OCEANOGRAPHY

Hill et al.
University of California, Davis

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Oceanography

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This text was compiled on 04/04/2022

TABLE OF CONTENTS

Welcome to the Oceanography page! This wiki is a collaboration between current and former students at UC Davis, with Professor Tessa Hill. Content will include a broad survey of oceanography, including geological, chemical, physical and biological aspects, as well as significant content on major issues in Oceanography and human impacts on this environment.

7: OCEAN CIRCULATION

An ocean current is a continuous, directed movement of seawater generated by forces acting upon this mean flow, such as breaking waves, wind, the Coriolis effect, cabbeling, temperature and salinity differences, while tides are caused by the gravitational pull of the Sun and Moon. Depth contours, shoreline configurations, and interactions with other currents influence a current's direction and strength.

8: WAVES & TIDES

9: COASTAL PROCESSES

10: AN OCEAN FULL OF LIFE

11: FOOD WEBS AND OCEAN PRODUCTIVITY

12: MARINE ENVIRONMENTS

13: HUMAN IMPACTS ON THE OCEAN

14: SPECIAL TOPICS - THE OCEAN IN A WARMER WORLD

This page will provide a summary of impacts on the ocean from rising temperatures and carbon dioxide concentrations. Please see "articles" tab above for subheadings if they do not appear here.

15: SPECIAL TOPICS - FISHERIES MANAGEMENT

16: SPECIAL TOPICS - ENERGY FROM THE SEA

17: SPECIAL TOPICS - MAJOR ENVIRONMENTAL EVENTS

18: SPECIAL TOPICS - OCEAN ENGINEERING

19: SPECIAL TOPICS - INTERNATIONAL COOPERATION AND MANAGMENT

BACK MATTER

CHAPTER OVERVIEW

1: A VOYAGE OF DISCOVERY

CHAPTER OVERVIEW

FRONT MATTER

TITLEPAGE
INFOPAGE

1: A Voyage of Discovery

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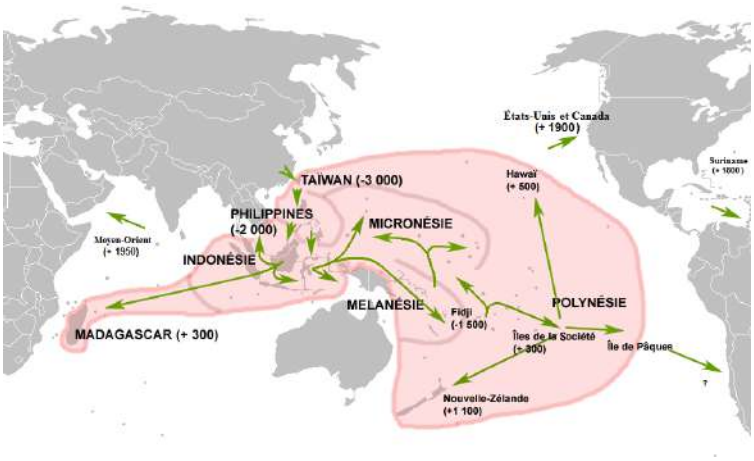
1.1: Early Trade and Navigation

The history of ocean exploration is one filled with danger, discovery, and romance. For nearly 100,000 years intrepid individuals have traversed the oceans and crossed the seas of this planet. The first oceanographers were traders, navigators, conquers, and explorers who dared to cross the sea.

A depiction of an Egyptian boat, from c. 1420 B.C. (Wikipedia)

THE FIRST OCEAN GOERS

Ocean exploration has slowly, but steadily gained more and more interest as the desire to expand, trade, and explore have become more enticing and necessary to understand the world around us. Contrary to popular belief, the European Age of Exploration was not the start of this tradition. The earliest known explorers originated from Southeast Asia over 100,000 years ago during what is known as the Melanesian exploration. Inhabitants of what is now known as Indonesia began discovering and exploring islands to the East. These people did not stray far from land but stayed close to coastal areas. They used small simple watercraft, designed primarily for littoral fishing and travel. This early period of exploration was superseded by superior navigation and cartography techniques developed by later cultures such as the Polynesians.



Dates of human migration in the Indian and Pacific Oceans. (Wikimedia)

The Polynesians

The next wave of ocean exploration was the Polynesian Period. They were the first to develop open ocean exploration and navigation techniques. They consistently traveled across much of the South Pacific, passing New Zealand, Easter Island, and many others, and eventually making their way to Hawaii. This period also overlaps with the Greek exploration of the Mediterranean. There exist many conflicting theories as to how this culture was able to disperse across such a vast area or why they choose to do so, but they developed larger, stronger, and more stable boats that allowed them to endure the harsh conditions of the open ocean.

The Polynesians relied upon a complex and rich oral tradition to pass on knowledge of their navigation techniques, known as wayfinding. Historically, this knowledge has been confined to local navigation guilds on each island, but renewed interest has seen that these techniques are recorded for all time. These oral traditions have shown not only a detailed knowledge of natural phenomena such as wind patterns but also an extensive and precise knowledge of the locations of islands all across Polynesia. There is still discourse on whether early Polynesian colonizers made use of these techniques. However, there is a strong academic consensus that the Islands of Eastern Polynesia, such as Easter Island, were explored and colonized purposively using this knowledge.

Initially, researchers thought that the Polynesians and their culture originated from an Asiatic country and migrated to the Polynesian Triangle. However, researchers were able to use pottery to date the migration of Polynesian settlements and found that the Polynesian culture started on the Polynesian islands. Specifically, they started from the southeastern Solomons and northern Vanuatu before expanding to the Fiji archipelago which is west of the Polynesian Triangle around 1100-1000 B.C. They then settled in the Lau Islands then Tonga around 896-880 B.C. and further traveled east. Colonization of eastern and southern Polynesia occurred later. A study suggests explaining the delay in colonization was due to the unique climate patterns which finally allowed off wind sailing routes to the east. Gradual improvements in their sailing technology also attributed to the delay. The invention of the double-hulled canoe became beneficial in their colonization of eastern and southern Polynesia.

A tepukei, an ancient type of boat used by the inhabitants of Taumako in Melanesia. (Wikimedia)

WESTERN NAVIGATORS

Some of the first ocean-faring people were the Minoan, Greek, and the Phoenician civilizations of the ancient Mediterranean. They utilized the Mediterranean for both trade and war, at first staying within sight of shore, but eventually using the sun, moon, and stars as navigational aids. The Phoenicians were some of the first to use celestial bodies to take them beyond the sight of land, but the knowledge eventually spread throughout the region to facilitate maritime commerce and navigation. The most famous Phoenician explorers were Hanno the Navigator and Himilco, both from Carthage. In the sixth or fifth centuries B.C., Hanno sailed from Carthage, in modern day Tunisia, out of the Mediterranean and along the coast of Africa, reaching as far as Cameroon. Himilco, in the fifth century, sailed from North Africa to the British Isles. These journeys sought to establish and control trade routes.

Homer wrote of Odysseus using Ursa major to find his way home from Troy, and Greek navigators were using nautical charts as early as 600 BC. Some Greeks are known to have sailed all the way to India after Alexander's conquest of the east.

A Phoenician ship depicted on a sarcophagus, 2nd century A.D. (Wikimedia)

NAVIGATION IN THE EAST

After the Polynesian people had migrated across the South Pacific, the first cultures to successfully navigate the waters around Asia were the Indians in the 4th century BC and the navy of the Chinese Qin dynasty around 200 BC. Much of the ocean navigation for these groups relied on the seasonal monsoon winds, which limited travel direction and time. Regardless, both the Indians and Chinese cultures were able to sail and explore much of Southeast Asia, and even to the eastern coast of Africa. The Qin dynasty fielded a large navy to control the South China sea as early as 200 BC. The ships were as long as 100 feet and could carry up to 30 tons of cargo.

Pottery boat from the Han Dynasty, from the Hong Kong Museum of History. (Wikimedia)

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1.2: Explorers and Oceanographers

Prince Henry the Navigator (1394 - 1460)

Henry the Navigator lived from 1394 to 1460. Prince Henry of Portugal was interested in sailing and commerce, and studied navigation and mapmaking. He established a naval observatory for the teaching of navigation, astronomy, and cartography around 1450. From 1419 to his death, Prince Henry made many expeditions south along the west coast of Africa to secure trade routes and establish colonies.

Prince Henry of Portugal organized and financed many voyages that went south from Portugal and eventually rounded the African continent. His goals were to create maps of the West African coastline, establish trade routes, and spread Christianity. He encouraged voyages of expeditions and the scientific study of navigation. Furthermore, he ran an observatory and school of navigation. Prince Henry played a vital role in the development of more accurate maps and the engineering of a new ship that was more ideal for exploring rough seas.

Prince Henry the Navigator, a key figure in Portuguese exploration. (Wikipedia)

Zheng He (1371 - 1433)

Zheng He [pronounced as JUNG HUH] lived from 1371 to 1433. He was born in Yunnan at the foothills of the Himalaya Mountains. As a child, his name was Ma He. He grew up a Hui, a Chinese Muslim. When he was only 10 years old, Chinese soldiers, under the orders of the Ming Dynasty, invaded Yunnan in effort to overtake one of the last Mongol holds. They killed his father and he was captured. Along with many other boys who were taken, he was castrated and forced to serve for a Chinese prince known as Zhu Di. In 1402, Zhu Di took the throne as Emperor Yongle. He made Ma He the chief of staff for all the servants and changed his name to Zheng He. The Yongle Emperor proved to be one of the most ambitious emperors of his time and chose Zheng He to be the commander in chief of a series of missions across the Indian Ocean in order to increase China's influence.

From 1405 to 1433, Zheng He led seven naval expeditions throughout the Chinese Seas and the Indian Ocean, and he reached locations from Taiwan, the Persian Gulf, and Africa. He saw the commission of 3,500 ships and commanded at least 62 ships and 27,800 men (more than half of London’s population at the time). Zheng He’s led nine-masted flagships that measured about 400 feet long (Christopher Columbus’s Santa Maria was only 85 feet long). These were some of the largest wooden ships ever built in this time period. These naval expeditions did not serve the purpose to colonize or conquer but rather served as “treasure hunts” that brought back items of great value as tribute to the Yongle Emperor. Zheng He brought back gold, jewelry, and other delicacies. He even brought Zebras, Rhinos, and Giraffes. In 1424, the Yongle emperor died and his successor suspended all naval expeditions abroad. Zheng He went on his seventh and final voyage from 1431 to 1433. He died at sea and was buried off the coast of India.

Zheng He and his naval voyages had a great impact on the status of China at the time. These voyages increased maritime and commercial influence of China throughout the Indian ocean up until the 19th century. Foreign goods, medicines, and geological knowledge flowed through China at an unprecedented rate even though these ships only served as treasure ships. Many historians argue that China could have become a great colonial power many years before the age of great exploration if the leadership had decided to use their technology for outreach rather than for isolation.

