ENVIRONMENT AND ECOLOGY: OCEANS IN PERIL



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Oceans in Peril Chapter for BIOL 124

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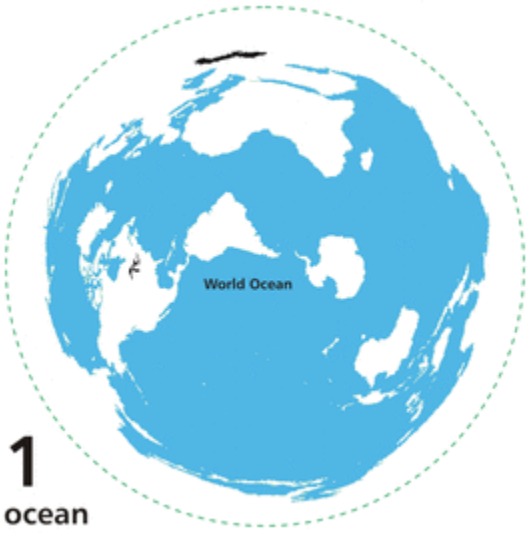
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1: Oceans and Coastal Environments

Significance of the Oceans

The oceans make up 70 percent of the planet and contains 97 percent of all the water on Earth. The vast amount of water stores the majority of the planet's moisture, terrestrial energy, and heat from the Sun. This energy is transferred between the equator and the two poles by larger surface currents by winds and deep ocean currents driven by differences in ocean density. It also provides the moisture and energy for storm systems and ultimately global climates. Phytoplankton, microscopic plants and animals in the oceans provide the foundation of the global food web of species. The earth's oceans are so vital for life that over 40 percent of the world's population live 7.4 billion people near coastal areas.	An interactive or media element has been excluded from this version of the text. You can view it online here: http://pb.libretexts.org/es/?p=94



MODERATE CLIMATES

As terrestrial creatures, humans think of the importance of the planet's land surfaces, yet Earth is a planet consisting of 70 percent water. From space, the dominance of water is obvious because most of it is stored in Earth's oceans.Earth would not be the same planet without its oceans. The oceans, along with the atmosphere, keep Earth's surface temperatures fairly constant worldwide. While some places on Earth get as cold as -7 degrees Celsius and others as hot as 55 degrees Celsius, the range is only 125 degrees Celsius. On Mercury temperatures go from -180 degrees Celsius to 430 degrees Celsius, a range of 610 degrees Celsius. The oceans, along with the atmosphere, distribute heat around the planet. The oceans absorb heat near the equator and then transport that solar energy to polar regions. The oceans also moderate climate within a region. At the same latitude, the temperature range is smaller along coastal areas compared to areas farther inland. Along coastal areas, summer temperatures are not as hot, and winter temperatures are not as cold, because water takes a long time to heat up or cool down.



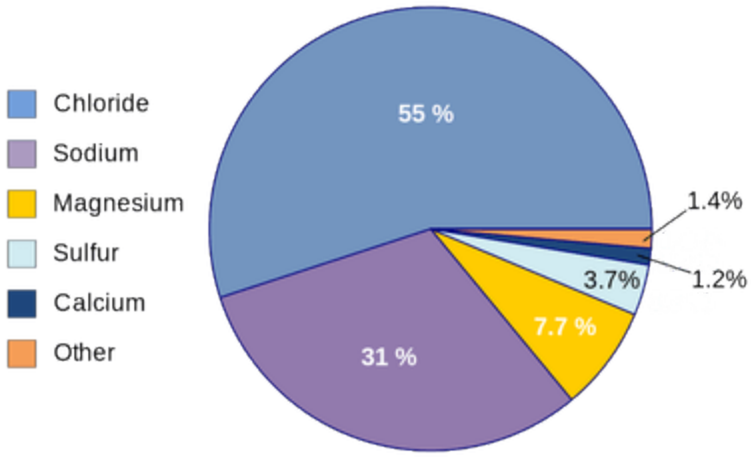
BIOLOGICALLY RICH

The oceans are an essential part of Earth's water cycle. Since they cover so much of the planet, most evaporation comes from the ocean and most precipitation falls on the oceans.The oceans are also home to an enormous amount of life. That is, they have tremendous biodiversity. Tiny ocean plants create the base of a food web that supports all sorts of life forms. Marine life makes up the majority of all biomass on Earth. (**Biomass** is the total mass of living organisms in a given area.) These organisms supply us with food and even the oxygen created by marine plants.



CONTINENTAL MARGIN

Recall from the chapter on Plate Tectonics that the ocean floor is not flat: mid-ocean ridges, deep sea trenches, and other features all rise sharply above or plunge deeply below the abyssal plains. In fact, Earth's tallest mountain is Mauna Kea volcano, which rises 10,203 m (33,476 ft.)meters) from the Pacific Ocean floor to become one of the volcanic mountains of Hawaii. The deepest canyon is also on the ocean floor, the Challenger Deep in the Marianas Trench, 10,916 m (35,814 ft). The mapping of the ocean floor and coastal margins is called **bathymetry**.The continental margin is the transition from the land to the deep sea or, geologically speaking, from continental crust to oceanic crust. More than one-quarter of the ocean basin is continental margin.

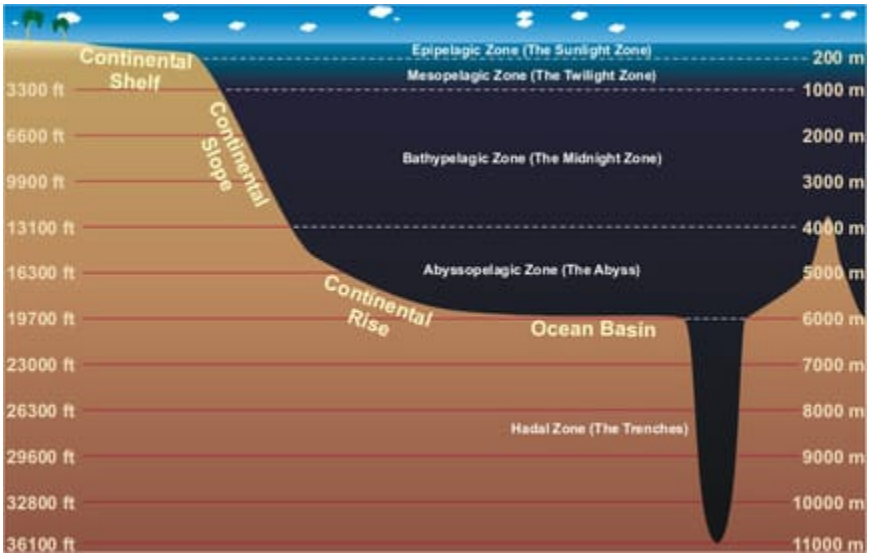


Average composition of the ocean.

COMPOSITION OF OCEAN WATER

Water is a polar molecule so it can dissolve many substances such as salts, sugars, acids, bases, and organic molecules. Where does the salt in seawater come from? As water moves through rock and soil on land it picks up ions. This is the flip side of weathering. Salts comprise about 3.5% of the mass of ocean water, but the salt content or **salinity** is different in different locations.In places like estuaries, seawater mixes with fresh water, causing salinity to be much lower than average. Where there is lots of evaporation but little circulation of water, salinity can be much higher. The Dead Sea has 30% salinity—nearly nine times the average salinity of ocean water. It is called the Dead Sea because nearly nothing can survive within it because of its salinity. Earthquide has aninteractive ocean maps can show salinity, temperature, nutrients, and other characteristics.Differences in water density are responsible for deep ocean currents. With so many dissolved substances mixed in seawater, what is the density (mass per volume) of seawater relative to fresh water? Water density increases as: salinity increases; temperature decreases; pressure increases

Layers of the Ocean



In 1960, two men in a specially designed submarine called the **Trieste** descended into a submarine trench called the Challenger Deep (10,910 meters). The average depth of the ocean is 3,790 m, a lot more shallow than the deep trenches but still an incredible depth for sea creatures to live in. There are three major factors that make the deep ocean hard to inhabit: the absence of light, low temperature, and extremely high pressure.

VERTICAL DIVISIONS

To better understand regions of the ocean, scientists define the **water column** by depth. They divide the entire ocean into two zones vertically, based on light level. Large lakes are divided into similar regions. Sunlight only penetrates the sea surface

to a depth of about 200 m, creating the **photic zone** (consisting of the Sunlight Zone and Twilight Zone). Organisms that photosynthesize depend on sunlight for food and so are restricted to the photic zone. Since tiny photosynthetic organisms, known as **phytoplankton**, supply nearly all of the energy and nutrients to the rest of the marine food web, most other marine organisms live in or at least visit the photic zone. In the **aphotic zone** (consisting of the Midnight Zone and the Abyss) there is not enough light for photosynthesis. The aphotic zone makes up the majority of the ocean, but has a relatively small amount of its life, both in diversity of type and in numbers.

HORIZONTAL DIVISIONS

The seabed is also divided into the zones described above, but the ocean itself is also divided horizontally by distance from the shore. Nearest to the shore lies the **intertidal** (littoral) **zone**, the region between the high and low tidal marks. This hallmark of the intertidal is change: water is in constant motions in waves, tides, and currents. The land is sometimes under water and sometimes is exposed. The **neritic zone** is from low tide mark and slopes gradually downward to the edge of the seaward side of the continental shelf. Some sunlight penetrates to the seabed here. The oceanic zone is the entire rest of the ocean from the bottom edge of the neritic zone, where sunlight does not reach the bottom. The sea bed and water column are subdivided further, as seen in the figure above.

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TSUNAMIS

Tsunami are described in the Earthquakes chapter as damaging waves that result from the sharp jolt to the water from an undersea earthquake. Landslides, meteorite impacts, or any other jolt to ocean water may form a tsunami. Tsunami can travel at speeds of 800 kilometers per hour (500 miles per hour). Tsunami have small wave heights and long wavelengths so they are usually unnoticed at sea. As the wave rides up the continental shelf the wave height increases.

The wave speed of a tsunami is also slowed by friction with the shallower ocean floor, which causes the wavelength to decrease, creating a much taller wave. Many people caught in a tsunami have no warning of its approach. Since the wavelength is long, a long time can pass between crests or troughs onshore. In 1755 in Lisbon, an offshore earthquake caused a great deal of damage on land. People rushed to the open space of the shore and discovered that the water was flowing seaward fast. The trough of the tsunami wave reached shore first. People who went out onto the open beach were drowned when the crest of the wave reached shore.	An interactive or media element has been excluded from this version of the text. You can view it online here: http://pb.libretexts.org/es/?p=94

Tidal Waves



Tides are the daily rise and fall of sea level at any given place. The pull of the Moon's gravity on Earth is the primarily cause of tides and the pull of the Sun's gravity on Earth is the secondary cause. The Moon has a greater effect because, although it is much smaller than the Sun, it is much closer. The Moon's pull is about twice that of the Sun's.

DAILY TIDE PATTERNS

To understand the tides it is easiest to start with the effect of the Moon on Earth. As the Moon revolves around our planet, its gravity pulls Earth toward it. The lithosphere is unable to move much but the water is pulled by the gravity and a bulge is created. This bulge is the high tide beneath the Moon. The Moon's gravity then pulls the Earth toward it, leaving the water on the opposite side of the planet behind. This creates a second high tide bulge on the opposite side of Earth from the Moon. These two water bulges on opposite sides of the Earth aligned with the Moon are the **high tides**. Click here to learn more.

Since so much water is pulled into the two high tides, **low tides** form between the two high tides. As the Earth rotates beneath the Moon, a single spot will experience two high tides and two low tides every day.

The **tidal range** is the difference between the ocean level at high tide and the ocean at low tide. The tidal range in a location depends on a number of factors, including the slope of the seafloor. Water appears to move a greater distance on a gentle slope than on a steep slope.

MONTHLY TIDAL PATTERNS

If you look at the diagram of high and low tides on a circular Earth above, you'll see that tides are waves. So when the Sun and Moon are aligned, what do you expect the tides to look like?

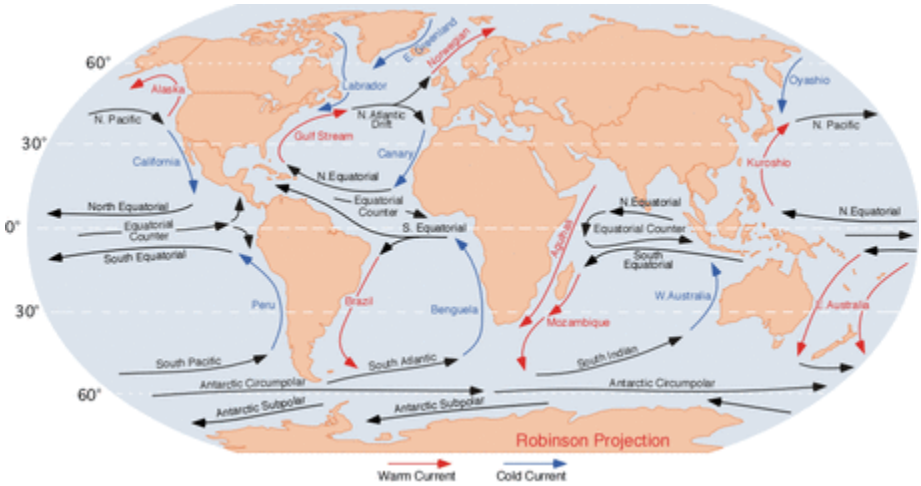
Waves are additive so when the gravitational pull of both bodies is in the same direction the high tides add and the low tides add. Highs are higher and lows are lower than at other times through the month. These more extreme tides, with a greater tidal range, are called **spring tides**. Spring tides don't just occur in the spring; they occur whenever the Moon is in a new-moon or full-moon phase, about every 14 days. The National Oceanic and Atmospheric Administration (NOAA) has a simple diagram of this process.

Neap tides are tides that have the smallest tidal range, and they occur when the Earth, the Moon, and the Sun form a 90o angle. They occur exactly halfway between the spring tides, when the Moon is at first or last quarter. How do the tides add up to create neap tides? The Moon's high tide occurs in the same place as the Sun's low tide and the Moon's low tide in the same place as the Sun's high tide. At neap tides, the tidal range relatively small. Here is another simple animation of spring and neap tides from NOAA.

High tides occur about twice a day, about every 12 hours and 25 minutes. The reason is that the Moon takes 24 hours and 50 minutes to rotate once around the Earth so the Moon is over the same location 24 hours and 50 minutes later. Since high tides occur twice a day, one arrives each 12 hours and 25 minutes. What is the time between a high tide and the next low tide? This animation shows the effect of the Moon and Sun on the tides.

Some coastal areas do not follow this pattern at all. These coastal areas may have one high and one low tide per day or a different amount of time between two high tides. These differences are often because of local conditions, such as the shape of the coastline that the tide is entering.

Surface Currents



Ocean water moves in predictable ways along the ocean surface.**Surface currents** can flow for thousands of kilometers and can reach depths of hundreds of meters. These surface currents do not depend on weather; they remain unchanged even in large storms because they depend on factors that do not change.

Surface currents are created by three things: *global wind patterns*, the *rotation of the Earth*, and the *shape of the ocean basins*.

Surface currents are extremely important because they distribute heat around the planet and are a major factor influencing climate around the globe.

GLOBAL WIND CURRENTS

Winds on Earth are either global or local. Global winds blow in the same directions all the time and are related to the unequal heating of Earth by the Sun — that is, more solar radiation strikes the equator than the polar regions -- and the rotation of the Earth — that is, the **Coriolis effect**. The causes of the global wind patterns will be described in detail later when we look at the atmosphere. Water in the surface currents is pushed in the direction of the major wind belts:

- **trade winds**: east to west between the equator and 30 degrees North and 30 degrees South
- **westerlies**: west to east in the middle latitudes
- **polar easterlies**: east to west between 50 degrees and 60 degrees north and south of the equator and the north and south pole

ROTATION OF THE EARTH

Wind is not the only factor that affects ocean currents. The Coriolis effect describes how Earth's rotation steers winds and surface ocean currents. Coriolis causes freely moving objects to appear to move to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. The objects themselves are actually moving straight, but the Earth is rotating beneath them, so they seem to bend or curve.

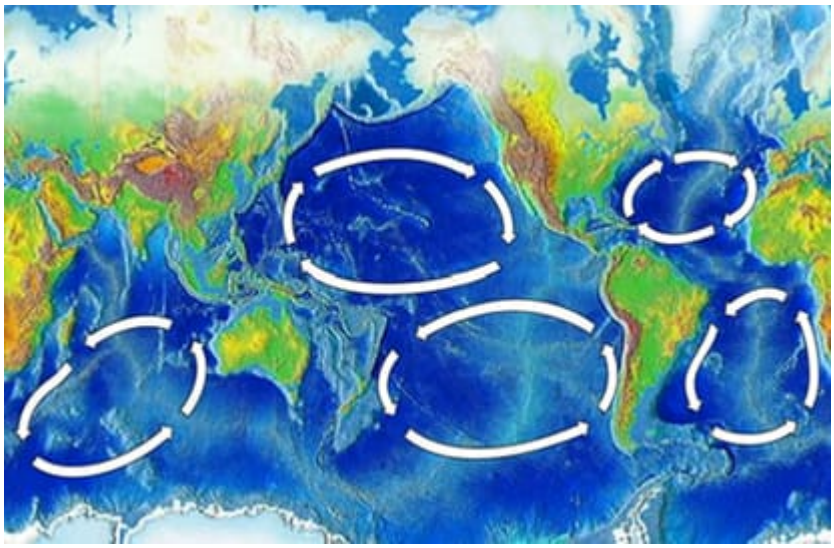
An example might make the Coriolis effect easier to visualize. If an airplane flies 500 miles due north, it will not arrive at the city that was due north of it when it began its journey. Over the time it takes for the airplane to fly 500 miles, that city moved, along with the Earth it sits on. The airplane will therefore arrive at a city to the west of the original city (in the Northern Hemisphere), unless the pilot has compensated for the change. So to reach his intended destination, the pilot must also veer right while flying north.

As wind or an ocean current moves, the Earth spins underneath it. As a result, an object moving north or south along the Earth will appear to move in a curve, instead of in a straight line. Wind or water that travels toward the poles from the equator is deflected to the east, while wind or water that travels toward the equator from the poles gets bent to the west. The Coriolis effect bends the direction of surface currents to the right in the Northern Hemisphere and left in the Southern Hemisphere. Coriolis effect is demonstrated using a metal ball and a rotating plate in this video. The ball moves in a circular path just like a freely moving particle of gas or liquid moves on the rotating Earth.	An interactive or media element has been excluded from this version of the text. You can view it online here: http://pb.libretexts.org/es/?p=94

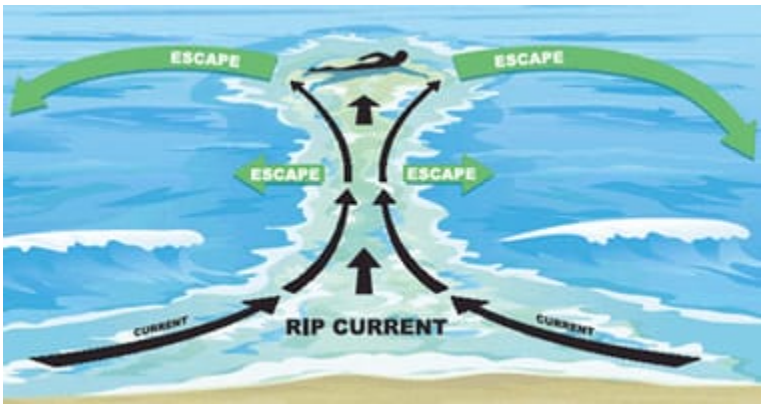
Shape of the Ocean Basin

When a surface current collides with land, the current must change direction. In the figure below, the Atlantic South Equatorial Current travels westward along the equator until it reaches South America. At Brazil, some of it goes north and some goes south. Because of Coriolis effect, the water goes right in the Northern Hemisphere and left in the Southern Hemisphere.

You can see on the map below the major surface ocean currents that the surface ocean currents create loops called **gyres**. The Antarctic Circumpolar Current is unique because it travels uninhibited around the globe. Why is it the only current to go all the way around?

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Local and Surface Currents



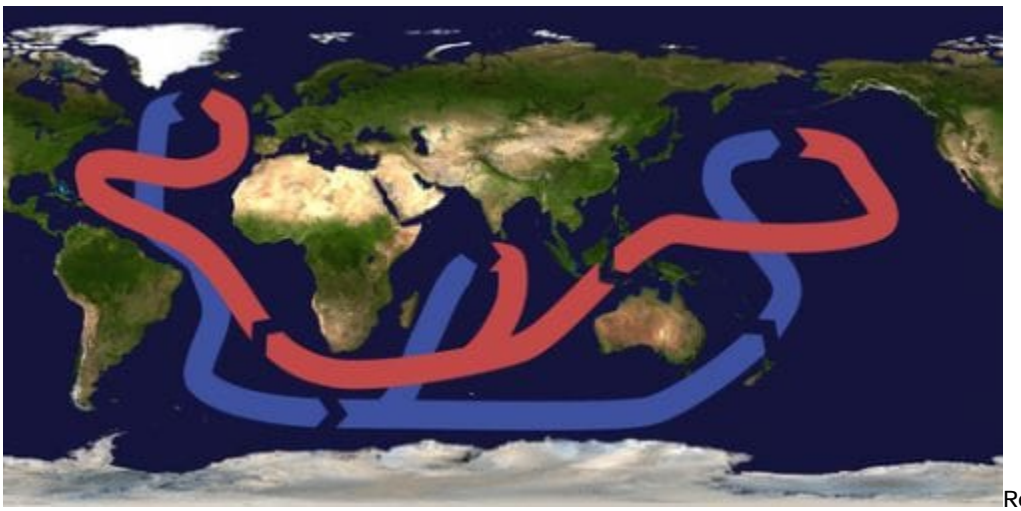
The surface currents described above are all large and unchanging. Local surface currents are also found along shorelines. Two are *long shore currents*and *rip currents*. **Rip currents** are potentially dangerous currents that carry large amounts of water offshore quickly. Look at the rip-current animation to determine what to do if you are caught in a rip current. Each summer in the United States at least a few people die when they are caught in rip currents.

Surface currents play an enormous role in Earth's climate. Even though the equator and poles have very different climates, these regions would have more extremely different climates if ocean currents did not transfer heat from the equatorial regions to the higher latitudes.

The Gulf Stream is a river of warm water in the Atlantic Ocean, about 160 kilometers wide and about a kilometer deep. Water that enters the Gulf Stream is heated as it travels along the equator. The warm water then flows up the east coast of North America and across the Atlantic Ocean to Europe. The energy the Gulf Stream transfers is enormous: more than 100 times the world's energy demand.

The Gulf Stream's warm waters raise temperatures in the North Sea, which raises the air temperatures over land between 3 to 6 degrees C (5 to 11 degrees F). London, U.K., for example, is at the same latitude as Quebec, Canada. However, London's average January temperature is 3.8 degrees C (38 degrees F), while Quebec's is only -12 degrees C (10 degrees F). Because air traveling over the warm water in the Gulf Stream picks up a lot of water, London gets a lot of rain. In contrast, Quebec is much drier and receives its precipitation as snow.

Deep Currents



Red arrows indicate surface water currents and blue arrows indicate deep water currents.

Thermohaline circulation drives deep ocean circulation. Thermo means heat and haline refers to salinity. Differences in temperature and in salinity change the density of seawater. So thermohaline circulation is the result of density differences in water masses because of their different temperature and salinity.

What is the temperature and salinity of very dense water? Lower temperature and higher salinity yield the densest water. When a volume of water is cooled, the molecules move less vigorously so same number of molecules takes up less space and the water is denser. If salt is added to a volume of water, there are more molecules in the same volume so the water is denser.

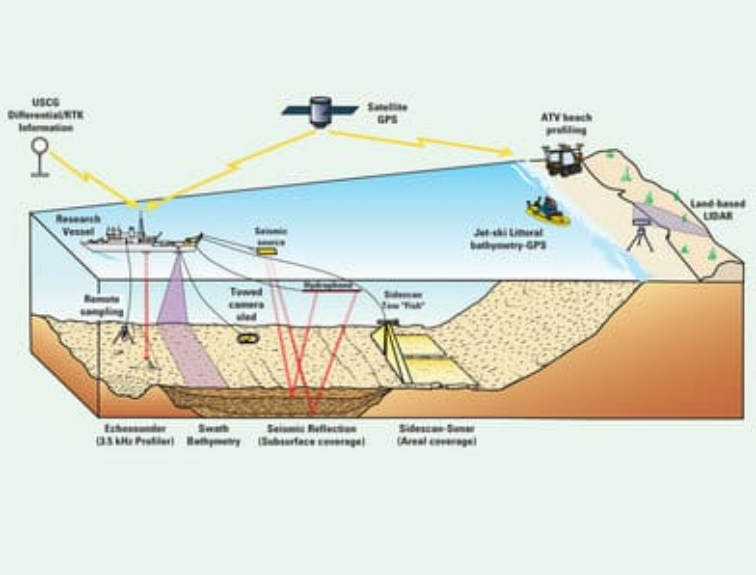
Changes in temperature and salinity of seawater take place at the surface. Water becomes dense near the poles. Cold polar air cools the water and lowers its temperature, increasing its salinity. Fresh water freezes out of seawater to become sea ice, which also increases the salinity of the remaining water. This very cold, very saline water is very dense and sinks. This sinking is called **downwelling**.

Two things then happen. The dense water pushes deeper water out of its way and that water moves along the bottom of the ocean. This deep water mixes with less dense water as it flows. Surface currents move water into the space vacated at the surface where the dense water sank. Water also sinks into the deep ocean off of Antarctica. Since unlimited amounts of water cannot sink to the bottom of the ocean, water must rise from the deep ocean to the surface somewhere. This process is called **upwelling**.

Generally, upwelling occurs along the coast when wind blows water strongly away from the shore. This leaves a void that is filled by deep water that rises to the surface. Upwelling is extremely important where it occurs. During its time on the bottom, the cold deep water has collected nutrients that have fallen down through the water column. Upwelling brings those nutrients to the surface. Those nutrient support the growth of plankton and form the base of a rich ecosystem. California, South America, South Africa, and the Arabian Sea all benefit from offshore upwelling.

Upwelling also takes place along the equator between the North and South Equatorial Currents. Winds blow the surface water north and south of the equator so deep water undergoes upwelling. The nutrients rise to the surface and support a great deal of life in the equatorial oceans.

Studying the Seafloor



Oceanographers like to say that we know more about the dark side of the Moon than we do about the oceans. That statement is doubly true of the seafloor. Although modern technology has allowed us to learn more about the seafloor, vast regions remain unexplored. Scuba divers can only dive to about 40 meters and they cannot stay down there for very long. Although this is good for researching the organisms and ecosystems very near a coast, most oceanic research requires accessing greater depths.

MAPPING

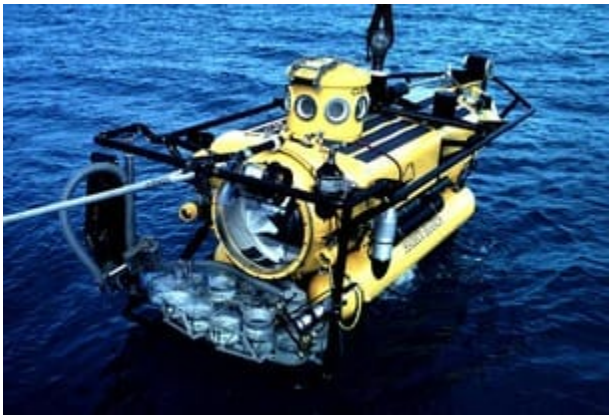
In the Plate Tectonics chapter you learned that echo sounders designed to locate enemy submarines allowed scientists to create

bathymetric maps of the seafloor. Prior to this advance, explorers mapped a small amount of the seafloor by painstakingly dropping a line over the side of a ship to measure the depth at one tiny spot at a time.

SAMPLING REMOTELY

Samples of seawater from different depths in the water column are needed to understand ocean chemistry. To do this bottles are placed along a cable at regular depths and closed as a weight is dropped down the cable. The water trapped in the bottle can be analyzed later in a laboratory.

Scientists are also interested in collecting rock and sediment samples from the seafloor. A dredge is a giant rectangular bucket that is dragged along behind a ship to collect loose rocks. Gravity corers are metal tubes that fall to the seafloor and slice into the sediments to collect a sample. The research vessel, the Joides Resolution, drills deep into the seafloor to collect samples of the sediment and ocean crust. Scientists analyze the samples for chemistry and paleomagnetism.



SUBMERSIBLES

Samples of seawater and rocks can be collected directly by scientists in a **submersible**. These subs can take scientists down to make observations and the subs have arms for collecting samples. The submersible Alvin is an HOV, a human operated vehicle. Alvin can dive up to 4,500 m beneath the ocean surface and has made more than 4000 dives since 1964. Other submersibles can dive deeper. View a slide show of DSV Alvin and its history from the Woods Hole Oceanographic Institution

REMOTELY OPERATED VEHICLES

To avoid the expense, dangers, and limitations of human missions under the sea, remotely operated vehicles or ROV's, allow scientists to study the ocean's depths by using small vehicles carrying cameras and scientific instruments. ROVs were used to study the Titanic, which would have been far too dangerous for a manned sub to enter. Scientists control ROVs electronically with sophisticated operating systems.

