH, type of sea bottom, amount of oxygen, and concentration of dissolved nutrients.

Each zone will be slightly different. Organisms living in each zone must be adapted to the conditions present there. Organisms must also adapt to other living things present. These living things will interact with organisms as predators, prey, competitors, food sources, or in other ways.

Try to identify the important factors in each zone studied, and be able to state how each organism found there is adapted in order to survive.

12. 2. 3. Examples of Ocean Zones

The littoral zone is a constantly changing environment that is a difficult one for many organisms. At low tide, organisms are exposed to the atmosphere and are in danger of drying out.

Wave action can be high on exposed shores, and both salinity and temperature show great fluctuations. Typhoons and other storms, runoff from land, and evaporation of sea water can cause great changes in short periods of time. Littoral zone organisms must contend with competition and predation from both marine organisms and some land organisms.

Organisms in the littoral zone often have hard coverings or cover themselves with a slimy layer to slow down evaporation and water loss. Many of the organisms also attach themselves to rocks or bury themselves in mud and sand to prevent them from being washed away by waves and tidal currents.

The sublittoral zone is below the range of tides but it is still an environment where conditions change a great deal. Wave action can affect the sea bottom, and fresh water and nutrients running off from land can change salinity.

Organisms such as these barnacles survive in the littoral zone by virtue of their hard covering and ability to firmly attach themselves to rocks.

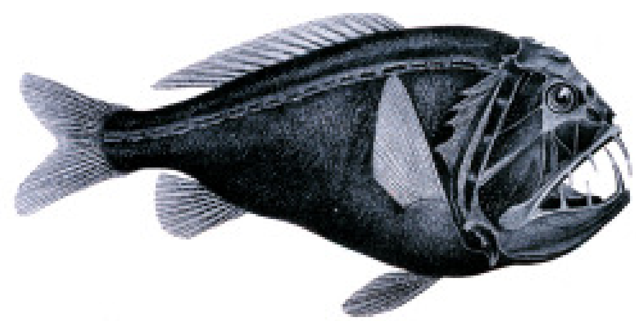
Light can penetrate to the bottom of this zone, allowing photosynthesis to occur. Through photosynthesis and the mixing of air with water due to wave action, dissolved oxygen is fairly abundant. While not as variable as the littoral zone, the sublittoral also experiences temperature changes.

The bathyal, abyssal and hadal zones are much less variable. These are benthic regions which are aphotic, below the limit of light penetration, so photosynthesis does not occur in these zones. Wave action does not affect bottom sediment, and fewer nutrients reach the bottom. Salinity and temperature are almost constant.

Organisms in these dark, cold zones must depend upon food falling from upper layers as the basis of food webs. Because the food supply is limited, the total biomass of organisms in these deep ocean zones is usually very small.

Pelagic zones near the surface of the sea include the neritic and epipelagic zones. In both of these, light penetrates deeply enough for photosynthesis to occur. Wave action mixes waters in these zones and temperatures can change.

The neritic zone, shallow water near land, is the more variable zone because it receives fresh water and sediment runoff from nearby land areas. While these zones are where humans obtain food by fishing, only certain regions where nutrients are available will be highly productive.



Cololepis longidens, a species living primarily in the aphotic zone.

Below the thermocline, temperatures are almost constant and near freezing. Food material falling from above forms the basis of food webs. In the constant darkness, some organisms use light-producing organs for communication or to attract prey. (See more on flashlight fish below).

12. 2. 4. The Photic Zone, Open Ocean Desert, and Upwellings

Almost all food production in the open ocean occurs in the top region, within the photic zone. This photic zone is really only a small portion of the ocean, never more than 200 meters (660 feet) deep, even in the clearest ocean waters.

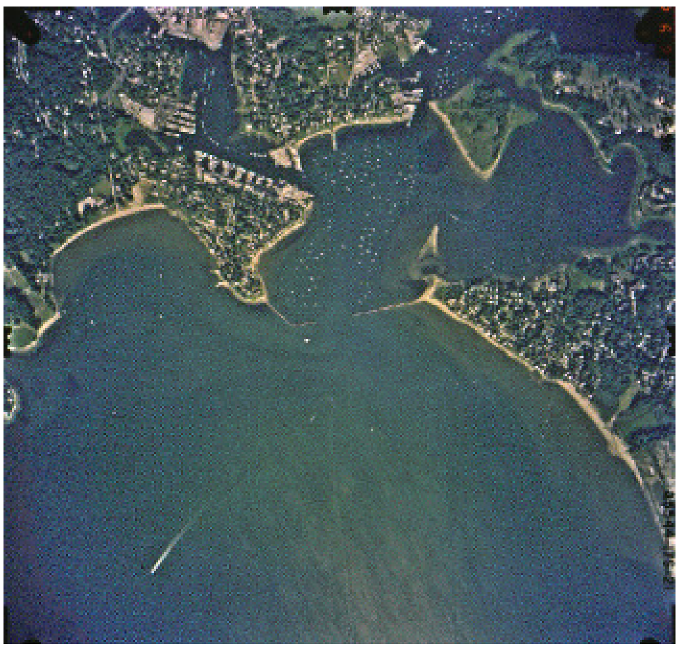
This very small photic zone means that photosynthesis cannot occur in most parts of the oceans; almost all regions of the oceans below the photic zone depend for food on dead material that falls from above.

As organisms in upper layers of the oceans die, their bodies fall to deeper regions where scavengers pick up the material. Dead organisms that fall to deep parts of the ocean also contain nutrients, including nitrates and phosphates, that act as fertilizers.

Because much of the ocean is stratified, many of these nutrients remain in deep ocean sediment and cannot easily return to surface regions of the ocean. A shortage of important nutrients at the surface of much of the open ocean environment leads to low productivity there.

Therefore, much of the open ocean surface is like an "oceanic desert." This is in contrast to coral reefs, mangrove forests, and regions where runoff from land provides nutrients that allow productivity to be high.

However, open ocean regions that do have high productivity are the "upwelling" regions. Here, water from deep ocean layers is brought up to the surface. Upwelling regions can be very productive, and commercial fishing vessels seek out these regions for large catches.



The green areas in the ocean which appear in this aerial photograph clearly show eutrophication due to runoff.

Remember that one important upwelling region is off the coast of Peru. This is where anchovies and other fish used to be caught in large numbers.

As we noted above, one special problem of the tropical open oceans is the permanent thermocline. This does not allow for any overturning of ocean waters during the year.

Upwelling regions, coastal regions receiving runoff from land, and other regions with high nutrient concentrations are very productive. Scientists often describe these ocean regions as **eutrophic** regions.

Most of the food produced in the open ocean occurs in a limited number of eutrophic regions. While eutrophic regions are productive, excess nutrients put into ocean waters can sometimes cause problems.