Here is a good map of the travels of Zheng He: https://cdn.kastatic.org/KA-share/BigHistory/KU8.1.8-4_Zheng_He-Map.pdf

A statue of Zheng He in Stadthuys, Melaka. (Wikipedia)

Christopher Columbus (1451 - 1506)

Christopher Columbus lived from 1451 to 1506. He made four voyages across the Atlantic Ocean in an effort to find a new route to the East Indies by traveling west rather than east. Having inaccurate estimates of Earth's magnitude, he underestimated the distances necessary for the voyage and believed he had found islands off the coast of Asia when, in reality, he had reached the "New World."

Christopher Columbus believed sailing west would be a faster way to get to India and to all the spices and riches it held. When his idea was rejected by Portugal, Columbus went to Spain where the King and Queen agreed to sponsor him. Columbus was granted three ships (the Niña, Pinta, and Santa Maria) and funds to finance his voyage across the ocean. After two months of sailing, Columbus and his crew arrived in the present-day Bahamas. Due to his excellent navigation records, he was able to sail back to Spain with proof, in the form of gold and other materials, of his success. However, the rest of Columbus' voyages were unsuccessful. Although he died bitter and believing he had found Asia, Columbus' discovery opened up a whole new world for his successors to explore.

Ferdinand Magellan

Ferdinand Magellan lived from 1480 to 1521. He left Spain in September 1519 with 270 men and five vessels in search of a westward passage to the Spice Islands. The expedition eventually lost two ships even before finally discovering and passing through the Strait of Magellan and rounding the tip of South America in November 1520. Magellan crossed the Pacific Ocean and arrived in the Philippines in March 1521, where he was killed in a battle with the natives on April 27, 1521. Magellan's skill as a navigator makes his voyage probably the most outstanding single contribution to the early charting of the oceans.

Magellan had the idea to sail west across the ocean to get to Asia. Contrary to his expectations, Magellan sailed past modern-day Argentina and found a route to the Pacific Ocean. He was the first person to sail across the Pacific Ocean. It took him six long months to arrive in Asia though he had been looking for a shorter route. Eventually, Magellan and his crew sailed into charted waters in East Asia. Unfortunately, Magellan was killed in battle in the Philippines. His crew continued without him and reached Spain a total of three years after they had first set out on their voyage. Though Magellan perished during the voyage, his belief that the Earth is round was proven to be true. This important discovery altered the way people thought about the world and had a significant impact on future voyages.

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1.3: Voyages for Oceanography

The Challenger Expedition

In December 1872 the HMS Challenger sailed out of Portsmouth England to begin its four-year voyage circumnavigating the globe. The voyage was the first of its kind, as the ship had recently been re-purposed from military service into a research vessel. Much of the interest in the voyage was to gain understanding in the composition and structure of the seafloor, as in 1851 the first submarine telegraph cable had been laid across the English Channel, and many government agencies and investors realized that further knowledge was the key to expanding in that enterprise.

The vessel was outfitted with both a natural history laboratory, as well as a chemistry laboratory, and carried a variety of scientific instruments. Funded by the Royal Society of London, and captained by George Nares, the ship would travel 127,580 km around the Earth over a four year period. Over the course of the journey, they performed hundreds of depth soundings, open sea trawls, and collected well over 4500 new species specimens. The voyage of the Challenger was the largest oceanographic research expedition of its time and established a new order of scientific and natural research.

Sir George Strong Nares (Wikimedia)

The Albatross

The Albatross was a ship that made three expeditions designed to collect specimens and explore the depths of the ocean. It was built by the US Fish Commission in 1882. It is a scientific research vessel used to study fish population and hydrographic surveys. It is the first ship designed for this type of research, outfitted with laboratories, large storage spaces for specimens, and more technologically advanced dredge systems for studying sediments on the seafloor.

The scientific expeditions investigated the eastern Pacific Ocean, islands and atolls in the South Pacific, and the eastern tropical Pacific. It collected different marine life forms and described over 170 new species on its first expedition. During the second expedition, the ship sounded and collected specimens at a new record depth at 4,137 fathoms. On the third expedition, it collected a wide range of marine life in areas relatively unknown.

Early Arctic Exploration

In 1868, Carl Koldewey led Germany's first Arctic expedition on the GRÖNLAND sailing vessel for the east coast of Greenland. Unfortunately, the ice stopped them from reaching Greenland, so they ended up at Spitsbergen instead. The purpose of this expedition was that the geographer August Petermann, the person who initiated the first German expedition to the Arctic in 1868, wanted to confirm his theory that the Arctic Ocean was completely ice-free and therefore navigable. Even though they did not reach their desired location, they still collected data on current velocity, temperatures, and elevations in the deep sea, and magnetism.

In 1869, the second German expedition to the arctic reached their desired location. In both of these expeditions, they learned more about ice cover in the arctic, local ecosystems, Arctic flora and fauna, mineral deposits and the relevance of the Arctic to our climate. Because of these two expeditions, Germany launched many further expeditions to the polar regions, including Antarctica.

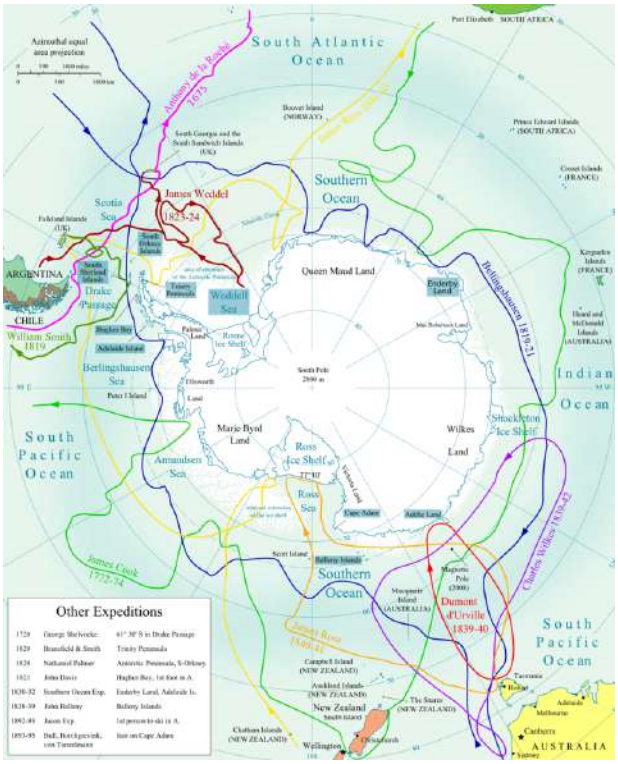
Carl Koldeway (Wikimedia)

Early Antarctic Exploration & History

Before the age of modern science and discovery, the continent of Antarctica was merely a concept postulated by ancient philosophers. In the 4th century BC, the Greek philosopher Aristotle reasoned that the large, northern, frigid landmass (the Arctic) would be balanced by a southern, frozen landmass. He named this unknown landmass “Antarktikos” which means “opposite to the north”.

Fast forward to the 1400s and many explorers began to make voyages south to try and discover this mysterious land. Bartolomeu Dias, a Portuguese sailor, kicked off the “Heroic Age of Exploration” by sailing down the west coast of Africa in 1487, but was turned back north after encountering storms near South Africa. Several more voyages were made by sailors all around the world, however, firm contact (visual and physical) with the mysterious southern continent would not come until the early 1800s.

A lot of early Antarctic exploration was driven by the search for hunting ground for seals. William Smith, a sealer, discovered the South Shetland Islands off the west coast of the Antarctic Peninsula and was then hired by the British Admiralty to survey the islands the following summer. Although William Smith may have been the first recorded to have sighted the continent, it is thought that the first to set foot on the Antarctic continent was John Davis and his crew from the Cecelia, a group of American explorers searching for these hunting grounds. Although, this is not accepted by all historians.



Major Antarctic expeditions taking place before 1897 (all pre-dating the Heroic Age of Antarctic Exploration) (Wikipedia)

Here is a helpful timeline of ocean exploration by National Geographic: https://www.nationalgeographic.org/media/ocean-exploration-timeline/

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1.4: Modern Ocean Science

Though the methods and purposes at the center of what thrusts humanity into oceanic exploration have greatly varied throughout human history, such exploration has allowed for a better understanding of the vast space that is our oceans. It wasn't until the early 1800s, that President Jefferson funded the United States Coast survey for ocean exploration (NOAA). In 1872, Challenger Expedition conducts the first oceanic expedition. On this mission, salinity, density, temperature and hundreds of new species were discovered and looked at for the first time (NOAA). In 1912, with the sinking of the Titanic in the deep seas, prompted the need to develop ways of exploration using acoustics, so objects could be detected before making contact with a ship. This was accelerated during WWI, with both sides devising ways of being able to detect enemy submarines (National Geographic).

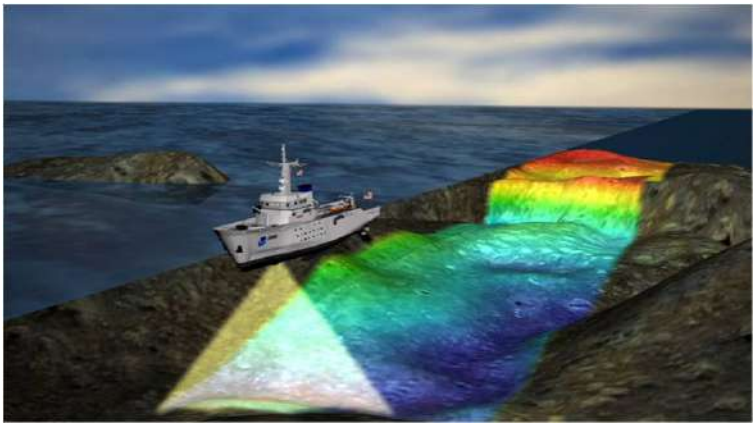
The Challenger at Juan Fernandez (Wikimedia)

Mapping the Ocean Floor

Mapping of the seafloor is typically done by measuring the water depth at a certain point, which was historically done using a "lead line". This process was extremely time consuming and inaccurate. Advanced seafloor mapping became possible in the 1920s due to the advent of underwater sound projectors (called "sonar") (NOAA). The technology was created in order to allow allied ships to combat German U-boats, precursors to modern submarines, by projecting sound through the ocean and measuring amounts of echolocation (OIC). This could give users distance and direction measurements of underwater objects.

Post World War 1, the Coast and Geodetic Survey (which would later become NOAA) turned the military tech down into the depths to allow them to begin mapping the western coast of text Atlantic, producing the first detailed maps of the ocean floor (NOAA). Even with the advance of this technology, mapping the seafloor was still a difficult task, as early sonar systems could only take depth measurements directly below the vessel, making mapping a tiresome process of moving back and forth over the surface and connecting individual data points together.

As countries throughout the globe plunged into a second world war, significant advancements in sonar technology that allowed for more accurate and improved measurements of the ocean floor. The data that was acquired from such systems was crucial in the construction of maps that included key features such as mid-ocean ridges and deep-sea trenches (NOAA). In the 1970s, methods became more accurate and efficient when the US Navy declassified "multi-beam" sonar, which allowed research vessels to make more accurate and larger images of the ocean floor. This, along with the increase of computer processing power, has allowed researchers to collect large amounts of data and quickly compile them into detailed and accurate maps.