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2: Climate and Carbon Cycle

Video

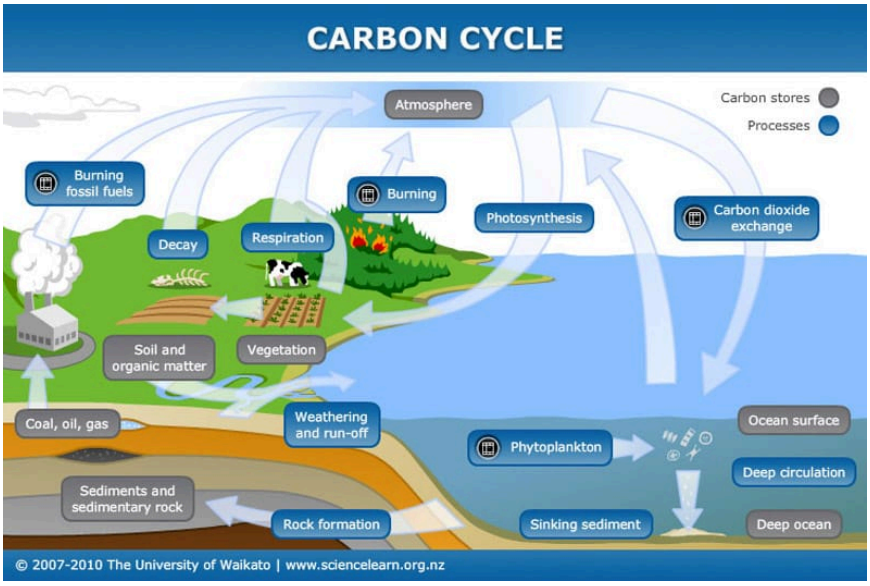
This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this Video online

What is the Carbon Cycle?

https://oceanservice.noaa.gov/facts/carbon-cycle.html

The carbon cycle can be described as the flux of carbon between the Earth's sediments, life, the atmosphere, and the ocean. The amount of carbon present within all these systems is always the same but the amount it can be in each form can vary with time and with increased human activities.



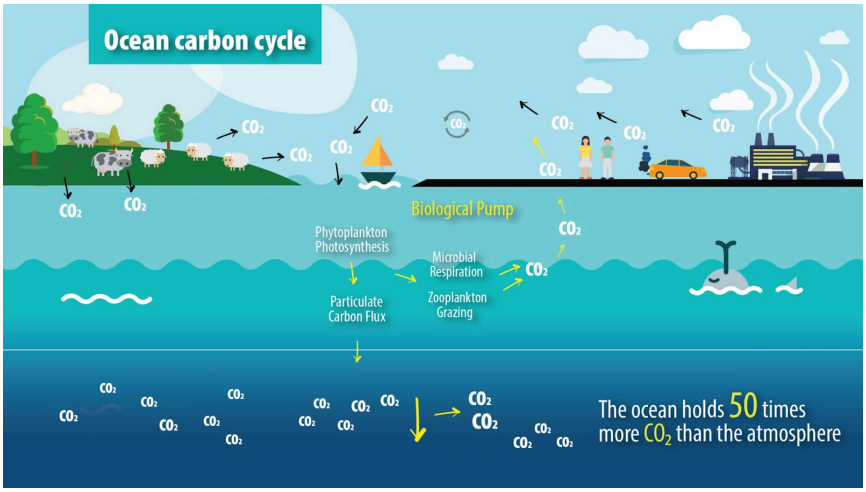
The Carbon Cycle: a map illustrating how carbon moved thought the environment.

https://www.sciencelearn.org.nz/resources/689-the-ocean-and-the-carbon-cycle

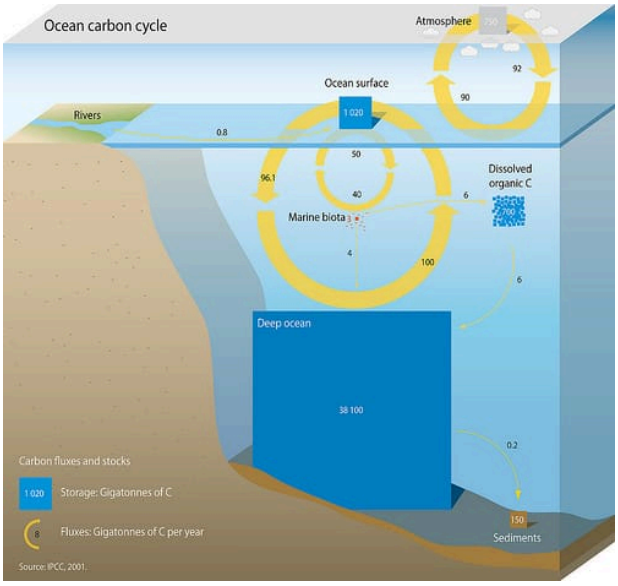
As depicted in the figure above, we can see that there are multiple natural and unnatural sources of carbon dioxide present in the atmosphere, which release carbon. Some of these natural sources include respiration of macro- and microorganisms, the decay of organic material, and fire. Burning fossil fuels is an example of an unnatural carbon dioxide source. Carbon sinks, which absorb carbon, are also present in this cycle and include photosynthesis and carbon dioxide exchange with the ocean. The ocean takes in nearly 48% of all CO2 emissions from fossil fuel burning (NASA). Data produced by NASA describes how carbon moves throughout these pools described as the Geosphere (rock), Atmosphere (gases), Biosphere (life), and the Hydrosphere (water), at a constant equilibrium that has been thrown off-balance by the amount of anthropogenic atmospheric carbon dioxide emissions. We can't rely on the ocean as a carbon source indefinitely; we know from studies that increased carbon dioxide is harmful to marine organisms, such as corals, and oceanic circulation cycles including thermohaline circulation.

Since the industrial revolution, humans have been burning fossil fuels and pumping more CO2 into the atmosphere leading to serious alterations to the carbon cycle. Without the burning of fossil fuels, the net amount of CO2 in the atmosphere remains the

same as it moves throughout various forms. The biggest source of carbon on earth is within sediments on land and in the ocean. This means that when we extract and burn coal and fossil fuels the sediments, we are adding carbon to the atmosphere. This is different than burning wood because the carbon within trees is taken from the atmosphere and therefore a part of the carbon cycle while the carbon from these sediment sources was not. This is a problem because we are adding carbon to the atmosphere and the carbon cycle. This has serious implications for the ocean because as the atmosphere becomes more saturated with CO2, more of it dissolves into the oceans. The mixing of CO2 in the oceans leads to ocean acidification; which can have a series adverse effect on all kinds of marine life (See our section on Ocean Acidification [Add Link on LibreTexts]).



This image shows the global carbon cycle but with a focus on the ocean. Also, note the main organisms in the ocean that help facilitate the process. https://www.sciencelearn.org.nz/resources/689-the-ocean-and-the-carbon-cycle



The distribution of carbon in the ocean varies starkly between actors in the carbon cycle. This will ultimately influence the global circulation of carbon. Note the differences in the amount of carbon stored between the deep ocean, surface ocean, and sediments below. https://en.Wikipedia.org/wiki/Oceanic_carbon_cycle

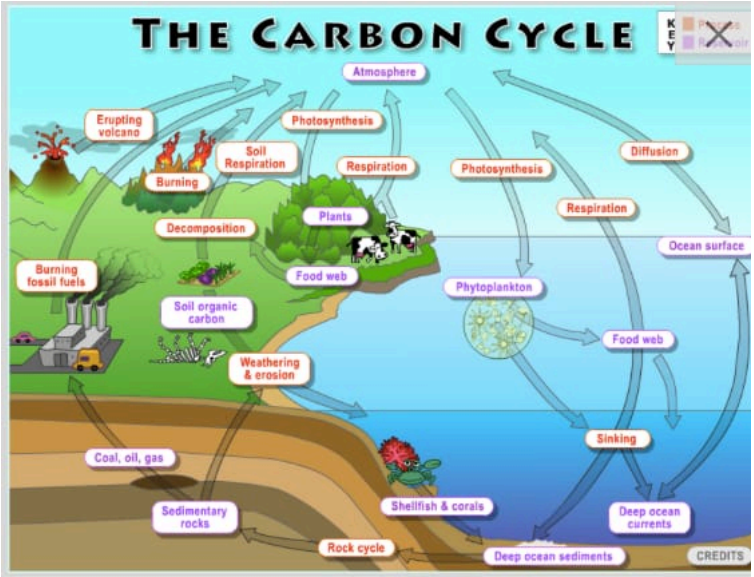


Diagram showing the physical, biological, and chemical processes affiliated with the Carbon Cycle. https://serc.carleton.edu/eslabs/carbon/index.html

Multimedia - Carbon Cycle Interactive Diagram

https://www.sciencelearn.org.nz/resources/689-the-ocean-and-the-carbon-cycle

Use this interactive diagram to explore the various ways that carbon movies from the earth to the atmosphere, and the ocean.

Video - Southern Ocean Carbon Sink

Watch video this video to see the current state of our southern oceans and how the carbon cycle is being affected by climate change.

Carbon Cycle Glossary

Here is a link to a Carbon Cycle Glossary

References

1.https://www.sciencelearn.org.nz/resources/689-the-ocean-and-the-carbon-cycle

2. The Global Carbon Cycle Crash Course Video

3. 5 Human Impacts on the Environment: Crash Course Ecology

4. "Carbon Cycle | Science Mission Directorate." *Science.nasa.gov*. N. p., 2019. Web. 7 Mar. 2019.

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3: El Niño and La Niña

As we saw in the previous section, coastal upwelling off of Peru makes that region one of the world's most productive fishing grounds. But every so often, the conditions in the region are very different. Every few years, the cold, nutrient-rich water is replaced by unusually warm water that is low in nutrients, leading to a decline in fish populations. In addition, the normally dry areas receive lots of rain. Because this phenomenon occurs in the northern winter close to Christmas, it is called **El Niño** (the child). More formally, the event is referred to as **El Niño-Southern Oscillation (ENSO)**. The Southern Oscillation portion refers to the fluctuating atmospheric conditions that lead to the localized ocean warming of El Niño. While the exact reasons for the oscillation events are unclear, it is easier to understand how they lead to an El Niño.

Under normal conditions in the equatorial Pacific, the trade winds blow towards the west, moving large amounts of warm surface water towards the western Pacific around Southeast Asia. As the surface water moves west, it is replaced by cold, nutrient-rich deep water through upwelling (Figure 3.1). The coastal upwelling leads to a shallow thermocline in the eastern Pacific. In terms of atmospheric conditions, the trade winds are part of a convection cell called the Walker Cell. There is low pressure over the western Pacific, leading to rising moist air and significant precipitation in the region. In the eastern Pacific near South America, there is high pressure, leading to drier conditions (Figure 3.1).

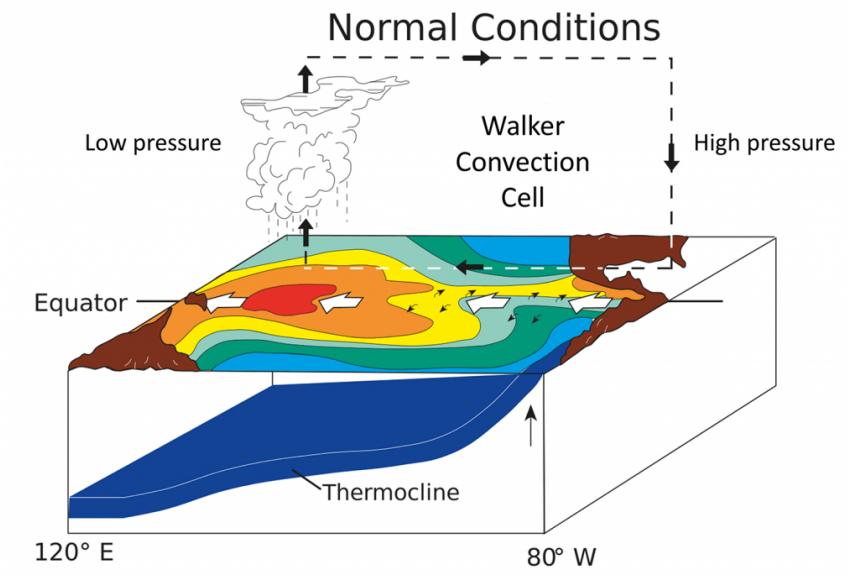


Figure 3.1 Normal conditions in the equatorial Pacific. Low pressure in the western Pacific and high pressure in the eastern Pacific cause the trade winds to move surface water to the west, leading to upwelling and a shallow thermocline near South America (Modified by PW from Fred the Oyster (Own work) [Public domain], via Wikimedia Commons).

During an El Niño-Southern Oscillation, the high pressure system over the eastern Pacific diminishes, so the trade winds are weakened, or in extreme cases will even reverse. When this happens, warm surface water begins to flow east across the Pacific towards South America (Figure 3.2), warming the coastal South American water by up to 8^{o} C in strong ENSO years. This influx of low density warm water deepens the thermocline and prevents upwelling, which dramatically reduces productivity and can devastate populations of fish and other marine life.

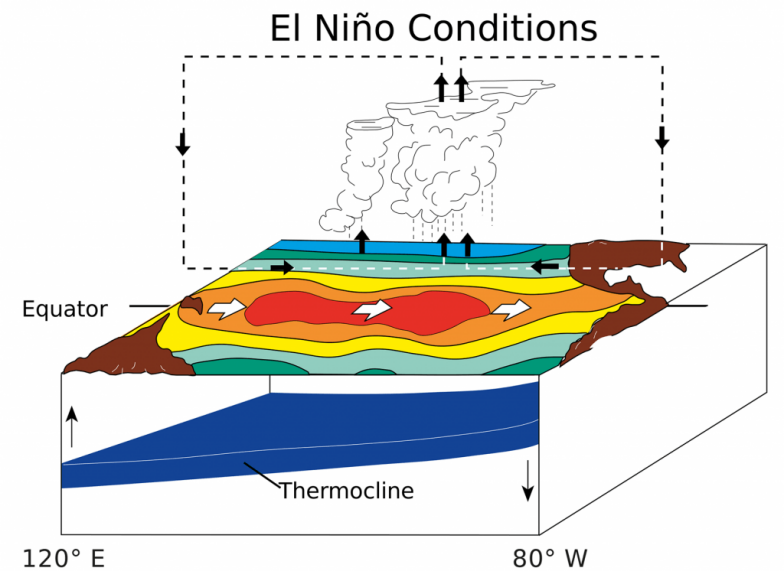


Figure 3.2 El Niño conditions in the equatorial Pacific. Weakening or reversal of the trade winds transport warm surface water eastward towards South America, disrupting coastal upwelling (Public domain, via Wikimedia Commons).

In the atmosphere, the low pressure system in the western Pacific is replaced by high pressure, bringing dry or even drought conditions to Southeast Asia and Australia. The low pressure system moves east across the Pacific, potentially reaching as far as South America in strong El Niño years. The low pressure over the eastern Pacific brings lots of rain and flooding to South America (Figure 3.2). But the effects of El Niño are not just limited to the Pacific; it can influence weather patterns throughout the globe (see box below).

Because the Southern Oscillation is a cyclic pattern, the eastern Pacific is not subject just to unusually warm conditions. There are also periods of abnormally cold water in the region known as **La Niña** events. During a La Niña the trade winds are unusually strong, leading to increased upwelling and transport of deep, cold water to the surface (Figure 3.3). The effects of a La Niña are essentially the opposite of an El Niño, bringing cooler and wetter conditions to the northwestern United States and Canada, while the southeastern US receives below-average precipitation. Monsoon seasons in Asia are drier during El Niños but wetter during La Niña events.

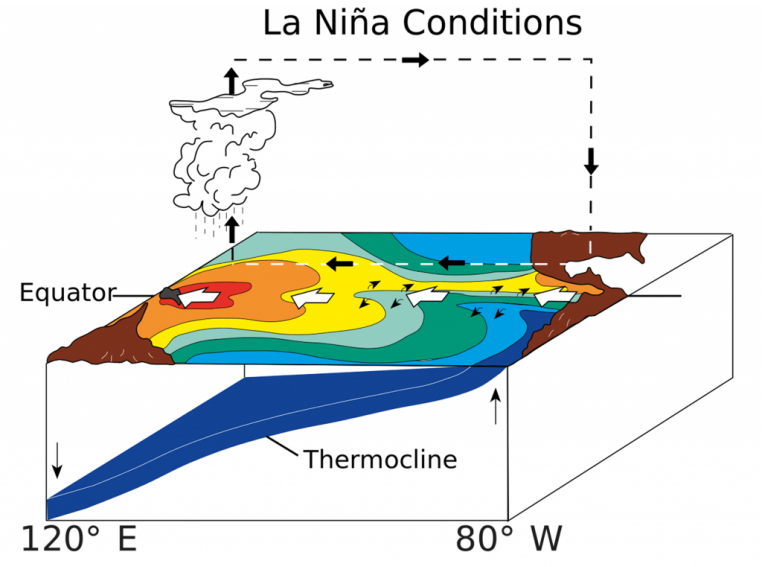


Figure 3.3 La Niña conditions. Stronger trade winds promote more intense upwelling in the eastern Pacific, leading to cooler than usual water temperatures (Public domain, via Wikimedia Commons).

El Niño and La Niña events alternate, although the presence of one does not always mean the other will automatically follow. El

Niños occur roughly every 2-7 years, and each event may last from a few months to a year or more. Although we do not understand exactly why or when the ENSO events will occur, we can anticipate their arrival by monitoring a number of ocean and atmospheric phenomena that make up the Multivariate ENSO Index (MEI). Examination of the MEI over time demonstrates the cyclic nature of ENSO events (Figure 3.4).

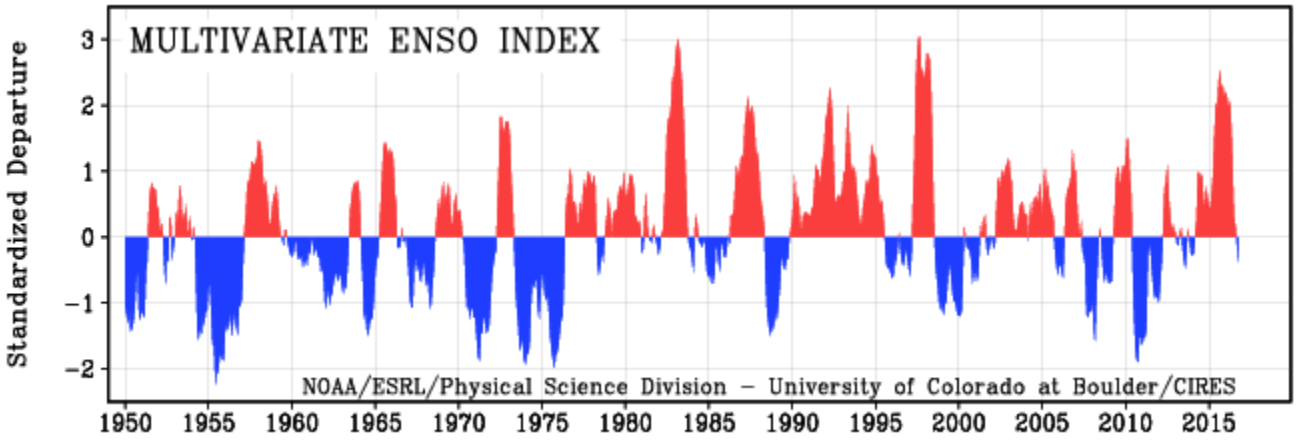


Figure 3.4 Multivariate ENSO Index over time. Positive (red) values indicate warmer than normal conditions, while negative (blue) values represent conditions that are cooler than average. The greater the deviation from zero, the stronger the event. Note the intense El Niños in 1983, 1997-1998, and 2015 (NOAA, https://www.esrl.noaa.gov/psd/enso/mei/).

Figure 3.5 shows a comparison of sea surface temperatures in the equatorial Pacific during normal, El Niño, and La Niña periods.

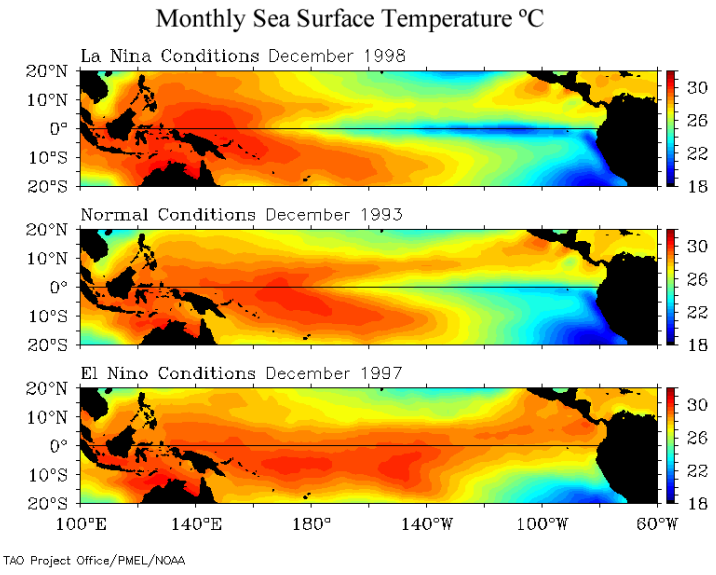


Figure 3.5 Comparison of mean December sea surface temperatures in the equatorial Pacific during La Niña (top), normal (middle), and El Niño (bottom) conditions (NOAA, http://www.pmel.noaa.gov/elnino/site...mal-elnino.gif).

Impacts of El Niño

The 2014-2016 El Niño was one of the strongest ENSO events on record (Figure 3.4). Some of the recorded global impacts of this El Niño included:

- Widespread droughts in the Philippines and many South Pacific island nations.
- Severe coral bleaching on the Great Barrier Reef in Australia.
- One of the most destructive bushfire seasons in Australia, in part due to low rainfall.
- High rainfall in the southeastern United States and parts of California, leading to flooding.

- Mild, low-precipitation winter in the New England region of the United States.
- Severe flooding in Peru and Argentina.
- Droughts in many portions of southern Africa.
- Nearly 100 million people worldwide suffered a lack of food or water from flooding and droughts.
- Peru suspended its second anchovy fishing season due to low biomass, and an anticipated 20% reduction in the yearly catch.

Additional links for more information

- What are the current ENSO conditions?: https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml

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4: The Warming of Our Oceans

When talking about the warming of our oceans, it's important to first talk about global warming. Is global warming real?

This topic has been debated for years and even more so now with the new United States president. This topic has sparked a great debate among caring citizens, politicians, and news outlets on whether or not global warming is real or a hoax. However, scientists all over the world have scoured over all relevant data and facts and harmoniously agree the planet is indeed warming.

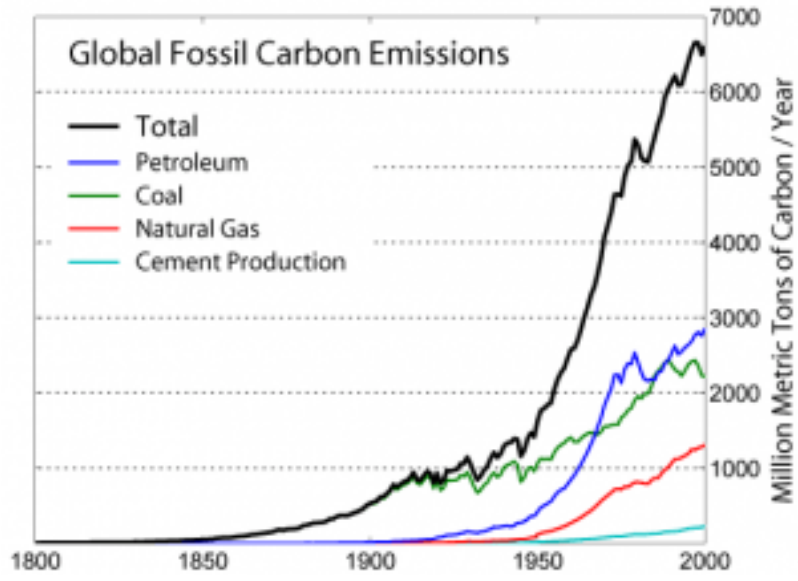
Many might ask, "well what exactly is global warming?". Global warming is the term used to describe a gradual increase in the average temperature of the Earth's atmosphere and its oceans; a change that is believed to be permanently changing the Earth's climate.

There are cold hard facts that prove climate change is prevalent. The EPA has over forty data contributors from different government agencies that provide indicators of the cause and effects of climate change. These indicators effect the oceans in detrimental ways like thermal stress, ("stress in a body or structure due to inequalities of temperature"), and the warming of the oceans.

Greenhouse Effect

The greenhouse effect is the result of greenhouse gases trapping heat in the Earth's atmosphere radiating from earth toward space, resulting in the warming of the oceans and melting glaciers. When the glaciers melt, it increases the sea level which adds to the ocean that is already expanding.

Examples of greenhouse gases are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor (H_2O). From 1990-2010 gas emissions caused by humans have increased by 35%. Electricity generation is the worlds largest contributer of emissions followed by transportation. Climate forcing, which is a change in the earth's energy balance that results in a warming or a cooling effect on the climate. Over the past several years we have also steadily increased our use of fossil fuels, which has ultimately produced 5x more carbon dioxide emissions.The graph below shows how our use of fossil fuel emissions has skyrocketed in the last decade.



"Global Carbon Emission" by Wikimedia Commons [CC by 2.0]

How is the warming ocean impacting the marine life?

One of the most vulnerable organisms to global warming is coral. Higher temperatures cause coral bleaching, which results in

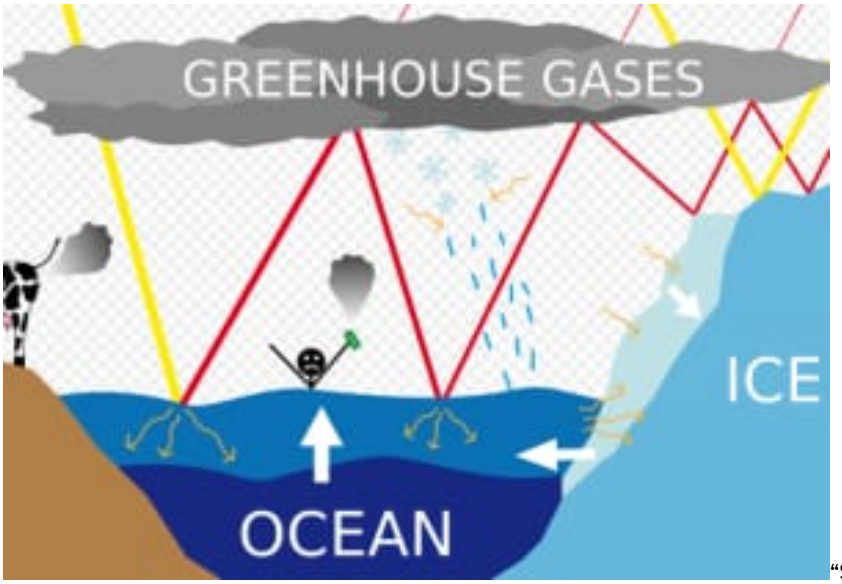
disease, lack of nutrients and even death of the coral. The zooxanthellae's enzyme systems are effected from rising temperatures which makes it hard to protect the coral from toxicity. Even an increase of 1-2 degrees Celsius can cause bleaching. Coral Bleaching occurs when corals experience stress such as temperature change. This harms corals because they have a limited temperature range in which they can live. When water is above the corals ideal temperature, the coral expels the symbiotic algae that reside in its tissue and provide it with nutrients. This turns the reefs a ghostly white (thus the term 'bleached'), and, while the coral is not exactly *dead* at that point, it is more susceptible to diseases which lead to death.


"Coral Bleaching" by Wikipedia [CC by 2.0]

As humans burn fossil fuels and release carbon dioxide, those gases enter the atmosphere where they cause an increase in global temperature. However, did you know that **not** all of the carbon dioxide ends up in the atmosphere? In fact, about 40% is said to get absorbed by the ocean waters. The amount of carbon dioxide that the ocean can hold is dependent upon the temperature of the ocean. For example, colder water can absorb more carbon where warmer water absorbs less. Today, scientists believe that as the oceans warm they will become less and less capable of taking up and absorbing carbon dioxide. As a result, more of our carbon pollution will stay in the atmosphere and therefore further the contribution to global warming. For now, the oceans are considered our saviors by absorbing large amounts of our carbon pollution. This buys us some time to reduce our use of fossil fuels. However, there is always a consequence. The increased carbon uptake by the ocean means that the ocean waters will become acidic more rapidly than they otherwise would. This acidification threatens many components of the food chain.

When the ocean temperature increases, this can cause a bottleneck in the food chain, which can result in an interruption in the marine food web. The higher the temperature, the higher the growth of zooplankton. Zooplankton reproduce faster than the phytoplankton and end up eating all of the plankton in an area. This can have a drastic effect on any organism that feeds off of them.

Rising sea levels are a result of the ocean expanding from warming. When the sea levels rise, they interrupt ecosystems and habitats of thousands of organisms such as sea turtles and seals. A rise in sea level results in coastal flooding, which has increased in the United States on coastlines such as the Carolina's, New Jersey, and Maryland. Floods are now 10 times more likely to happen than they were years ago. These floods are endangering species and ruining coastline habitats.



“Sea-Level-Rise” by Wikimedia Commons [CC by 2.0]

The information in this chapter in thanks to the content contributions from Haley Zanga and Marisa Benjamin

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- Data Structure and Algorithms (Njoroge) by Harrison Njoroge is licensed CC BY-SA 4.0. Original source: https://oer.avu.org/handle/123456789/679.