Sewage from fish canneries, piggeries, or from large towns can sometimes cause rapid growth of algae and plankton. These organisms make water less clear and can affect the tourist industry.

When these organisms die and decay, the oxygen content of the water becomes low and can cause fish to die. **Eutrophication** is the word that describes unwanted or excess productivity due to high nutrient content.

Oligotrophic regions, on the other hand, refer to those ocean regions with low concentrations of nutrients. Much of the ocean's surface is oligotrophic.

12. 2. 5. Plankton and Open Ocean Ecology

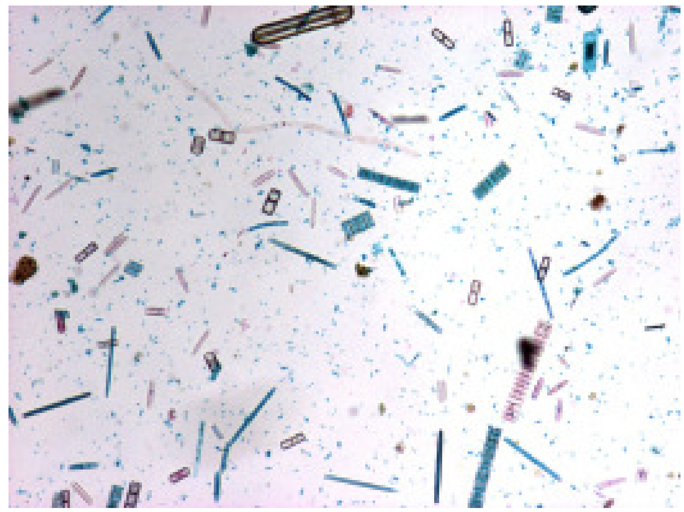
In the open ocean, food chains and food webs usually start with **plankton**. These are floating and drifting organisms that cannot swim against waves and currents.

In contrast to the drifting plankton, **nekton** are those organisms that can swim against waves and currents. Thus, nekton includes fish, marine reptiles, and marine mammals.

While many people think of seaweeds and sea grasses as the primary producers in the oceans, most photosynthesis is actually performed by microscopic, usually single-celled, organisms that float in the photic zone and are responsible for almost all primary production in the sea.

The planktonic producers are called **phytoplankton**, or “plant plankton”, because they are simple plants that perform the same function as grass, trees and other plants on land.

Phytoplankton are then eaten by other organisms called **zooplankton**. Some zooplankton are herbivores that feed upon phytoplankton, while others are carnivores which feed upon the herbivores. Oceanic food chains and food webs are often quite long and quite complex, with many steps.



Plants such as these diatoms comprise the phytoplankton.

Plankton form the basis of food webs in the open ocean. Sometimes called the “pastures of the sea”, these floating and drifting organisms support other life. They are a very important part of the oceanic ecosystem.

Not only do plankton form the basis of oceanic food webs, but the plankton community contains many **larval** forms of marine organisms.

Larvae of corals, crabs, fish and many other marine organisms are part of the **meroplankton**, planktonic organisms that spend only part of their lives as drifting plankton. **Holoplankton**, by contrast, spend all of their existence floating and drifting about. We will examine some planktonic organisms that are important in the ocean.

Plankton are most abundant near the surface of the sea, where nutrients and sunlight allow phytoplankton to grow and reproduce. Because plankton cannot swim strongly, many planktonic organisms show special adaptations to keep them near the surface.

Animals such as this copepod comprise the zooplankton.

Some organisms produce oil droplets or air bubbles for flotation. Others have special structures for movement. Many planktonic organisms use long spines or large antennae to increase their surface area; a large surface area can help an organism float.

Small organisms also have a surface area that is large compared to their size. For this reason, most planktonic organisms are small.

Eyespots in some plankton allow them to orient themselves towards sunlight. Because they can detect light, certain plankton show vertical migrations towards the surface at specific times of the day.

The abundance of plankton varies greatly. Where nutrients are in low concentration, numbers of plankton will be very small. However, upwelling or runoff from land can increase nutrient concentration suddenly. This can then result in rapid increases in the concentration of plankton.

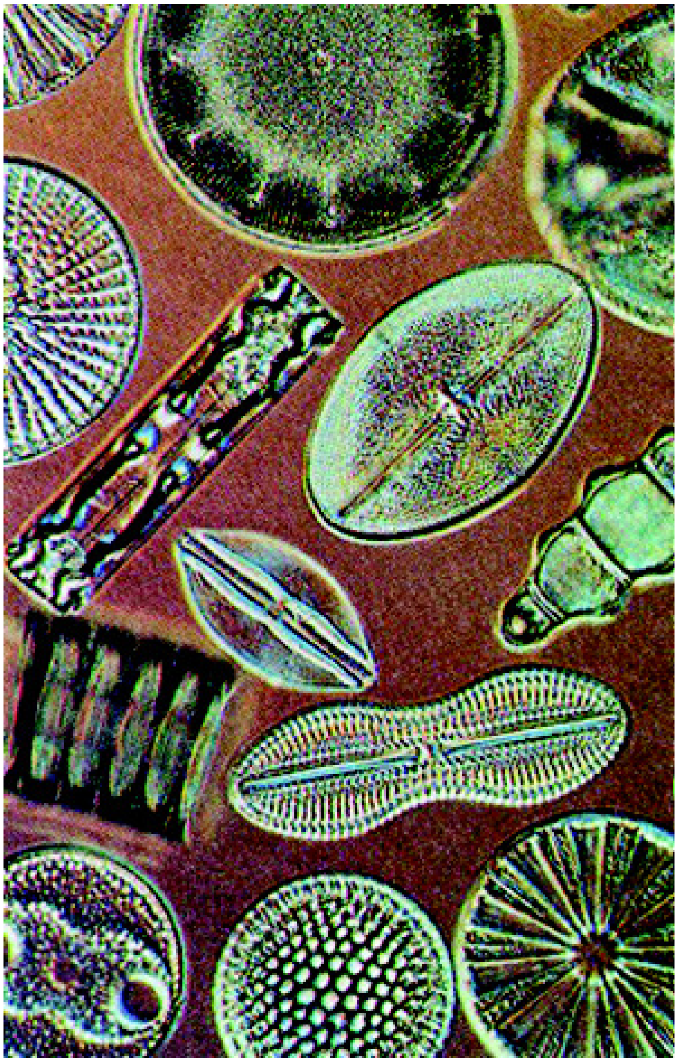
These sudden increases in plankton production are called **plankton blooms**. They can result in high productivity of an ocean region.

However, they can also cause problems. Some phytoplankton produce poisons that kill fish. Large concentrations of certain other phytoplankton color coastal waters, making the waters undesirable for recreation.