Multibeam echosounder (Wikimedia)

Autonomous Underwater Vehicles (AUV's)

The first American submersible vehicle was called "Turtle." In Saybrook, Connecticut 1775, David Bushnell and his brother constructed a small, wooden egg-shaped submarine that was effectively used in naval combat (the first to do so) in the New York Harbor (1776). Over a century of technological advancements later, in November 1879, the Reverend George W. Garrett designed the "Resurgam;" the first modern submarine was powered by a Lamm steam engine and could travel for nearly ten hours using power stored in an insulated tank.

Turtle Submarine (Wikimedia)

With submarine evolution came the development of AUV's, which commenced in the 1960s. During the 1970s, many testbeds were developed in hopes of experimenting with technology to explore and define the potential of AUV's. For example, the University of New Hampshire's Marine System Engineering Laboratory collaborated with efforts at the US Navy's facility in San Diego to develop an open space-frame AUV, the EAVE. Subsequently, the Institute of Marine Technology Problems, Russian Academy of Sciences initiated their AUV program with the development of SKAT vehicles and the first deep-diving AUVs L1 and L2. Generally, there are two types of AUV's, manned and unmanned systems, both of which are primarily used for military missions and underwater investigations and assessment, and data gathering. As software systems and engineering advanced, funding expanded, and technologists converged (like at the 1980 international symposium for submersible of technology), AUVs finally were able to grow into first-generation operational systems capable of accomplishing defined objectives. New systems including the Autonomous Oceanographic Sampling System provided resources essential to the AUV market commercialization that flourished from 2000-2010. In terms of AUV technology, systems have constantly changed in accordance with addressing new technology problems or findings.

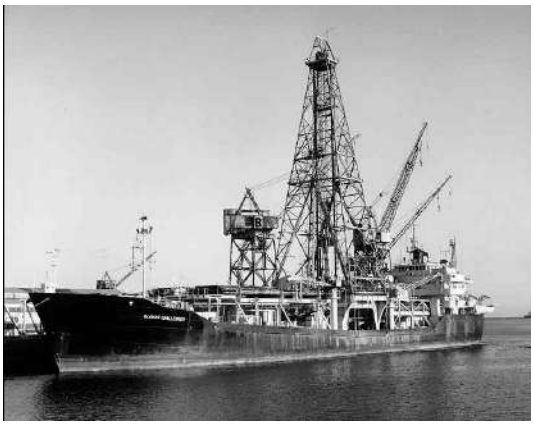
Over the past three decades, the industry has majorly focused on the following technologies: autonomy, energy systems/energy management, 3D imaging, navigation, processing, sensors, and communications. In the area of ocean science, vehicles such as

ABE, AUTOSUB, and others have successfully gathered scientifically significant data. The technology constantly evolves, as new sensors for oceanography are being developed for future data acquisition programs. In addition, the US Navy is supporting a coordinated effort called the AOSN, with the goal of creating a network of multiple AUVs to obtain oceanographic data and information in temporal and spatial resolutions.

Autonomous Benthic Explorer in operation (Wikimedia)

The Deep Sea Drilling Project

In 1966, a collaboration between the National Science Foundation and The Regents, and the University of California began. The goal was to start an oceanic drilling project for the purpose of studying the ocean floor and finding any evidence of plate tectonics. The result of this collaboration was the *Golmar Challenger*, which left the port of Orange, Texas in 1967. The four hundred foot long ship was equipped with enough laboratories, living quarters, and mess halls to accommodate hundreds of crew members. However, the most notable part of the ship was its drill. It was capable of reaching depths of 20,000 feet underwater, which gave scientists a chance to obtain samples that could not have been collected before.

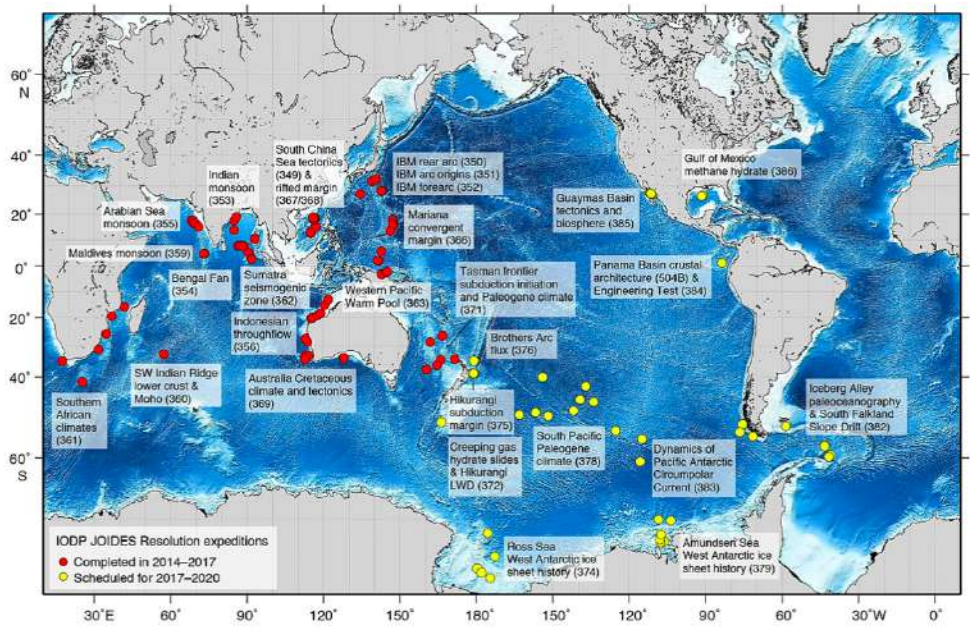


The *Golmar Challenger*. (Wikipedia)

The ship and its crew began its first thirty months coring and drilling in all major oceans and as well as the Red and Mediterranean Seas. The core samples themselves were 30 feet long and 2.5 inches in diameter. With being such an advanced means of sampling at the time, the crew found some of the most important discoveries in oceanography. Their efforts allowed the discovery of salt domes, and in turn, oil at the bottom of the ocean. When the crew drilled at mid-ocean ridges, scientists on board found that parts of the ocean floor were only 200 million years old. This meant that the seafloor was being recycled since Earth's oceans formed, providing substantial evidence for seafloor spreading and continental drift. With over 300,000 nautical miles traveled, 19,000 cores collected, and approximately 600 sites investigated, The *Golmar Challenger* retired in 1983. However, in 1985, the project

continued under the new titles of the Ocean Drilling Program and the International Ocean Drilling Program. In place of the *Golmar Challenger* was the *JOIDES Resolution*, an even larger ship with more advanced drilling equipment. To this day both the programs and *JOIDES Resolution* continue to operate, taking samples from all over Earth's oceans. Sample cores from these ships are stored in research centers all over the world and are considered priceless by many oceanographers.

The *JOIDES Resolution*, still in use to this day. (Wikipedia)



JOIDES Resolution expedition map of 2013-2020 (Wikipedia)

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3. OIC, Oceanic Imaging Consultants, oicinc.com/history_sonars.htm
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Back Matter

Index

CHAPTER OVERVIEW

2: EARTH - FORMATION AND STRUCTURE

2.1: EARLY EARTH

Earth in its early stages was like a depiction of hell, scalding rock and choking fumes, due to accretion from cosmic debris. The surface was essentially a magma ocean, much too harsh of conditions for anything to survive. Some water and a very early atmosphere was present, and crustal rocks began to form. But the mantle was convecting and volcanism was intense. Large asteroids kept falling in, producing craters and an overall large-scale disturbance.

2.2: STRUCTURE OF THE EARTH

The structure of the earth has been classically divided into four major groups. The crust, the mantel, and the outer and inner cores have all been defined by their unique chemical properties based off of studies of volcanic and seismic activity as well as mass estimates of the earth that have been able to determine the densities of the different layers. The way these layers interact with each other has significant implications to volcanic, seismic, and electromagnetic activity.

2.3: CONTINENTAL DRIFT

Continental drift was first conceived by scholars and philosophers named Francis Bacon, George Buffon, and Alexander von Humboldt. As maps grew more accurate the landmasses began appeared as puzzle pieces. The continents once had fit together but had drifted apart after millions of years. The continents now far apart showed similar sediment, rock formation, and vegetation supporting the theory that they were one landmass in the past.

2.4: EVIDENCE FOR PLATE TECTONICS

2.5: TYPES OF PLATE BOUNDARIES

Categorization of plate boundaries is based off of how two plates move relative to each other. There are essentially three types of plate boundaries, which are divergent, convergent, and transform.

2.6: CONTINENTAL MARGINS AND OCEAN BASINS

2.7: SUMMARY

2.1: Early Earth

Molten Earth

Earth in its early stages was like a depiction of hell, scalding rock and choking fumes, due to accretion from cosmic debris. The surface was essentially a magma ocean, much too harsh of conditions for anything to survive. Some water and a very early atmosphere was present, and crustal rocks began to form. But the mantle was convecting and volcanism was intense. Large asteroids kept falling in, producing craters and an overall large-scale disturbance.

http://ngm.nationalgeographic.com/20...penzeller-text

earthguide.ucsd.edu/virtualmu...itu/02_2.shtml

The Earth formed approximately 4.56 billion years ago out of the dust and gases surrounding the sun called the protoplanetary disk. A combination of solar radiation not allowing for the condensation of lighter materials inside the frost line, as well as solar wind forcing lower density hydrogen and helium into the outer solar system left behind only the heavier rocky materials to create the smaller terrestrial planets. The rocky dusts and gases which were left in the inner solar system coalesced together through processes of collision, condensation and accretion forming planetesimals of approximately 10-100km in size. Once they reached that size, the planetesimals had enough mass to begin attracting additional matter through gravitational forces and the largest grew quickly from planetesimals to protoplanets. As protoplanets slowly transformed into planets, heating caused by gravitational pressure, impacts from small and large solar bodies, and higher concentrations of radioactive elements melted the material the protoplanets were conglomerated from allowing the denser materials such as magnesium and iron to sink towards the center while the lighter silicate materials such as feldspar and quartz rose to the surface. This differentiation of materials created the Earth's core of iron and the mantle and crust of lighter materials.

While the Earth was still in this hot molten form there was a collision with the Earth knocking the planet’s tilt off of the axis to approximately 23.5 degrees away from the plane of the ecliptic or celestial equator.