5: Ocean Acidification

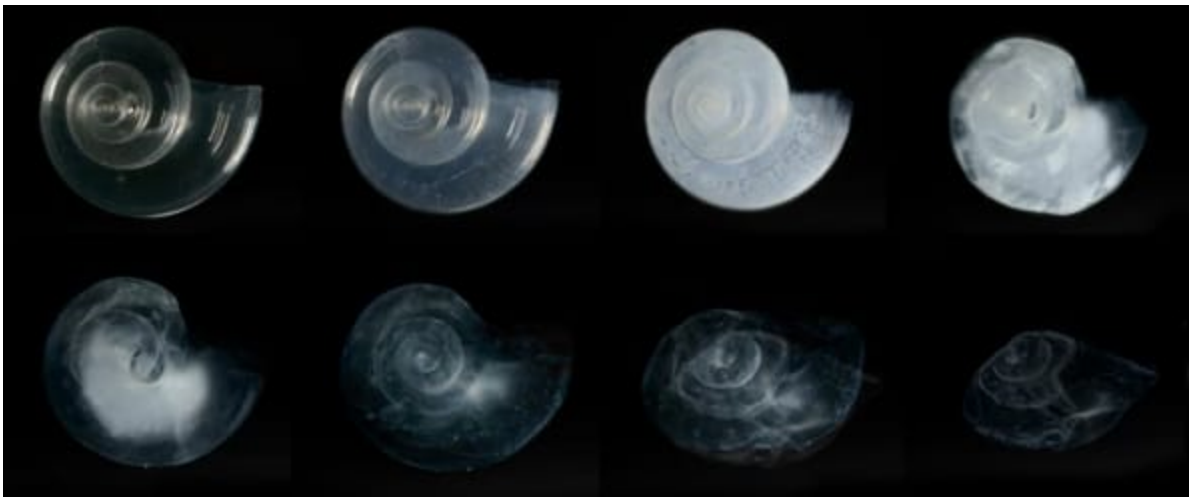
Ocean acidification is simply the decrease in the pH of all of the oceans on Earth. But is it really that simple? The answer is no, it is not that simple. The ocean absorbs about 25% of the atmosphere's carbon dioxide or CO_2, and as atmospheric CO_2 levels increase, so does the amount of CO_2 that the ocean absorbs. Therefore, as the amount of greenhouse gases increase, not only does the temperature of the ocean begin to rise, but the increase in CO_2 levels causes the ocean's pH levels to decrease. The rising acidic conditions cause a multitude of deleterious effects from limiting the formation of skeletons for marine organisms, to limiting coral growth, and corroding already existing coral skeletons.

While natural levels of carbon dioxide are fine, the excess CO_2 that humans have managed to produce through burning fuels are the major problem. This is largely because when CO_2 dissolves in the sea water, (CO_2 + H_2O-> H_2CO_3), it produces carbonic acid. While carbonic acid is not as strong of an acid, as say HCl, it still acts as an acid by donating protons, and interacting with surrounding molecules. Now, when excess acid is added to a solution, it causes the pH of that solution to drop, or become more acidic, and while H_2CO_3 is not considered a strong acid, it still has the potential to massively impact the entire chemical makeup of the ocean environment. The lower the pH of a solution gets, the higher the concentration of H+ ions in that solution. This has become a massive problem for many species.

Chemical reactions can be extremely sensitive to any fluctuation in pH levels, however, in the ocean, these pH changes can affect marine life through chemical communication, reproduction, as well as growth. In particular, the building of the skeletons in marine life is extremely sensitive to any change in pH. Thus, the current increase in CO_2 levels that have caused a more acidic environment, have greatly and negatively impacted the growth of new shells.


"Nautilus pompilius" by Wikimedia [CC BY SA 2.0]

This is because Hydrogen ions easily bond to carbonate (CO_3^{2-}) molecules to create carbonic acid, and a marine animal's shell consists of Calcium Carbonate ($CaCO_3$). In order for marine animals to build shells, they take Calcium ions (Ca2+) with a carbonate molecule from the seawater surrounding it, to form the Calcium Carbonate needed to build their shells . So, instead of the carbonate giving all of it's attention to Calcium so that the marine animal can build it's shell, it now pays more attention to the Hydrogen ion. In addition, Hydrogen ions have a greater attraction to carbonate, than a Calcium ion does to carbonate, and when two Hydrogen ions bind to carbonate, it produces a bicarbonate ion, and a marine animal does not have the capability to extract only the carbonate ion . Ultimately, this limits marine animals from building any new shells for themselves, and even if the marine animal has the ability to build a new shell, it takes a lot of energy to do so, essentially taking away from other important processes and activities.



“Impacts of Ocean Acidification” by Wikimedia [CC BY SA 2.0]

Not only can this affect the formation of new shells, but in the right conditions, it can corrode already existing shells. When there are too many Hydrogen ions floating around, and not enough molecules for them to bind to, they can actually start breaking the already existing Calcium Carbonate molecules apart, ultimately breaking down the marine animal’s shell that already exists.

Another organism that feels the effects of ocean acidification are corals. Similar to other marine animals that build their homes with calcium carbonate, reef-building corals also use calcium carbonate to build their own bodies and structures. These reef-building corals are also home to other coral animals and other organisms. As mentioned before, the increased acidification greatly limits any further growth of new coral, as well as corrodes any pre-existing coral reefs. Even if a coral reef has surpassed all the odds, and has been able to grow, it will be a weaker reef that is subject to natural erosion. It has been predicted that by the middle of the century, healthy coral reefs will be eroding more quickly than can be reproduced.



“Blue Starfish on Hard Coral” by Wikimedia [CC by 3.0]

This is bad news for the species that live in these coral reefs. If these species are not able to grow and develop in a safe settlement, such as the coral reef, these larvae will be unable to reach adulthood , thus being unable to reproduce. This will ultimately lead to a mass extinction in the future.

The information in this chapter in thanks to content contributions from Jaime Marsh and Morgan Tupper.

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6: POLLUTION- SOURCES AND TYPES

6.1: Introduction
6.2: Plastics in Our Oceans
6.3: Noisy Oceans
6.4: Eutrophication
6.5: Harmful Algal Blooms
6.6: Oil Spills and Marine Life

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6.1: Introduction

There are two sources of pollution: point source (PS) and non-point (NPS) pollution. 80% marine pollution comes from the land. NPS is considered one of the largest source of pollution which accrues as a result of agricultural runoff.

- **Point Source**: Sources of pollution that directly pollutes the water. Examples include: septic tanks, cars, boats, etc.
- **Non-Point Source**: Sources of pollution that indirectly pollutes the water. Examples include, urban agricultural lands, etc.

According to the EPA Victoria, there are two types of pollution sources, the point and nonpoint. The point source pollution is defined as a single source of pollution that runoff from a pipe or a drain to the sea or ocean. Besides, the federal and the state require businesses, cities, or industries to have limited permit of allowing pollutants pipes and drains. However, the cost of protecting this pollution is costly and the EPA is trying to create regulation that best preventing pollutants to the sea and ocean.

On the other hand, the nonpoint source pollution is defined as a result of runoff from urban land use, agricultural land use, and forestry land use. In urban area, storm water such as rainfall is a major pollution because it affects the water quality of the water ways and bays. Despites this, the storm water can carry car oil and chemicals from constructions site to the sea or ocean. When this occurs, it can affect the aquatic species and impact human health.

As the world's population growth increase and technology continues to spread worldwide, the navigation of the ocean has become a shipping route and dumping ground for human activities. The continuations of human activities deplete biodiversity and disrupt the natural ecosystem in the ocean. According to the Science Learning, wasting such as chemical, sewage, and industrial run-off have a big problem worldwide. Besides that, a country's without strong government to enforce existence policies, the chance of protecting and conserving ocean ecosystem seem slim. In addition to that, as countries continue to pursue economic growth, the release of carbon dioxide cause the ocean to become more acidic and warmer.

Two type of sources cause pollution for the ocean are the point source pollution and nonpoint source pollution. The point source usually come from the run-off such as "septic tanks, cars, trucks, and boats, plus larger sources, such as farms, livestock ranches, and timber harvest areas" (National Oceanic Atmospheric Administration 2011). This source has negative impact on the economic especially cities that are located along the coast. For example, the U.S Coastal and marine water support 28.3 million jobs, generate $54 billion in goods and services, and contribute $30 billion for recreational fishing. With the run-off causing dirty-looking water and die-off fishes can have financial loss for investors and workers. Overall, this can be concluding that nonpoint source pollution does not only affect the ecosystem but also the economy as well. On the other hand, the nonpoint source pollution is usually factories and sewage treatment plants. With unregulated discharge can result in unsafe drinking and lead to restrict activities such as fishing and swimming. It can also cause damage to human health and the environment when sewage plants go untreated (National Oceanic Atmospheric Administration 2011).

Nutrients and algal blooms can be a problem. With overabundant nutrients such as nitrogen and phosphorus in the ocean can also affect the living organism and overgrowth of algae. Marine debris is also harmful to the ocean because it "injures and kills marine life, interferes with navigation safety, and poses a threat to human health" (National Oceanic Atmospheric Administration 2011). This impact the fisheries industries since heavy metal and other contaminants make it harmful for people to eat. With all of this pollution, education may play a big role to help decrease pollution.

While pollution caused by oils, land run off, and sewage are bad, there is another pollution which is plastic pollution. Plastic pollution covers about 40% of the world's ocean surfaces (Hasselberger). The problem with this is that when the plastic disintegrates and breaks in to smaller pieces it sinks in to the ocean depths. Then the smaller toxic pieces of plastic are ingested by sea life causing them much harm and death.

Off of the coast of California, there is a large mass of floating plastic which is two times the size of Texas and the plastic pieces in it outnumber sea life six to one (Hasselberger). This means that for every sea creature, there are six pieces of plastic

Land Pollution

Causes

Around 80% of the pollution in our ocean is found from land, with most of it being from plastic, one of the many materials involved

in littering by humans. Other land-related sources of ocean pollution can mainly be traced back to sewage, toxic chemicals from industries, and oil spills. Littering occurs when objects that are far inland are blown into the ocean over long distances. These objects include anything from sand and dust, but mainly man-made materials such as debris and trash. This trash is mainly consisted of plastics, which essentially do not degrade. When plastics end up in the ocean, 70% of that gets deposited into the deep ocean. Animals that mistake these objects as food are killed, while other animals end up getting snagged and die rather slowly.

As the global demand for oil increases, the more amount of oil we're bringing into the oceans increases as well. As another major source of pollution, oil can spill into the ocean in a variety of ways—natural sources, from shipping operations, with a majority of oil pollution coming from drilling rigs (this image shows the sources of oil pollution: worldoceanreview.com/en/files...betrieb_en.jpg). This crude oil consists of around 10,000 individual substances, including heavy metals and nitrogen compounds, and is extremely toxic to marine animals. One of the largest oil spills recorded in history was the oil spill from the Deepwater Horizon in April 2010. Since it is extremely difficult to clean up oil spills, it can remain in the sea for years and provide devastating effects for our marine environment.

Image source: http://worldoceanreview.com/en/wor-1/pollution/oil/

Source:

http://oceanservice.noaa.gov/facts/pollution.html

http://www.epa.vic.gov.au/your-envir...ater-pollution

www.oceanservice.noaa.gov

National Oceanic Atmospheric Administration. (2011). Ocean Pollution [Data File]. Retrieved from http://www.education.noaa.gov/Ocean_...Pollution.html

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grist.org/living/a-surprising...tic-pollution/

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6.2: Plastics in Our Oceans

Plastics are an integral part of our modern lives. They are found everywhere from Home Goods to electronics, and are by far one of the most versatile and useful technologies humans have been able to harness. On top of their usefulness, plastics are easily re-purposed, with more than 40% of plastic being recycled. Although plastic helps us go about our everyday lives, it is having a serious effect on the ocean and marine life. In 1975 it was reported by the National Academy of Sciences that an estimated 14 billion pounds of garbage, much of it plastic, were being dumped into the oceans every year. Today, that number has shrunk to around 8 billion pounds a year thanks to public awareness.

So what are the effects plastic has on marine life?

For starters, "...Plastic has been found in more than 60% of all seabirds and in 100% of sea turtle species..." according to the group Ocean Conservancy To a sea turtle, a plastic bag can look extremely similar to a jellyfish, which is a common food source for them. For other species such as seabirds, fish are a common food source. When smaller pieces of plastic get consumed by small fish, the plastic will move its way up the food chain to bigger fish and bigger fish until it is consumed by a seabird, or other marine animal. The accumulation of plastic in these species impacts their health in many ways including nutrient uptake, general fitness, and feeding efficiency.


"Contrasts of Concern" by Leonard J Matthews [CC by 2.0]

While fish and turtles are motile animals, sessile species such as corals are not free from the effects of plastics in their environment either. A study has been done by Hall et al. that shows corals will consume micro-plastics at the same rate as their food. Micro-plastics are any piece of plastic under 5mm in size. The corals in this study were found to starve at a very slow rate because the plastic pieces that they were consuming overloaded their stomach and they were not getting the amount of nutrients that they needed. Corals are very non-selective feeders, but they are sensitive to their environment.

Although the oceans are huge, they are not big enough to disperse all of the plastic that winds up in them. It is estimated that there are between 15-51 trillion pieces of plastic in the worlds oceans, and due to ocean currents, millions of tons of plastics congregate in massive gyres in the ocean. There are 5 major subtropical gyres, each containing its own garbage patch. The most notorious of these is the Great Pacific Garbage Patch, an island of plastic waste 1.6 million kilometers squared in area, or three times the size of France. In this garbage patch, it is estimated that there is 6 times more plastic than plankton. Plankton is a necessary food source for some marine life. It is also up to 9 feet deep in some portions of the garbage patch. For more information on garbage patches, watch the video below:



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"Gyre" by Chris Jones via Vimeo

One of the questions this raises is how does it all get there? How does 8 million tons of plastic waste end up in the ocean each year? In the developed world, which contributes for roughly 10% of the worlds plastics problem, plastic enters our oceans through our sewer systems, and as consequences of storms and heavy rains. While the developed world contributes in part to the plastic problem, we are by no means the biggest culprit. According to the World Economic Forum, 90% of all plastic waste that pollutes our oceans comes directly from 10 rivers in China, Southeast Asia (Laos, Thailand, Vietnam, etc), Egypt, and Niger. What these areas have in common are massive populations centered around these rivers combined with poor waste management systems and general lack of education about environmental preservation.

“Garbage in the River Ganges in Varanasi” by Brett Cole Photography [CC by 4.0]

So what is being done to combat this?

There have been a number of laws put in place in an attempt to stop the plastic pollution. The Act to Prevent Pollution from Ships (APPS) (PDF) was amended in 1987 by the Marine Plastic Pollution Research and Control Act. It is meant to reduce the amount of improperly disposed plastic that is released into the environment. It also studies the effects that this plastic is having on the environment.

The Marine Debris Research, Prevention, and Reduction Act (MDRPRA) (PDF) has established programs within the National Oceanic and Atmospheric Administration (NOAA) and the United States Coast Guard. Its goal is also to reduce the amount of plastic and trash that gets put into the marine environment.

The Shore Protection Act (SPA) is another Act that was put into place in order to stop this growing problem. This Act controls the transportation of waste in coastal waters.

One of the most important Acts put into place is the Marine Protection, Research, and Sanctuaries Act (MPRSA). It is also known as the Ocean Dumping Act and it prohibits the following:

- Transporting material from the United States with the intention of ocean dumping
- Transporting material from anywhere for the purpose of ocean dumping by U.S agencies or U.S flagged ships
- The dumping of material transported from outside the U.S into the U.S. territorial sea

Outside of the US, thanks to efforts by international and local organizations, agreements have been signed and efforts are being made to reduce plastic wastes across the globe. China for example has ordered 46 cities to recycle 35% of all plastics by the year 2020, and India has begun to ban disposable plastics in some cities.

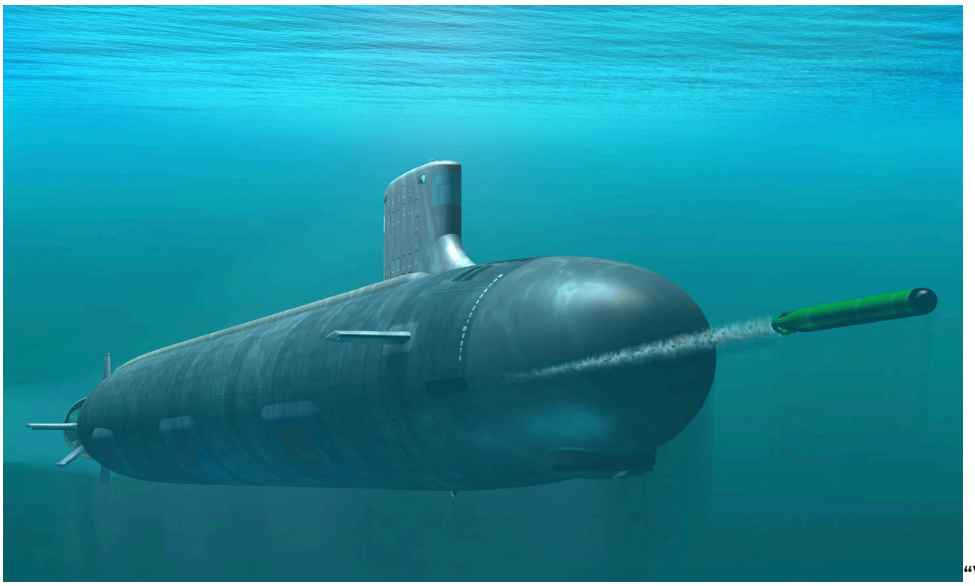
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6.3: Noisy Oceans

Human noise in the ocean is becoming a major concern. From sonar on our submarines to cargo ship traffic and even oil drilling rigs, we are filling our oceans up with lots of unnatural noise. This noise is linked to altering the calling, foraging, and migration patterns for many species. In extreme situations, scientists also believe it is a reason there have been so many beached whales.

Here is a video that shows what some different noises in the oceans sound like, and how loud they really are.


"Virginia Class Submarine" by Owly K Under U.S. Federal Government

EFFECTS OF SOUND ON WHALES

It seems that whales and dolphins are the marine animals that are most affected by the noisy oceans. Although natural noise in the ocean from wind, waves or other marine animals is a common occurrence, they are not nearly as intense as noise from humans. This more intense and frequent noise can be causing stress to whales and contributing to them beaching themselves. One scientist has said that he has seen whales abandon a location because of noise. These locations sometimes contain a food source necessary for the whales survival.

Sound waves from military submarine sonar systems can get as loud as 235 decibels. They are able to travel hundreds of miles and can maintain the intensity of 140 decibels as far as 300 miles from the source.

Cargo Ships create what is known as ambient noise. This is particularly concerning for low-frequency great whales. Right whales are endangered and it has been proven that noise from cargo ships constantly crossing the ocean is causing them stress.



“Cargo Ship” by Peter Griffin Under Public Domain

Here is a video on the process of deep water oil rigging. It would be hard to believe that these rigs don’t make a ton of noise. It is understandable that hearing noise from these rigs constantly could cause stress to a whale or confuse it considering they rely heavily on acoustics for survival.

RECENT BEACHED WHALE STORIES

On February 10th, 2017, New Zealand had over 600 Pilot whales wash ashore. Volunteers were able to save about 80 of the whales, who went on to join a nearby pod. After they were saved, later that night the pod that they joined got stranded on Farewell Spit. Although the cause of these whales stranding and beaching themselves is unknown, one theory is underwater noise. The loud sound waves that humans create can panic the whales into surfacing too quickly or swimming into the shallows.


“Whales on Beach, Farewell Split, South Island New Zealand” by Chagai Under Public Domain

In May 2016, more than 20 whales beached themselves near San Felipe, Mexico. According to one statement, there were no signs of injuries noted on the whales, but they seemed disoriented. Since the whales had no signs of injury, it is very reasonable to believe that sonar and loud ocean noise drove them out of deep water towards the beach.

Less than a year after 330 whales washed ashore on Patagonian Inlet, 70 whales were found on a beach in southern Chile.

Although they are not the same species, this is a terrible trend that is happening. The whales were smaller this time and they had been dead for about 2 months before they were found.

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6.4: Eutrophication

Eutrophication occurs when excess nutrients are introduced into a body of water. This process increases the rate of supply of organic matter in an ecosystem and stimulates aquatic plant growth. At normal levels, these nutrients feed the growth of organisms called cyanobacteria or algae. But with too many nutrients, cyanobacteria grow out of control. Excess algae block the sunlight needed by bottom-dwelling plants and lead to a decrease in oxygen in the water and consequently leads to negative outcomes.

Eutrophication occurs naturally but anthropogenic activities such as industrial effluent and runoff of fertilizers rich in nitrogen and phosphorus contribute heavily to eutrophication events. When supplied with an excess of nutrients, the algae can grow out of control. This event is known as an “algal bloom,” and disrupts the balance of the ecosystem. As described above, the increased growth blocks the availability of sunlight to benthic organisms and other plants and organisms in the photic zone. The overgrowth of algae eventually begins to die off and is broken down by microbes that consume oxygen during the decomposition process. This creates a hypoxic environment and decreases oxygen availability in the water to other organisms.

Video

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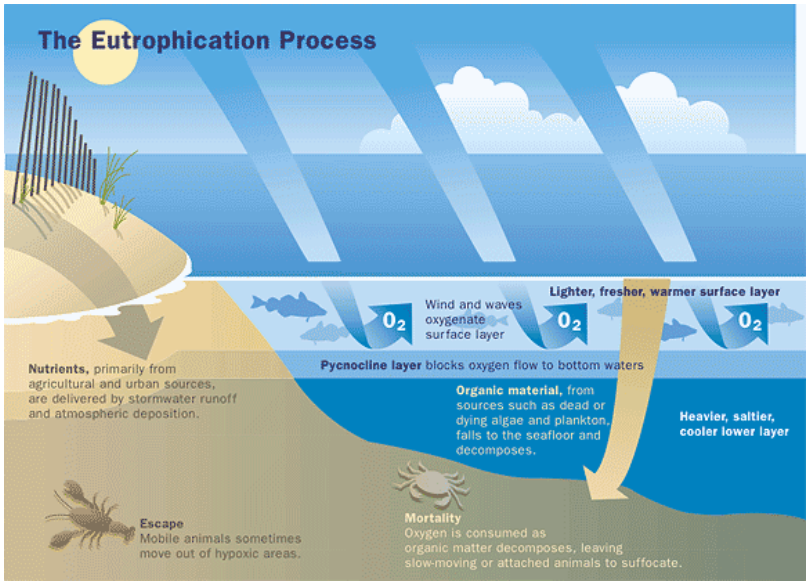
View this Video online

This video by NOAA explains Eutrophication

https://aamboceanservice.blob.core.windows.net/oceanservice-prod/facts/eutrophication.mp4

Some of the negative effects of this excessive algae production, or algal blooms, are:

- The production of dangerous toxins that can kill animals and people
- The creation of "dead zones" (low oxygen *hypoxic zones*, or no oxygen *anoxic zones*) in the ocean
- An increase in treatment costs for cleaning water
- Harm to industries and communities that rely on the affected watershed



The Eutrophication Process and how it leads to hypoxia. Source: https://www.wri.org/our-work/project/eutrophication-and-hypoxia/about-eutrophication

Multimedia - Khan Academy Video

The following link directs you to a video made by Khan Academy that explains the process of eutrophication and how dead zones are formed.

https://www.khanacademy.org/science/biology/ecology/biogeochemical-cycles/v/eutrophication-and-dead-zones

Sources of Eutrophication

Point source

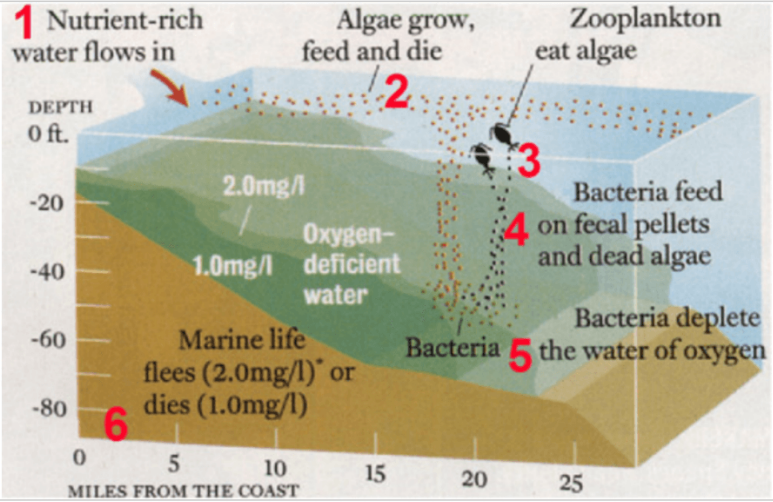
A point source pollution is one that is directly identifiable and can be traced back to a singular distinguishable source. Factories and sewage treatment plants are the most common types of point sources that cause eutrophication. Some factories discharge their waste, called effluent, directly into a water body from sewage pipes. Unregulated discharge of effluent can cause severe damage to human health and the environment. The consequences of unregulated discharge include water pollution, unsafe drinking water, and restricted recreational activities. The sewage dump can deposit nutrients in streams that can be carried out to sea and cause eutrophication events. Symptoms caused by exposure to algal toxins in drinking water can include nausea, vomiting, and throat irritation. When water is consumed in sufficient quantities, the toxins can affect the liver and nervous system. This can also indirectly affect the economy because of the loss of working days due to such health problems.

Non-point source

Non-point source pollution is pollution where the origin is less specified and more diffuse. Non-point source pollution is difficult to remedy as the source cannot be pinpointed. Agricultural runoff is the largest non-point source cause of pollution leading to eutrophication in the Delta. More than 200 million pounds of pesticides are applied to California farms every year which are washed into the delta. Water runoff over landscapes with excess fertilizer can pick up nutrients and carry them out to bodies of water. Urban runoff is also considered a non-point source of pollution affecting eutrophication.

Hypoxia

Eutrophication can lead to hypoxia in the water column. Hypoxia event occurs when there is low oxygen level in the water. This incident is a consequence of eutrophication due to an excess of nutrient input (nitrogen and phosphorus) in the water that stimulates the growth of phytoplankton and consequently affects fishes and other organisms. Human activities have increased the rate of eutrophication through point source and non-point discharge of nutrients such as nitrogen and phosphorus.



Nutrient-based Hypoxia Formation:1) Nutrient-rich water flows in, 2) Algae grow, feed, and die, 3) Zooplankton eat the algae, 4) Bacteria feed on fecal pellets and dead algae, 5) Bacteria deplete the water of oxygen, 6) Marine life flees or dies

Source: Gulf of Mexico Hypoxia https://gulfhypoxia.net/about-hypoxia/

As plant and animal biomass increase, species diversity decreases and the affected area will become overpopulated by phytoplankton feeding off the increased algae. This will also change the dominant biota in the region.

Turbidity is the clouding of water due to sediment. It can be caused by excessive phytoplankton, algae growth, urban runoff, or sediments from erosion. These suspended particles, in addition to making the water look dirty, also help promote the toxins in water as heavy metals and toxic organic compounds can attach easily to the suspended sediment. These suspended particles also absorb heat from the sun, making turbid waters warmer. This also reduces the oxygen content in the water, as more oxygen is dissolved in colder waters. The suspended particles also scatter light, decreasing the photosynthetic activity of plants and algae, which results in a positive feedback loop for decreasing oxygen even more. Some biological impacts include: fish eggs and larvae will be covered and suffocated, and gills will become clogged and damaged. Thus, turbidity is a plausible and extremely harmful effect of eutrophication.

Dead Zones

The Black Sea is one of the many dead zones that have been identified. The dead zone resulted from the contaminants from the Danube River which courses from Germany. During the 1960s to 1989, huge input to watersheds from several sources occurred. The nutrient sources are rising fossil fuel use and NOx input from atmospheric sources, intensive fertilizer use in farming practices, sewage input to water systems. This resulted in the loss of fisheries and marine habits disrupted and reduced tourism.

The Gulf of Mexico is essentially a large drain for the network of rivers known as the Mississippi-Atchafalaya River Basin (MARB), which includes major rivers such as the Mississippi and Missouri. MARB passes through 31 states, and agriculture is the dominant industry in several of those states, which is where the overflow of nutrients originates. The eutrophication process in the Gulf of Mexico is cyclical and grows in the summer and shrinks during the winter due to decreased agriculture only to return the following summer. This dead zone along the northern edge of the Gulf stretching along Texas and Louisiana measured 13,080 square kilometers in the summer of 2014, and it is the largest dead zone in the United States



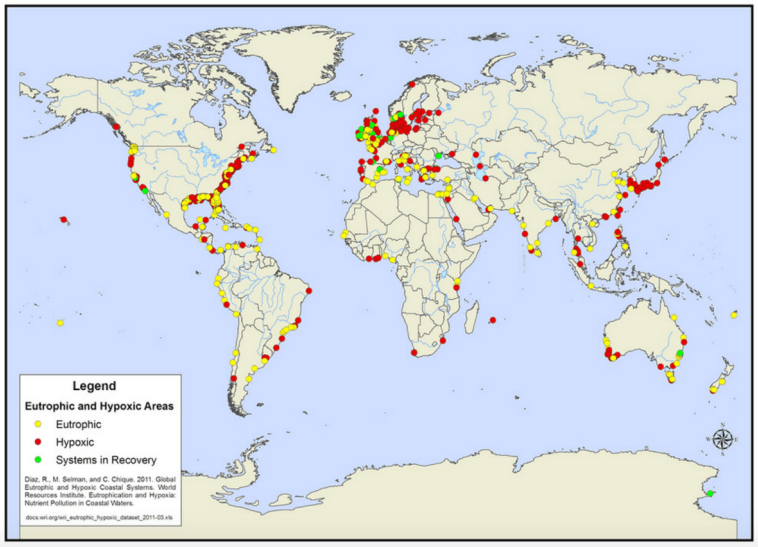
The Mississippi River Basin:The Mississippi River Basin is divided into six sub-basins outlined in color here.

Source: Gulf of Mexico Hypoxia https://gulfhypoxia.net/about-hypoxia/

Video - Dead Zone in the Gulf 2017

This following video gives a short summary of the 2017 Gulf of Mexico Hypoxic Zone. https://oceantoday.noaa.gov/happnowdeadzone/

World Hypoxic and Eutrophic Coastal Areas



The following image shows current areas around the globe that are hypoxic, eutrophic, or in recovery. This map shows dead zones (red) areas where excess nutrients might allow dead zones to develop (yellow). In some parts of the world, areas that had dead zones are getting better (green).