12. 2. 6. Planktonic Organisms

Phytoplankton

Two major groups of phytoplankton are the most important photosynthetic organisms forming the basis of food webs in the open ocean. These are **diatoms** and **dinoflagellates**. While both are producers in the ocean ecosystem, they can be distinguished by some important characteristics.



Diatoms

Diatoms are microscopic, floating or benthic organisms that have cell coverings partly made of a glasslike substance called **silica**, or **silicon dioxide** (SiO_2).

Diatoms do not have special structures for movement. However, some can creep on top of rocks and other surfaces. Some diatoms form long chains of cells, and others exist as single cells.

Diatoms can be in circular, triangular, or even modified square shapes. Some have a boatlike **pennate** shape, with left and right sides. Diatoms are very important as food sources for many other organisms. They also produce much of the world's oxygen.

Dinoflagellates (sometimes called 'dinophytes') have cell coverings of **cellulose**. This is the same material that constitutes cotton, paper, wood, rayon, and cellophane. Dinoflagellates also can be identified by two long, whiplike **flagella** used for movement.

Dinoflagellates are important as producers. However, some cause problems for humans when large numbers are produced during plankton "blooms". Some dinoflagellates produce poisons, or **toxins**, that can poison fish and even affect humans.

Certain dinoflagellates are **luminescent**, or light producing. They can cause the sea surface to glow at night. Others color the sea red when they are present in large numbers. Some dinoflagellates stop using their flagella. They then live in the tissues of corals and giant clams on coral reefs. If stressed, however, they reactivate their flagella and swim out from the body openings of these organisms.

Zooplankton

Zooplankton feed upon phytoplankton or upon one another. Many zooplankton are important prey for fish and other marine organisms.

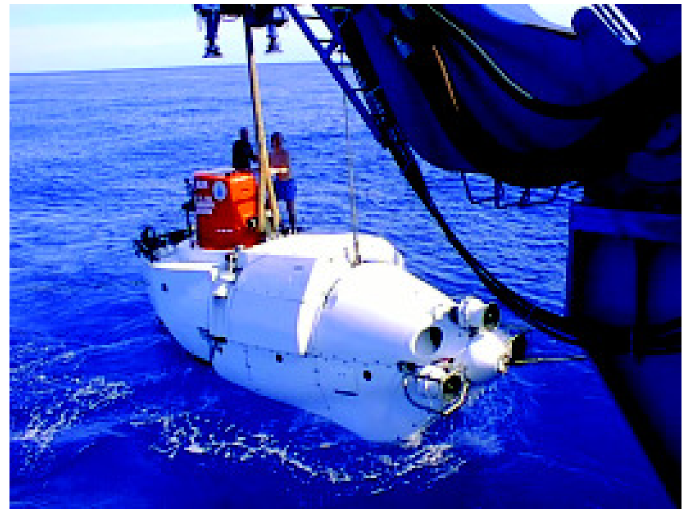
Copepods are probably the most easily recognized planktonic organisms. They are large enough to be seen without a microscope. They are often the most abundant planktonic organisms. Copepods are **crustaceans**, organisms similar in structure to crabs and lobsters, that feed largely upon diatoms.

Under a microscope, copepods appear similar to small shrimp with long antennae. The many leglike appendages of copepods are used to filter out food from the water around them. Other, larger crustaceans are also part of the zooplankton. *Lucifer* is a predator crustacean that feeds upon copepods.

Arrow worms, or *Chaetognatha*, are also predators of copepods.

Streamlined, rapidly moving arrow worms capture their prey with jaws containing pointed bristles.

Other common members of the zooplankton community include many larval forms of common marine organisms. Often seen in a plankton sample are **zoea larva** of crabs. These are easily identified by a long spine along the back of the organism. Larval forms of corals, clams, marine worms, starfish and many other organisms are also seen.



The submersible Alvin prepares to decend.

12. 2. 7. Thermal Vent Communities and Chemosynthesis

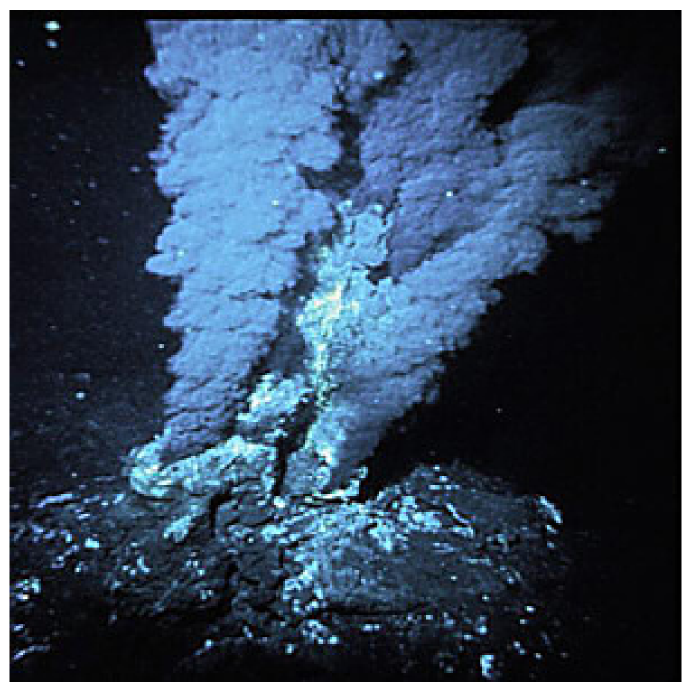
Oceanographers long believed that the deep sea floor was always a region of low productivity and little life. This was because photosynthesis occurs only in the photic zone. However, this belief was revised after scientists discovered large numbers of clams, crabs and giant wormlike organisms more than one mile deep in the ocean!

These scientists were diving aboard the submersible vessel *Alvin.* They had come to observe **thermal vents**, in the Galapagos Rift Zone near South America in 1977. These vents are cracks in the sea floor that produce hot water, rich in minerals.

Suddenly, in their dive, these scientists came upon a whole community of deep sea organisms that was completely unknown. Scientists throughout the world were astonished by this news!

How could this community exist in a region of the ocean far below the region where light supports photosynthesis?

Scientists were then eager to discover the process that supports an abundance of life deep in the sea. The **thermal vent community** became the focus of many scientific studies.



A deep ocean thermal vent

Water samples taken from near the vents showed high concentrations of **hydrogen sulfide** (**H_2S**), a chemical produced in hot springs and other volcanic regions.

Scientists found many unusual bacteria in these water samples. These bacteria obtain energy through chemical change, without using sunlight as a source of energy. They were **chemosynthetic**, rather than photosynthetic.