Links

1. geowiki.ucdavis.edu/Geochemis...ts_Lithosphere
2. geowiki.ucdavis.edu/Geochemis...n_of_the_Earth
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6. science360.gov/obj/tkn-video/...s-solar-system
7. www.seti.org/weeky-lecture/su...g-giant-impac

2.2: Structure of the Earth

The structure of the earth has been classically divided into four major groups. The crust, the mantel, and the outer and inner cores have all been defined by their unique chemical properties based off of studies of volcanic and seismic activity as well as mass estimates of the earth that have been able to determine the densities of the different layers. The way these layers interact with each other has significant implications to volcanic, seismic, and electromagnetic activity that have characterize earth and have contributed to the dramatic changes over geological time. The uppermost layer of the mantle and the crust tend to act together as a rigid shell. Together they are called the lithosphere, the "sphere of rock". The lower level of the mantle is called the asthenosphere and it is softer and weaker, particularly in its upper portion where a small amount of melting can occur. It is at this level where the model of plate tectonics suggests that horizontal movement can occur as a result of convection of heat upward from the Earth's core. Contributing to volcanic activity and continental drift over time. Modeling the core of the Earth must rest upon even more indirect evidence. Its observed that the metallic meteorites have cores of iron and nickel, and this correlates with other evidence that suggests that the Earth's core is similarly composed of iron and nickel. Modeling the density of the center of the Earth yields densities of about 14 times that of water, which could be obtainable by compressing iron and nickel, but not surface type rocks. An iron core also gives us a circulating electrical conductor, which could provide the necessary mechanism for creating the Earth's magnetic field.

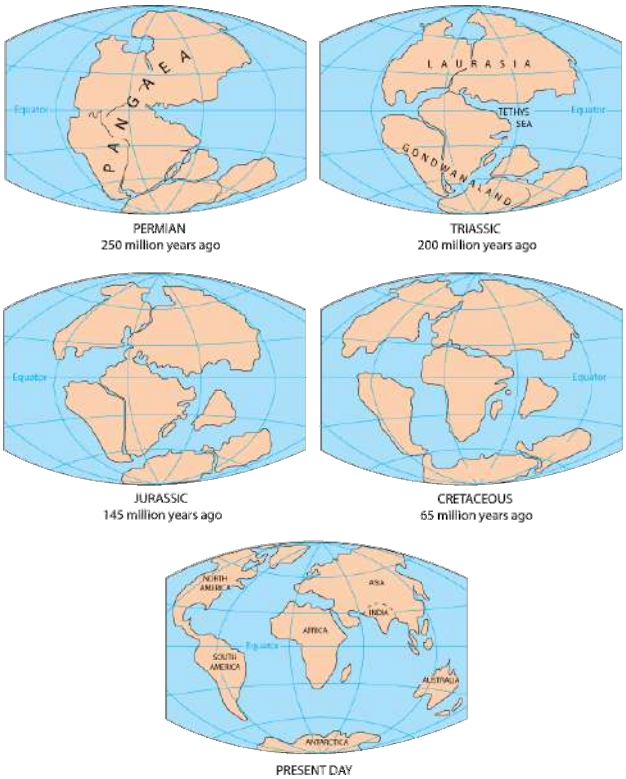
The earth consists of either three layers, or five layers depending on the model used. The first model divides the Earth based on its mineral framework into the crust, the mantle and the core. The crust is the outermost layer and is very thin and solid. There are two variants of crust, the oceanic and continental crusts. The oceanic crust is mainly composed of basalt and is denser and thicker than continental crust, which is made of granite. More about how these two forms of crust interact will be discussed in 2.5. The buoyant crust floats on top of the iron and magnesium rich layer: the mantle. This massive layer takes up roughly 84% of the Earth's volume and is composed of slightly molten rock, constantly being squeezed by the pressure which increases significantly as one approaches the center of the earth called the core. Discovered in 1906, the metallic core is incredibly dense and thus most seismic waves are unable to pass through.

The second model divides Earth based on its strengths and properties into the lithosphere, the asthenosphere, the mesosphere, the outer core, and the inner core. The lithosphere consists of the crust and uppermost section of the mantle. Composed mostly of stone, this layer varies in width around the globe, but is responsible for plate tectonics. However, the lithosphere floats atop the weak asthenosphere, the next layer that is relatively thin and barely melted. As the pressure increases moving inward, the rock melts more, slowly rotating outwards and inwards in the lower mantle, also known as the mesosphere. The rock in the outer core is a fluid and is dense enough to where certain waves cannot pass it, unlike the mantle which all seismic waves pass through. The rotation of the outer core is what creates Earth's magnetic field. Eventually the pressure is so great that the liquid rock gets compacted into a solid again in the inner core.

http://en.Wikipedia.org/wiki/Earth#m...ic-english.svg

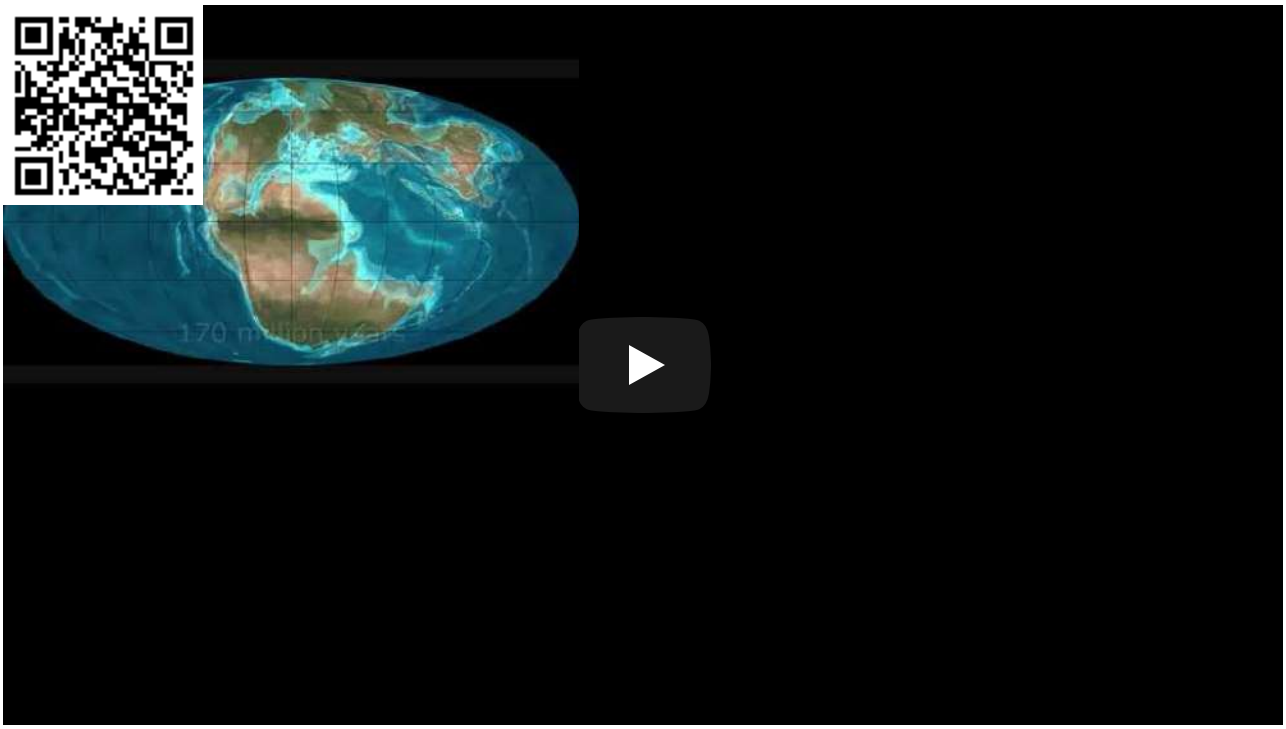
2.3: Continental Drift

Continental drift was first conceived by scholars and philosophers named Francis Bacon, George Buffon, and Alexander von Humboldt. As maps grew more accurate the landmasses began appeared as puzzle pieces. The continents once had fit together but had drifted apart after millions of years. The continents now far apart showed similar sediment, rock formation, and vegetation supporting the theory that they were one landmass in the past. These men helped establish the idea of continental drift, but Alfred Wegener spent much time exploring and researching to prove this theory.



According to the continental drift theory, the supercontinent Pangaea *began to break up about 225-200 million years ago, eventually fragmenting into the continents as we know them today.*

Wegener named Earth's super continent Pangea. The explanation for their movement is due to the theory of plate tectonics. Under the Earth's crust there are a series of plates that move and collide with each other causing landmasses on the Earth's surface to shift and drift. Our continents will continue to move and in the future (millions of years) will be in completely different location's on the earth. However, Wegener did not base his argument off of the idea of plate tectonics. Wegener supported his theory with evidence of fossils, mountain ranges, and patterns of glaciation. While the continents were formed as Pangea, Wegener called the super ocean Panthalassa. As Earth's landmasses shifted to what we know it as today, Wegener gave names to each of the stages formations. Laurasia was the combination of what we know as Europe, Asia, and North America. The remaining continents at this time were called Gondwanaland.



Video 2.3.1: https://www.youtube.com/watch?v=cQVoSyVu9rk

2.4: Evidence for Plate Tectonics

In 1912, after many years of research, Alfred Wegener proposed that the continents drifted across the Earth. His evidence included the fact that the continents seem to fit together, and similar fossils and glacial patterns were found on two different continents. Despite this evidence, he could not figure out what was causing this movements of the continents. Unfortunately, Wegener passed away before any new discoveries were made about the mechanisms behind this movement of continents across the ocean.

New theories started to arise as more evidence was collected. A particularly strange discovery was made when scientist discovered that the rock age of the ocean was less than 200 million years old. This was very different from the much older rock age on land. From this, scientist found that in the ocean, there were subduction zones where the old ocean crust was subducted into deep ocean trenches. New ocean crust was then created at the mid ocean ridge. This was called sea floor spreading. More evidence was needed to support this theory, however. When scientist mapped out earthquake patterns around the world, they discovered that the location of earthquakes were associated with the locations of the subduction zones. This further provided evidence for plate tectonics. More evidence came when scientist examined the sea floor and saw that there were reversals of polarity of Earth's magnetic field that was in a striped pattern. The strips of polarity reversal were mirror images on each side of the mid- ocean ridge. All this evidence complied together convinced scientists of the existence of plate tectonics and continental drift.

2.5: Types of Plate Boundaries

Categorization of plate boundaries is based off of how two plates move relative to each other. There are essentially three types of plate boundaries, which are **divergent**, **convergent**, and **transform**. In the case of divergent plate boundaries, two of earth's plates move away from each other. Spreading centers and areas where new ocean floor are generally located at divergent plate boundaries. An example of a divergent plate boundary is the Mid-Atlantic Ridge. Depending on what type of lithospheric crust each diverging plate is, whether oceanic or continental, varying geographic features are formed. For example, when two continental plates diverge from each other, an ocean basin is created due to the separation of land. On the other hand, if two oceanic plates diverged, a mid ocean ridge would form, which is also known as a spreading center. Divergent plate boundaries are commonly associated with shallow earthquakes.

When two plates move towards each other, the boundary is known as a convergent boundary. As previously mentioned, depending on what type of crust each converging plate is, different geographic features are formed. When two continental crusted plates converge, they eventually collide and end up producing mountains; this was how the Himalayan Mountains were created. Neither continental crust will subduct underneath one another because of their similar densities. When two oceanic plates converge, the denser plate will end up sinking below the less dense plate, leading to the formation of an oceanic **subduction zone**. When an oceanic plate converges with a continental plate, the oceanic crust will always subduct under the continental crust; this is because oceanic crust is naturally denser. Convergent boundaries are commonly associated with larger earthquakes and higher volcanic activity. Whenever a subduction zone is formed, the subducted plate will end up being partially melted by the earth's internal magma and molten. This melting leads to heat being transferred upwards and uplifting the crust, eventually developing into a volcano. Subduction zones are the reason why oceanic crust older than 200 million years old cannot be found. Old, dense crust tends to be subducted back into the earth. An example of a subduction zone formed from a convergent boundary is the Chile-Peru trench.