Source: Science News for Students (https://www.sciencenewsforstudents.org/article/suffocating-waters)

References

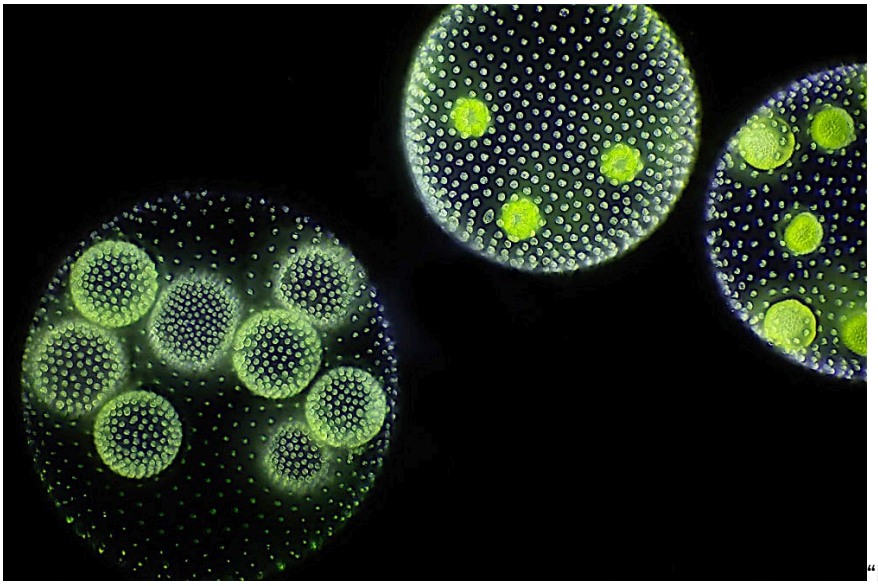
1. http://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466
2. www.globalpartnershipforocean...black-sea-blue

3. http://oceanservice.noaa.gov/educati...intsource.html
4. www2.epa.gov/nutrient-policy-data/cyanohabs
5. http://dujs.dartmouth.edu/winter-2012/eutrophication-in-the-gulf-of-mexico-how-midwestern-farming-practices-are-creating-a-%E2%80%98dead-zone%E2%80%99#.VObsBFPF9fw
6. http://water.epa.gov/type/watersheds/named/msbasin/zone.cfm
7. http://water.epa.gov/type/watersheds...hypoxia101.cfm
8. https://www.youtube.com/watch?<wbr/>v=rZFcLYqOxZQ
9. http://1.bp.blogspot.com/-HAO2PgXGXd...ia+diagram.png
10. http://www.nytimes.com/interactive/2...-map.html?_r=0
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12. http://www.lenntech.com/eutrophicati...on-effects.htm
13. http://www.lenntech.com/turbidity.htm

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6.5: Harmful Algal Blooms

Ever been told to only eat shellfish during the months that have the letter “R”, (September-April)? Well this rule is actually pretty important for keeping the health of people safe and to allow for many species of shellfish to repopulate. But why are the other months of the year not safe for people to eat shellfish? In short its because of the algae that grow during this time of year and as ocean temperatures rise. During these specific months of warmer weather, billions upon billions of these microorganisms start to take over our oceans and can have many consequences for us.


“Multicellular Green Algae” by Frank Fox [CC by 2.0]

Before going into what red tide is or how the populations of thesemicroorganisms seem to be increasing significantly as oceans warm up, lets take a closer look at algae. Most species of algaeare single-celled organisms but some species can be multi-cellular as seen in the photo above. Algae are autotrophs, meaning they use photosynthesis as their means of producing energy for themselves. Though similar to plants in the way they are both producers, algae have no stems or leaves and are more closely related to other groups of protists. Habitatsfor algae include any bodies of water including fresh and salt water, or have extreme external environment factors. There are few cases where they have been found on land such as rocks, trees, hot springs, etc... Species of algae have been well documented to be able to survive many harsh environments and have been on earth far longer than most living organisms to this day. They contributed to the Earth being able to house life by producing oxygenthrough photosynthesis. Overall Algae species are very tough and can survive in a wide range of environments, which can be seen as both a positive and negative situation.



A YouTube element has been excluded from this version of the text. You can view it online here: http://pb.libretexts.org/marine/?p=96

The red tide occurs when the algae from algal blooms becomes so numerous that it discolors the water. It is also sometime referred to as a Harmful Algal Bloom or “HAB”. This is where the name “red tide”comes from. Some key factors involved in red tides forming are warm ocean surface temperatures, low salinity, high nutrient content, calm seas, and rain followed by sunny days during the summer months. Some effects of the red tide are that it could deplete the oxygen in the water and/or release toxins into the water. The toxins in the water could have negative effects on the health of humans and animals exposed to them. There are three types of algae that can release these harmful toxins, they are *Alexandrium fundyense*, *Alexandrium catenella* and *Karenia brevis*.



“Red Tides in Isahaya Bay, Japan / Algal Bloom in Pelee Island, Ontario” by Marufish and Tom Archer [CC by 2.0]

What is important to recognize about “Red tides” and Algal blooms is that it isn’t always obvious that algae growth is there. They are not always a red color. The photos above show two examples of Algal blooms from two very different parts of the world, yet both species are considered “Red Tide” and harmful to some shellfish and animals that eat the shellfish. Algae alone is not an issue and even during the time of the year where there seems to be an excess amount of growth, this is a natural occurrence. What becomes a problem or what classifies as a “Red Tide” are the algae that release toxins in the air and water when they grow. Very few algae species can produce this toxin but when a large enough group forms on shores it can have a negative effect on both the marine environment and humans. The toxins produced can often affect the respiratory and nervous systems of all life forms. Thus when smaller marine animals feed on the algae, the trophic level above them can become poisoned as well. Paralytic Shellfish Poisoning is typically found along the Pacific and Atlantic coasts of the United States and Canada. It can cause paralysis and in

extreme cases death. Some of the toxins that cause Paralytic Shellfish Poisoning can be 1,000 times more potent than cyanide. Diarrhetic Shellfish Poisoning is another example of a harmful effect from eating contaminated shellfish. It is caused by Okadaic acid, which is produced by several species of dinoflagellates, and is usually non-deadly to humans. Small amounts of the okadaic acid usually do not have any harmful effects and only become an issue when large amounts are consumed. Amnesic Shellfish Poisoning is the third common poisoning that humans will get from eating contaminated shellfish. It can be life threatening and cause both gastrointestinal and neurological disorders. These disorders are caused by domoic acid. After an incident in Canada in 1987 where 4 people died from Amnesic Shellfish Poisoning, the levels of domoic acid in shellfish are now being monitored.


"Toxic Algae Bloom in Lake Erie" by NASA Earth Observatory Under Public Domain [CC by 2.0].

Algal Blooms can have serious effects on corals. Red algae, brown algae, and green algae are a few examples of macro-algae that can have a very negative effect on corals. They do this by outcompeting, overgrowing and eventually replacing sea-grasses and coral reef habitats. According to some research that is being done, harmful tropical algal blooms are increasing in frequency and intensity. This can have a significant impact on coral reefs.

Notable Red Tides:

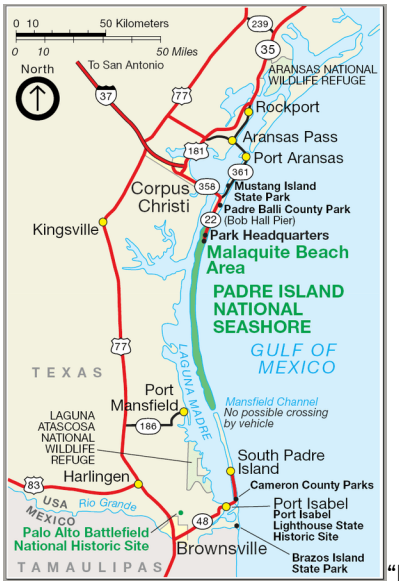
1844: First recorded case off the Florida Gulf Coast.

1972: Red tides killed 3 children and hospitalized 20 adults in Papua New Guinea.

2005: The Canadian red tide was discovered to have come further south than it has in years prior by the ship (R/V) Oceanus, closing shellfish beds in Maine and Massachusetts. Authorities were also alerted as far south as Montauk to check their beds. The experts who discovered the reproductive cysts in the seabed warned of a possible spread to Long Island in the future. This halted the area's fishing and shellfish industry.

2013: In January, a red tide occurred on the West Coast Sea of Sabah in the Malaysian Borneo. There were two fatalities reported after they consumed a shellfish that had been contaminated with the red tide toxin.

2015: In September, a red tide bloom occurred in the Gulf of Mexico, affecting Padre Island National Seashore along North Padre Island and South Padre Island in Texas.



"Map of Padre Island National Seashore" By U.S. National Park Service Under Public Domain [CC 0]

Scientists have been able to help control the spread of the effects of harmful algal blooms by developing new technology to help track them better. Tracking these harmful algal blooms could help prevent people from eating contaminated shellfish and knowing which areas will be most effected by them. Some examples of the technology that can help with monitoring them are better and more advanced satellite imagery. Also the development of an antidote to the toxins produced is another way to reduce the harmful effects. Even though they are a natural occurrence, what is alarming some scientists is that they may start to last longer and occur more often during the year as ocean temperatures and CO_2 levels rise.


"Red Tide in Naples" [CC by 2.0]

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6.6: Oil Spills and Marine Life

According to the National Oceanic and Atmospheric Association, there are thousands of oil and chemical spills each year. The Ocean Service's Office of Response and Restoration is the first to come to the scene and assess the impacts that a spill may have, identify risks, and recommend different cleanup methods. However, when oil spills occur, the first organisms to come into contact with the oil are marine organisms. Many of the issues that occur for marine life are due to the bioaccumulation of oil components by organisms. Biological organisms lower in food chains such as zooplankton accumulate the oil's chemicals within their tissues. When these zooplankton are consumed by organisms such as fish at higher trophic levels, the concentration of chemicals is magnified. With each successive trophic level, this biomagnification continues and the concentrations of the chemicals can be extremely dangerous especially for apex predators causing health and reproductive problems.

The effects of oil spills are varied across species, the distance from the spill, how big the spill is, and where the oil disperses. Organisms such as shellfish can be unaffected by oil or only slightly. This is because most of the oil floats within the water column and the amount that sinks to the ocean floor is limited, although thereare still some circumstances where the oil spill has a large effect on the shellfish. Oil spills that are in shallow or confined waters are the most at risk for effects. Oxygen depletion can occur due to the formation of oil slicks at the surface of the water.


"Louisiana_Oil_Spill" by US Coast Guard, under public domain

Oil slicks in deeper water can also have an effect. For example, the BP Oil spill in the Gulf of Mexico had well leaks at deep depths. Organisms such as shellfish that don't move often or far and are filter-feeders, are unable to avoid exposure to oil. Juvenile and adult fish are much more mobile, are more selective in what foods they eat, and they also have a variety of enzymes that allow them to detoxify many oil compounds. As a result, they are often better suited to limited oil exposure and related impacts. In spite of this, many fish are killed as a result of light oils and petroleum in shallow water. Also, oil spills can completely kill or wipe out fish egg populations.

"Port Sulphur, La. (Nov. 29)–An aerial view of a section of the Mississippi River containing a dense amount of the Nigerian 'sweet' crude oil spilled by the M/V Westchester Nov. 28, 2000 by USCG" by PA1 Jeff Hall

Effects of oil spills can be direct or indirect. Direct impacts include when oil directly touches, is consumed, or is injected through a cut in the skin. When these things happen they can deteriorate the thermal insulation of some organisms. They can also result in changes in the behavior and reproductive systems of those organisms that come into contact with the oil. Indirect effects of oil spills are those that result from consuming individuals who have direct contact with the oil as well as effects from the mass mortality and decomposition that occurs during oil spills such as oxygen depletion. Another indirect effect can be losing a major food source which could result in the death or extinction of one or more species.

Another factor that can affect marine organisms is the type of oil that is spilled. Light oils and petroleum products can cause acute toxicity in fish, but the toxic event is generally over fairly quickly. Heavier oils sometimes do not affect fish, however they can be detrimental to fish that are in the larval and spawning stages. The type of oil and the timing of the release influences the severity of oil effects on fish. Heavier oils can have great impacts on sea birds. This is because the feathers on birds are naturally waterproof, and in order to maintain this, the feathers on the birds bodies must be aligned. This is so the water cannot leak through the microscopic barbs, and barbules that are part of the vane of each feather. The bird, through a process referred to as preening, distributes natural oils on the feathers to keep the feathers in place. The oil floating in the ocean water sticks onto the birds feathers, causing it to become matted. The matting causes the feathers to separate ultimately making the feathers no longer waterproof. The bird then suffers from hypothermia or hyperthermia when it can no longer protect itself from extreme temperatures. Birds react to the presence of oil by preening, and by doing so the birds end up ingesting the oil that is toxic to them. During this time all of the birds energy is put into preening and they are left vulnerable and malnourished. Death, in most cases, is what the birds are facing without proper treatment. The washing treatment can not begin until the bird is at an acceptable weight, with good blood values while displaying active and alert behavior.

"Oiled Pelican 03 Dawn IBRRC 2010" by International Bird Rescue Research Center [CC by 2.0]

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7: CORAL REEFS AND DIVERSITY

7.1: Coral Reefs- An Introduction

7.2: Different Types of Corals

7.3: Reef Types and How Coral Reefs are Formed

7.4: Coral Reef Colors

7.5: Importance of Coral Reefs

7.6: Coral Reefs are Complex Ecosystems

7.7: Coral Bleaching

7.8: Reef Conservation

7.8.1: Protecting the Reefs- Organizations

7.8.2: Artificial Reefs

7.8.3: Bioremediation to Clean Our Oceans

7.8.4: Biocontrol in Hawaiian Reefs

7.8.5: Ecotourism, Recreation, and Reefs

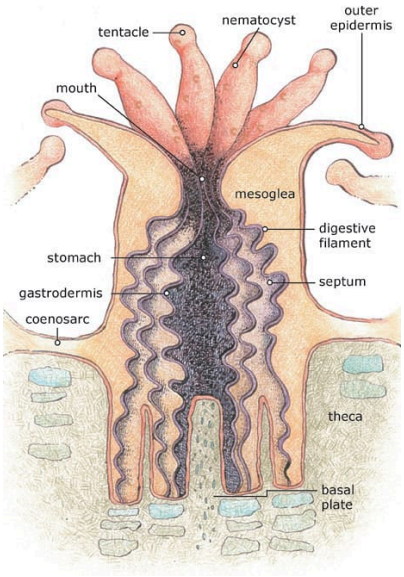
7.8.6: How Technology is Saving the World's Coral Reefs

7.8.7: Indigenous People and Conservation

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7.1: Coral Reefs- An Introduction

What are corals you ask? " A little bit algae, a little bit rock, and a lot animal." Corals are close cousins to sea anemones and jellyfish, meaning they all belong to the same phylum of Cnidarians.Coral is a marine invertebrate that is composed of simple structures known as polyps. The polyp has one opening which is the coral's mouth that is surrounded by a ring of tentacles. These tentacles have stinging cells called cnidocytes, used for food and protection. These cells fire tiny toxic barbs called nematocysts when they are touched to ward off predators or capture food. Inside the polyp are reproductive and digestive tissues. Coral can live as an individual polyp, but most corals exist as large colonies of interconnected polyps.



"Coral Polyp" by Wikimedia Commons under CC by 2.0

How do Corals Survive?

Sunlight: Corals grow in shallow water where the sunlight can reach them. The algae that live inside of them, zooxanthellae, need sunlight to survive, since the coral animal depends on the zooxanthellae, corals need sunlight to survive.

Clear Water: Clear water is needed for corals to survive because it lets the sunlight in. When the water is opaque the corals will not thrive.

Warm Water Temperature: Most corals, though not all, require warm waters to grow and survive. Corals general live in water temperature of 68-90°F

Clean Water: Corals are very sensitive to pollution and sediments that can be in the sea. Sediments can create cloudy water conditions which won't allow for sunlight to get through which will harm the polyps. Corals do not typically do well in environments where there is little sunlight, except for the deep-sea corals. Another issue that may arise is the addition of too many nutrients. An overflow of nutrients in the water can cause things such as algae to grow, in turn taking over the reef. Sediments and pollutants can also cause direct harm to coral tissue.

Salt Water: Corals require a certain balance between the concentration of salts and water (salinity).

Nutrients: Though zooxanthellae do provide some nutrients, the coral animals still need to receive other sources of nutrition. Corals can also grab passing nutrients (like zooplankton) by using their tentacles to snag passing organisms flowing by.

Coral Reef Functions:

Protection: Functions as a form of protection for the shores from harsh waves and storms

Habitat: Provides shelter and safety for many organisms

Nutrients: Many forms of heterotrophic marine life are supported from the primary production of the coral zooxanthellae. Carbon and nitrogen-fixing is an important part of the marine food chain. Nutrient cycling within the coral polyps is very efficient and contributes to the high production of reefs.

How do Corals Reproduce?

Some species have distinct male or female polyps while other coral can alternate gender. Many coral reef species only reproduce once or twice a year. For some coral that only have single-gender polyps, certain events (i.e. full moon) trigger the polyps to release massive amounts of sperm or eggs that flood into the seas, where the gametes eventually come together. Most coral species spawn by releasing eggs and sperm into the water; but the period of spawning depends on the type of coral. When an egg and sperm meet, the fertilized egg eventually develops into a larva called planula. Planula can form by two different ways, either fertilized within the body of a polyp or fertilized outside the polyp, externally in the water. Fertilization of an egg within the body of the coral polyp happens when sperm that is released through the mouth of another polyp, is taken in by a polyp with an egg. When the larva is matured enough the mother will spit it out via the mouth. If fertilization is external, corals will eject large amounts of egg and sperm into the water which eventually find each other. The release of larvae or gametes is known as coral spawning. Most species also reproduce asexually, budding new polyps or fragments, that grow either on an older polyp or drift around before landing on a new surface.



"Cauliflower coral spawning, French Frigate Shoals" by USFWS – Pacific Region under CC by 2.0

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7.2: Different Types of Corals

What Types of Coral Exist?

When people think about coral they often think about the stony calcified coral they get at a gift shop during a vacation to a tropical island. However, these are only the skeletons of stony corals, and are only one type of coral that exists. There are also deep water and soft corals. Each of these types of corals is unique structurally and in how they interact with their surroundings. There are over two thousand different types of coral which form colonies that play a key role in marine environments.

1. Hard Corals



"Hard Corals" by Amal FM under CC BY-SA 2.0.

Hard coral is a fundamental part of building the coral reef. The polyps of hard corals secrete skeletons of calcium carbonate (Limestone), that will eventually become rock. Hard coral includes species such as brain coral and elkhorn coral. Hard coral are considered to be hermatypes, which are reef-building corals. These corals require a certain type of algae called zooxanthellae that live within their tissues, this important mutualism is necessary for their survival. These organisms are what give corals their colors, which is dependent upon where they are living. The shape and appearance of each coral are dependent upon its species type, location, depth, water movement, and many other factors. Hard coral polyps are very similar to sea anemones, as they also have stinging cells called cnidocytes. Hard coral species can be found in all of the world's oceans, yet their populations are expected to decrease due to global changes and ocean acidification.

As mentioned earlier, hard corals build coral reefs. A coral reef begins when the coral polyp attaches itself to a rock on the seafloor. This one coral polyp then begins to divide or bud into thousands and thousands of clones of itself. Polyps and their calcareous skeletons connect to one another which creates a colony that will act as one. As this colony grows over hundreds and thousands of years it will join with other colonies and become a reef. Read more in our chapter on coral reef formation.



"Maldives reef" by Alexander Semenov under CC by 2.0

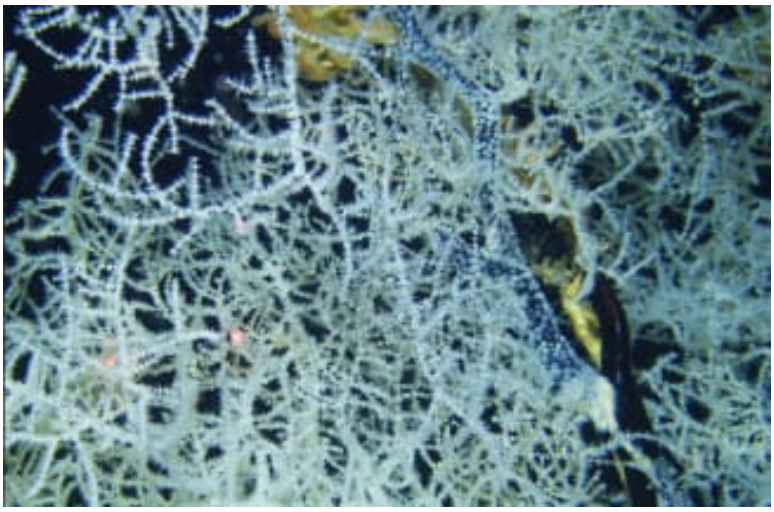
2. Soft Corals



"SOFT CORALS" BY NAJIM ALMISBAH UNDER CC BY-SA 2.0

Soft corals often resemble plants and trees. They are soft and bendable so they do not have stony skeletons like hard coral. For protection and support, they grow woodlike cores for stability. These cores are made of structural proteins such as gorgonin and other protein similar to those of nails and horns of other animals. These types of coral are referred to as Ahermatypes(non-reef building corals). Examples of soft coral in the Bahamas and Caribbean include sea fingers or sea whips. This type of coral also does not always have a symbiotic relationship with zooxanthellae. Though many utilize their presence, soft corals will typically eat any type of passerby out of the water column. These types of corals do not produce calcium carbonate, rather they contain spiny skeletal sclerites. These give the softer corals some protection and support. Soft species also prefer to live in nutrient-rich waters with less intense light. In other parts of the world, fleshy true soft corals have no rigid internal skeleton at all.

3. Deep-Sea Corals



DEEP SEA CORAL, WHITE “BLACK CORAL” *LEIOPATHES GLABERRIMA* BY NOAA PHOTO LIBRARY UNDER CC BY 2.0

Deep-sea coral can be found in the dark depths of up to 6,000 m (20,000 ft) below the surface of the ocean. These corals live in icy cold water with little to no sunlight. These corals, like shallow species, can exist as single polyps or multiple, living in complex colonies made up of different species. Since these species do not require sunlight or warm water, they are able to grow in a vast array of waters around the world. They have even been found in waters as cold as -1-degree celsius. Since these corals live without sunlight they contain no zooxanthellae. This means these corals must obtain their energy and nutrients elsewhere. They do this by trapping tiny organisms in passing currents. The main reason many scientists had no idea of the existence of these deep-sea corals, is because, for many years, the oceans deep depths were inaccessible. In addition to being surprisingly diverse, scientists have also discovered that deep-sea corals are amongst the oldest marine organisms on record. Since corals are constantly growing, regenerating new polyps, some coral reefs have been actively growing for almost 40,000 years. To your and my surprise, scientists have identified nearly as many deep-sea corals as shallow-water species.

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7.3: Reef Types and How Coral Reefs are Formed

Have you ever wondered how coral reefs are formed? It has been established by the scientists in the Tropical Marine Biology field that coral reefs can be divided into three types: Fringing reefs, Barrier reefs, and Atolls which all require very specific conditions to develop. Coral reefs begin to form when free-swimming coral larvae attach to a rock or other submerged object on the edges of islands. As the corals grow, over very long periods of time, they form into a reef. The three types of reef represent stages in development of a coral reef over time.

1. Fringing Reefs:

Fringing reefs grow near the coastline around islands and continents. These types of reefs are the most common type we see and are considered to be the youngest of the 3 types of coral reefs. They are separated from the shore by shallow lagoons. The first stage of the formation is when the coral larvae attach itself to rocks or soil near the coasts. In certain parts of the world, they tend to form where volcanoes have also formed due to the shallow sloped walls being ideal to make shore reefs. The larvae become polyps and excrete calcium carbonate, which forms their exoskeleton. The secreted calcium carbonate sediments on the rocks and provides a substrate for more polyps coming to attach themselves. As more and more polyps attach, and layer over time, they create a coral reef. Calcareous Algae also add their sediments to the structure. Other organisms with calcareous skeletons, also add their own remains to the reef as they die and sink. Since fringing reefs are the youngest and grow onshore, they tend to have less diversity of species within that ecosystem. Some locations of these reefs include Kenya, Australia and other parts of Africa shores.



Fringing Reef in Eilat, Israel
Photo by: Mark A. Wilson [CC by 2.0]

2. Barrier Reefs:

As the name states, these reef types border along coastlines with a very wide and deep lagoon separating the two structures. The term “barrier” comes from the more shallower coral that sticks out of the water and creates a barrier or wall-like structure. One of the most famous and largest barrier reefs is “The Great Barrier Reef” in Australia. This reef is around 1200 miles and consists of many complex reefs making it up. This type of reef is formed when the fringing reefs slowly combine with each other and form a borderline along the coast. The calcium carbonate structures attract more polyps and the spaces are filled up. It forms a line along the coast and a ring around an island. Large barrier reefs are the rarest type of coral reef and only seen in a select few places on earth such as Belize and parts of the southern Pacific Ocean. Smaller barrier reefs are seen in places where islands are in an earlier stage of becoming submerged.



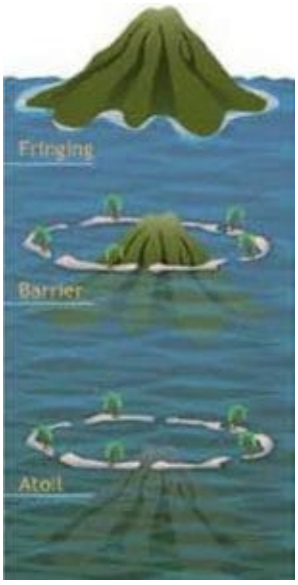
Great Barrier Reef by Studio Sarah Lou by Flickr

Most of the reefs surrounding the Turks and Caicos Islands are barrier reefs that formed from the precipitation of $CaCO_3$ on the remnants of continental debris resulting from the separation of North America from South Africa 200 million years ago (continental drift). Dissolved minerals in the seawater form small particles called ooids that become cemented together to form oolite rock which makes up most of the Turks and Caicos islands and bank.

3. Atoll Reefs:

An Atoll Reef is a ring-like shaped coral reef or small islands of reefs in a circle with a lagoon in the middle and are usually located in the middle of the sea. These types of reefs are formed when an island has sunk completely (or nearly) in the middle of the ocean from rising sea levels around a pre-existing structure (these islands are often the tops of underwater volcanoes). Most atoll reefs can be found in the Pacific ocean where the waters are warm and salty. They can grow between the sizes of 12.6 km^2 (Great Chagos Bank) and as small as 1.5 km^2 (Ontong Java reef). More animals are found in an atoll than in earlier stage reefs. Over a million species can live in one square kilometer of coral reef. The three types of reef from fringing to barrier to atoll, form in this sequential order and represent stages of development of a reef.

Watch a great animation clip of how an atoll forms.



"Formation of Coral" by NOAA Ocean Service Education via Wikimedia Commons

Below is a link to a video created by three undergraduates at Keene State College who discuss more about the different types of coral reefs:



A YouTube element has been excluded from this version of the text. You can view it online here: http://pb.libretexts.org/marine/?p=35

4. Patch reefs

Patch reefs are small, isolated reefs that grow from the open bottom of the island platform or continental shelf. They usually occur between fringing reefs and barrier reefs. They vary in size and rarely reach the surface of the water.


Patch reefs in Hoopers Bay area by James St. John Via Flickr

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7.4: Coral Reef Colors

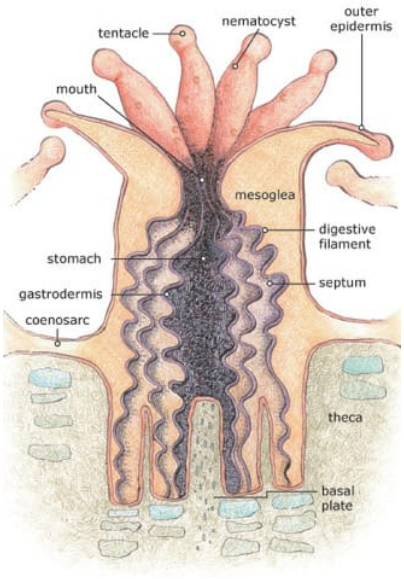
When you first see this picture below of a coral reef landscape, you are captivated. Captivated by the beautiful, bright, elegant colors popping through the clear blue water. But why? Why do these coral reefs have such bright, bold colors? The colors found in colorful corals are mostly due to three things – photosynthetic pigments, fluorescent proteins, and non-fluorescent chromoproteins.



"Colorful underwater landscape of a coral reef" by Wikimedia Commons under Public Domain

Coral Polyps

In order to understand why corals get their color, it is important to first learn the structure of the coral polyps. The majority of polyps have clear, transparent bodies over their hard, white skeletons. Millions of zooxanthellae live inside the tissues of these polyps. These zooxanthellae produce pigment, and because they reside in the clear tissue of the polyp, the pigments are visible, and the corals get their beautiful colors.



"Anatomy of a coral polyp" by Wikimedia Commons under public domain

Light Intensity Dependency

Zooxanthellae are photosynthetic algae, and in order to ensure there is a continuous amount of nutrients being delivered to the coral, the coral regulates the number of zooxanthellae cells, as well as the amount of chlorophyll in them. Because zooxanthellae is a photosynthetic algae, zooxanthellae are sensitive to light intensity, which can ultimately alter the color and overall health of the coral. Too much light intensity can release some zooxanthellae, or the amount of chlorophyll will be decreased. In the presence of harsh light intensity, it can potentially be detrimental to the coral reef by excess oxygen production, causing it to accumulate and have toxic effects on the coral. If the light intensity is insufficient, the zooxanthellae will not be able to provide enough nutrients for the host coral, and thus the number of zooxanthellae and amount of chlorophyll will increase. When the zooxanthellae cells use light to produce large organic compounds, oxygen is also released. The brighter the color of the coral, the more photosynthesis and oxygen production. Corals can decrease or increase the chlorophyll production from the zooxanthellae cells, depending on environmental requirements. They can also expel zooxanthellae when under stress.

So, what does this mean? Essentially, the number of zooxanthellae and the amount of chlorophyll affect coral coloration. Because zooxanthellae cells range in color from a golden-yellow to brown, and when there is a large number of zooxanthellae cells present the coral color appears brown, it suggests that the light intensity affects the number of zooxanthellae and the amount of chlorophyll.