These chemosynthetic bacteria form the basis of the food web in thermal vent communities of the deep sea. Chemosynthetic bacteria of the thermal vents use oxygen dissolved in sea water to convert hydrogen sulfides to sulfates. This chemical change produces energy for bacterial metabolism, the life processes of the cells.

Other organisms, including giant wormlike creatures (*Riftia)*, obtain food from the chemosynthetic bacteria. *Riftia* is an unusual organism because it does not have a digestive system. Instead, a specialized organ contains chemosynthetic bacteria that form a partnership with the worm.

Clams filter out bacteria from the deep sea water, while crabs and other scavengers feed upon thermal vent organisms that die. Unlike oceanic food webs at the surface of the ocean, the thermal vent food webs depend upon chemosynthesis rather than photosynthesis.

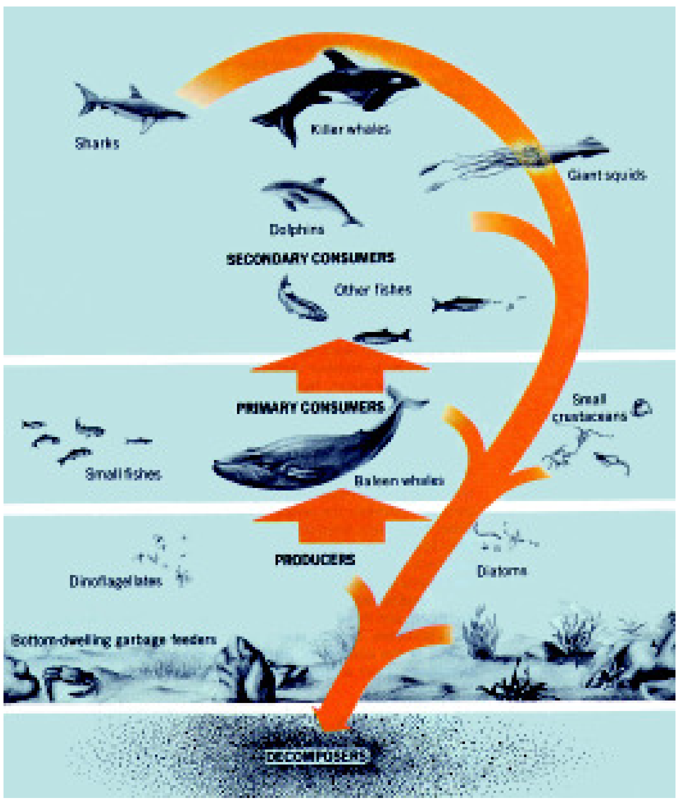
Since 1977, scientists have discovered thermal vent communities in many regions where volcanic activity occurs on the ocean floor. Because Micronesia is a region where ocean trenches and volcanism are common, it would not be surprising to find thermal vent communities of organisms on the ocean floor near our islands.

At the beginning of the 21st Century, the proportion of total food production within the ocean that depends upon chemosynthesis was still unknown. It is speculated to be only a small fraction of the amount that depends upon photosynthesis.

12. 2. 8. Food Webs and Nutrient Cycling in the Open Ocean

Food chains that make up food webs in the open ocean can be long. In an oceanic food chain, six or seven trophic levels can separate a photosynthetic diatom from the yellowfin tuna that humans catch commercially. For example, one food chain in the open ocean could be:

diatom → copepod → arrow worm → fish larva → flying fish → tuna



Cycling of nutrients in the ocean realm

A tuna contains only a very small amount of the energy available in the diatoms at the beginning of the food chain. This is because only a fraction of the food energy available in each trophic level is passed on to the next one. Great amounts of food energy are dissipated at each link of the food chain.

Unfortunately, the amount of food energy available in much of the ocean is quite limited. Because much of the ocean surface is in oligotrophic regions, few nutrients are available to support large numbers of top carnivores such as large, predatory tuna.

Pyramids of biomass occur in the sea as well as on land. The biomass of organisms at the top level is much less than the biomass of organisms at the base of the pyramid. This is because only 5–20% of the food energy at one trophic level is passed on to the next higher level.

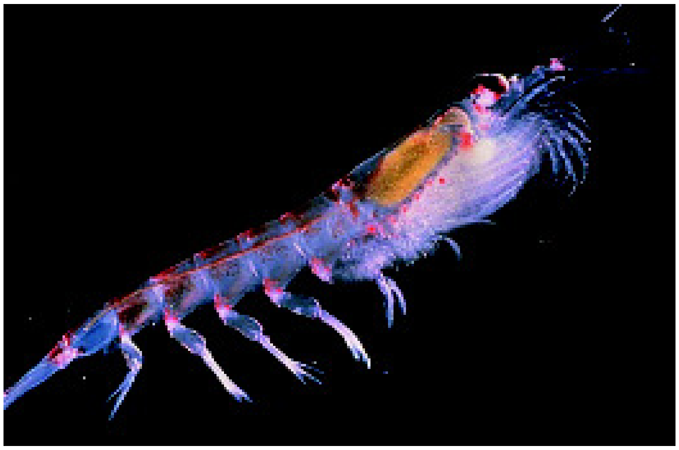
Production of one kilogram of yellowfin tuna may depend upon nearly 1,000 metric tons of diatoms in the open ocean! Even though oceans cover large amounts of the earth's surface, catching top level organisms alone, such as tuna, cannot support the large and growing human populations. This is the dilemma. Only a few food chains in the open ocean are relatively short and can support large numbers of organisms at the top levels.

In upwelling regions near Peru, small fish called anchovetas (*Engraulis ringens*) can feed upon the diatoms that are producers. When humans catch anchovetas, they are able to obtain more of the food energy from the diatoms than from tuna. This is because they are eating from nearer to the bottom of the food chain. Unfortunately, overfishing and changes in ocean conditions have caused the anchoveta fishery to collapse.
Like anchoveta, **baleen whales**, those that filter out shrimp-like

crustaceans called **krill**, also feed from near the bottom of the food chain.

In some ways, nutrient cycles in the open ocean are like those on land. Carbon, nitrogen, phosphorus and other important elements are transferred from producers to consumers. These nutrients eventually re-enter the cycle by decomposers. In the ocean, however, many nutrients fall to sea bottom sediments and are not quickly returned to the sea surface.

As mentioned, stratification of ocean water layers prevents mixing of surface waters and lower layers, except in regions of upwelling. Only the ocean regions where runoff or upwelling occurs will receive large amounts of nutrients and will be highly productive. These productive, in other words 'eutrophic', though still well oxygenated regions, are only a small proportion of the ocean surface area.



The small shrimp-like crustaceans called krill are the primary diet of baleen whales.

12. 2. 9. Deep Sea Food Webs

Below the photic zone, photosynthesis cannot occur. Food webs in the deep sea, then, must depend on other sources of food energy. The thermal vent organisms of rift zones depend upon chemosynthetic bacteria.