The last type of plate boundary is the transform boundary, which is where two plates slide past one another. Unlike the other two types of plate boundaries in which new seafloor is created at divergent boundaries and where old seafloor is subducted at convergent boundaries, transform plate boundaries neither create nor destroy the seafloor. The rubbing caused by the sliding is what causes earthquakes along the transform faults; one example would be the San Andreas fault.

https://www.youtube.com/watch?v=dXDYoCqwSbM

2.6: Continental Margins and Ocean Basins

2.7: Summary

CHAPTER OVERVIEW

3: SEDIMENTS - THE MEMORY OF THE OCEAN

Ocean sediments can help us reconstruct Earths history. The sediments deposited on the ocean floor often have markers of the Earths environment when they were deposited and can tell us a lot about how the environment of our planet has changed throughout its history. Scientists have used sediment cores, long vertical tubes of sediment drilled from the bottom of the ocean, to estimate how the ocean reacts to global temperature changes.

CHAPTER OVERVIEW

FRONT MATTER

TITLEPAGE
INFOPAGE

3: Sediments - the Memory of the Ocean

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This text was compiled on 04/04/2022

3.1: Sources and Types of Marine Sediment

There are four kinds of marine sediments, Lithogenous, biogenous, hydrogenous and cosmogenous. Lithogenous are from the land, they form through the weathering process and are composed of small particles from weathered rock and volcanic activity. And within Lithogenous sediments there are two sub categories: Terrigenous and red clay. Terrigenous sediments are produced when the weathering process occurs above water. Wind and other natural sources then carry these particles to the ocean where they sink. Red clay, also known as abyssal clay however, is mostly located in the ocean and is formed from a combination of terrigenous material and volcanic ash. In terms of size, terrigenous particles are generally larger than abyssal clay particles so they sink faster.

Biogenous sediments are formed from the remnants of organisms that refused to be dissolved. Good examples of these organisms include shellfish, clams, anything that has a shell. Other things that could avoid being dissolved include bones and teeth and other appendages. In deeper waters, shells of plankton and other microscopic organisms form these kinds of sediments. Hydrogenous sediments are sediments solidified out of ocean water. As such, chemical reactions create these kinds of sediments. The precipitation of dissolved chemicals from seawater. These kinds of sediments are found commonly near hydrothermal vents. Cosmogenous sediments are probably the most interesting of all four kinds of sediment because they are alien in nature. These kinds of sediments are carried to earth on meteorites or asteroids. They are usually a conglomeration of different kinds of metals and due to their nature, are not easy to find.

Source(s): http://www.articlemyriad.com/types-marine-sediments/

Sedimentary rocks are made of sediments. In general, sediments occurred when the organic or inorganic material are broken down by processes of watering and erosion. There are four types of sediment: cosmogenous (from outer space), volcanogenous (ash from volcanic eruptions), terrigenous (continents erosion and river runoff), and biogenous (skeletons of marine creatures). Sediments are classified according to their size. In order to define them from the smallest size to the largest size: clay, silt, sand, pebble, cobble, and boulder. According to the video that I found online, named "Sediments: Definition, Type & Feature" by Dr Rebecca Gillaspy, delves deeper into the three types of sediments: clastic, biogenic, and chemical that forms sedimentary rocks. Sediment rocks, generally formed from the compaction and cementation of sediments are known as the rock capable of containing fossils. clastic sedimentary rocks are the compacted sediments and are composed of silicate minerals, for example, shale and sandstone. Biochemical sedimentary rocks are the products of organisms who used materials dissolved in water to build their tissue, for example, corals, radiolaria, and diatoms. Chemical sedimentary rocks are form when mineral constituents in solution become supersaturated and inorganically precipitate, for example, oolitic limestone, barite, and gypsum. As we mention earlier, sedimentary rocks are the only type of rocks that may contain fossils. In the other words, they contains the evidence of past life.

3.2: Distribution of sediments around the world

Continental margins are edges of continents or land that are below the ocean's surface and the large, deep slopes that plunge to the sea floor. There are two types of continental margins: passive margins and active margins.

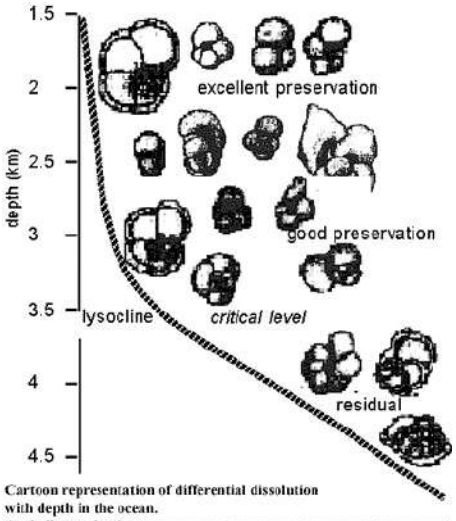
Passive margins are where continental and oceanic transitions are not on a plate boundary. There is no transitions from one plate to another; there is simply one plate. They tend to be fairly wide and have little seismic or volcanic activity. They form after continents rupture apart, creating a new ocean basin between them.

Active margins are where continental and oceanic transitions are located on a plate boundary. There is a transition from one plate to another; there are two plates involved in this activity. Active margins are relatively narrow and there is a fair amount of active volcanic activity and earthquakes that occur.

3.3: The Lysocline and the CCD

The **lysocline** and **carbonate compensation depth (CCD)** are two phenomena that affect the stability of calcite and aragonite in the deep ocean. The lysocline is the depth at which the rate of dissolution of calcite begins to increase dramatically. The water above the lysocline is supersaturated in calcite structures ($CaCO_3$), but as depth and pressure increase and temperature decreases, the solubility of calcite increases. This continues until the lysocline is reached. The lysocline is the point where there is a dramatic decrease (up to 90%) in the amount of calcite structures present, but below this exists the CCD. At the CCD the rate of supply of calcite equals the rate of dissolution, and no more calcite is deposited below this depth. In the Pacific, this depth is about 4,5000 below the surface; in the Atlantic, it is about 6,000 m deep. This dramatic variation is due to differences in ocean chemistry. The Pacific has a lower pH and is colder than the Atlantic, so its lysocline and CCD are higher in the water column because the solubility of calcite increases in these conditions.

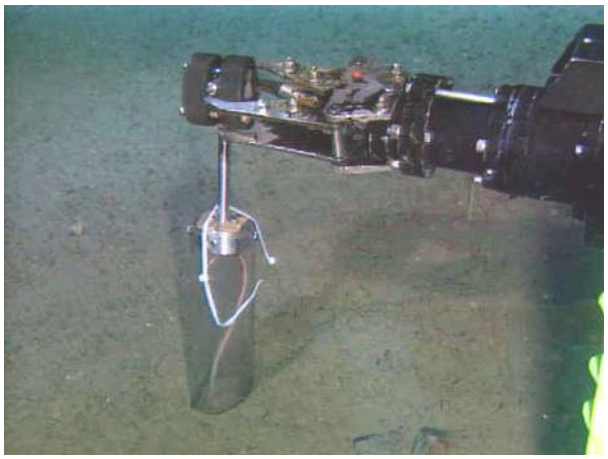
This is why ocean acidification is such a major issue in modern oceanography. Because of our constant burning of our fossil fuels following the industrial revolution, we have dramatically increased the amount of CO_2 in our atmosphere and essentially tilted the carbon cycle. This tilting of the carbon cycle has thrown off the equilibrium between the atmosphere and the ocean. By increasing the amount of CO_2 in the atmosphere we have also increased the amount of CO_2 in the ocean. By increasing the CO_2 in the ocean we are increasing the amount of H^+ ions present.



Cartoon representation of differential dissolution with depth in the ocean. At shallower depths, usually <3000 m, planktonic foraminiferal tests are well preserved in the sediment. Below the lysocline, preservation rapidly deteriorates with depth. Below the CCD, tests are not preserved.

3.4: Reconstructing Earth history

Ocean sediments can help us reconstruct Earths history. The sediments deposited on the ocean floor often have markers of the Earths environment when they were deposited and can tell us a lot about how the environment of our planet has changed throughout its history. Scientists have used sediment cores, long vertical tubes of sediment drilled from the bottom of the ocean, to estimate how the ocean reacts to global temperature changes. This is an invaluable tool in understanding what to expect in the future and to help us learn about our past



webapp1.dlib.indiana.edu/virt...diment_500.jpg

Oceanographers know about past climates and weathers by studying foraminifera that can be found in ocean sediments. Foraminifera, also known as forams, have shells that are made of calcium carbonate which can explain how past climate were by showing how much “the oxygen in the carbonate reflects the isotopic abundance in the shallow waters where the creatures lived” (Past Climates). As their shell dissolves when they sink further down, it withholds and contains isotopic oxygen. The ratio between these two oxygen isotopes, oxygen 18 and oxygen 16, can tell us the temperature in the Cretaceous Period. Oxygen 18 is known as the heavier oxygen and oxygen 16 is known as the lighter oxygen. When there is more oxygen 18 found in foram shells, the weather is usually warmer because the lighter oxygen is easier and takes less energy to evaporate than the heavier oxygen, so the heavier oxygen usually gets left behind in warmer temperatures. It is said that “only a tiny 0.2 parts per million decrease [in oxygen 16 will result] for each degree of temperature increase” (NASA). From the ratios of the isotopes, we are able to see that during the Cretaceous Period, the temperature was about 10-15 degrees Celsius warmer than today which shows that there were no ice glaciers millions of years ago. Also, paleoclimatologists study the layers of sediment called varve which are fine deposited silt or clay. The layer of varve is able to tell us temperatures, amount of rainfall, and amount of snow fall years ago.

Another way of examining the weather/climate years ago is through studying ice cores. Ice cores can help us predict the abundance of greenhouse gases. Paleoclimatologist studies greenhouse gases and atmospheric temperatures by studying the bubbles trapped in ice cores. After obtaining the cross-section from the ice sheet, they bring it back to the laboratory and heat it “carefully in a vacuum chamber (to avoid contamination by modern air), releasing the ancient air for analysis” (Past Climates). From the analysis, it is observed that methane barely changed over the course of 160,000 years, “staying to about 750 parts per billion” until the 1970’s when the industrial revolution began (Past Climates) which paleoclimatologists believe caused Earth to begin increasing in temperature. Information from ice cores can tell us many facts about past climates. When examining the ice core, the light bands in it corresponds to summer/warmer weather and darker bands corresponds to winter where there is more wind and dust blown from on land. We can see these bands with the naked eye. Also, thick layers of greater snow leads to a heavier winter. Examining trapped bubbles in ice cores, we see that certain elements corresponds to certain effects of the climate. For example, with more beryllium-10 concentrations, there was more solar radiation.