Why are some more colorful than others?



"Scuba diving Bali Nusa Lembongan, Coral Reef off Nusa Lembongan, Bali" by Wikimedia Commons under CC 2.0

Corals are home to different types, or clades of zooxanthellae, that vary in light intensity sensitivity and temperature. While zooxanthellae color can range from a golden-yellow to a brown pigment, zooxanthellae can also fluoresce deep red color under certain circumstances. For example, Phycoerythrin is a photosynthetic pigment that fluoresces a bright orange color that's found in zooxanthellae. In addition, there are about 85 more fluorescent pigment colors produced by colorful corals, typically cyan, green, yellow, and red, and they can even glow in the right lighting! These proteins absorb light of one color (wavelength) and emit (fluoresce) a different (lower energy wavelength) color. There are also other pigments produced by the coral called chromoproteins, they are non-fluorescent, or reflective, and there are about 24 chromoproteins found in corals. Of the 24 chromoproteins, the pigments can appear as purple, red, blue, to name just a few.



Coral Reef by Jan-Mallander via Pixabay [CC 2.0]

What Are the Roles of the Corals Colors?

It is thought that these fluorescent compounds may help corals survive, however, the role is not yet well understood. A few possibilities are that they may serve as a “sunscreen” protecting corals by filtering out harmful ultraviolet rays. Corals can manipulate the zooxanthellae cells in response to light. Only recently have scientists begun to comprehend the relationship between color-producing light and how it appears at different depths. Wavelengths of light become diluted the deeper down they have to travel. UV light rays are naturally filtered out by water in deeper oceanic regions. That’s why shallow-water reefs are bright with color and deeper coral tend to appear more gray-like. It has also been shown thatinjured corals often form colorful patches. This is due to the fact that the coral is makingfluorescent molecules that act as antioxidants, capturing toxic oxygen radicals that threaten to damage cells.

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7.5: Importance of Coral Reefs

Why Are Reefs Important?

Coral reefs are very complex ecosystems that provide valuable habitat for fish and other animals with their beautiful and unique structures. These structures provide shelter for many organisms such as fish, marine worms, clams and many other animals and plants that all play a vital role in the coral reef ecosystem. Coral reefs are important for a variety of reasons which we will discuss below.



Coral Outcrop Flynn Reef by Toby Hudson via Wikimedia [CC by 2.0]

Biodiversity:

Coral reefs are often thought of as a busy city; the buildings being made of coral and the thousands of organisms inhabiting this city acting like the humans interacting with each other and performing daily jobs. Coral reefs provide protection and shelter to nearly one-quarter of all known marine species and have evolved into one of the largest and most complex ecosystems known to humans. Coral reefs are home to over 4,000 species of fish, 700 species of coral and thousands of other plants and animals. This diversity of species provides a large gene pool giving communities more resilience during extreme environmental conditions and climate change. This is important to the overall health of an ecological community. With greater species diversity, the impact of losing any one species to extinction will be less. The enormous diversity of coral reef organisms also provides potential for new medicines or other products that may be developed from biochemicals that these organisms produce. Most coral reef organisms have not been studied for their potential benefits to medicine and industry.

Coastal Protection:

Coral reefs act as a natural barrier protecting coastal beaches, cities, and communities from the waves of the ocean. Nearly 200 million people depend on coral reefs to protect them from storm surges and waves. Without coral reefs, many buildings would become vulnerable to storm damage.



Reefs Protect Costallines by NOAA via Flicker [CC by 2.0]

Food:

Coral reefs are an important food source for the people who live near the reefs and are crucial for worlds fisheries providing them with a significant source of protein. In developing countries, the reef is said to contribute to one-quarter of the total fish catch providing food resources for tens of millions of people.



"Commercial Fisherman" by NOAA [CC by 2.0]

Medicine:

Many of the compounds now being used in human medicines are found on the coral reef with the potential of more to be discovered. A number of organisms found on reefs produce chemical compounds that have been isolated for human applications. Scientists have developed treatments for a variety of illnesses such as cardiovascular diseases, skin cancer, ulcers, and leukemia. Other compounds can help with reducing inflammation, kill viruses and relax muscles. Not only do the organisms inhabiting the coral reef provide medical treatments but the coral's unique skeletal structure has been used for bone-grafting material.

Tourism:

Coral reef ecosystems are among the most biologically diverse and economically valuable ecosystems on Earth, as they not only support local but global economies. Through tourism (i.e. snorkeling, scuba diving, swimming) and fisheries, coral reefs generate billions of dollars, as well as jobs in more than 100 countries around the world. The annual value of the ecosystem services provided by coral reefs to millions of people is estimated to be over $375 billion. The coral reefs can indirectly bring economic value to these countries by letting visitors enjoy beaches, eat local seafood, paddleboard and sail. All of this is possible due to coral reefs acting as a buffer against waves, storms, and floods. The downside is when tourism harms the coral reefs it not only affects the organisms and the coral reefs, but local people and their economy who rely on the income from tourism.



Snorkel by Angelique800326 via Wikimedia [CC by 2.0]

A good example can be found in Bonaire, a small Caribbean island. Bonaire earns about $23 million (USD) annually from coral reef activities, yet managing its marine park costs less than $1 million per year. A study conducted in 2002 estimated the value of coral reefs at $10 billion, with direct economic benefits of $360 million per year. For residents of coral reef areas who depend on income from tourism, reef destruction creates a significant loss of employment in the tourism, marine recreation, and sport fishing industries. This large amount of money of revenue generated is being threatened by the degradation of coral reefs. As you can see there is a positive feedback loop occurring because of this situation. Many components of tourism, including recreational activities, are the cause of damage to the reefs but ironically it has been shown that ecotourism is as well.

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7.6: Coral Reefs are Complex Ecosystems

Coral Reefs as Ecosystems

An ecosystem includes all of the living organisms (biotic) in a given area, interacting with each other, and also with their non-living components and environmental factors (abiotic). In an ecosystem, each species has its own niche or role to play. All of the aspects of the coral reef act together in a unit called an ecosystem. Coral reefs are a very high functioning ecosystem and are home to thousands of species of marine life. Algae, fish, echinoderms and many other species depend on the reef for their habitat and food too. The number of species is directly proportional to the mass of the coral reef. Mesophotic coral ecosystems (MCEs), are a common type of ecosystem that are home to light-dependent life, such as corals and their zooxanthellae. MCEs are typically at depths of 30-40 m and can extend over 150 m in tropical and subtropical regions.

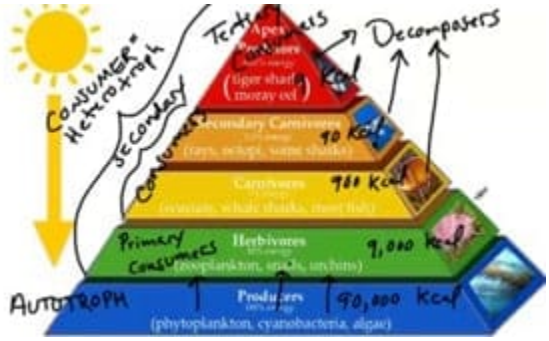
Roles of Marine Organisms

The biotic portion of the marine ecosystem includes three main groups called producers, consumers, and decomposers. The organisms in these groups all play a key role in contributing to a functioning ecosystem.

Producers– These are autotrophic organisms which make their food through photosynthesis. Green plants, algae, and chemo-synthetic bacteria are all examples of producers in marine habitats.

Consumers– These organisms obtain food from other organisms or organic matter and are animals, zooplankton, and heterotrophs. Consumers are broken down into primary, secondary, tertiary, and quaternary categories. Primary consumers feed on producers and are herbivores. These organisms include sea turtles, zooplankton, and sea urchins. The secondary level feed on the primary producers and are organisms like rays and fish. The last levels are tertiary and quaternary, which feed on the secondary consumers and are the large fish, sharks, and sea lions.

Detritivores and Decomposers– These organisms feed on dead organic matter. Crustaceans like crabs and lobsters which shred and consume dead animals are examples of detritivores. Bacteria and fungi are decomposers that gain energy by breaking down dead organic matter into nutrients such as nitrates, nitrites, phosphates, and carbon dioxide. These are released back into the surrounding environment along with heat energy.



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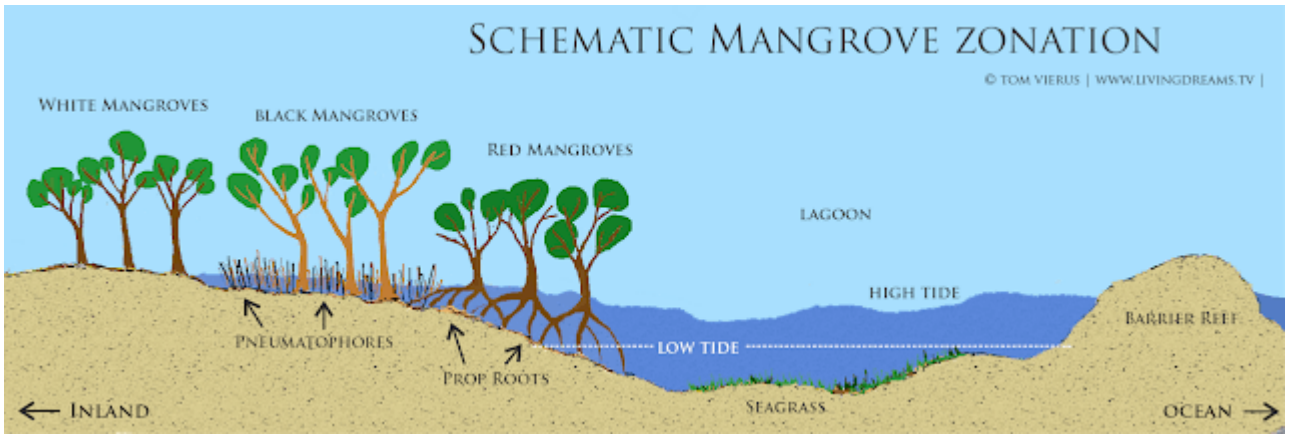
"O-BIO-15 Energy Pyramid" by eLearn.Punjab via Vimeo

The health, abundance, and diversity of the organisms that make up a coral reef are directly linked to other surrounding terrestrial and marine environments. Mangroves and seagrass beds are two of the most important associated habitats of the greater coral reef ecosystem.

Mangroves:

Mangroves are salt-tolerant trees that grow along tropical and subtropical coasts. They provide protection by stabilizing the coastline with their complex root system. They protect uplands from erosion, wind, waves, and floods. They also act as carbon storage systems, and help produce nutrients and filter out pollutants. Their complex root system serves as breeding and feeding grounds for marine organisms such as fish, invertebrates, and others. They are especially important as **nursery grounds** for juvenile and larval reef organisms, many of the animals raised in mangroves migrate to coral reefs.

There are around 80 different species of mangrove trees that live in many places around the world. In Florida, the Bahamas and the Caribbean, there are three main types of mangrove. Red mangroves grow on the ocean's edge, black mangroves occur a bit upland from the reds, and white mangroves are found at the highest elevations furthest upland.



The schematic mangrove zonation done by Tom Vierus on www.livingdreams.tv.

In Mumbai, the shores once used to be covered in mangroves but those forests were severely degraded from housing developments encroaching on the edge of the land and mismanagement of waste disposal. Mumbai alone has lost about 40% of its mangrove forests in just a few decades from being destroyed for houses to be built or also from the wastes left behind which can clog the roots of the trees preventing them from getting oxygen and filtering the freshwater they need.

Mission Mangroves, a project run by NGO United Way Mumbai, is making changes towards protecting the remaining mangroves and planting new ones. Every month volunteers partake in a clean up of the wetlands and twice a week there are planting sessions to restore the forests. At the time of this writing, they have already planted 55,000 new trees. United Way Mumbai's director of community impact, Ajay Govale, stated that "the mission is to green 20 acres of wetland by planting mangroves, and to educate thousands of Mumbai people about the importance of mangroves."

India is at the top for countries that are the worst at mismanaging plastic wastes and Mumbai is one of the worst cities for air pollution. The destruction of mangroves has contributed to this problem as they help filter pollutants out of the air and can absorb four times more carbon than tropical forests. The loss of mangrove forests also impacts other parts of the ecological community. Since they serve as shelter and breeding grounds for marine wildlife, this affects local fisheries and communities reliant on these marine animals. The loss of the mangrove forests also leaves the coastlines more vulnerable to be affected by rising sea levels from global climate change.

Seagrasses:

Seagrass – Seagrasses are flowering plants that often form meadows between mangrove habitats and coral reefs. They provide nutrients to organisms such as sea turtles, sea urchins and thousands of other species. Seagrasses also provide protection and shelter for crustaceans like crabs and lobsters, as well as fish such as snappers. Similar to mangroves, they also function as nursery grounds for juveniles, perform water filtration , release oxygen necessary for most marine life, and prevent seabed erosion.



Seagrass Meadows by U.S. Department of Agriculture via Flicker

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7.7: Coral Bleaching



“Eco Cafe” by Phuket [CC by 2.0]

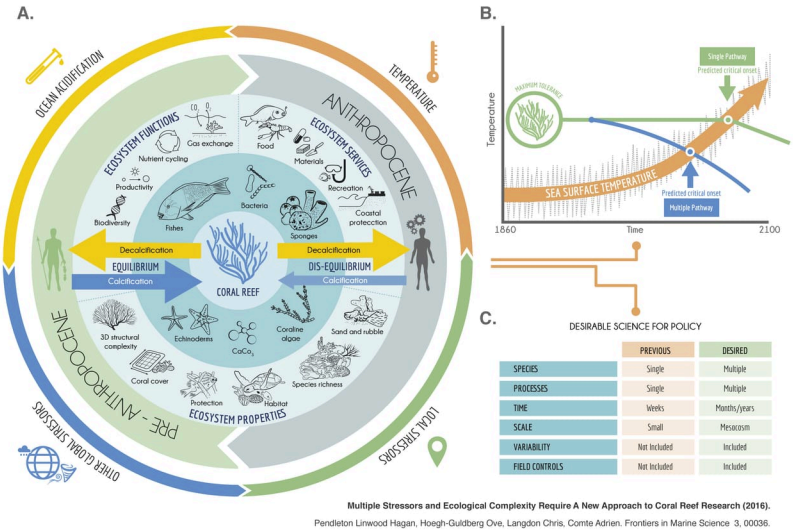
Coral bleaching is a phenomenon that occurs when coral turns white due to environmental stress. It is a reoccurring event that frightens marine biologists and raises a lot of concern for marine ecosystems all over the world. When the water is too warm, corals will expel the algae (zooxanthellae) living in their tissues. As a result, the coral loses its vibrant color and becomes more prone to developing disease. Corals have a mutualistic relationship with these algae. This means that the organisms depend on each other for survival. From their photosynthetic products, zooxanthellae give the coral the nutrients they need to survive while the coral in exchange give the zooxanthellae carbon dioxide and safe harbor. When they are lost, it is a huge loss for the coral because these symbiotic algae provide the coral with 90% of its energy through the process of photosynthesis. Without the zooxanthellae, the coral begins to lose its color and eventually has a bright white appearance, hence the term coral bleaching. In essence, the coral will starve and die without the needed nutrients from the zooxanthellae. Global warming is a big cause of coral bleaching but other environmental factors also play major roles.

The video below explains more about what coral bleaching is, what causes it and the effects that it is having!



A YouTube element has been excluded from this version of the text. You can view it online here: http://pb.libretexts.org/marine/?p=98

The corals may be able to survive for a short period of time without the zooxanthellae, but since the algae provides its primary food source it cannot survive for long. Once the coral has died, its begins to degrade. Another cause of coral bleaching is oxygen starvation. This is caused by an increase in the zooplankton population in a given area, most likely due to over-fishing. Another trigger that is less common but still notable is sedimentation. This occurs from silt runoff from land into the ocean via rain and other bodies of water leading into the ocean. Also, La Nina or EL Nino can also play a role by not only changing the temperature of the water but also by bringing some silt/sand along with nutrients up from the bottom of the ocean. The biggest cause of coral bleaching is from the stress created from warmer water temperatures due to global climate change.



Multiple Stressors and Ecological Complexity Require A New Approach to Coral Reef Research (2016).

Pendleton Linwood Hagan, Hoegh-Guldberg Ove, Langdon Chris, Comte Adrien. Frontiers in Marine Science 3, 00036.

"Ecological Processes Coral Reefs" by Wikimedia [CC by 2.0]

Corals provide shelter for a number of marine organisms and they also protect shorelines. Without coral reefs, marine life would most likely leave the area which in turn, could cause harm to marine ecosystems. Coral reefs help to support approximately 25% of marine species. They are also a huge benefit to the fishing industry since they attract so much marine life.


"Coral Reef Story Intro Video" by GRID-Arendal [CC by 2.0]

There have been three major coral bleaching events recorded in history, the first occurred in 1998, an underwater heatwave spread, killing 16% of corals around the world. The second major coral bleaching event occurred in 2010, caused by an El Niño. The most recent coral bleaching event occurred in 2015, which was caused by ocean warming.

The warming of the ocean is a huge threat to coral reefs. As stated previously, ocean warming is the number one cause of coral bleaching. A shocking 93% of climate change heat is absorbed by the ocean.

But what is the underlying cause of all of this?

Global climate change is caused by increased greenhouse gases, primarily carbon dioxide, that are released into Earth's atmosphere. The carbon dioxide and other gases trap heat in the atmosphere, causing the Earth to heat up. When the Earth heats up, water temperatures increase and result in coral bleaching.

Humans are the main source of greenhouse gases that are produced and released into the atmosphere due to the burning of fossil fuels. Vehicles are one of the many producers of Carbon Dioxide. Burning one gallon of gas produces approximately 24 pounds of Carbon Dioxide. Another way in which humans produce these gases is by burning coal for electricity. Burning wood to produce fire for cooking is also another every day activity that contributes to the emission of these gases. The other major factor that contributes to increase in greenhouse gases in Earth's atmosphere is deforestation. For years, humans have been cutting down trees in large numbers to make room for the construction of buildings and also to use the wood as fuel. Trees are very important to our ecosystems because they absorb a lot of the carbon dioxide that is in the Earth's atmosphere. By absorbing carbon dioxide, they are able to perform photosynthesis and release Oxygen as a byproduct. As trees are removed in large numbers, this sink for carbon dioxide is greatly reduced and the amount of carbon dioxide in the atmosphere continues to increase.


“Blackback Butterflyfish” by Wikimedia [CC by 2.0]

Most people don’t realize how important coral really is to not only marine life, but also to human life. For fish communities and other reef dwelling creatures, the coral is everything to them and they all rely on the coral structure in some way. The reefs provide shelter for smaller fish and can be a food source for others. Coral reefs are essential for life for a countless number of organisms and without the coral, a good number of these organisms will perish, leading to a much bigger problem. If the smaller fish can no longer survive without the coral reef, then that will lead to less food for the larger fish that feed on them.

Around 100 million people around the globe rely on coral reefs for survival. With a decrease in healthy coral ecosystems, there will be less fish which are an important food source for many humans. People also rely on coral reefs for other economic purposes such as tourism. The impact of coral reef loss on the tourism industry is estimated at around 10 to 40 billion dollars, followed by fisheries losing 7 to 23 billion dollars and biodiversity impacts resulting in losses of 6 to 22 billion dollars.

Marine Species Impacts:


“Polyp Butterflyfish” by Bernd [CC by 2.0]

Butterfly fish are fish that feed exclusively on coral polyps. With their food source disappearing. their chance of survival is small. Butterfly fish also keep algae from smothering corals and if this population decreases, the corals that are still living could end up dying because of too much algae.


“Spiny Lobster Approaching” by Eric Kilby [CC by 2.0]

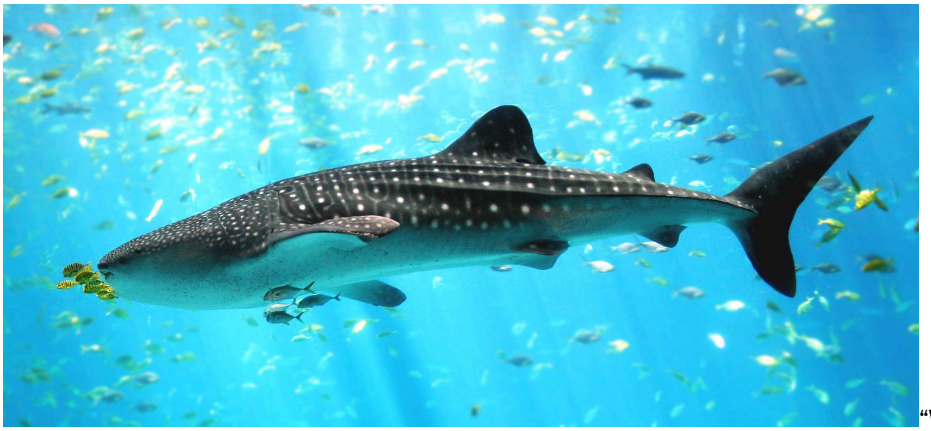
Spiny lobsters need coral reefs for protection, especially when they are molting because that is when they are most vulnerable. These lobsters play a significant role in maintaining a balanced ecosystem. Spiny lobsters are predators of sea urchins, which feed on kelp forests and can destroy them if populations are not predator-controlled.


“Dolphin” by Wikimedia [CC by 2.0]

Dolphins and most whales are predatory animals and they are all carnivorous. They survive by eating fish that rely on coral reef habitats. Each species that is lost from coral bleaching has the potential to affect the rest of the ecosystem.


“Hawksbill sea turtle” by Raymond™ [CC by 2.0]

Hawksbill Sea turtles have become a critically endangered species and are very dependent on coral reefs for their food sources. Their diet mostly consists of sponges. Sea turtles play a very important role in their ecosystems by helping with nutrient cycling from ocean to land, maintaining healthy sea grass beds, and balancing food webs.


“Whale Chark” by Zac Wolf [CC by 2.5]

Studies have shown that whale shark populations have decreased in the 1980s and 1990s and this may be due to the destruction of corals. Many corals were destroyed in this time period from people and coral bleaching. Although it is not certain that these two are related to each other, the times frames suggest that they are.

“Healthy Corals” by Wikimedia Commons [CC by 4.0]

Solutions:

There are many ways that people can help reduce the amount of coral bleaching that is occurring. One way that we can do it is by reducing fuel pollution by using alternative transportation methods such as running or biking instead of driving a motor vehicle, or kayaking and canoeing instead of using your boat. Not touching and breaking corals when diving or snorkeling can be a huge help since just touching a coral with your bare hand can have negative effects on it. Not using harmful fertilizers and pesticides in your yard and garden can also help a lot because they will eventually find their way to the ocean. Volunteering for a community reef and beach cleanup can also help keep trash out of the ocean which will keep it from getting into the reefs.

The information in this chapter is thanks to content contributed by Alana Olendorf, Simone McEwan, Haley Fantasia and Devon Audibert

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7.8.1: Protecting the Reefs- Organizations

The Current Coral Situation

With the current environmental crisis occurring on our planet, and the large amount of data we have to aid us in understanding the degree of the phenomenon, it is important now more than ever to utilize our knowledge to protect these ecosystems. Earth has a diverse array of natural habitats including Coral Reefs. It has been reported by the Global Reef Monitoring Network (GCRMN) that about 19% of the Earth's coral reefs are now dead, with multiple factors to blame including rising sea temperatures and ocean acidification.



Table coral of genus Acropora by Yumi Yasutake via NOAA, 2008 under [CC BY 2.0].

Coral reef ecosystems and the accompanying organisms that depend upon them are in danger of disappearing if we do not take action to protect these reefs. Coral reefs make up only 0.2% of our oceans, but they are home to over 25% of all marine fish species. The United Nations predicts that the Earth is on the brink of a massive extinction event, with some studies even suggesting 25% of the planet's species will be extinct by 2050. If we do not stop the effects of these factors we may lose a whole lot more than just the corals. The rapid decline of coral reefs will result in a significant number of social, economic and environmental tragedies around the world. We as humans must intervene knowing this current situation. In the US, the decline and danger from the loss of corals started to gain attention by the government in 1998. Since then, many reef protection organizations have emerged varying from government-funded to non-profits.

United States Coral Reef Task Force (USCRTF)

The USCRTF was established in 1998 by Bill Clinton who was President of the United States at that time. It's mission is aimed to protect and conserve coral reefs.

The USCRTF accomplishes this mission by mapping and monitoring the U.S. coral reefs, as well as helping to identify the problems causing the decline in reefs. Their goals as a task force is to find solutions to these problems, and to promote conservation and the sustainable use of coral reefs to the public. By working together with other organizations they try to find the best possible strategies to save the reefs. The USCRTF is responsible for many tasks which include but are not limited to:

- Implementation of Executive Orders
- Developing efforts to map and monitor coral reefs
- Research the cause and find solutions to these causes of reef decline

- Reduce cord reef degradation from pollution, and over fishing
- Implementing strategies to promote conservation and education to the public internationally

In 2000, the USCRTF adopted the *National Action Plan to Conserve Coral Reefs (National Action Plan)*. This was the first blueprint for U.S domestic and international actions to address the issues of coral reef decline. This plan consists of conservation strategies to address the challenges that reefs are facing today. Not long after, the USCRTF developed the *U.S. Coral Reef National Action Strategy (National Action Strategy)* to further regulate the *National Action Plan*. *The National Action Strategy's* documents provide the framework for the priorities, strategies, and actions of the USCRTF and its members.

Similar to USCRTF there are many organizations out there trying to make a difference by saving coral reefs and the ecological communities that surround them. Below are four well known organizations trying similar tactics by identifying the problems and finding solutions for coral reef ecosystem protection.

Coral Reef Alliance (CORAL)

One organization working to protect our coral reefs is the Coral Reef Alliance (CORAL). They work with people from very different backgrounds: politicians, scientists, divers, and even fisherman. Their holistic conservation programs can be seen around the world, anywhere from Hawaii to Indonesia. After seeing the success of their programs many other communities and organizations have emulated their programs and efforts. Some of their work consists of creating healthy fisheries for reefs, assisting in ensuring clean water for reefs, protecting intact reef ecosystems, improving knowledge of the science of adaptation, among other things.

If you are interested in helping the Coral Reef Alliance there are many things that you can do. CORAL suggests a couple of things that can let you take action in your daily life such as traveling sustainably and working to educate others. If you want to take a more active role you can donate to their cause or even volunteer.

National Oceanic and Atmospheric Administration (NOAA)



NOAA by Wikimedia Commons under [CC BY 2.0]

A second organization working to protect the worlds coral reefs is the NOAA's Coral Reef Conservation Program. This organization was founded in the year 2000 by the Coral Reef Conservation Act and they have four main pillars of work: Increase resilience to climate change, reduce land-based sources of pollution, improve fisheries' sustainability, and to restore viable coral populations. In order to preserve the Coral Reefs they are working with many scientists involved in many different facets of NOAA. They believe that collaboration is the key to coral reef conservation. They partner with governments, academic institutions, and community groups to help save the coral reef environments. If you are interested in getting involved with the NOAA's coral reef conservation efforts there are a few ways you can do that. You can join the U.S. Coral Reef Task Force. If you are interested in heading your own efforts for Coral Reef conservation here is some information on how to get funded through the NOAA's grant programs. The NOAA also has job opportunities- here is a link to follow if you're interested. You can follow them on Twitter to see how they are getting the word out to the public.

Ocean Conservancy


Cleaning up trash by Wikimedia Commons, 2013 under [CC by 2.0]

Ocean Conservancy is another organization whose goal is to conserve every part of the ocean and marine life that surrounds it. This organization promotes health and diverse ocean ecosystems and aims to stop/limit the practices that threaten marine and human life. They focus on some of the main problems threatening marine life such as ocean acidification, trash, and helping set up sustainable fisheries to prevent over-fishing and the harmful effects of tourism.

National Fish and Wildlife Foundation (NFWF)

NFWF was created by Congress in 1984 and since then has become one of the world's largest conservation organizations. They work with both public and private sectors to help protect and restore the nation's fish, wildlife and habitats that surrounds them. They support conservation efforts in all 50 states and U.S. territories. NFWF has a primary focus on bringing together parties, getting results, and finding better solutions to help the future world. NFWF leads conservation financially with a funding budget up to $3.8 billion dollars.

Due to the major threats happening to coral reef ecosystems, NFWF has been responding to these problems by taking on multiple coral conservation initiatives in an aim to limit the threats, increase public awareness and find solutions to the problems of the decline of coral reefs both domestically and internationally.

To do this, NFWF works with many different partners to achieve these ideas for coral conservation. Some of these programs include programs that were discussed above such as managing the Coral Reef Programs with NOAA's Coral Program and USDA-NRCS. NFWF specializes in bringing all parties together (i.e. individuals, government agencies, nonprofit organizations and corporations). This promotes a solid foundation to protect and restore species, promote healthy oceans, improve wildlife habitat, help with sustainable fisheries, and water conservation. To date, NFWF has supported projects for coral reef conservation totaling over $34 million in about 39 countries giving them a global outreach.

Reef Check International

Reef Check International is an organization whose mission is to preserve the oceans and reefs emphasizing how critical they are to our survival. They work to not only protect tropical coral reefs but also California rocky reefs through education, research and conservation. Impressively, Reef Check has volunteer teams in more than 90 countries and territories.

The results of citizen science divers are used to improve the management of these critically important natural resources. Reef Check programs are notable for providing ecologically sound and economically sustainable solutions to save reefs, by creating partnerships among community volunteers, government agencies, businesses, universities and other nonprofits.

Dr. Karen Cangialosi of Keene State College is the Reef Check International Team Coordinator for the Turks and Caicos Islands. Read about her reef monitoring and youth education program here.

The information in this chapter in thanks to content contributions from Allie Tolles and Haley Zanga .