Most deep sea organisms, however, do not live near thermal vents. They must receive food as dead material, or **detritus**, falling from surface waters. This material may be dead or dying organisms, fecal material, or even kitchen garbage from ships. The detritus falls to the sea bottom, where it becomes part of the ocean floor sediment.

The food webs of the deep sea, then, are based upon food energy that originally came from the surface. Because the amount of food energy falling as detritus is limited, productivity in the deep sea is low. Little food energy is available, and both size and numbers of organisms are small.

Oceanographers have sampled the deep sea and have obtained specimens of fascinating and unique species from this region. Some of the fishes and other organisms appear very fierce, with sharp teeth and gaping mouths. However, these organisms are really quite small.

Many have huge mouths and can swallow prey nearly as large as themselves. Others use **luminescent organs** for communication, to attract a mate, or to attract prey. One fish (*Anomolops katoptron)* found in Micronesia, has a "flashlight" under each eye; these organs are filled with bacteria that produce light.

Animals such as deep-sea squid often possess luminescent organs.

Angler fish

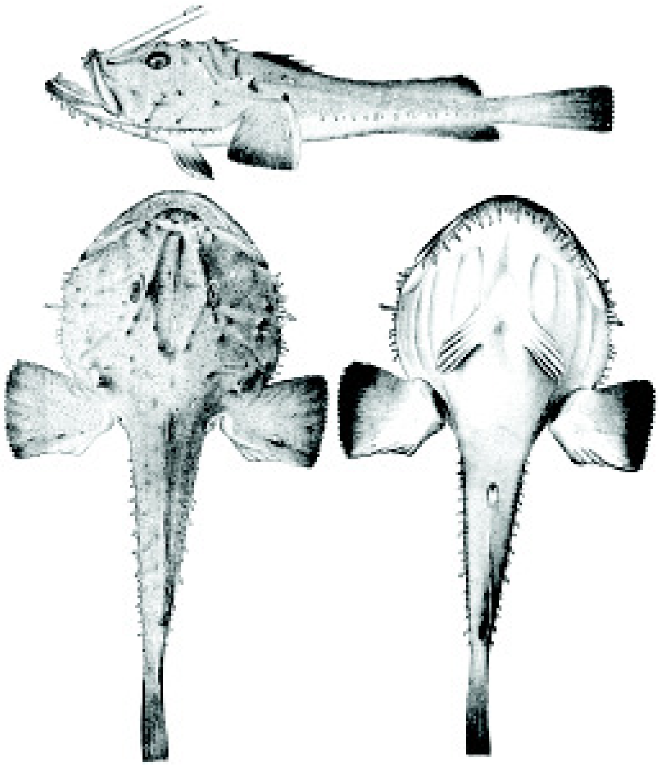
A deep sea angler fish is a true "angler," with a fishing pole and lure. Instead of a hook, though, the angler fish uses its teeth to catch prey. Because food is limited in the deep sea, populations of angler fish are also limited. Thus, their opportunities to find suitable mates are restricted as well.

How can a female angler fish be sure to find a male for reproduction? She carries the male attached to her own body! The male angler fish is a small, reduced 'appendage' that only serves to fertilize the female, while the female angler fish moves about and obtains food. These "anglers" are not fishermen, but fisherwomen.

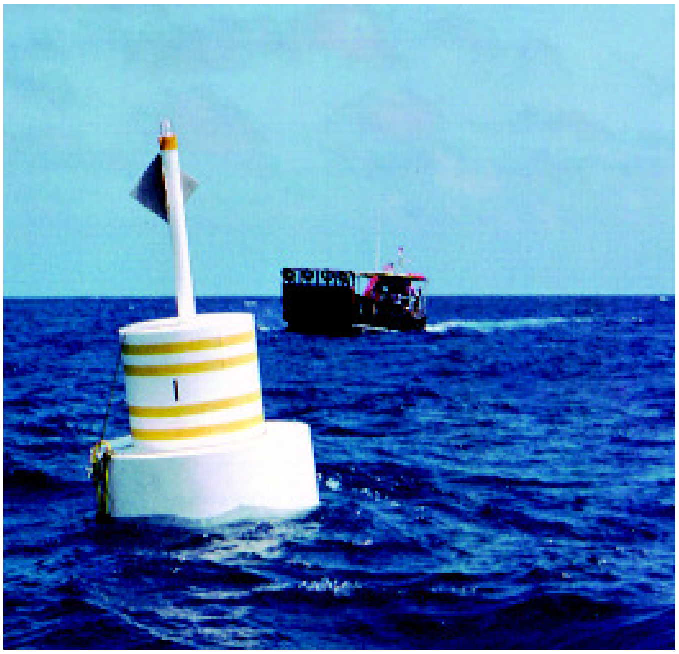
12. 2. 10. Drifting Logs, Food Webs, and Fish Aggregating Devices

A special kind of food web can exist near drifting logs or other floating structures in the deep sea. Sea weeds attached to floating logs, buoys, or drifting boats form the base of a food web that often supports large numbers of organisms. Herbivorous fish, crabs, and other small organisms eat the seaweeds. Small carnivorous fish then feed upon the herbivores.

Free-swimming pelagic fish, including tuna and mahimahi, are found near floating objects because they feed on the smaller fish. After floating logs and fishing floats were seen to support food webs and to attract large fish, fisheries agencies began to build large structures. They would anchor these to the sea bottom to improve sport fishing. These floating structures, **Fish Aggregating Devices** (**FADs**), have been placed in a large number of locations throughout the Pacific region. (Read more about pelagic fishes in our Fisheries Management Chapter).



The deep sea angler fish, Lophius piscatorius, has a fishing pole and lure and uses its teeth to catch prey.



Fish Aggregating Devices (FADs), have been placed in a large number of locations throughout the Pacific region.

12. 3. OPEN OCEAN ORGANISMS

12. 3. 1. Adaptations to Life in the Open Ocean – Fishes and Birds

Open ocean organisms are either the floating plankton or the swimming nekton. While planktonic organisms form the basis of most food production in the open ocean, nekton are usually the organisms that humans easily observe and seek for food.

The large marine organisms seen in the open ocean are fishes, marine reptiles, mammals and birds. Some of these organisms are discussed in other sections.

Fishes of the open ocean have special adaptations for survival. Open ocean fishes are usually **streamlined**, with a smooth, tapered shape, much like a missile.

Anything that moves quickly through water must be streamlined. It is interesting to see that submarines, whales, and even many sharks all have the same shape.

To avoid being seen by enemies or prey, a color pattern called **countershading** is very common on organisms that live near the ocean surface. This countershading pattern is one where the top (dorsal) surface is dark and the bottom (ventral) surface is a light color. Countershaded animals will be hidden against the deep blue sea when seen from above, and they will be hidden against the lighter ocean surface when seen from below.