Resource: www.globalchange.umich.edu/gl...g/paleoclimate

Picture: jonova.s3.amazonaws.com/graph...-10000-new.png

Back Matter

Index

CHAPTER OVERVIEW

4: PROPERTIES OF WATER

4.1: Unique properties of water

[This page could use image]

[Water is "bipolar"? Maybe meant to say water is considered a polar molecule]

[physical property- why does water make a good solvent?]

[what makes water unique to other substances? This is called "unique properties"? Perhaps mention that if water were not formed the way it were, life on earth would not have been the way it is, or even possible.]

[surface tension- should mention capillary action]

Physical Properties of Water

Water is the only naturally occurring substance on Earth that can be found in three physical states: solid, liquid, and gas. In its solid form (ice), it is less dense than when it is in its liquid form (This is why ice floats in a glass of water).

The molecule has a cohesive property, allowing it to "stick" to other water molecules (Forming water "droplets" when molecules stick to one another, with the effect of gravity). It is also adhesive, meaning it "sticks" to other surrounding molecules in contact (An example of this being a water droplet on a blade of grass).

At sea level, water freezes at 32°F (0°C) to its solid state, and boils at 212°F (100°C) and becomes water vapor.

Density: 1 gram/cubic centimeter (g/cc) at 39.2°F (4°C), and 0.95865 g/cc at 212°F (100°C)

Weight: 1,000 kilograms/cubic meter (kg/m^3) at 32°F (0°C), and 993 kg/m^3 at 212°F (100°C)

In its pure form, water does not conduct electricity. However, it can conduct water once it starts dissolving substances around it. Water is the best solvent out of all liquids--it can dissolve more substances than the rest.

Chemical Properties of Water

Water is made up of two hydrogen (H) atoms and an oxygen (O) atom. It is unique in that it is bipolar, where the molecule has a slightly positive charge on one side (where hydrogen atoms are attached), and slightly negative on the other (just oxygen).

Since electrons are not equally distributed in a water, it is considered a polar molecule, despite it having the same number of protons and electrons. Also, because of its tetrahedral arrangement around the oxygen atom and the presence of lone pair electrons on the oxygen atom, water is considered to have a bent shape.

One water molecule can connect with another molecule via a hydrogen bond (around 1/20 the strength of a covalent bond) between a hydrogen atom of one and an oxygen atom of the other. This hydrogen bond creates the surface tension in a group of water molecules.

The pH of pure water is about 7 at room temperature (25°C or 77°F).

http://water.usgs.gov/edu/waterproperties.html

www.ozh2o.com/h2chem.html

Each hydrogen atom in water is covalently bonded to the oxygen via a shared pair of electrons. Oxygen also has two unshared pairs of electrons, thus there are four pairs of electrons surrounding the oxygen atom, two pairs involved in covalent bonds with hydrogen, and two unshared pairs on the opposite side of the oxygen atom.

Water is a polar molecule means that there is an uneven distribution of electron density. Water has a partial negative charge near the oxygen atom due the unshared pairs of electrons,and partial positive charges near the hydrogen atoms. An electrostatic attraction between the partial positive charge near the hydrogen atoms and the partial negative charge near the oxygen results in the formation of a hydrogen bond. And the ability of ions and other molecules to dissolve in water is due to polarity.

Online resource: watereducation.utah.gov/water...es/default.asp

4.2: Heat capacity, the ocean, and our weather

Solar radiation is responsible for warming up the Earth, and we rely on the Earth to hold on to this heat that comes in and regulate the flow. The amount of heat required to increase the temperature of a substance by 1 degree Celcius is quantified as heat capacity, and this value determines how well a substance retains the heat.

When you heat up a pot of water on the stove, which one heats up first: the pot or the water? The pot heats up faster! Although you are putting the same amount of heat on both substances, the pot responds quicker than the water because water has a high heat capacity. Heat capacity is a measure of the heat required to raise the temperature of 1g of a substance by 1 Celsius. In this example, water has a very high heat capacity, which means it requires a lot of heat or energy to change temperature compared to many other substances like the pot.

Additionally to temperature, it takes a tremendous amount of energy to change the water molecules from one state to another. In Earth, we have all three states of water - solid, liquid, and gas - and they're actually resistance from going back and forth from one state to another because of water's heat capacity. This relates to our ocean since the presence of the ocean moderates our daily lives and weather quite a bit in California through the amount of water molecules in the air.

Water has an especially high heat capacity at 4.18 J/g*C, which means it takes more heat to warm a gram of water. This is why, throughout the course of a warm summer day, the water in the ocean does not experience a significant change. Land, on the other hand, has a much lower heat capacity, which is usually less than 1 J/g*C.

If you're interested in more about specific heat, check this out: http://oceanservice.noaa.gov/educati...cific_heat.swf

For these reasons, the ocean takes a long time to change temperature significantly, whereas land can heat up very quickly (think of the hot sand and cool water at the beach in the summer). Since air travels around, air temperature is also regulated by these principles. Air that is in contact with the ocean will be much cooler from energy transfer between water and air, while air that sits above land will heat up much more quickly. Therefore, coastal climates are much more temperate because a body of water is nearby to regulate the temperature and keep it more constant. In the hot days of summer, landlocked places such as the Midwestern United States are much warmer than coastal cities at the same latitude because the land gets heated quickly and can’t disperse the heat. Temperate coastal areas are regulated by the ocean through land and sea breezes, which fluctuate depending on the temperature differences.

Learn more about land and sea breezes here: www.classzone.com/books/earth...page01.cfm?cha

http://ww2010.atmos.uiuc.edu/(Gh)/gu...w/sea/htg.rxml

Uneven heating of the Earth creates differences in pressure, which result in winds. The larger the difference between pressures, the stronger the wind is created. These pressure differences can also result in hurricanes, or spirals of wind. Hurricanes are conducive to conditions with warmer sea surface temperatures, which need to be above 26 degrees Celcius. When hurricanes hit land, they usually stop traveling because their humidity and temperature requirements are hard to maintain with the rapid changes in land temperature that occur.

http://www.hk-phy.org/contextual/hea...temch03_e.html

http://science.nasa.gov/earth-scienc...e-variability/

4.3: Light in the ocean

[This page needs more information on each of its main points (light in each zone, photosynthesis). Photosynthesis is important when regarding light in the ocean and so it should be discussed in more depth. This page also needs some visual aids, maybe of each of the zones of the ocean showing the difference amount of light that is distributed though the ocean. The affect of light on the marine life in each zone could probably be included as well.]

Light does not penetrate very far down into the vast depths of the ocean but can be detected about 1,000 meters in the ocean.Only the uppermost 200 meters of the ocean, called the epipelagic zone or sunlight zone, is suitable for photosynthesis: deeper than this, too little light is available for significant amounts of light-driven primary production to occur. From the base of the epipelagic zone to a depth of about 850 meters, there is still enough light for a human to see. The second zone between 200 meters and 1,000 meters is known as the "twilight zone". Some light penetrates as far as 1000 meters down into the ocean. No sunlight reaches a depth greater than 1000 meters, this part of the ocean is referred to as the aphotic zone or know as "midnight" zone. Seawater preferentially absorbs shorter wavelengths of light, leaving mainly bluish light to continue traveling to greater depths. This is why much of the ocean appears blue.

The disadvantage of having bright light in the ocean is that bright light can cause living organisms to leave part of the ocean that light is the brightest because those organisms are light-sensitive organisms.

Many organisms take advantage of this differential absorption of wavelengths of light. Because most red light is absorbed higher up in the water column, many animals living in the twilight zone are colored with red pigments: without red light available, these animals appear black and are nearly invisible against the dark backdrop.

Although photosynthesis is impossible below 200 meters, most organisms living in the twilight and aphotic zones are still reliant on primary producers living in the surface zone.

Sources

1. http://www.whoi.edu/oceanus/feature/...t-in-the-ocean
2. www.whoi.edu/page.do?pid=7545...3622&cid=74755
3. oceanworld.tamu.edu/resources...nefoodwebs.htm
4. oceanworld.tamu.edu/resources...apter06_10.htm
5. http://oceanservice.noaa.gov/facts/light_travel.html

4.4: Pressure

At sea level, 14.7 pounds per square inch (psi) of water pressure push on our bodies. Our bodies have to push out with the same amount of force to make up for the pressure from water. Humans are only able to go 3 atms into the water before our bodies are unable to compensate the for the pressure. Past this point, a submarine is needed so that humans are not crushed by the water pressure.

There are many species living deep in the ocean. These species require special adaptations that allow them to undergo large pressure changes in short periods of time so that they can swim through different depths of the ocean. One example is the sperm whale, which swims through the ocean and experiences pressure changes from 223 atms.

http://onpoint.wbur.org/2012/02/13/humans-and-whales

CHAPTER OVERVIEW

5: CYCLES: SALT, CARBON, GASES, HEAT & NUTRIENTS

Carbon is the building block of life, which is constantly cycled throughout the Earth in physical, biological, and chemical processes. Carbon can exist in many forms, and although these are always changing, there exists a stable equilibrium where a constant amount of carbon is cycling. This carbon is stored in the atmosphere, plants, animals, rocks, and water. When organisms die or rocks decay, carbon is released into the atmosphere and the cycle continues.

5.1: Influences on Salinity of the Ocean

Topic hierarchy

5.2: Distribution and Solubility of Gases in Seawater

---Still needs information about distribution of gases in the ocean---

The solubility of gases in seawater is a temperature dependent relationship, solubility is highest in cold water, and lowest in warm water. Henry's Law explains the relationship between the partial pressure of a gas and the solubility of the gas in water in this equation:

$$[C] = kP_{gas} \tag{5.2.1}$$

where

- $[C]$ is the solubility of the gas
- k is Henry's Law Constant
- P_{gas} is the partial pressure of the gas