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7.8.2: Artificial Reefs

Uniqueness of Coral Reefs and their Structure

Coral reefs are home to an abundant number of organisms and many different highly specialized species. Many of these species are endemic to these reefs, meaning they are only found here. Coral reefs also act as a nursery to some species that may not spend their whole life there. Reefs provide structure that promote safety and initiate the settlement of larvae of some species. Not only do they provide valuable services to the marine world, but also act as protection against storm swells and beach erosion for the terrestrial world (to learn more about corals visit here). However, they are in rapid decline as they face many challenges including climate change, ocean acidification and coral bleaching. So, what can be done about this decline? One possible solution is to construct artificial reefs.

What are Artificial Reefs?

Artificial reefs are man-made structures that are designed to imitate natural reefs. They imitate the physical structure that these reefs provide. They can be made from pretty much anything. Some are unintentional, such as oil rigs or boats that have sank, while others are constructed exactly for this purpose. Some are made from concrete or rock, others are made of metal or tires, but the most common object used to make artificial reefs are old ships. One example includes artificial reefs made from sunken New York city subway cars.



Subway cars being pushed into the water by unknown source under [SC DNR, CC 3.0]

Structures are usually placed in open, featureless areas of ocean. These new structures act as a place for new coral polyps to settle, as well as larvae of many species. They can also act as a connection between different reef communities. Many marine organisms, including corals, have a planktonic larval stage. These larva have a set time and distance they can travel. If they don't settle before then, they will die. Artificial reefs can help connect different populations by serving as points for dispersing organisms to settle. These connections would be multigenerational in most cases as settlement means that individuals don't move from one reef to another, or in extreme cases, not at all. However, the offspring from one population could move to the next reef, and so on. Eventually, corals and sponges that are found in natural reefs take over and cover the man-made structures, and fish and invertebrates will be attracted to them like they are to natural reefs.



Biscayne National Park by US National Park Services under [CC open access].

Research on Artificial Reefs

A study done by Arena, et al. (2007) that took place off the coast of Florida looked at the differences between natural and artificial (vessel) reefs. They found greater fish abundance and biomass on the vessel reefs, as well as greater species richness. There were also many economically important fish species found on artificial reefs. However, different assemblages of fish were associated with the different reef types. The vessel reefs housed a much greater proportion of planktivores compared to the natural reef. Planktivores on the younger vessel reefs are lower in the food chain, they represent resources yet to be unlocked and transferred to higher trophic levels. Over time, artificial reefs are expected to transition to be more similar to natural reefs as they age.

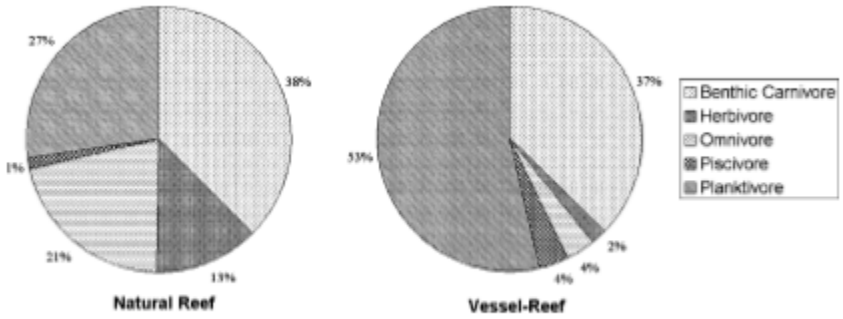


Fig. 3 Trophic composition as a percent of total fish abundance on vessel- and natural reefs

Figure 3 from Arena, Jordan and Spieler, 2007

Artificial reefs can provide a valuable solution to help with the threats that natural coral reefs face, but if things don't change and stressors continue to increase, then artificial reefs won't be sufficient.

There are many well known artificial reefs around the world primarily created from old machinery but there are also some that have been placed there initially for this purpose. "The Silent Evolution" by artist Jason de Caires Taylor, is a beautiful project where art sculptures were placed underwater to serve as artificial reefs. Visitors can enjoy the diverse underwater creatures but also take in the mystifying and magical art that is helping to protect Mexico's rich beauty and important ecology.

Below is a video tour of "The Silent Evolution"



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Below is a video about Artificial reefs by Texas Parks and Wildlife:



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It is worth mentioning that there are other types of reefs in the world besides coral reefs. Some, such as oyster reefs, can also be artificially made using simple materials such as oyster shells for spat (oyster larvae) to grow on and cement the loose materials into a solid reef structure. Many organizations such as The Elizabeth River Project and Chesapeake Bay Foundation work to restore oysters and reefs in the Chesapeake Bay and waterways of the US.

The information in this chapter is thanks to content contributions from William Trautman.

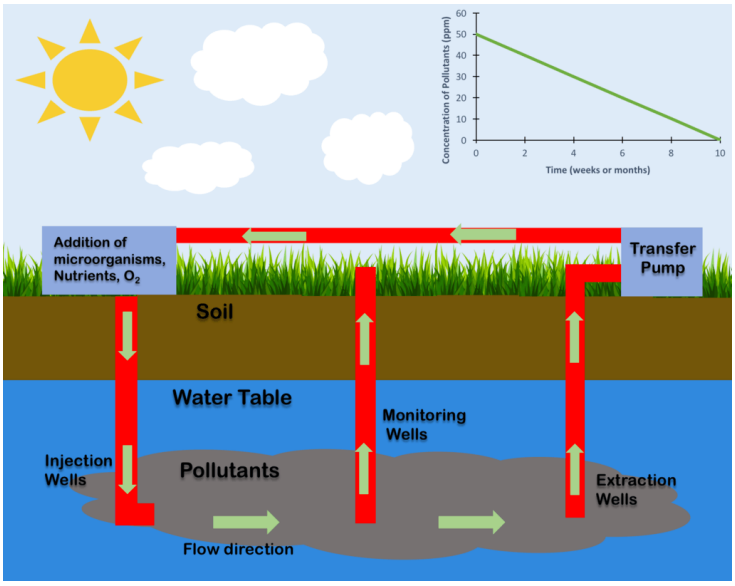
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7.8.3: Bioremediation to Clean Our Oceans

What is Bioremediation?

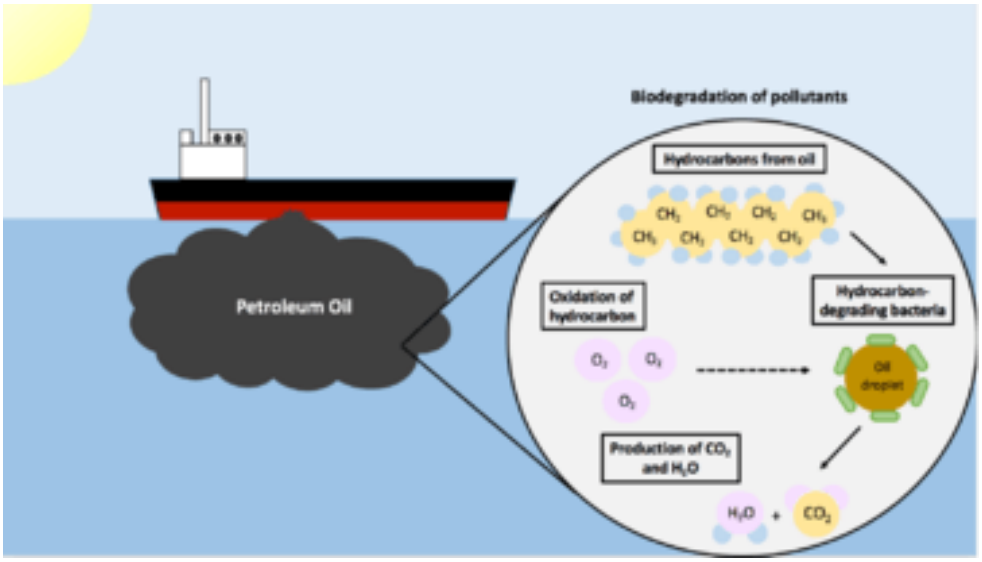
Bioremediation is a possible solution for the growing problem of pollution and global warming. Bioremediation involves using living microbes to clean waste. These microbes can naturally occur in the area or scientists can extract them and place them into areas that need them. When scientists place cultured microbes into an area for purposes of bioremediation it is called bioaugmentation.



"In Situ Bioremediation" by Jørgensen, K. S. via in situ bioremediation under [CC BY-SA 4.0]

The Process of Bioremediation

Microbes in the environment break down organic material. Some microorganisms can degrade contaminants by breaking down these materials into harmless substances. Bioremediation is about creating an ideal environment for microbes that degrade pollution by providing these organisms with fertilizer, oxygen, and other conditions that encourage their rapid growth. Microbes often break down pollutants into small amounts of water and harmless chemicals like carbon dioxide.



"Mechanisms involved in bioremediation of toxic compounds" by Timmer26, via bioremediation of oil spills [CC BY-SA 4.0]

In order for bioremediation to work successfully, conditions need to be ideal for cell growth. Adequate temperature and food must be present in the area. If conditions are not already ideal, amendments can be used. Amendments can consist of common materials like molasses or vegetable oil that increase the chance of survival for microbes by making conditions more suitable for their growth and enhancing their ability to break down contaminants. The process of bioremediation can be as short as a few months or as long as a few years. If the contamination concentration is high, or the contaminated area is very large, then clean up will take longer. Many people worry about the safety of using microbes. However, microbes are completely safe because they are already naturally occurring in the environment and are not harmful to humans. After the contaminants they needed for growth are depleted, the microbes from bioaugmentation will no longer have ideal living conditions and will not survive long. One downside of bioremediation includes creating noise pollution from the use of mixers and pumps that could be irritating to businesses and households.

Advantages of Bioremediation

Bioremediation is relatively cheap compared to other pollution cleanup methods. It is safe and can lead to cleaner water and soil in the area. Another advantage is that contaminated soil and groundwater are treated onsite without having to dig and transport materials elsewhere for treatment. One common example of a successful bioremediation process is composting. This video explains how bioremediation has been used to help clean up oil spills.

Information in this chapter is thanks to content contributions from Bryce Chouinard .

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7.8.4: Biocontrol in Hawaiian Reefs

What is Biocontrol?

Biocontrol or Biological Control is the introduction of a natural predator into an environment in order to control a pest species. It is an important way to aid in the management of terrestrial and aquatic habitats that have been invaded by non-native species. Using natural methods is a great way to help troubled ecosystems without many of the negative impacts associated with chemicals and other non-natural interventions.

Here is a video by the Hawaiian Conservation Alliance of the work completed in the bay of Oahu, HI for the urchin biocontrol project.

Native Sea Urchin Biocontrol Example

Native sea urchins have been used as a form of biocontrol for algae overgrowth in Hawaiian coral reefs.



Two sea urchins in Hawaii by Opencage under [CC BY-SA 2.5]

A non-native species of algae was introduced to Hawaiian coral reefs in the 1970's that quickly became invasive and invaded Oahu's coral reefs. The algae grew so uncontrollably that it smothered out local flora and fauna and is still causing major issues for the Hawaii's reef areas today. Herbivorous fish are highly impacted by this overgrowth. People spent up to 8 hours a day pulling algae from the reefs in attempts to control its growth to little avail.

Finally researchers discovered the idea that native sea urchins could be used to control the algae. Urchins are great at controlling algal growth because they graze on the algae. After the introduction of 100,000 urchins to the reefs, an 85% decrease of algae cover was observed after just 2 years!

Biocontrol Successes and Failures

Though there have been biocontrol failures highlighted in the media, such as the Cane Toad introduction to Australia, there have also been many great successes.

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7.8.5: Ecotourism, Recreation, and Reefs

Recreational activity is one of the joys in life that so many people share. Various types of recreation get people outside in all conditions from the 10^{0} F New England winter weather to the hot beaches of a Caribbean island. Some tropical island activities include: boating, kayaking, scuba diving, snorkeling, sailing, wind surfing, and wake boarding- but they all have one thing in common, that is they are located in the ocean. Although some take place in deeper water, many of these activities are performed in shallow waters full of coral reef habitats. We know how fragile and important these reefs are and we also know how easily us humans have caused damage to them. Coral reef ecosystems are among the most biologically diverse and economically valuable ecosystems on Earth. Worldwide precious coral reefs attract millions of tourists annually and yield a significant economic benefit to those countries and regions where they are located. According to the National Oceanic and Atmospheric Administration (NOAA), recreation and tourism account for $9.6 billion of the total global net profit of coral reefs. This large amount of revenue generated is being threatened by the degradation of coral reefs.

As you can see there is a positive feedback loop occurring because of this situation. Many components of tourism, including recreational activities, are the cause of damage to the reefs, but ironically it has been shown that ecotourism is damaging as well. Ecotourism is defined as: “Responsible travel to natural areas that conserves the environment and improves the well-being of local people.”



A YouTube element has been excluded from this version of the text. You can view it online here: http://pb.libretexts.org/marine/?p=120

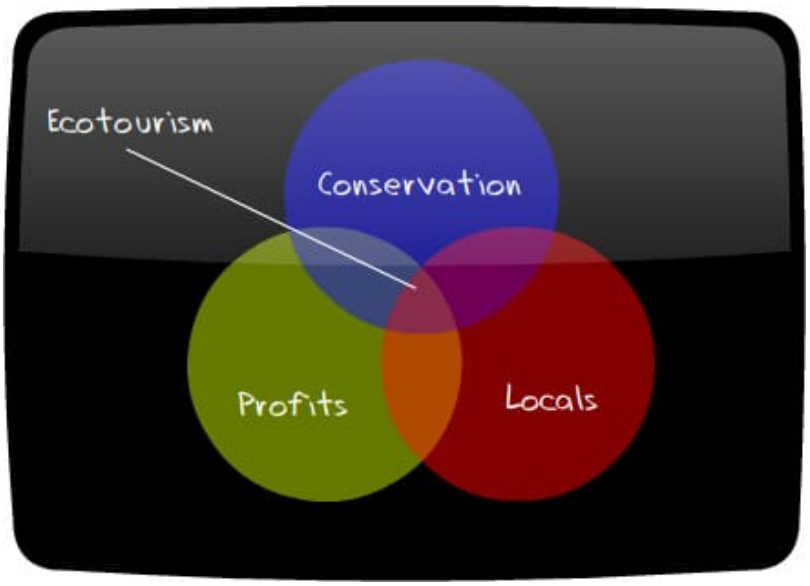
However, increased tourism to sensitive natural areas such as coral reefs, without appropriate planning and management, can threaten the integrity of ecosystems and local cultures. The increase of visitors to ecologically sensitive areas can lead to significant environmental degradation. Likewise, local communities and indigenous cultures can be harmed in numerous ways by an influx of foreign visitors and wealth. Mass tourism poses a threat to reefs and to the revenue generated from these ecosystems. Although branded under the word ecotourism many businesses and organizations are contributing to the increase in coral reef degradation. Once coral reefs are damaged, they are less able to support the many creatures that make their home on the reef and in turn lose value as a destination for tourists.



Little Venice quay flooded with tourists. Mykonos island. Cyclades, Agean Sea, Greece. Photo by Mstyslav Chernov. [CC BY-SA 3.0]

Most tourism in natural areas today is not ecotourism and is not, therefore, sustainable. Specifically, ecotourism possesses the following characteristics:

- Conscientious, low-impact visitor behavior
- Sensitivity towards, and appreciation of, local cultures and biodiversity
- Support for local conservation efforts
- Sustainable benefits to local communities
- Local participation in decision-making
- Educational components for both the traveler and local communities



What is ecotourism? Photo by Ron Mader via Flikr. [CC BY-SA 2.0]

“Tourism will never be completely sustainable, as every industry has impacts. However, it’s important to know if the revenue created from tourism is reinvested correctly in order to benefit the coral reefs and build a sustainable future. For ecotourism to be sustainable, companies must take responsibility and allocate revenue it generates from its eco-attractions into the protection of reefs instead of further investing in tourist structures and attractions that have negative impacts on the health of these

ecosystems."

Recreational activities can harm coral reefs through:

- Breakage of coral colonies and tissue damage from direct contact such as walking, touching, kicking, standing, or gear contact
- Breakage or overturning of coral colonies and tissue damage from boat anchors
- Changes in marine life behavior from feeding or harassment by humans
- Water pollution
- Invasive species
- Trash and debris deposited in the marine environment

There are lessons to learn from the ecological destruction in Australia, Hawaii, Indonesia and other Pacific Islands where recreational activities are high in the bays of resort-filled areas and multiple-use marine parks.

In a study in Australia, activities such as diving, snorkeling, ski jets, and motor boats with surfing skis had high impacts on coral reef ecosystems. These activities can cause direct damage to the corals and increase pollution in the water. Surfing had less negative impact as it is superficial.

Some activities and their impacts are listed below.

[material below 1-4 is copied from How Does Tourism Affect Coral Reefs?]:

1.) Scuba Diving and Snorkeling

While most diving and snorkeling activities have little physical impact on coral reefs, physical damages to corals can and do occur when people stand on, walk on, kick, touch, trample, and when their equipment contacts corals. Coral colonies can be broken and coral tissues can be damaged when such activities occur. Divers and snorkelers can also kick up sediment that is damaging to coral reefs.


Divers. Photo by skeeze via Pixbay. [CC0 Public


Divers coming into contact with coral. Photo by Jjharvey8 via Wikimedia Commons. [GNU Free Documentation License]


Snorkeling on the Great Barrier Reef. Photo by Great Barrier Reef Encounter via Wikimedia Commons. [CC BY-SA 3.0]

2.) Boating and Anchors

Boats grounding in coral reef habitat can damage corals, as can anchors. Anchors can cause a great deal of coral breakage and fragmentation, particularly from large boats like freighters and cruise ships. Heavy chains from large ships can break or dislodge corals. These damages to corals can last for many years.

Anchoring can also damage the habitats near reefs such as seagrasses that serve as nurseries and habitats for the juveniles of different coral reef organisms. Marinas may inappropriately dispose of oils and paint residues, polluting local waters, and additional pollution may occur during fueling.

Two brothers ship anchor. Photo by United States National Oceanic and Atmospheric Administration (NOAA)/Greg McFall via Wikimedia Commons. [Public Domain].

3.) Fishing and Seafood Consumption

An abundance of tourist fishing and consumption of local fish stocks may lead to overexploitation and competition with local fishers. Inappropriate fishing techniques such as bottom trawling can cause physical damage to reefs.

CIMG2733 Fishing Net On Reef. Photo by Tim Sheerman-Chase via Flikr. [CC BY 2.0]

4.) Cruises and Tour Boats

These vessels can cause physical damage to reefs through anchoring and grounding, as well as through the release of gray water and human waste into coral reef habitat. Chemicals added to paint used on boats and fishnets that are intended to discourage the growth of marine organisms can also cause pollution in coral reef waters.


Boats in the corals of Red Sea. Photo by kallerna via Wikimedia commons. [CC BY-SA 3.0] 
Water Sailboat Sea Ocean Wind Sailing Yacht. Author unknown via Maxpixel. [CC0 1.0 public domain]

The variety of marine life and protected beaches supported by coral reefs provide beautiful sights for sightseers, sunbathers, snorkelers. Healthy reefs support local and global economies. Through the tourism industry and fisheries, coral reefs generate billions of dollars, and millions of jobs, in more than 100 countries around the world. Studies show that on average, countries with coral reef industries derive more than half of their gross national product from them. A good example can be found in Bonaire, a small Caribbean island. Bonaire earns about $23 million (USD) annually from coral reef activities, yet managing its marine park costs less than $1 million per year. A study conducted in 2002 estimated the value of coral reefs at $10 billion, with direct economic benefits of $360 million per year. For residents of coral reef areas who depend on income from tourism, reef destruction creates a significant loss of employment in the tourism, marine recreation, and sport fishing industries.

As we all know, coral reefs are undergoing major stress-related side effects because of human impacts. Through over-use, direct damage and ill-considered tourist operations, the World Wildlife Fund predicts that 24% of the world's reefs are under imminent risk of collapse through human pressures; and a further 26% are under a longer term threat of collapse. Another significant anthropogenic problem facing coral reefs is sedimentation. Sedimentation (losing soil from upland areas) is an extremely important cause of coral reef destruction. Coastal construction and shoreline development (back to the ecotourism concept) often result in heavy sediment loading. Watersheds cleared of their forests and other vegetation cover is vulnerable to erosion and flooding, resulting in increased levels of sediments reaching the reefs. Excessive sedimentation also exceeds the clearing capacity of some filter feeders and smothers the substrate. It reduces light penetration and can alter the vertical distribution of plants and animals on reefs. Sediments can also absorb and transport other pollutants.

When tourists accidently touch, pollute or break off parts of the reef, corals experience stress. The coral organisms try to fight off the intrusion, but this process often leads to coral bleaching—when corals react in a stressed way to expel the brightly colored algae that live in them this in turn, starves themselves and eventually become completely white. Once corals are bleached, they die and can no longer contribute to the biodiversity of the reef community. Since the disruption of one ocean system impacts all the others, sea grass and mangroves—shallow-water plant species vital to the health of the marine ecosystem—are also threatened by coral stress. Many of these events of accidental coral destruction are caused by recreational activities.

One study examined diver behavior at several important coral reef dive locations within the Philippines and also assessed how diver characteristics and dive operator compliance with an environmentally responsible diving program, known as the Green Fins approach, affected reef contacts. The role of dive supervision was assessed by recording dive guide interventions underwater, and how this was affected by dive group size. **Of the 100 recreational divers followed, 88 % made contact with the reef at least once per dive**. Divers from operators with high levels of compliance with the Green Fins program exhibited significantly lower reef contact rates than those from dive operators with low levels of compliance.

Although it's difficult for an individual to stop the entire coral reef dilemma it's easy to take small but powerful steps in the right direction.

Some of these steps include:

- Don't touch living coral and don't pick up wildlife for souvenirs, including shells, coral rubble and plants.
- Be conscious of what you bring with you, for example, reusable water bottles instead of plastic bottles and a backpack for your trash in case there isn't an area nearby to dispose of waste properly.
- Take the bus instead of a car, and if possible, do your research on the hotels or hostels where you stay.
- Try to stay at hotels that are environmentally friendly. Many coastal hotels dump their graywater—wastewater from laundry, cooking and household sinks—into the ocean, contributing to sedimentation and the contamination of coral reefs.

So, the message of this post is to be aware of corals and precious ecosystems when recreating! Also, try to vacation more sustainably by researching and traveling more eco-friendly. Some places that offer eco-tourism travel are green loons. Travel Tips for eco-traveling can be found below.



A YouTube element has been excluded from this version of the text. You can view it online here: http://pb.libretexts.org/marine/?p=120

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7.8.6: How Technology is Saving the World's Coral Reefs

The Global Coral Reef Monitoring Network found that over 19% of the world's coral reefs are dead due to factors such as climate change and ocean warming causing an epidemic of coral bleaching across the world.

The decline in coral reefs causes major problems. Coral reefs make up only 0.2% of our ocean however they are home to over 25% of marine fish species and other organisms. They play many roles including protection of shorelines from major storms. The loss of coral reefs can disrupt many other ecosystems in and around the ocean.

Although the destruction of coral reefs have been caused by human activity, it is also humans that are saving these systems and finding solutions using technological advancements. Scientists from all over are exploring different technologies aimed at protecting coral reef ecosystems.

EXAMPLES INCLUDE:

1. UNDERWATER ROBOTS THAT MIMIC OCEAN LIFE

Underwater robots may be a key in helping us understand coral reef systems. Underwater robots were recently developed by researchers at Scripps Institution of Oceanography at the University of California San Diego. This new tool can offer a new way to study ocean currents as well as the creatures that are in the ocean. Right now the goal of these underwater robots is to use them to help answer questions about the most abundant form of life in the ocean: plankton.

The researchers at Scripps have designed and built these underwater explorers to study small scale environmental processes that are taking place in the ocean. These robots include probes that are equipped with temperature and other sensors to measure ocean conditions by swimming up and down or by maintaining a constant depth. These small robots could potentially be deployed in the hundreds to thousands to capture a multi-dimensional view of the interactions between the physical ocean and marine life.

During a study using these robots, scientists wanted to test theories behind how plankton form dense patches under the ocean surface, which then later leads them to rise to the surface as red tides. These robots were the perfect way to mimic the underwater swimming behavior of plankton and examine the organisms' movements with the ocean currents.

This was the first time that a mechanism like this has ever been tested underwater. The biggest advancement is that these small robots are made inexpensively and are able to be tracked continuously underwater. What this means is that these robots could potentially be used as a small army and be deployed in a swarm. This swarm-sensing approach opens up a new world of ocean exploration. These small, low cost robots with cameras would allow for the photographic mapping of things such as corals. This technique could be huge in identifying the problem as well as seeing the effects of coral bleaching in almost real time.

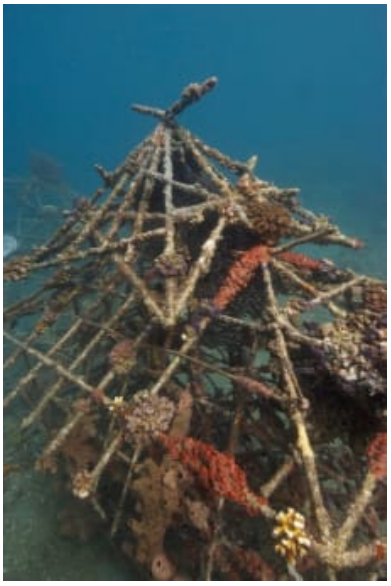
You can check out the video and experiment that went along with this study HERE

2. ELECTRICAL BIOROCK STIMULATES CORAL GROWTH

To help preserve and restore coral, scientists are using an innovative technology called biorock. Biorock is a piece of technology that has a low-voltage direct current which is run through steel. This electricity can then interact with minerals in the seawater and cause solid limestone to grow on the structure. It uses the same principles as electrolysis, where the electric current causes a chemical reaction to occur that wouldn't normally happen. Coral fragments from other reefs can than be translocated to the biorock structure where they can grow due to the natural mineral crystals that were formed.

This type of technology is being used as conservation measures for coral reefs. This is because this type of technology can speed up the normal processes of coral growth. When a diver sees an injured coral they can move them to these structures so that they can continue to grow and heal. The coral then have 50% greater chance of survival then they had before. Biorocks have also helped fish and lobster populations, especially juveniles who shelter in the structures.





"Biorock Stimulation" by Ultra Kulture

3. 3D MAPPING AND BATHYMETRY TO MONITOR REEFS

Coral reef mapping and monitoring have helped scientists gather data on these habitats. With this technique scientists can collection biological, socioeconomic and climatic data needed to evaluate the conditions of the coral reefs and the surrounding area.

Monitoring operations include the National Coral Reef Monitoring Program (NCRMP), a new integrated and monitoring effort that will provide a precise picture of the U.S. coral reefs condition. To learn more about the NCRMP click here.

Mapping underwater coral reefs with 3D mapping allows volunteers and researchers to spend more time studying fish and invertebrates in water, while still getting the data needed from the reef. Cameras are used to take a multitude of underwater images and specialized software is used to analyze those images. More precise numeric data can be obtained with this technology. Before the use of technology such values could only be estimated by expert divers. Another advantage of this technology is its non-invasiveness, allowing the study of an environment in the office with less stressful field operations and coral extractions. The ease of repetitive surveys will make an amazing database for following coral reef changes over time, with the possibility to quantify all changes in near-real-time.

4. 3D PRINTED CORAL ENCOURAGES REEF RESTORATION

3D Printing Could Potentially Save our Coral Reefs: Check out this video showing the work being done to create artificial reefs

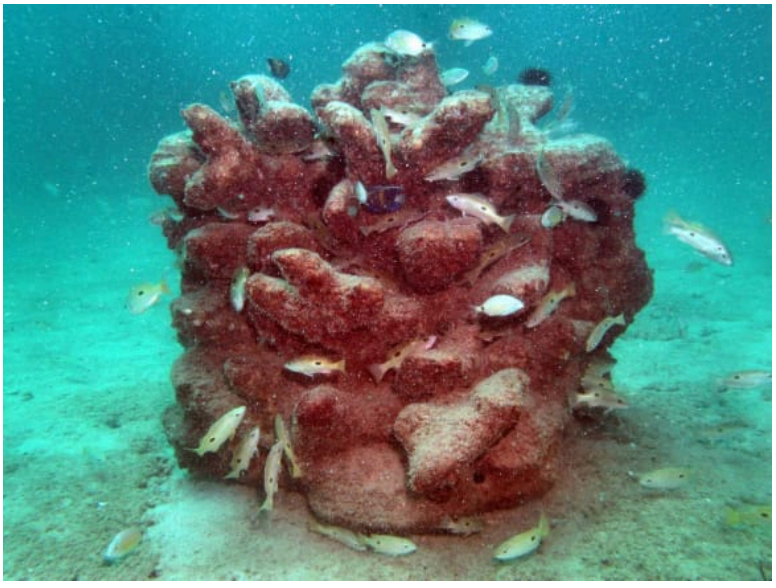


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"3D-Printing Creates Artificial Coral Reefs" by Youtube under CC by 2.0

As coral reefs are declining at fast rates, scientists are struggling to find effective and innovative ways to save them. One of the new ways they are doing this is by 3D printing. 3D printing has become a common way to construct many things such as human organs. 3D printing of portions of reefs can replace lost pieces of coral. These "fake" reefs are thought to be less vulnerable to climate change and more resilient to changing environmental conditions. Scientists are using 3D printing technology that helps them to create fake reefs to mimic the texture and structure of the natural reefs in an effort for restoration.

These experimental 3D printed reefs have already been implemented in the Mediterranean, the Caribbean, the Persian Gulf, and Australia. If they succeed, it will allow for new habitat for fish, but also baby coral polyps to attach themselves and multiply to grow into new reefs.



"3D Printed Coral Reefs" by Popularscience

Artificial reefs have also been used to provide habitat and act as an ecosystem by mimicking a coral reef. They have been made of sunken shipwrecks, plastic, concrete blocks, old tires, and old cars—all heaped onto the ocean floor in hopes that fish and other marine life will come to call them home. However, many of these reefs fail because they do not fit in. A 3D printed reef is a better option since it can recreate the small spaces needed to protect the species that live in the community, it can act as a passageway and door. It can also provide angles that cast light or shades in a certain directions enabling fish to avoid predation. Since this technology is so new there are still so many questions behind it like how well will they actually work? How sustainable are these structures? Can they withstand harsh storms?