Other adaptations are found in fishes of the open ocean. A **lateral line** system helps them detect vibrations, such as those from a predator that might be chasing them.

Fins on rapid swimmers can act like the wings of airplanes, to lift them up and allow them to move smoothly through the water. Some fish even have fins that allow them to "fly" through the air! The GAAGA (*Cypselurus poeciliopterus)* is one of the flying fish **Family**

Exocoetidae found in Micronesia. In Carolinian, these are called TAAGH. While (according to those who define such events) this organism cannot really fly, it can "glide" through the air for long distances to escape predators.

A few rapid swimmers, such as tuna, have adapted by keeping a warm body temperature for their swimming muscles.

Seabirds

Birds are very important in open ocean ecosystems, and many of them have special adaptations. Long wings and light bodies allow birds such as the frigate bird to spend long periods away from land, without even resting on the water. Other birds, such as our fairy tern, return to land each evening.

Early Micronesian navigators became aware of nearby land when they saw the flight of fairy terns. All birds must nest and lay eggs on land, and certain islands have large colonies of sea birds. Their eggs were a source of food for humans. On Nauru and at other places, thick deposits of bird waste (**guano**) have been collected for sale as fertilizer. (See Chapter 16 on Coastal Strands for more details on our local seabirds).

Exocaetus californiensis, the Flying Fish, have fins that allow them to "fly" through the air.

12. 3. 2. Marine Reptiles: Sea Snakes and Crocodiles

Reptiles found in the oceans of some of the islands of Micronesia include sea turtles, saltwater crocodiles and sea snakes. While crocodiles and sea snakes can be dangerous, all of these reptiles are interesting marine organisms.

Sea Snakes

Sea snakes, KINEPLANTASI and KINEBLAL SAAT, found in Micronesia are related to the cobras. Like their relatives, they produce a poison that can be very deadly. However, these snakes are not aggressive and do not attack people. They swim with flattened tails and capture fish for food. While they look like moray eels, they breathe air and do not have gills. One species seen in Palau is the banded sea snake (*Laticauda colubrina*). It has been seen by biologists in our waters only on very rare occasions.

Laticauda colubrina, the Banded Sea Snake, is related to the cobras.

A local species of eel, called the 'snake eel', looks much like a sea snake and is often mistaken for one. Snake eels are common around Managaha Island, off Saipan's leeward coast.

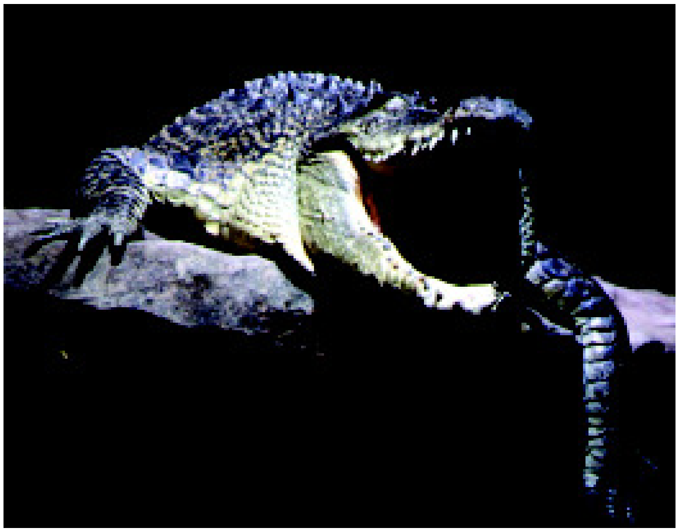
Saltwater Crocodiles

Indo-Pacific crocodiles (*Crocodylus porosus),* [Chamorro and Caro-
[redacted]: KAIMON] live in some parts of Micronesia, especially in man-
[redacted] swamps. They can be as long as 7 meters, and are good swim-
[redacted], sometimes traveling far out to sea.

[redacted]odiles lay eggs in nests on shore, with the female guarding her
[redacted]until they hatch. Salt water crocodiles must have special struc-
[redacted] to remove excess salt. These are on the tongue of the Indo-
[redacted]ic crocodile.

[redacted]nately, no crocodiles are known to have been seen in nature
[redacted] in the CNMI.

[redacted]e end of the 20th Century, an attempt to import saltwater crocodiles for zoo display purposes was proposed with a permit application submitted to the US Fish and Wildlife Service.



Crocodylus porosus live in some parts of Micronesia, especially in mangrove swamps.

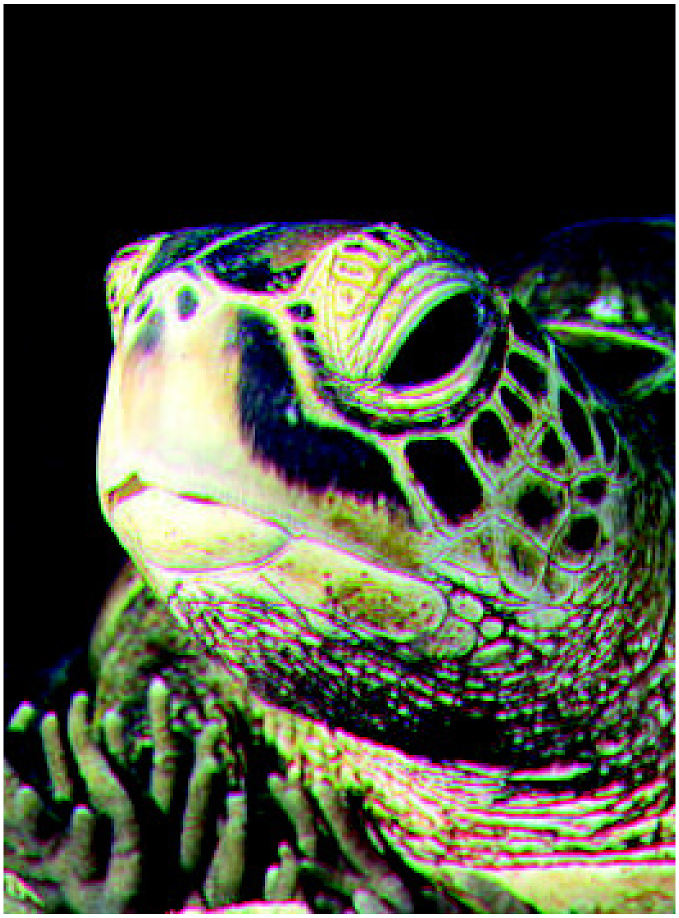
The CNMI's CRM program commented against the proposal, citing human and environmental health concerns potentially resulting from such a noxious species, should an unanticipated escape occur. [Just imagine!!,,, "Public announcement: 'escaped and now swimming somewhere in the Saipan Lagoon, a seven meter long saltwater crocodile. All lagoon users, are advised to be on the lookout",,,]. The permit was ultimately denied.