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5.4: The Carbon Cycle

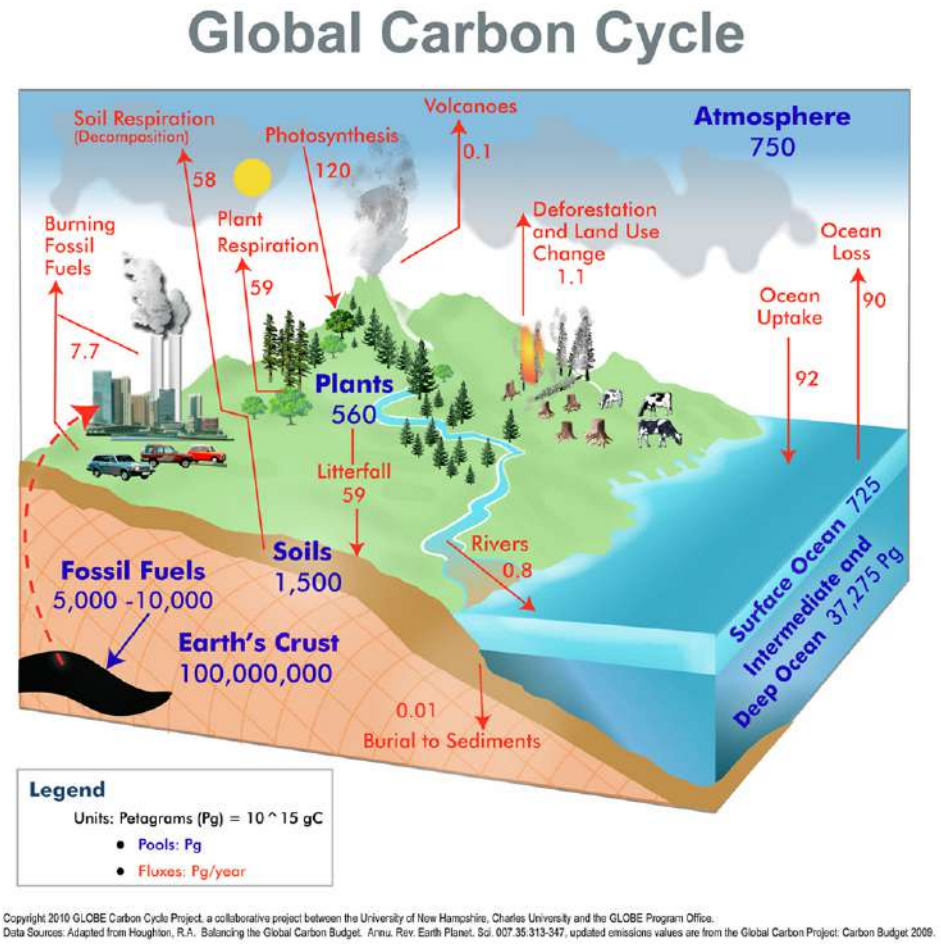
The Carbon Cycle

Carbon is the building block of life, which is constantly cycled throughout the Earth in physical, biological, and chemical processes. Carbon can exist in many forms, and although these are always changing, there exists a stable equilibrium where a constant amount of carbon is cycling. This carbon is stored in the atmosphere, plants, animals, rocks, and water. When organisms die or rocks decay, carbon is released into the atmosphere and the cycle continues. Volcanic eruptions can also expel large amounts of carbon in the form of CO_2. There has also been a large increase in anthropogenic contributions of carbon to the atmosphere with use of fossil fuels and cement production, which have had significant impacts on the cycle.

The CO_2 in the atmosphere can dissolve into the ocean or other bodies of water at the surface, it then goes through another cycle. Once in solution, CO_2 reacts with water to form carbonic acid. This acid can further dissociate to form bicarbonate and carbonate in the ocean. This is a buffering process that prevents the oceans from acidifying rapidly due to the addition of atmospheric CO_2 in the oceans. Ocean acidification is a term that describes the increase in CO_2 that is being absorbed by the oceans and the resulting decrease in pH. Since the oceans make up a huge part of the earth, most of the earth's carbon is stored in the ocean.

As far as biological processes go, the cycle starts when carbon is dissolved into the water. In shallow waters, phytoplankton take up carbon dioxide and produce much of the oxygen which we breathe, as well as transform carbon dioxide and transport it when the algae sink or are consumed. Small organisms such as coccolithophores, which take up calcium and carbonate to form their shells, can distribute carbon throughout the ocean depths when the organism dies.

Physically, carbon is cycled within oceans between various layers by upwelling and downwelling. When carbon dioxide dissolves in cold waters, this denser water can downwell and join the ocean conveyer belt on a journey that may last more than 500 years before it reaches the surface again.



[Definitely not complete and may need work]

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1. www.visionlearning.com/en/lib...arbon-Cycle/95
2. teeic.indianaffairs.gov/er/ca...boninfo/cycle/
3. http://serc.carleton.edu/eslabs/carbon/6a.html
4. http://www.gdrc.org/oceans/fsheet-02.html
5. science.nasa.gov/earth-scienc...-carbon-cycle/

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CHAPTER OVERVIEW

6: THE ATMOSPHERE IN MOTION

EL NIÑO

El Niño (meaning "Christ child") is a periodic climatic event described by the warming of surface water in the Southwestern Pacific and weakening or reversal of equatorial trade winds. The El Niño-Southern Oscillation (ENSO) is a dominant force that affects global climate patterns. It is especially pronounced in the central and eastern equatorial Pacific regions of South America and Australia. ENSO events occur, on average, every two to seven years.

INTENSIFICATION OF STORMS DUE TO CLIMATE CHANGE

SPECIAL TOPIC: DROUGHT

A drought, also defined as a extended period of exceptionally low rainfall resulting in a scarcity of water, develops in many different ways. Elevated levels of reflected sunlight and raised occurrence of high pressure systems, winds carrying continental, rather than oceanic air masses, and ridges of high pressure areas which put a hold on the production of rainfall are the main culprits that cause droughts. There are four different types of droughts.

SPECIAL TOPIC: HURRICANES

SPECIAL TOPIC: LAND/SEA BREEZES AND MONSOONS

6.1: Seasonal and latitudinal variation in solar radiation

6.2: Idealized circulation on a non-rotating Earth

6.3: Coriolis Force

Coriolis effect is an inertial force described by the French mathematician Gustave-Gaspard Coriolis. Based on Newton's laws of motion Coriolis determined that a "mass moving in a rotating system experiences a force acting perpendicular to the direction of motion and to the axis of rotation"[1]. This principle has a visible effect on the movement water in the oceans and air and objects in the atmosphere.

But in order to understand the Coriolis forces' effects on atmospheric circulation, we must first understand some basic physical premises. Firstly, The Earth is wider around at the equator compared to higher latitudes and is rotating from West to East. Because of these facts we can determine that near the equator the Earth is rotating faster in an easterly direction than it does at higher latitudes. These facts coupled with Newton's first law that objects in motion tend to stay in motion, explain the effect on how objects move throughout the atmosphere. If you were to launch a missile from the Equator to the North Pole, the initial high velocity of rotation at the Equator is maintained in the system and the missile carries this initial speed from rotation due to Newton's first law. This is visualized as an object launched into the atmosphere moving from west to east as it is launched from the equator to the pole in the northern hemisphere. (opposite in the southern hemisphere). A little tougher to understand are objects moving from east to west. In order to understand this we need to apply the principle of centripetal acceleration, which is defined as the acceleration needed to keep an object moving in a circle at a particular radius[2]. Basically if you go faster than you are allowed you will increase your radius, and if you slow down you will decrease your radius. So as objects move eastward in the northern hemisphere they want to push out to space because of their increased speed relative to the earth, but the constraint of gravity stops it from moving outward and instead moves it south in order to increase its radius. Objects and air moving west want to fall towards Earth's axis, but are restrained by the surface, and thus are pushed north where the radius of circulation is smaller.

Now that we understand how the Coriolis force effects atmospheric motion we can apply it to our knowledge other atmospheric and oceanic phenomena. Every aspect of atmospheric circulation from the presence of jet streams to Hadley cells to oceanic gyres, is indicative of this phenomena, and prove that the Coriolis force, while not incredibly strong, (10 microns per second squared)[2] still plays a major role in the movement of water and air on earth. One of the most extreme examples of how the Coriolis effects weather is in Hurricane systems. The low pressure center of the system attracts high pressure air from all directions. Because of the large difference in pressure gradient the speed of the air is more rapid than normal, but because of the Coriolis effect the air regardless of which direction it came from, will be directed to its' right. The circular motion of the high pressure air around the low pressure center, creates the eye of the storm that is indicative of a Tropical storm or hurricane.[3]

1. "Coriolis Force | Physics." Encyclopedia Britannica Online. Encyclopedia Britannica, 18 July 2013. Web. 12 Feb. 2015.

2. Domelen, Dave Van. "The Coriolis Effect." The Coriolis Effect. N.p., 20 Feb. 1996. Web. 12 Feb. 2015.

3. "The Coriolis Effect." YouTube. NOVA PBS, 19 July 2013. Web. 12 Feb. 2015.

6.4: Idealized "average" global atmospheric circulation

Atmospheric Circulation

Global atmospheric circulation is influenced by temperature and pressure differentials, among several other factors. This section will cover atmospheric circulation in idealized terms. That is, circulation solely dependent on temperature-based fluid dynamics.

- Atmospheric pressure patterns and atmospheric circulation cells

  Air molecules in the atmosphere move following the laws of physics and fluid dynamics. Hot air will rise, just as cold air will sink. The processes that set the global circulation cells in motion are as follows:

  1. On land, solar radiation heats up Earth's surface and surface atmosphere. This results in air molecules rising through the atmospheric column. It also creates a system of **low pressure** on the surface, since molecules float away, and form a system of **high pressure** at the top of the column as molecules bunch together.

  2. In the atmosphere, air molecules are cooled at the top of the atmospheric column, and begin to sink. Like with the previous scenario, sinking molecules create a system of low pressure at the top of the column, and a high pressure system at the surface below.

  3. Fluids move from high pressures to low pressures. In this case, at one point on earth molecules sink from the top of the atmosphere on to land as they are cooled, creating low pressure. At another point molecules that are rising due to higher temperatures on land are creating high pressure at the top of the atmosphere. This **pressure differential** results in molecules at the high pressure area at the top of the atmosphere to move towards the low pressure area at the top of the atmosphere. This is the same on land, where the molecules at the surface high pressure area move towards the surface low pressure area. This motion results in an **atmospheric circulation cell**.

- Where do these cells form?

  These atmospheric circulation cells begin in areas where solar radiation results in increased temperatures in land. On the **equator**, the intense solar radiation creates low pressure systems on the surface that initiate the circulation of air molecules. At 30N and 30S, the cooling molecules sink and form high pressure systems on the surface. These patterns are repeated every 30 degrees in both directions with the equator as the original low pressure area, alternating every 30 degrees thereafter.