As the years go on scientists will be able to determine the effectiveness of these structures. This technology is a step in the right direction to trying to find alternative ways to save coral reefs.

OTHER TECHNOLOGIES BEING USED:

- Meet RoboRay
- Soft Robotics

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7.8.7: Indigenous People and Conservation

The People and the Location

Native peoples living near coral reefs have been displaced for centuries for many reasons some including tourism, agriculture, and conquering of land. Today, nearly 40% of the world's 6,000-8,000 indigenous groups encompass coastal ocean and island regions within their homelands, territories, and nations.

Below is a list of some native populations that live/lived near reefs around the world

- The Ciboney and Carib peoples from mainland America inhabited some land the West Indies.
- Giraavaru people were the ancient owners and rulers of the Maldives**.**
- The Taíno were an Arawak people who were the indigenous people of the Caribbean and Florida.
- Aboriginal people and Torres Strait Islander people belong to Australia and are connected with the Great Barrier Reef.
- Sentinelese people an indigenous people who inhabit North Sentinel Island in the Bay of Bengal in India. They are considered one of the world's last uncontacted peoples.
- The many tribes of Papuans living on Papua New Guinea.
- Malagasy people of Madagascar make up many different groups.

Below is a map of coral building reefs around the world. As seen they are located along the tropics where high densities of human populations live.

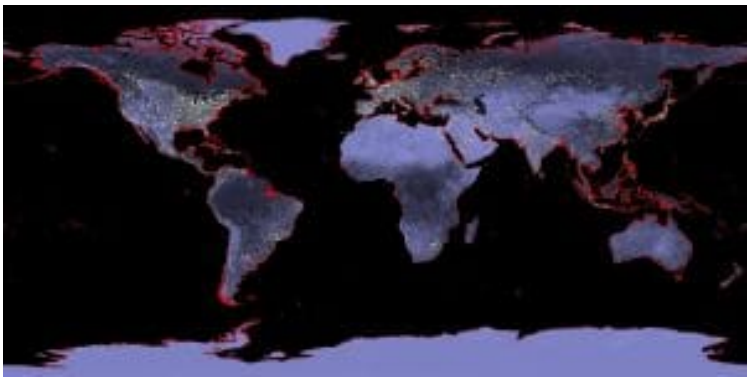


"Reef building corals" by National Oceanic and Atmospheric Administration licensed under [public domain]

Climate Change Threats

Many inescapable threats besides displacement affect indigenous cultures today. One heavily discussed is Climate Change. Climate change is impacting many indigenous communities by endangering sacred and traditional living sites, cultural practices, local forests and ecosystems, traditional foods and water quality. In response to this crisis, scientists in the US are attempting to work with coastal communities to study the impacts of climate change on the health and vitality of the social, economic and natural systems of these communities.

As climate change affects coral reefs intensely, these impacts influence the people that live near and depend on these ecosystems. Two studies in Hawai`i are exploring climate change impacts on coral reefs and in particular the flooding of coastal communities from rising sea water levels. It is agreed widely by scientists that climate change poses the greatest long-term threat to coral reefs and among other impacts, climate change is expected to result in more frequent severe tropical storms and severe coral bleaching events. Coral bleaching is caused by environmental stress from warm water which causes corals to expel their symbiotic algae from their tissues, turn white and eventually the afflicted coral may die. Threats from increasing storms, rising sea level and direct effects of ocean warming will continue to have devastating impacts on coastal ecosystems and their human communities.



"6M Sea Level Rise" by NASA under [public domain]

Indigenous Solutions

Scientists, along with members of Washington State's Swinomish Indian Tribal Community, are addressing climate change threats to the Tribe's land, wildlife, culture and community health. As sea levels rise, coastal erosion intensifies which lead to many negative side affects on land and in the ocean. One important part of preparing for climate change is identifying a full range of potential impacts from declining natural resources such as fish, to damaged infrastructure such as roads and buildings, to compromised community health. The Swinomish fishing tribe in Seattle WA are taking action to build community resilience by implementing the Swinomish Climate Change Initiative. With funding from the Northwest Climate Science Center and the North Pacific Landscape Conservation Cooperative, the Swinomish have conducted a pioneering study to combine assessments of ecological health with newly developed community health indicators to identify priority adaptation tactics. For more information watch a webinar about the project here. Other funding has been granted towards these areas such as from the Interior Department which recently claimed to make $8 million available to fund projects that promote tribal climate change adaptation and ocean and coastal management planning through its Tribal Climate Resilience Program.

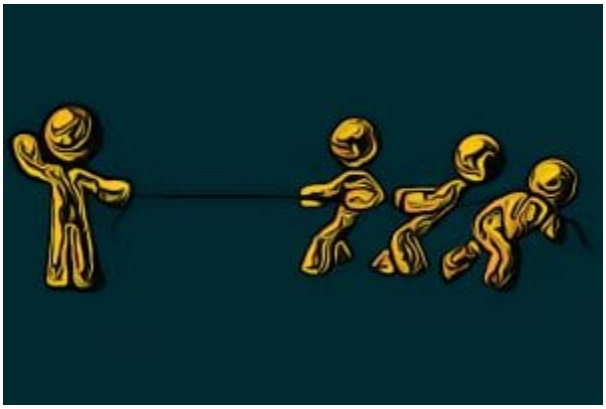
On the island of Maui scientists are developing a tool to help coral reef managers make science-based decisions; this tool can map, assess, value and simulate changes in the coral reef ecosystems under different climate change scenarios. Hawai`i's coral reefs provide seafood, areas for recreation and tourism, coastal protection and support the traditional lifestyles and values of the state's native cultures. The research will show potential climate change impacts and help land and coastal managers make informed decisions to create resilient coral reefs and coastal communities.



Divers from the Commonwealth of the Northern Marianas Islands reef resiliency team conduct assessments of reef resilience in the Marianas archipelago by USGS licensed under [public domain].

The Battle of Good VS Good

Traditionally native peoples were displaced due to other nations conquering the land and many now assume it is all over. Unfortunately, this problem still occurs today with a strange and complicated twist. Many indigenous people are being pushed out of their homes in the name of conservation because governments can acquire money for conservation projects like setting aside land. When the economic priority is to generate revenue from conservation, humans get pushed away from the protected areas so they can become "protected for nature". Most of the world's 6,000 national parks and 100,000 protected places have been created by the removal of tribal peoples. Hundreds more parks are being created every year as countries commit to meeting the UN's goal to protect 17% of land by 2020. And the human toll is rising accordingly.



Resist tug of war: by author unknown via Pixabay, July 9, 2019. [Simplified Pixabay License].

Popular Books Written on this Topic

Conservation Refugees: The Hundred-Year Conflict Between Global Conservation and Native Peoples by Dowie, Mark

Asserting Native Resilience: Pacific Rim Indigenous Nations Face the Climate Crisis by Grossman, Zoltan

Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants by Kimmerer, Robin Wall

Misc. Resources

- MinorityRights.org provides information on indigenous peoples in all countries and regions on the world.
- Reefbase.org is a coral reef database full of information open to all

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8: Invasive Species

The impact of increased average global temperature due to global warming on terrestrial ecosystems has been prevalently studied and the commonly accepted result is that there will be increased domination of invasive who alter the habitat and disturb the species associations by outcompeting the native species. And this concept also applies to the marine ecosystems, as well. The study was conducted at the marine fouling community of Bodega Harbor, Bodega Bay, CA, where human-mediated colonization is frequent. The species composition of this particular site has been known to have nonnative species representing 71% of cover in the dock fouling community. The researchers took 10 sessile species (4 native and 6 invasive) and put them on tile and placed them into 1L tank. Then they raised the temperature gradually, observing total of 6 intervals between the temperature 14 to 32 degrees Celsius. The result concluded that the invasive species were more tolerant to higher temperature and that native species showed taunted growth or death by stress.

Ever since humans had the ability to sail from one continent to the other, they have unintentionally transported marine organisms, an introduction of invasive species to new community. Once invasive species are introduced to new community, they can outcompete the native species and disrupt the species associations that may result in less biodiversity and migration of upper predators. The reduced number of fish which fisheries rely on can then take huge economic damage and overall socioeconomic benefits degrade to some degree. The solution to mitigate such a problem is then to cooperate both the regional and the global trading partners, approaching the most effective management system.

An invasive species can be defined as an introduction of any non native living organism

to an environment resulting in some type of harm to the environment/native inhabitants. In fact,

“invasive species are one of the leading threats to native wildlife,” (www.nwf.org) since they are

able to reproduce and spread so rapidly as a result of having no predators or natural controls.

This proves to be the reason why disturbances such as timber harvesting, tree falls, and

flooding along creeks can encourage these invasive species. Native species have not yet

evolved any defenses against these invaders which leads the natives susceptible to preying,

out-competing, disease, and prevention of reproduction. (www.nwd.org). In addition to these

direct threats, there are also a plethora of indirect threats that invasive species bring to native

species, including but not limited to, changing food webs, decreasing biodiversity, and altering

ecosystem conditions.

Invasive species can spread through a number of mediums including ships, pet trade,

wood products, and ornamental plants. These mediums are primarily made possible through

unintentional human activity. Corridors such as forest roads, trails, and creeks prove to be

excellent routes for spread of these species to new areas because they’re wide open areas that

allow for speedy travel (www.indiana.edu). There are thousands of types on invasive species

which can include, but are not limited to, Asian carp, West Nile Virus, Brown marmorated stink

bugs, and feral pigs.

http://www.nwf.org/wildlife/threats-...e-species.aspx

www.indiana.edu/~preserve/InvasiveSpread/

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Nicholas Bax, Angela Williamson, Max Aguero, Exequiel Gonzalez, Warren Geeves. 2003. Marine invasive alien species: a threat to global biodiversity. Marine Policy 27: 313-323. doi:10.1016/S0308-597X(03)00041-1

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9: FISHERIES MANAGEMENT

9.1: Managing Fisheries

9.2: Overfishing

9.3: Destructive fishing methods

9.4: Fisheries Law, Policy and International Issues

9.5: Marine Protected Areas

9.6: Whaling

9.7: Diseases and Pathogens

9.8: Aquaculture

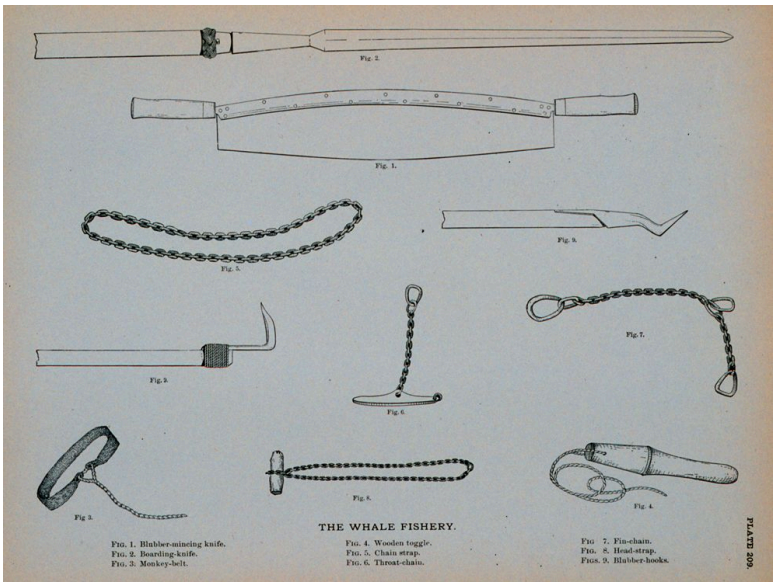
9.9: Human Factors

9.10: Climate Change

9.11: Management Mechanisms, Catch Quotas

9.12: Population Dynamics

[note: these images need to be moved over to the subchapter on Whaling, 15.2]



Tools used to kill whales education.nationalgeographic....haling/?ar_a=1


Eskimos butchering whale

education.nationalgeographic....haling/?ar_a=1


Whale blubber

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9.1: Managing Fisheries

Learning Objectives

- Explain the impact that the collapse of marine fisheries will have on human diet and health

Managing Wild Food Resources

In addition to growing crops and raising animals for food, humans obtain food resources from wild populations, primarily fish populations. For approximately 1 billion people, aquatic resources provide the main source of animal protein. But since 1990, global fish production has declined dramatically. Despite considerable effort, few fisheries on the planet are managed for sustainability.

Overfishing

Overfishing is the harvest of an aquatic population to a level that is too low for that population to replenish itself. Resource depletion, low biological growth rates, and critically low biomass levels result from overfishing. For example, overfishing of sharks has disrupted entire marine ecosystems.



Figure 9.1.1: Overfishing: When a fish stock is reduced to a level that is too low to allow that stock to replenish itself, overfishing has occurred. In addition to eliminating major food sources, overfishing is a threat to aquatic biodiversity.

The ability of a fishery to recover from overfishing depends on the species' natural ability to replenish itself as well as the ecosystem's conditions. Dramatic changes in species composition can result in an ecosystem shift, where other equilibrium energy flows involve species compositions different from those that had been present before overfishing occurred. For example, once trout have been overfished, carp might take over in a way that makes it impossible for the trout to re-establish a breeding population.

Sustainable Ecosystem Management

Fishery extinctions rarely lead to complete extinction of the harvested species, but rather to a radical restructuring of the marine ecosystem in which an abundant species is so over-harvested that it becomes a minor player, ecologically. In general, the fish taken from fisheries have shifted to smaller species as larger species are fished to extinction. In addition to humans losing

the food source, these alterations affect many other species in ways that are difficult or impossible to predict. The collapse of fisheries has dramatic and long-lasting effects on local populations that work in the fishery. In addition, the loss of an inexpensive protein source to populations that cannot afford to replace it will increase the cost of living and limit societies in other ways. In general, the fish taken from fisheries have shifted to smaller species as larger species are fished to extinction. In addition to humans losing the food source, these alterations affect many other species in ways that are difficult or impossible to predict. The collapse of fisheries has dramatic and long-lasting effects on local populations that work in the fishery, not only the fishermen who depend directly on the fish stocks but all of the workers who are part of the industry, such as chefs, fish mongers, truck drivers, boat mechanics, and many more. In addition, the loss of an inexpensive protein source to populations that cannot afford to replace it can increase the cost of living and limit societies in other ways. The ultimate outcomes of overfishing and the commercial extinctions of fish stocks could include the loss of aquatic systems as food sources and economic crises for societies that depend on them.

Sustainable seafood is a movement that has gained momentum as more people become aware of overfishing and environmentally-destructive fishing methods. Sustainable seafood is seafood from either fished or farmed sources that can maintain or increase production in the future without jeopardizing the ecosystems from which it was acquired. In general, slow-growing fish that reproduce late in life, such as orange roughy, are vulnerable to overfishing and are considered unsustainable seafood. Seafood species that grow quickly and breed young, such as anchovies and sardines, are much more resistant to overfishing and are therefore labeled “sustainable” and promoted as good alternatives.

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Key Points

- Dramatic changes in species composition can result in an ecosystem shift, where species compositions differ from those that had been present before the depletion of the original fish stock.
- In general, the fish taken from fisheries have shifted to smaller species as larger species are fished to extinction; if such trends continue, aquatic ecosystems could become unavailable as food sources.
- Sustainable seafood is seafood from either fished or farmed sources that can maintain or increase production in the future without affecting the ecosystem in which it lives.

Key Terms

- **sustainability**: configuring society so that each can meet his own needs and greatest potential, while preserving biodiversity and natural ecosystems, and planning for future generations to maintain this potential.
- **overfishing**: fishing that reduces an aquatic population, or stock, to a level that is inadequate for the stock to replenish itself

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9.2: Overfishing

Overfishing: A Non-Sustainable Use of the Oceans

The simplest way to define overfishing is "to catch so many fish that there are not enough remaining to replenish the population"(1). Overfishing occurs when we take too many marine resources at a rate faster than they can reproduce or recover. And as a result, fish populations are becoming severely depleted and some commercial species (e.g Southern Bluefin Tuna) are even at the edge of extinction (2,3). The end result of overfishing is a permanent collapse in fish supplies (10). Even when these events are isolated to specific regions, they have the potential to affect the global marine food web (12).

Situation

Until 2012, about 85% of global fish stocks have been "over-exploited, depleted, fully exploited, or in recovery from exploitation" (4). Large areas of seabed in the North Sea and Mediterranean, as well as the East China Sea of Asia, have become "desert[s] in the sea", where overfishing has wiped out almost all of the fish stocks (4,5). Fisheries in other parts of the world are also declining. West Africa, for example, has lost 50% of its coastal fisheries in the past 30 years (6).

Another example of overfishing is the Atlantic Cod stock between the 1970s and the 1990s. As technology increased in these years, cod stocks became more accessible to fishermen. Although these populations were once believed to be unlimited, the fish population soon plummeted to unsustainable levels. To ensure sustainable harvest of species, Total Allowable Catches (TACs) must be set to allow for recovery of fish stocks, in order to prevent similar situations to that of the Atlantic Cod. However, there are numerous economical and political implications for implementing TACs, especially in coastal communities that rely heavily on marine resources. As a result, these TACs are not often followed, or may not reflect scientifically accurate determinations.

Causes

Each country has control over their Exclusive Economic Zone (EEZ), an area of no more than 200 nautical miles off the coast of their continental territory, in which they have complete control over fish stocks and regulations (7). Areas outside of this zone, known as the high seas (7) are not regulated by any clear authority and suffer from a lack of effective fishery management (8). Therefore, "Tragedy of the Commons" arises, which was first introduced by Hardin as the idea that individuals exploit resources in their own self-interest, or, whoever gets to the resource first controls it. As each individual does this, the resource is eventually depleted and no one benefits.

The Tragedy of Commons

YouTube Video

This interactive element is not available in this format. Visit the link or scan the QR code to access it online.

View this YouTube Video online

Here is a short video that explains the "Tragedy of the Commons".

Consequences of Overfishing

- Overfishing can completely alter large ecosystems within different areas of the ocean, both coastal and offshore, by creating a snowball effect of disruption (Fisheries and Oceans Canada 2009). For example, overfishing a certain species can alter the balance of predator and prey interactions, which can destroy an ecosystem due to the interruption of important trophic

cascades.

- Overfishing can threaten cities and smaller towns that live along the coast and depend on the seafood industry for employment and food. Depleting the fish stock in these areas threatens food security and livelihoods within the area (World Wildlife Fund 2019).
- Oil and waste pollute byproducts of the fishing industry continue to accumulate as overfishing becomes more prevalent. Fishing boats release toxic chemicals and oils into the water, as well as pollute the water with trash. This is increasing the pollution in the ocean, both solid and liquid waste, that poses significant threats to wildlife (Bhatnagar 2018).
- Damaging fishing practices can alter marine habitats, particularly when using bottom trawling nets. These nets are dragged along the ocean floor, disrupting the environment of any number of species. Additionally, trawling is a large source of bycatch, in which undesirable species are caught in a net and subsequently discarded. This has led to unintentional population decline in a number of species, most notably sea turtles.

Solutions

In order to prevent overfishing, fishermen need to be incentivized to stop catching specific amounts of fish at certain locations. It is all dependent on Maximum Sustainable Yield (MSY), which is the maximum amount of a species that can be harvested while maintaining the ability to recover the population (11). By limiting, banning, or regulating the use of bottom trawling nets, juveniles can be protected, allowing them to reach sexual maturity and reproduce before they are caught. Additional measures on trawling nets can reduce the bycatch of unwanted species. For example, Turtle Excluder Devices (TEDs) are a popular way of ensuring that sea turtles are not accidentally caught in fishing nets. Setting an Individual Fishing Quota would incentivize fishermen to catch the largest and most mature fish and avoid bycatch or juveniles (11). This would be beneficial to both the fish and the fishermen because it prevents exploitation of stocks and the economic collapse of species-specific fisheries that follows the crash of a population.

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9.3: Destructive fishing methods

When we think about destroying the oceans, most people think of destruction via pollution. Although chemical dumping and plastics have a drastic effect on marine life and ecosystems, it is very important to consider another major issue that is causing detrimental effects on marine systems. This issue is destructive fishing methods. Destructive fishing includes practices that leave marine populations irreversibly damaged and can destroy entire habitats for fish and other organisms.

According to the World Wildlife Fund (WWF), there will be no more fish left in the oceans by 2048. This is because more than 30 percent of the world's fisheries have been pushed beyond their biological limits. Therefore, we need stricter regulations and laws to prevent this disaster.

Destructive fishing is mostly done in underdeveloped countries which don't have regulations for fishermen to follow. These methods are used because they are effective in getting a large amount of fish in a short period of time saving fishermen time and effort. Some dangerous methods include over-fishing, blast fishing, bottom trawling, and cyanide fishing.

Over-fishing

Over-fishing is when fish are captured before they can reproduce, which can significantly reduce population sizes for the future. This disrupts not only the species that was harvested, but also the other organisms that depend on those species and potentially the whole ecosystem.



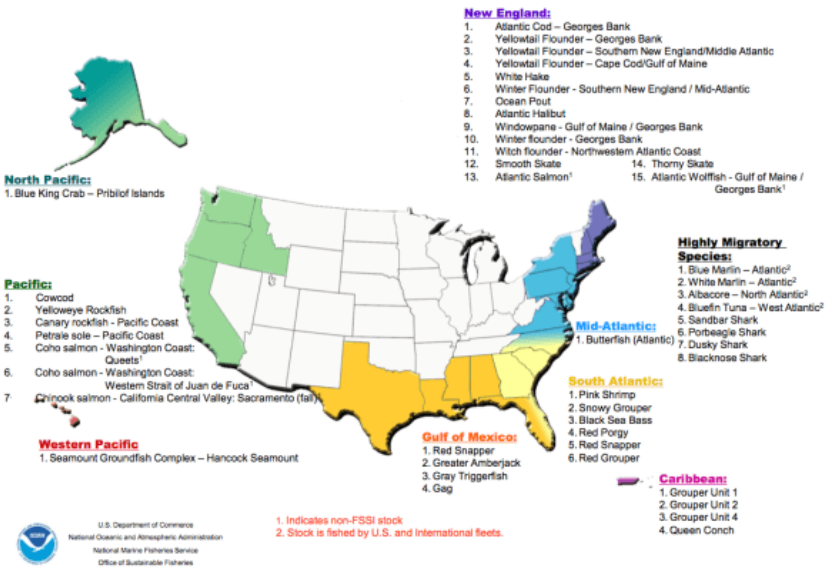
"Trawlers over fishing cod" by Asc1733 [CC BY SA4.0]

Facts from the WWF :

– In just over 40 years there has been a decrease in recorded marine species by 39%.

– Around 93 million tons of fish were caught world-wide.

– Entire species, such as the Pacific Blue-fin tuna and swordfish, are highly endangered and are at an all-time low.



"Overfished US stocks 2010" by NOAA [CC BY-SA 3.0]

– Other marine species, such as whales, dolphins and turtles, are unintentionally killed as a result of over-fishing.

Causes:

A major issue is the open access to the ocean and the absent regulations and monitoring of the water. Due to the increased number of fisheries, management has begun to slack. Current rules and regulations are not strict and do not mark a limit of intake. More importantly, there is little to no international fishing regulations. Even if the nations did come together to fight this issue, we still face illegal fishing. To reduce the intake of fish it should be mandatory to report intake and there must be a maximum limit that is determined by biologists and not companies. Also, we need stronger monitoring of the ocean, which may be hard due to the number of fisheries and the huge surface area the ocean covers.

Impacts:

The WWF states that the populations that are mainly targeted are top predators in the ecosystem such as Billfish, Tuna, Salmon, and sharks. This is because of the economic and social demands of the fishing industry. Decreases in the top predator population can severely disrupt other marine populations. A prime example of this is increases in population sizes of smaller marine animals at the bottom of the food web that are fed on by top predators. This impacts other aspects of the marine ecosystem such as increases in algal overgrowth, which can be dangerous to coral reefs. Algae, although essential for the ecosystem, can have negative effects if there is a large abundance.

Another issue that is closely related to over-fishing is by-catch. By-catch refers to non-target animals such as turtles or dolphins that are captured or killed in fishing nets. This threat causes the loss of billions of fish and other animals such as sea turtles and cetaceans.

“Sea Turtle Entangled in Ghost Net” by Doug Helton [CC BY SA]

Watch this Tedtalk on over fishing here and a video on by-catching here.

Over-fishing causes a cascade of effects in marine communitiesthat can destroy habitats and result in the loss of biodiversity both in terms of overall abundance and species richness (Coleman, 2002). Not only does over-fishing destroy marine ecosystems, it also impacts food security for people. Humans that live in coastal communities rely largely on fish as a protein resource. Over-fishing decreases food security by threatening the long-term food supply, especially for individuals in developing countries.

Solutions:

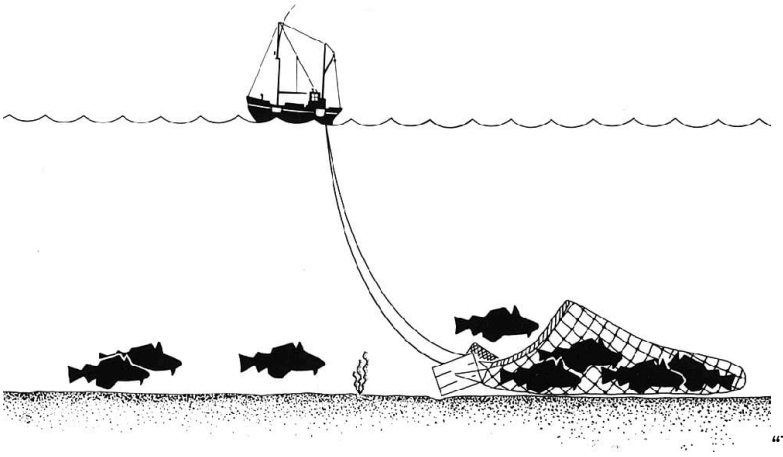
There have been new movements to push fisheries to practice sustainable fishing. The WWF has helped develop and set environmental standards to help set a plan for sustainable fisheries. Approximately 15,000 seafood products hold to the standard of sustainable fishing, which is a great first step. There are other ways to help with over-fishing and one way is by influencing the market for fish. By reducing the need for fish products, less fish will be caught and hopefully it will allow some time for re-population.

By Drajay1976 [CC by 3.0]

Blast Fishing

Blast fishing or dynamite fishing is a practice outlawed in most of the world, but is still used in southeast Asia. It involves using explosions to stun or kill large schools of fish for easy collection. The explosions often destroy underlying ecosystems from the

strength of the blast. Around 70,000 fishermen still use this practice. Researchers believe that destructive fishing practices like blast fishing are one of the biggest threats to coral reef ecosystems. Coral reefs are less likely to grow in places of constant disturbance. The damage done to coral reefs has an immediate negative effect on the fish population in the area. From a single blast, it takes a coral reef about 5-10 years to recover. From constant blast fishing it leaves coral reefs unable to grow leaving an ocean of rubble. To reduce the use of this method, enforcement officials patrol the seas to try to catch and reprimand offenders.



"Trawling Drawing via Trawl" by NOAA under Public Domain

Bottom trawling

Bottom trawling is a method that uses a large net that scrapes against the ocean floor to collect large groups of fish. Global catch from bottom trawling has been estimated at over 30 million tons per year, an amount larger than any other fishing method. The trawl doors disturb the sea bed, create a cloud of muddy water which hides the oncoming trawl net and generates a noise which attracts fish. The fish begin to swim in front of the net mouth. As the trawl continues along the seabed, fish begin to tire and slip backwards into the net. Finally, the fish become exhausted and drop back, into the "cod end" and are caught. The problem with bottom trawling is that it is un-selective in the fish it catches and severely damages marine ecosystems. Many creatures end up mistakenly caught and thrown overboard dead or dying, including endangered fish and vulnerable deep-sea corals that can live for hundreds of years or more.

Cyanide fishing

Cyanide fishing is a fishing technique used to gather fish for aquaria. In this process, a cyanide solution is used to stun fish for easier collection. This method can kill neighboring fish communities and severely harm coral reefs. Recent studies have shown that the combination of cyanide use and stress of post capture handling results in mortality of up to 75% of the organisms within less than 48 hours of capture. With such high mortality numbers, a greater number of fish must be caught in order to supplement post-catch death.

The information in this chapter in thanks to content contributions from Maddison Ouellette and Bryce Chouinard.

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9.4: Fisheries Law, Policy and International Issues

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9.5: Marine Protected Areas

Marine Protected Areas (MPAs) are zones of the ocean and/or Great Lakes that are protected by government agencies for the conservation and protection of marine life. In the United States alone, there are over 1,600 MPAs covering a large assortment of habitats. Locations of Marine Protected Areas include the open ocean, coastal areas, intertidal zones, estuaries, and the Great Lakes. MPAs are critical to protecting marine biodiversity, ecosystem function and sustaining healthy coastal communities.

There are varying degrees of protection in all of the United States' Marine Protected Areas. In 2009, the United States established the National System of Marine Protected Areas to effectively conserve the marine resources of our nation. There are 437 sites under the national system that span an area of 191,030 square miles. Yet, only 4% of United States waters are covered by the national system. Nearly 77% of this 4% is no-take and prohibits the extraction or significant destruction of natural and cultural resources. This is because the largest MPA (covering approx. 140,000 square miles) is a no-take area. The largest area of the United States MPAs is the Papahanaumokuakea Marine National Monument in the Hawaiian Islands.

The three goals of the national system are to conserve and manage natural heritage, cultural heritage, and sustainable production. About 55% of the number of MPAs under the national system is managed under the natural heritage focus. Natural heritage is described as the nation's biological communities, habitats, ecosystems, and processes and the ecological services, values and uses that they provide. Cultural heritage makes up 11% of the number of MPAs under the national system. Cultural heritage is a focus of the national system in order to protect the cultural resources that reflect the nation's maritime history and traditional cultural connections to the sea, as well as the uses and values they provide. About one-third of the MPAs listed under our national system is a mixture of the three focuses under our national system goals. Sustainable production is the third focus that describes the nation's renewable living resources and their habitats. Only 1% of our MPAs under the national system are protected by this conservation focus. 50% of the national system of MPAs is on the West Coast. The California Department of Fish and Wildlife manages 141 MPAs. A larger majority (61%) of MPAs are managed by state and territorial agencies, while a smaller percentage (36%) are managed by federal agencies. The other 3% are managed by partnerships between the two.