12. 3. 3. Marine Reptiles: Sea Turtles

Introduction

The waters of our Northern Marianas, and other parts of Micronesia, are the home of sea turtles, including the US federally listed endangered hawksbill sea turtle (*Eretmochelys imbricata),* and the green sea turtle (*Chelonia mydas*). Both sea turtles are called WONG in both Chamorro and Carolinian.

It is unfortunate that these fascinating animals are becoming rare and are listed as endangered species. While these animals are now protected by law, their populations are still decreasing.



The waters of our Northern Marianas, and other parts of Micronesia, are the home of sea turtles.

Sea Turtle Ecology

Green turtles begin their lives by eating small marine creatures. However, they become herbivores, feeding on turtle grass, when they are adults. These creatures often migrate long distances from their nesting sites to find beds of turtle grass. Hawksbill turtles feed on marine animals, including sponges, and are carnivores.

Sea turtles spend most of their lives at sea, but their lives begin on land. Female turtles lay eggs in nests dug within sandy beaches, laying dozens of eggs at a time.

Only certain beaches are used as nesting sites. It is believed, though it was *not*, by the end of the 20th Century, a scientific certainty, that sea turtles have the unusual ability to return to the same beach where they hatched.

The reason for this uncertainty results from the tremendous life changes each turtle displays at it grows and lives. This occurs as each turtle ages from a hatchling into a mature adult. Eventually one may hope the science of genetics will help us sort out who's who, and who's from where, in our sea turtle realm.

Turtle eggs remain buried in sand for about two months while the young turtles develop, then the young hatchlings dig themselves out of the sand and race to the edge of the sea.

The young hatchlings swim out to sea to develop and feed, migrating long distances away from their place of birth. Some unusual abilities allow sea turtles to navigate even to small islands. These abilities may be chemical, a sense of the earth's magnetic field, or some other unknown sense.

Threats to Our Sea Turtles

While sea turtles lay many eggs, only a very small percentage of these will survive to become adult breeding turtles. Sea turtles face many hazards. Humans and sharks kill adult turtles for food. Humans, pigs, crabs and other organisms eat turtle eggs. Young hatchlings are attacked by crabs, seabirds, sharks and reef fish. Few hatchlings survive to return to the beaches where they began life.

Female turtles lay eggs in nests dug within sandy beaches.

Turtle meat, turtle eggs and turtle shell have long been valuable to humans. Micronesians have captured turtles and dug for turtle eggs for centuries, while beautiful jewelry, fish hooks and other useful items have been made from turtle shell.

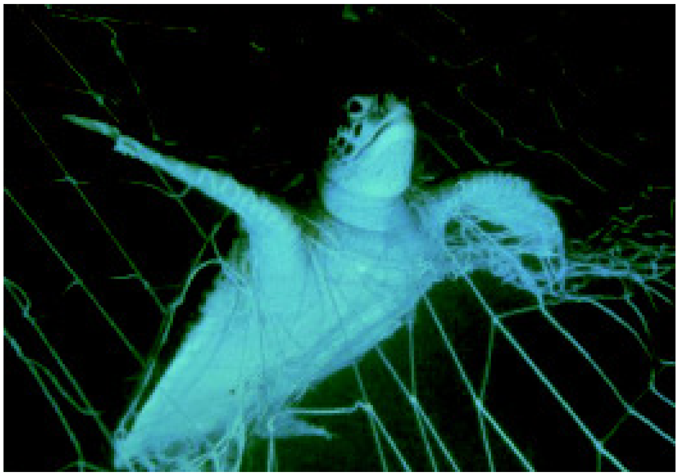
In modern times, however, turtles have been affected by humans in other ways. The effects of human activities on coastal and marine environments now threaten sea turtles.

Coastal development, marine pollution, fishing nets, and boat traffic have negative consequences for sea turtles. Turtles have lost many of their nesting sites as sidewalks, hotels and parking lots have covered beaches. Bright lights on beaches and loud noises drive turtles away from nesting sites. They discourage female turtles from coming ashore to lay their eggs.

Vehicles driving on beaches create ruts that prevent hatchlings from reaching the sea. Moreover, the weight of these vehicles hardens beach sand, so hatchlings cannot dig their way to the surface.

Oil and chemical pollution kills many turtles in coastal waters. Solid pollutants, such as plastic bags and styrofoam cups, can be accidentally eaten by turtles, choking them.

Fishing nets and lines trap and entangle swimming turtles. Turtles breathe air and will drown if held below the ocean surface. The propellers of motor boats also kill and injure turtles.



Fishing nets are just one of many hazards facing sea turtles.

Sea turtles are now protected by law. However, poachers still capture turtles, or dig for their eggs. Many visitors to Pacific island regions also buy souvenirs made from turtle shell. While it is illegal to bring sea turtles or articles made from turtle shell through customs, many tourists do not know about these rules. They continue to purchase items made from turtle shell. Demand for turtle shell jewelry and similar items increases the number of sea turtles killed.

12. 3. 4. Marine Mammals

Introduction

The marine mammals normally found in our Northern Marianas are whales and dolphins. Although these mammals live in the oceans today, they evolved from mammalian ancestors that lived on land.

Like all other mammals, they breathe air, have four-chambered hearts, well-developed brains and nervous systems, and have mammary (milk) glands by which they nurse their young.

After fertilization the fetus (or fertilized egg) develops inside the

Whales...

and dolphins are both found in the Northern Marianas.

uterus of the female. When development is complete, the young mammals are born. The newborn young whale or dolphin is called a calf.

After birth, it surfaces and begins to breathe air. From the moment of its birth until its death, it must swim to survive. This is a mode of locomotion for which dolphins and whales are highly adapted.

The body form of whales is highly streamlined, and their limbs are modified into flippers. Many species have the ability to hold their breath for long time periods. Some of these species can swim to deep depths in the ocean.

Dolphins and porpoises are relatively small (from 1 to 5 meters in length), but whales can grow to enormous sizes. In fact, the largest animal ever to live on the earth is still alive on earth today. This animal is the blue whale, which grows more than 30 meters (100 yards) in length and weighs some 150 tons (300,000 pounds).

Our Baleen Whales

There are many species of whales, but they can be classified into two types, namely toothed whales and untoothed whales. The untoothed whales (in Carolinian called RÓÓS), do not have teeth, but instead have straining devices made of **baleen** growing from their upper jaw. The baleen plates are used to strain plankton from the water.

These whales are the ones most commonly hunted by people. Hunting pressures have greatly reduced whale populations. International laws now restrict the hunting of whales. However, because certain countries do not obey those laws, extinction still threatens some whale populations.

Against sophisticated modern ships equipped with advanced tracking systems and guns, these, the largest animals on the earth, have little chance for escape.

Our Toothed Whales

Local toothed whales include both dolphins or porpoises (in Carolinian called GHUUW), and these are the most common type of marine mammal in the Northern Marianas. Dolphins and porpoises are very intelligent animals and communicate with each other in a very complex manner.

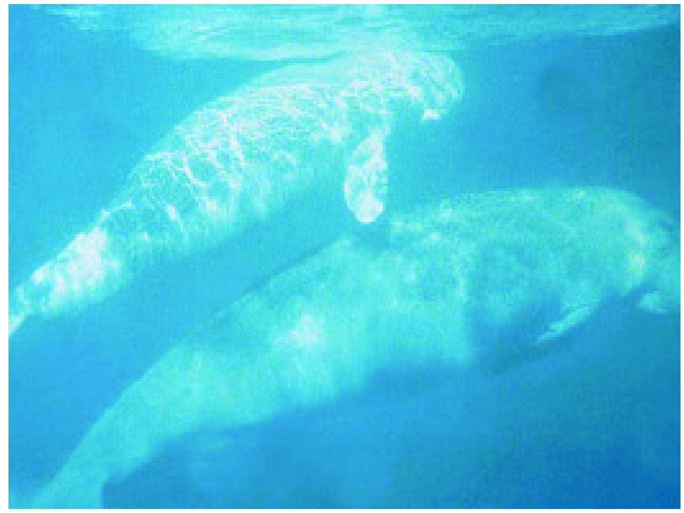
Whales, dolphins, and porpoises are very social animals and often live in groups, called **pods**. They navigate and communicate by the process of **echolocation**. This involves the use of high frequency sound waves.

This process is much like the process used by people when measuring the depths of the open oceans. This human process is called SONAR–SOund Navigation And Ranging.

GHUUW can be very playful creatures, and can be easily trained. Currently, the U.S. Navy is conducting studies on the utilization of dolphins to recover missing mines or objects lost in the sea.

Dugongs

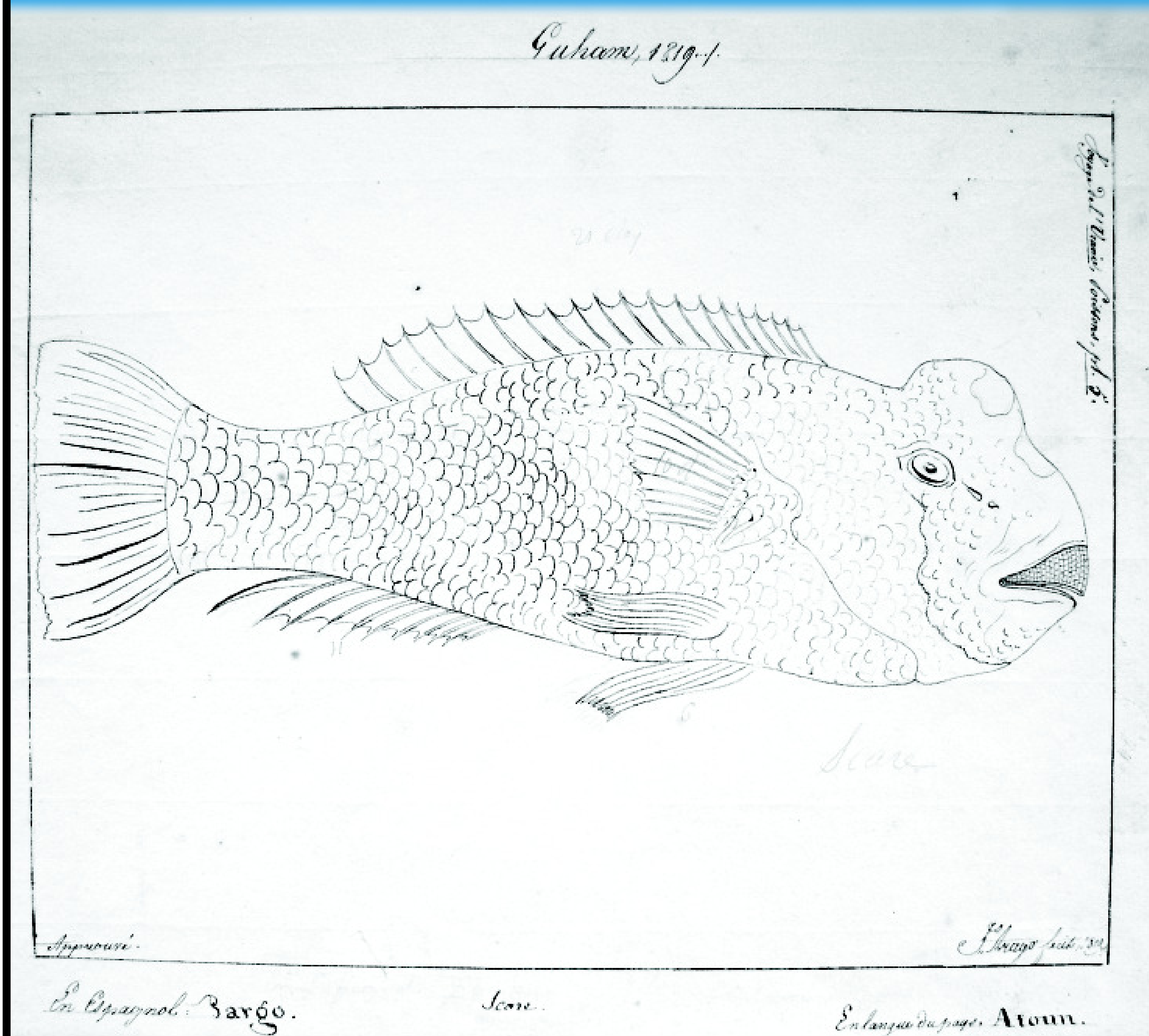
A very unusual and rare marine mammal found near Palau and northern Australia is the dugong, *Dugong dugon*, or *mesekiu* in Palauan, WAKKEEL LESET in Carolinian. It is a large, slow-moving animal with front limbs developed as paddles for swimming. It has a flattened tail. These gentle creatures are herbivores that feed on sea grasses in shallow waters.



A mother dugong and her calf

Because they have a face with features like that of humans and are sometimes seen holding and feeding their young, some people believe that these creatures are the original source of legends about mermaids!

Unfortunately, these harmless creatures are sometimes killed for food or are injured by motor boats. Without protection, their populations are in danger.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Approuvé.
En Espagnol: Bargo.
Scare.
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