A list of National System MPAs can be found here: http://marineprotectedareas.noaa.gov...slist_0713.pdf

References:

Building the National System of Marine Protected Areas, published in August 2013 can be found here: http://marineprotectedareas.noaa.gov..._mpas_0713.pdf

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9.6: Whaling

The history of whaling dates back to at least 4,000 years ago when indigenous people in areas with whales relied on whale meat for sustenance. Native Americans were noted for hunting whales back in the early 1600's. As whale meat and blubber became more of a commodity that could be used in products, the whaling industry emerged throughout Europe and North America. As technology grew, whale hunters were able to create new techniques in capturing and killing whales. Throughout the 18th and 19th centuries, whaling continued to be a profitable business with high competition. Whale oil was also used in lamps at the time but the decline in the whale industry was caused by the emergence of the petroleum industry as a more reliable fuel. In in 1946 the International Whaling Commission was created and included 89 nations who agreed to regulate whaling. A moratorium was implemented in 1986, although Iceland, Norway, and Japan continue to hunt whales through legal loopholes such as under pretenses of scientific research.

The process of whaling is inhumane and environmentally harmful. Whales have long life spans and are slow to reproduce, which is a large reason why they have been listed as an endangered species since 1971. Hunters use grenade harpoons to wound the whale until is immobile. The whale is then dragged closer to the boat where it will be continuously shot until it eventually dies slowly and painfully--sometimes it takes an hour to kill the whale.

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9.7: Diseases and Pathogens

Pathogens are transported into the ocean through variety of ways. The three main ways pathogens spread through the ocean are: untreated municipal sewage, sewage from ships, and livestock and animal waste. Human sewage is the most common source of pathogen pollution, particularly in South America, Asia, and Africa. Countries that are “poverty-stricken, war-torn, or politically unstable are generally more susceptible to pathogenic diseases because of poor infrastructure, lower standards of sanitation or hygiene, and inadequate maintenance of water supplies.” Waste from recreational and commercial vessels, particularly cruise ships, also introduce pathogens to ocean waters. Lastly, discharge of waste from farm, domestic, or wild animals can introduce bacteria, viruses, and parasites into local water systems and coastal waters.

In the ocean, different species of marine life are susceptible to varying types of diseases and pathogens. Different pathogens and diseases may either affect a wide variety of species or specialize on a few.

Marine mammals are known to be susceptible to nearly the entire range of marine pathogens. Pneumonia and botulism have both been reported in wild and captive species of marine mammals. Brucellosis, which can trigger abortions, has been noted with potential zoonotic capabilities. Erysipelas, also known as Diamond Skin Disease, is a disease affecting terrestrial mammals as well as fish. Lesions tend to form on marine mammals affected by Diamond Skin Disease. A much larger portion of marine pathogens and bacteria exist to affect the marine mammal population, with massive fatal outbreaks having occurred in the past.

Just as many, if not more, pathogens and diseases affect the planet's fish populations. The most commonly noted infections include "pop eye" and "fin rot" (both caused by gram-negative bacteria). Fish tuberculosis is a common condition as well that carries safety implications; fish tuberculosis is known to be zoonotic.

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9.8: Aquaculture

Aquaculture is the practice of raising aquatic plant and animal species. Much like a terrestrial farm, aquaculture usually includes breeding, rearing, and sometimes harvesting the organisms being raised. Aquaculture typically has two main purposes:

- The first is for the commercial production of organisms. This can be for food, ornamental fish for aquaria, or products like pearls from oysters.
- The other main purpose of aquaculture is to captively breed and raise organisms to bolster wild populations that may be threatened or in decline. For example, there are many salmon hatcheries in California that are intended to supplement populations for commercial fisheries as well as for sport fishing.

Marine aquaculture is the raising marine organisms either in enclosed cages and nets in the ocean or in man-made tanks on land. The most common species produced in U.S. aquaculture operations are mainly oysters, clams, mussels, shrimp, and salmon. There is also production of cod, moi, yellowtail, barramundi, seabass, and seabream, but these are in much smaller quantities. The potential for aquaculture to provide protein sources to the rapidly increasing global population is very high, and research into this technology has been heavily invested in around the world. (Source: NOAA Fisheries - Office of Aquaculture)

There are some issues with aquaculture, however, and marine aquaculture in particular. When fish are raised in a protected and controlled environment, they become adapted to an artificial environment and lack much of the selection pressures that would normally influence genetic traits in wild populations. This often means that fish produced in hatcheries have a lower fitness when released than wild populations. When the hatchery raised fish are released into the wild to build up population sizes, they can compete and breed with wild populations. This has the possibility of reducing the overall fitness of wild populations. (Source: U.S. Fish and Wildlife Service)

- Aquaculture, otherwise known as fish farming refers to breeding, nurturing and harvesting plants and animals from all types of environments; Ex. Ponds, lakes, rivers, and oceans. It includes the production of shellfish and hatchery fish, which are raised to market size in tanks, nets, cages, raceways, or ponds. They are raised for a variety of uses; some will be used for selling in the market for food, however, some are used for stock restoration in which they are raised and then released back into the wild to restore wild populations. Sometimes the fish and plants are traded to corporations/businesses, such as aquariums. They are also grown for pharmaceutical, neurological, or biotechnical purposes. Aquaculture is used in both marine and freshwater environments. The most popular marine species farmed are muscles, clams, shrimp, oysters, and salmon. In freshwater it is dominated by catfish farming, however, tilapia, trout, and bass also have a fair amount of farming. The countries that farm seafood the most are: China at 62%, 26% for all Asian countries besides China, 4.5% from Europe, and 4.5% from the Americas (According to The State of World Fisheries and Aquaculture- 2010). World aquaculture also has a production worth of nearly $100 billion.

The benefits of aquaculture are far and large. They help with sustainability because it lessens the strain on natural stocks. Aquaculture stocks are consistent as well, meaning they are available year round and do not have limitations on how many individuals can be caught. They are also an integral part of the economy, providing thousands of jobs in operations and secondary services. Lastly, and probably the biggest benefit is that aquaculture can be good for the environment; recent studies by NOAA illustrate that aquaculture poses a low risk to the environment. One reason is because there is no bycatch and in some cases, such as shellfish, they feed of the native zooplankton and phytoplankton. Although aquaculture has many benefits for wild populations of the species being farmed, there are also drawbacks because of poor farming habits. One major issue is that farming puts pressure on wild populations that are used to create the fish pellets. It can also intensify the spread of disease to wild populations and compromise the gene pool of native populations if farmed and wild populations breed. Lastly, it can pollute the environment with excess nutrients, such as with excess food and wastes. While there are negative effects to aquaculture, they are often restricted to small areas and for short periods of time.

Link to Resource: columbianewsservice.com/wp-co...quaculture.jpg

Sources:

1. www.nmfs.noaa.gov/aquaculture...01.html#12what

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3. fishery.about.com/od/Benefits...reBenefits.htm

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9.9: Human Factors



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9.10: Climate Change

Climate Change Overview

Climate change is a change in weather patterns that lasts for an extended period of time. Natural causes alone cannot explain all of these changes. Human activities are contributing to climate change by releasing carbon dioxide(CO_2) and other greenhouse gases into the atmosphere every year. The more greenhouse gases we emit, the larger the future climate changes will be[1].

Causes of Climate Change

Earth's temperature hinges on the energy balance of the Earth's system. The energy balance can be explained by incoming energy from the sun is absorbed by the Earth, Earth warmms.

Factors that have caused Earth's climate to change many times:

Greenhouse effect which the amount of heat retained by Earth's atmosphere. Greenhouse effects works by the solar energy

1. http://www.epa.gov/climatechange/sci.../overview.html

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9.11: Management Mechanisms, Catch Quotas

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9.12: Population Dynamics



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10: Energy From the Sea

In a world where renewable energy sources has become increasingly important, many have turned to the vast oceans as a source of power. As winds sweep across the ocean, they apply a force to the water at the surface. As the water is pushed one direction or the other, it creates waves. The energy contained in waves is clearly illustrated by the destruction that can be caused by tsunami's as well as the continuous erosion of coastlines. Although, not all of the potential sites for wave energy capture can be utilized (because of shipping lanes, fisheries, sensitive habitats, etc), there is still ample energy available to support our needs. The Electrical Power Research Institute (EPRI) conducted a study which estimated that the total amount of wave energy available along the outer shelf of the U.S. is around 1,170 TWh/year. To put this in perspective, the entire U.S. uses a total of about 4,000 TWh annually. See the full EPRI report here.

How do we harness the energy of a wave? There are many different variations, and new technologies are constantly being developed, but they all build off of a central theme. In order to generate electrical power from waves, you need mechanical energy. This can be in the form of a pump or a turbine which is rotated, and through movement of electromagnetic fields, an electrical current is created. There are four main types of devices for capturing wave energy:

Terminator Devices

These devices are typically situated perpendicular to the direction of the waves in order to utilize the vertical movement of the surface of the water. In a oscillating water column device, waves push water through an opening below the surface of the device. As the water level within the device rise, the air inside the chamber is compressed and forced out of a turbine to generate electrical power. Oscillating water column devices are most often found on shorelines, but floating systems have been produced as well.

owc.jpg

WEC_RTIMCS_WAVEC_PICO.jpg

Attenuators

- Attenuators are long, segmented devices that lie parallel to the direction of the waves. As a wave passes by, different segments are raised and lowered. The motion between segments at differing heights is used to drive hydraulic pumps or some type of converter which can then generate electricity.

  surfaceattenuator.png

Point Absorbers

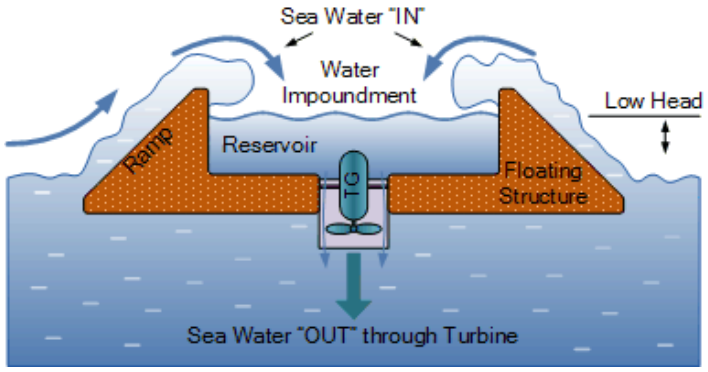
These devices use the vertical movement of a floating component to either compress a fluid through a turbine, causing rotational motion that can be used for generation of electricity. They are typically more compact than other devices, and require some component to be stationary (mounted to the seafloor) while a complimentary component moves due to the waves.



i-81b1cd35861d702cce4eeb261bc39743-mn_wave_power.jpg

Overtopping Devices

These devices have a reservoir that is filled by incoming waves. As the waves pile up, the water level in the reservoir increases, increasing it's potential energy. Much in the same way that a dam on a river does, the water in the reservoir is released through a turbine, and as it flows down into the surrounding water it generates electricity.





Source: (Bureau of Ocean Energy Management).

Thumbnail: the 300 kW 'SeaFlow' turbine off the north coast of Devon. (CC BY-SA 3.0 Unported; Fundy).

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11: MAJOR ENVIRONMENTAL EVENTS

11.1: Fukushima

11.2: Indonesian Tsunami

11.3: Santa Barbara Oil Spill

11.4: Exxon Valdez Oil Spill

11.5: Deepwater Horizon Oil Spill

11.6: Hurricane Katrina (and others)

11.7: Rachel Carson and DDT

11.8: Diadema in the Caribbean

11.9: Hurricane Katrina

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11.1: Fukushima

Fukushima

Tohoku Earthquake

The magnitude 9.0 Tohoku earthquake on March 11, 2011, which occurred near the northeast coast of Honshu, Japan, resulted from thrust faulting on or near the subduction zone plate boundary between the Pacific and North America plates at a depth of 32 km.[1] [2] The earthquake resulted in major loss of human life, as well as extensive damage to infrastructure along the entire east coast of Honshu. A tsunami, several fires, and catastrophic nuclear meltdown resulted from the earthquake.

Tsunami

The Tohoku earthquake resulted in a Pacific-wide tsunami with the highest run-up height of 38.9 at Iwate Prefecture.[3] It is considered to be the largest tsunami in Japan since instrumental record began in 1900 and is the fourth largest in the world.[4]

Nuclear Meltdown

The tsunami and earthquake triggered a destabilization at Fukushima Daiichi Nuclear Power Plant's reactors 1,3, and 4 resulting in hydrogen-air explosions and partial nuclear meltdown.

Ocean Radiation

As a result of the nuclear meltdown

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[1] USGS Significant Earthquake Archive: earthquake.usgs.gov/earthquak...01xgp/#summary

[2] www.ngdc.noaa.gov/hazard/tsun.../2011_0311.pdf

[3] Ibid

[4] Ibid

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11.2: Indonesian Tsunami

2004 Indian Ocean Tsunami

On December 25, 2004 a magnitude 9.1 earthquake ruptured off a subduction zone to the west of Sumatra, Indonesia. The energy produced from this earthquake, equivalent to 23,000 Hiroshima-type atomic bombs, would generate the most destructive tsunami waves in human history. Over 150,000 people in over 14 nations across nearly 3800 miles of the Indian Ocean were killed. The aftermath of the

How The Tsunami Spread

> Immediately following the magnitude 9.1 earthquake,

Damage
The death totalled atleast 150,00 people

Role of Ecological Destruction

> The death and destruction of the 2004 Indian Ocean Tsunami were exacerbated by the destruction of coral reefs and mangrove forests alone the coastlines of the hardest hit countries. Coral Reefs

Lessons Learned

> Despite a significant lag time (several hours) between the rupture of the earthquake in Indonesia and the arrival fo the killer waves in India and Sri Lanka, there was little to no preparation or evacuation of at risk areas. Despite the Indians Ocean proximity to fault lines and volcanoes in Indonesia, there was no early warning system, or network for communication in place.
>
> 18 months later, 28 Tsunami warning centers were placed in the Indian Ocean, cable of tracking both seismic and
>
> The disaster fueled tsunami early warning systems
>
> Future Forcast

portal.unesco.org/en/ev.php-U...CTION=201.html

http://nctr.pmel.noaa.gov/indo_1204.html

http://nctr.pmel.noaa.gov/Articles/5...niversary.html

news.nationalgeographic.com/n...6_tsunami.html

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11.3: Santa Barbara Oil Spill

On January 28th 1969 an offshore drilling rig operated by Union Oil off the coast of Santa Barbara experienced a well blowout. Platform Alpha as the oil rig was called was in the process of extracting a drilling pipe from a depth of 3500 feet so that a replacement drill tip could be installed when the blowout occurred. Sources differ on whether it was caused by the mud used to maintain the pressure in the well running low, or if the drill operators did not sufficiently compensate for the pressure while pumping the drilling mud back down into the well. The result was a natural gas blowout. The well was successfully capped however the pressure continued to build leading to cracks in the seafloor of the Santa Barbara channel causing oil to erupt out. There are different numbers quoted depending on the source regarding the quantity of oil flowing out from the spill. They range from the estimate by the oil company of less than 100 gallons per hour over the course of the eleven days which adds up to approximately 26,400 gallons to alternative estimates of 3 million gallons of crude oil total flowing through the cracks into the ocean.



Aerial view of 1969 Santa Barbara Oil Spill

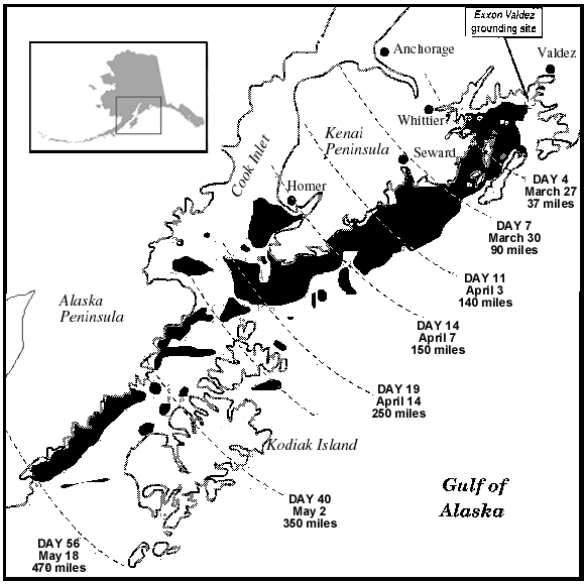
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- http://www.skidmore.edu/~rscarce/Soc...-Oil-Power.pdf
- http://www.geog.ucsb.edu/~jeff/sb_69oilspill/
- http://www.geog.ucsb.edu/~kclarke/Pa...lSpill1969.pdf
- http://response.restoration.noaa.gov...echnology.html
- nepis.epa.gov/Exe/ZyPURL.cgi?...y=9101CQ8N.TXT

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11.4: Exxon Valdez Oil Spill

On March 24, 1989, the oil tanker Exxon-Valdez ran aground whilst avoiding an iceberg, causing the world's second largest catastrophic oil spill. The spill released 10.8 million gallons (at a minimum estimate) of oil into the Prince Edward Sound in Alaska, and evidence of continuous effects of the spill still are apparent, nearly 25 years after the incident. The spill spread across 1,300 miles of immediate coastline by ocean current, and effects are seen even further. Ecosystems were severely disrupted and several species in the area effected.



http://www.evostc.state.ak.us/index.cfm?FA=facts.map

[The link above gives access to view the NOAA Hazmat Trajectory Model of the *Exxon Valdez* Oil Spill. This series of 7 slides charts the spread of the oil March 24-30, 1989, in Prince William Sound (this is not the full extent of the spill). *We should convert them into an animation]

Spread of the Oil

According to lingering oil reports, oil from the spill still is found across 264 shoreline segments and across 2,000 km of shoreline in both the Prince Edward Sound and Gulf of Alaska. The oil report summarizes the progress of the spill and the ecosystems and species that are still recovering.

http://www.evostc.state.ak.us/Univer...gOilReport.pdf

Species Recovery

http://www.evostc.state.ak.us/index....status.injured

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11.5: Deepwater Horizon Oil Spill

The Deepwater Horizon Oil Spill began on the 20th of April 2010 on a British Petroleum operated oil platform located in the Golf of Mexico. The explosion on the Deepwater Horizon rig claimed eleven lives and was caused by a wellhead blowout on the sea floor that subsequently poured the full flow of the blown well into the ocean for 87 days until it was finally capped on July 15th, 2010. This is considered the largest accidental oil spill in history with an estimated 4.9 billion barrels of oil discharged over the 87 days.

As the oil left the damaged wellhead 5000 feet below the oceans surface it spread throughout the water column. Immediately after the explosion BP and many government agencies attempted to control the spread of the oil. They used oil dispersion agents, skimmer ships, controlled burns, floating booms, and any other strategy available to mitigate the spread of the massive amount of oil to the surrounding coastal and ocean ecosystems. Today the Gulf is still not oil free, and NOAA is in the process of tracking oil from the spill and assessing damages to natural resources in the region.



Figure: Deepwater Horizon Blown Wellhead: www.defendersblog.org/wp-cont...n-wellhead.jpg

References

1. Smithsonian Deepwater Horizon information page: http://ocean.si.edu/gulf-oil-spill
2. NOAA Information on the Deepwater Horizon spill and response: response.restoration.noaa.gov/deepwaterhorizon

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11.6: Hurricane Katrina (and others)

Heat wave or drought in 1988 is considered as one of the most costly heat waves in U.S history. In the summer of that year, heat waves close to 90˚ Fahrenheit or more spread across Southeast to Northeast in the United States, this left $120 billion damaged (2014 USD, adjusted inflation) and approximated 6,000 to 10,000 people had died. Before that, global warming and climate change warned by experts did not caught public interest or the media headlines (Massey 2012). However, when the drought occurred, people and politicians were seeking for answers from the meteorologists and climatologists, which they had provided explanation for the change in temperature during that time (Massey 2012). With that, people were concerned about this temperature change but only temporarily, as the temperature change to normal, the attention to change human activities and concern for the greenhouse effect decline (Massey 2012).

Besides the heat wave mentioned above, Hurricane Katrina is one of the deadliest hurricane in the U.S besides Hurricane Ike and Hurricane Sandy. Hurricane Katrina began in the southeastern Bahamas and continued toward the Gulf of Mexico until it reached the U.S. The cities that were impacted included Florida, Mississippi, New Orleans, and other parts out of the country such as Cuba and Bahamas. Just within the United States, it damaged up to $108 billion (2005 USD) included economic and environmental effects and at least 1,833 people died. For environmental impacted, it caused erosion and subsidence in Louisiana's wetlands and bayous. The loss of wetlands and bayous were home to many different marine mammals such as brown pelicans, turtles, and fish (Wikipedia on Hurricane Katrina).

References:

1. http://www.eenews.net/climatewire/stories/1059968011
2. http://en.Wikipedia.org/wiki/Hurricane_Katrina

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11.7: Rachel Carson and DDT

In 1962, a former marine biologist for the U.S. Fish and Wildlife service, Rachel Carson, sent waves throughout both the scientific community and American society that would galvanize a country against the indiscriminate use of one of the most powerful pesticides available at the time.

When it was developed during World War II, DDT was hailed as a miracle chemical. It could eliminate the hordes of malarial mosquitos in the South Pacific and quickly de-louse troops in Europe. It was so effective, that it's inventor was awarded a Nobel prize. When DDT was made available for civilian use in 1945, its application exploded into agriculture and became the gold-standard for pest control. However, DDT soon proved to be *too* effective in it's ability to kill.

DDT (dichlorodiphenyltrichloroethane) is a considered a "bioaccumulative and toxic chemical" by the EPA. It gained this designation because of the relatively long time it takes to degrade in the environment (15+ years!) and its ability to be stored in biological tissues. As it goes up the food chain, from plants to insects to birds and fish and eventually even to humans, DDT accumulates in the fat tissue of organisms exposed to it. This process is termed bioaccumulation or biomagnification, and can have serious impacts on the structure of ecological communities and the human health. According to the EPA, harmful effects of DDT on humans include (see the full EPA summary here):

- Probable human carcinogen
- Damages the liver
- Temporarily damages the nervous system
- Reduces reproductive success
- Can cause liver cancer
- Damages reproductive system

In her book *Silent Spring*, Rachel Carson presented the possible effects of DDT on animal and human populations. Her warnings about the devastating impacts of unregulated DDT use sent fear and outrage through the country and within 10 years, DDT had been banned in the United States.

DDT is still used in some parts of the world today, despite a wealth of research that shows its harmful effects. However, the legacy of *Silent Spring* is in the way it demonstrated to the world the capability of humans to drastically alter and damage the natural world. Carson's work has inspired thousands, and many credit her with founding the field of environmental science.

(Source: Natural Resources Defense Council)

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11.8: Diadema in the Caribbean

One of the most common organisms in the Caribbean are the sea urchins from the genus *Diadema*. These sea urchins are facing great threats in the Caribbean. Sea urchin populations are diminishing at increasing rates. Sea urchins are a keystone species and are responsible for fauna growth regulation around the world. They are a very significant part of marine ecosystems that must be maintained and protected. *Diadema* are found in all tropical areas in the ocean.

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11.9: Hurricane Katrina

Meteorologists were able to warn people about the major storms known as Hurricane Katrina on August 23, 2005. It formed over the Bahamas and by August 28, evacuation took place. It was not a surprise that New Orleans was specifically at risk because in the past centuries, hurricanes have flooded New Orleans. Consequently, half of the city lies above sea level causing the aftermath of New Orleans to be completely surrounded by water. Although the Army Corps of Engineers had built a system of levees and seawalls, some were not as strong and sturdy as others. For instance, the levees along the MIssissippi River were strong and sturdy, but not the ones from Lake Pontchartrain, Lake Borgne and the water clogged swamps and marshes of New Orleans' east and west. This caused greater risk to those who lived below sea level. Before Hurricane Katrina hit New Orleans, the mayor Ray Nagin, ordered an evacuation. This allowed people who didn't have a safe shelter to withstand the storm or could not leave the city immediately to stay in one of New Orleans' stadium, the Superdome.

http://www.history.com/topics/hurricane-katrina

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12: Volunteer to be Victorious

What is Volunteering?

There are countless people and organizations working around the world at this moment to help protect coral reef ecosystems. Many of these people are unpaid volunteers and realize the importance of coral reef conservation and its effects on everyone around the world. Volunteering is an amazing form of work that anyone can do anywhere in the world, within any area. It is simply helping out or working without compensation other than self-satisfaction. According to Nationalservice.org the 2018 Volunteering in America report found that 77.34 million adults (30.3 percent) volunteered through an organization last year. Altogether, Americans volunteered nearly 6.9 billion hours, worth an estimated $167 billion in economic value, based on the Independent Sector's estimate of the average value of a volunteer hour for 2017. Millions more are supporting friends and family (43.1 percent) and doing favors for their neighbors (51.4 percent), suggesting that many are engaged in acts of "informal volunteering". There are so many different environmental organizations one can volunteer with and below is a list of just a few that involve coral reef projects.

Organizations and information from their websites:

Name: International Volunteer Head Quarters (IVHQ)

Mission: Our mission is to change the face of volunteer travel. Established in 2007, we have grown to become the world's leading volunteer travel company, working in over 40 destinations around the world and placing thousands of volunteers abroad every year.

We believe in a future where any traveler, anywhere in the world is empowered to make a meaningful difference in the community they are visiting, and we take pride in making this happen.

We're focused on providing affordable volunteer travel experiences that are responsible, safe and high quality. Our programs heighten global awareness and cultural understanding through the skills and expertise taken by volunteers to their host communities, and through the experiences and lessons that volunteers take back to their own countries and cultures.

Price: Fees from $1010 for 1 week

Time Commitment: 1-4 weeks

Tasks you would do!:

Volunteers on the Marine Conservation project in Australia have the opportunity to join a variety of important conservation efforts focused on the protection of Great Barrier Reef ecosystem.

When volunteering in Australia, you will work in collaboration with a number of oceanographic organizations to gather vital raw data and support the protection of the Great Barrier Reef through a range of initiatives, including:

Reef Monitoring – This portion of the Marine Conservation project involves snorkeling within an assigned area to collect data on the species living in the Great Barrier Reef. You do not require any previous reef surveying experience to participate, as you will be trained in the methodology of in-water surveying during your program orientation. A full-length lycra suit will be supplied and volunteers are just required to bring their own snorkel and waterproof watch.

Name: GVI

Mission: 20 years later, GVI has engaged over 35,000 participants, set up 600 community partnerships, and currently runs 21 programs in 13 countries worldwide. Richard and Ben's vision to not only facilitate global citizenship and leadership skills in young adults, but to allow them to have a truly positive impact on local communities and environment is very much alive.

Price: $4,965, $6,125, $7,285, $9,605

Time Commitment: 4, 6, 8, 12 weeks

Tasks you would do!: Travel to the crystal clear waters of the Indian Ocean as a member of an expedition and work on critical marine conservation projects amongst the beautiful islands of the Seychelles.

You will contribute towards various conservation-related surveys aimed at providing data to the local government on coral reef research, fish, and invertebrate surveys and assist with the development of an environmental education and awareness program as well as marine plastic pollution cleanups and surveys.

You will spend the majority of your time on this expedition scuba diving and as such you need to be qualified to at least PADI Open Water, or equivalent. For non-divers wishing to attend, we can recommend local dive centers that will help you qualify before your intended start date.

Name: Earth Watch

Mission: Earthwatch engages people worldwide in scientific field research and education to promote the understanding and action necessary for a sustainable environment.

Price: $1550

Time Commitment: 5+ days

Tasks you would do!: On this expedition, participants can get involved through scuba or snorkel activities. You will assist researchers in making baseline measurements of environmental conditions, actively removing algae, deploying coral recruitment (settlement) tiles, and assessing fish and invertebrate diversity and abundance. By joining this expedition, you'll be at the forefront of active reef restoration science. You will assist researchers in experiments that aim to develop best practice methods for removing this macroalgae and allowing coral to regrow. You will be directly involved in filling in the gaps that will enable reef managers to make evidence-based decisions about active interventions that support the recovery of the Great Barrier Reef, and reefs all over the world.

Name: OPERATION WALLACEA

Mission: Operation Wallacea is a network of academics from European and North American universities, who design and implement biodiversity and conservation management research expeditions.

Research is supported by students who join the programme, to strengthen their CV or resume or collect data for a dissertation or thesis. Academics benefit from funding for high quality fieldwork enabling them to publish papers in peer reviewed journals. This model enables the collection of large temporal and spatial datasets used for assessing the effectiveness of conservation management interventions.

Price: $5,925.00 ($2,370.00)

Time Commitment: 8 weeks

Tasks you would do!: IVHQ's affordable Sea Turtle and Marine Conservation volunteer projects offer international volunteers with the opportunity to provide vital support to ocean conservation organizations around the world that are focused on the protection of fragile ecosystems and threatened marine species.

Benefits of Volunteering

With busy lives, it can be hard to find time to volunteer. However, the benefits of volunteering can be enormous. Volunteering offers vital help to people in need, worthwhile causes, and the community, but the benefits can be even greater for you, the volunteer. Giving to others can also help protect your mental and physical health. It can reduce stress, combat depression, keep you mentally stimulated, and provide a sense of purpose. While it is true that the more you volunteer, the more benefits you'll experience, volunteering does not have to involve a long-term commitment or take a huge amount of time out of your busy day. Giving in even simple ways can help those in need and improve your health and happiness.

Just a few benefits of volunteering are listed below

1. Connects you to others
2. Good for your mind and body
3. Advance your career
4. Brings fun and fulfillment to your life
5. Doing things you would not do otherwise

The information in this chapter in thanks to content contributions by Audrey Boraski.

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GLOSSARY

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