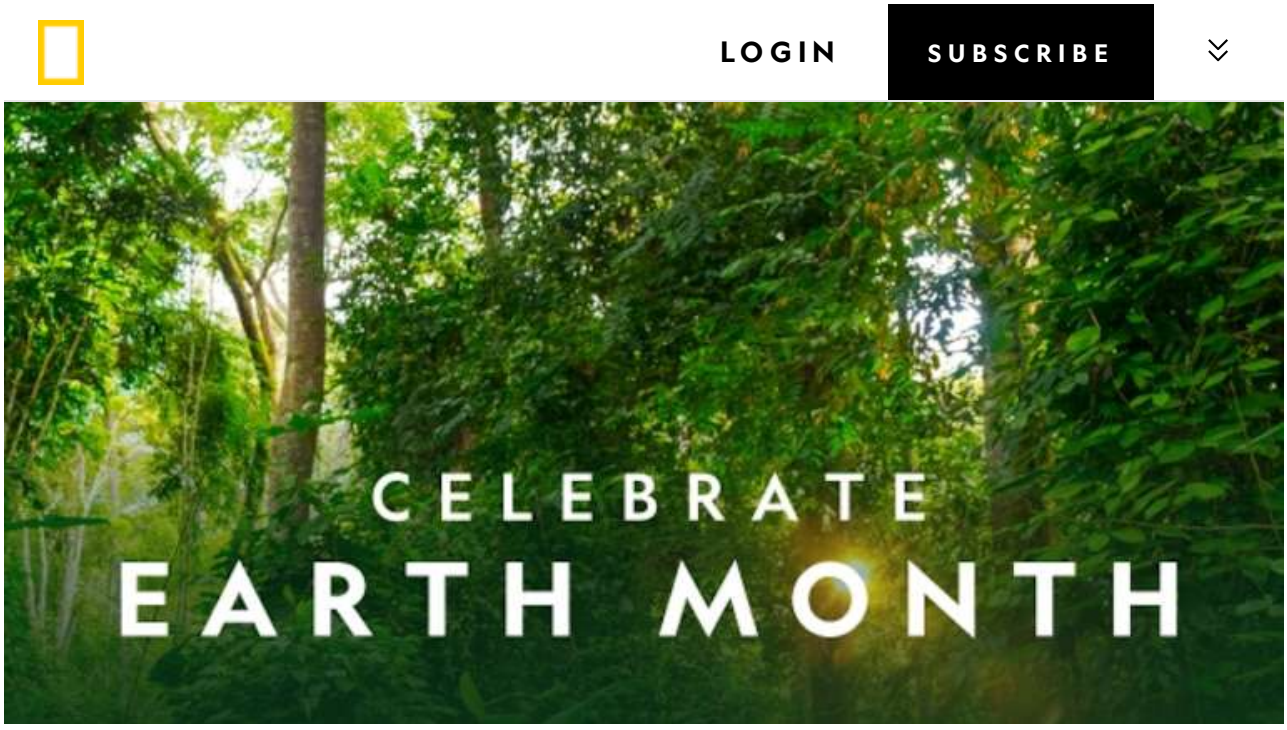
El Niño

El Niño (meaning "Christ child") is a periodic climatic event described by the warming of surface water in the Southwestern Pacific and weakening or reversal of equatorial trade winds. The El Niño-Southern Oscillation (ENSO) is a dominant force that affects global climate patterns. It is especially pronounced in the central and eastern equatorial Pacific regions of South America and Australia. ENSO events occur, on average, every two to seven years. These events are highly variable both in frequency and intensity, however, and their origins are still unknown to science.

During ENSO events, the classic Walker Cell either weakens or reverses, which leads to warm water propagating across the Pacific. This warm, low pressure system rises in the Eastern Pacific, which brings increased rain and flooding to Chile and Peru. Along the coast of South America, there is reduced nutrient upwelling. The colder, nutrient rich water does not rise to the surface, which leads to fishery collapse.

Across the Pacific Ocean, in Australia, the opposite processes occur. Descending low pressure systems led to a reduction in precipitation. This places Australia at risk for both drought and forest fires. Drought conditions in Asia have led to sever famine in China and India over the past few centuries.

Often increased precipitation, flooding, and weakening of trade winds are typical patterns for an El Niño event. With the warming of the sea surface temperatures and slowing of trade winds, fisheries start to collapse, and there is a positive feedback of other ecosystems failing. El Niño events have increased dramatically over the past 50 years and it is believed to be induced by anthropogenic factors.



Sources

1. www.nc-climate.ncsu.edu/clima...erns/ENSO.html
2. video.nationalgeographic.com/video/el-nino
3. earthguide.ucsd.edu/virtualmu...ge1/11_1.shtml

Intensification of storms due to climate change

Building your help center is easy!

Your help center is organized by category. Each category can have an unlimited number of guides and answers associated with it. Users can search within and across guides to find the answers they need to use your categories. If you have 5 minutes, please read the CXone Expert welcome guide.

Only have 1 category? That's OK! Your help center is designed to work well with 1 category or 50 categories. Once you add some categories, your help center will begin to look like this:

Special Topic: Drought

A drought, also defined as a extended period of exceptionally low rainfall resulting in a scarcity of water, develops in many different ways. Elevated levels of reflected sunlight and raised occurrence of high pressure systems, winds carrying continental, rather than oceanic air masses, and ridges of high pressure areas which put a hold on the production of rainfall are the main culprits that cause droughts (http://www.livescience.com/). There are four different types of droughts, one of them being a meteorological drought. This is defined by the degree of dryness or duration of the dry period to a specific region since those conditions can be variable depending on the area you're focusing on. A second type is referred to as an Agricultural drought which accounts for the lack of water available in order for crops to mature resulting in a yield of plant production. A third type of drought, hydrological, refers to decreased volumes in streams, rivers, and reservoirs. The final type of drought, also known as a socioeconomic drought, occurs when the demand of water exceeds the supply (http://drought.unl.edu)

It is widely believed that increased temperatures will result in more rainfall as opposed to snow, premature snow melt, and increased evaporation, leading to an increase in conditions favorable for a drought."Within the last decade, drought conditions have hit the Southeastern U.S., the Midwest, and the Western U.S. In 2011, Texas had the driest year since 1895. In 2013, California had the driest year on record" (http://www.ucsusa.org). We must prepare for an increase in these drought conditions by being being conscious and limiting our water supply, utilizing technology that reduces indoor and outdoor water use, increase recycling of water, and increasing use of ground water (http://www.ucsusa.org). Current focus tends to be on short term measures as a means of conserving water, however its long term management that will ultimately increase resilience.

Sources

1. http://www.ucsusa.org/global_warming...l#.VNPYjlpzvlJ
2. http://www.livescience.com/21469-dro...efinition.html
3. http://drought.unl.edu/DroughtBasics...ofDrought.aspx

Special Topic: Hurricanes

Hurricanes are extreme tropical storms that form in the ocean. They are referred to as tropical cyclones or typhoons depending on the region. Hurricanes begin as tropical disturbances, which is the slight circulation in low-pressure areas of warm seawater. A disturbance then becomes a tropical depression when winds increase in speed to at least 38 mph, which create a drop in pressure in the center of the depression. If wind speed increases to 39 mph it then becomes a tropical storm, and when a storm reaches wind speeds of 74 mph it becomes a hurricane. They receive names that identify them when they become storms and then keeps those names as hurricanes. The winds create a rotation around the central core (eye) of the storm.

Hurricanes can reach speeds of 160 mph and produce up to 2.4 trillion gallons of rain a day. They are rated 1-5 based on the Saffir-Simpson scale. This is scale is determined by the intensity of the winds of a hurricane. The highest category, which is 5, is reserved for hurricanes that reach speeds of 157 mph and greater. This scale also helps to determine the possible damage on land by a hurricane.

he average annual economic loss is estimated at some 5% of the gross national income. 45 tropical storms reach hurricane strength each year on average, 30% of them in the western North Pacific. Due to the short period in which observations can be made, Because of the short period of reliable observations, it is not yet feasible to determine a trend or reliable low-frequency variations. There is a variability and shifts in the number of major hurricanes in the Atlantic and the Caribbean.Superimposed on this slow variability are substantial variations from year to year, often influenced by El Niño-Southern Oscillation (ENSO) events.

Sources

1. http://environment.nationalgeographi...icane-profile/
2. http://ww2010.atmos.uiuc.edu/(Gh)/gu...rr/stages.rxml
3. http://www.sciencemag.org/content/293/5529/440.full

Special Topic: Land/Sea Breezes and Monsoons

CHAPTER OVERVIEW

7: OCEAN CIRCULATION

An ocean current is a continuous, directed movement of seawater generated by forces acting upon this mean flow, such as breaking waves, wind, the Coriolis effect, cabbeling, temperature and salinity differences, while tides are caused by the gravitational pull of the Sun and Moon. Depth contours, shoreline configurations, and interactions with other currents influence a current's direction and strength.

7.1: Effect of Atmospheric Circulation on water & Coriolis Effect

As winds blow across the Earth's surface, they interact with the surface of the ocean. This process occurs in predictable patterns, because of known/average locations of high and low pressure systems in the atmosphere.

As wind interacts with the surface of the ocean, the ocean is also influenced by the Coriolis Effect. Each layer of water responds by moving slightly at an angle to the wind (in the northern hemisphere, to the right; in the southern hemisphere to the left).

7.2: Major Gyres & Surface Currents

Global winds move water along the surface of the ocean in various directions, based on location. In the Northern Hemisphere, the ocean currents move in a clockwise spiral. In the Southern Hemisphere, the ocean currents move in a counter-clockwise spiral. The Coriolis effect is the major source of the direction the water moves in our oceans. Since the Coriolis effect is not present at the equator, neither are the major spirals of surface currents we see north and south of the equator. Instead, Currents in the Northern Hemisphere move along the equator to the West and then change direction. There is an Atlantic Equatorial Current System, a Pacific Equatorial Current System and two Indian Monsoon Gyres. Surface currents vary considerably in strength, width, temperature and depth. The five most notable gyres are as follows: Indian Ocean Gyre, North Atlantic Gyre, North Pacific Gyre, South Atlantic Gyre, and South Pacific Gyre. Global gyres contain both cold water from the deep ocean and warm water from the surface currents.

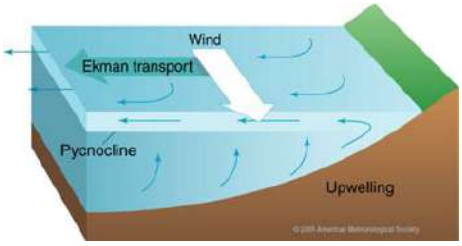
Look at these links for better visuals on movement:

https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=10841 (Perpetual Ocean: NASA)

Plastic Adrift (Adrift.org.au)

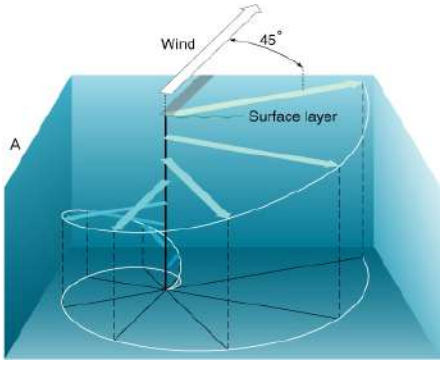
Sources
oceanmotion.org/html/backgrou...en-surface.htm
http://5gyres.org
eros.eas.gatech.edu/npgo/

Upwelling



Upwelling occurs where surface waters diverge, mostly due to wind, and deeper water is brought up to replace the surface waters. In the diagram above, the wind is blowing along the coast and Ekman transport is causing the surface layer of water to move 90 degrees away from the direction of the wind. This movement creates a void that brings deep water from below the Pycnocline to the surface.

Ekman transport is a result of the Coriolis Effect (the effect of the Rotation of the Earth) and Wind-Driven surface currents. These two forces creates the Ekman Spiral which moves each of the layers of water in the ocean in a different direction, the result is a net movement 90 degrees away from the direction of wind, shown in the diagram below.



Sources:

http://oceanmotion.org/html/backgrou...-in-motion.htm

http://oceanmotion.org/html/backgrou...ownwelling.htm

7.3: Wind driven upwelling

Upwelling is a phenomenon that brings cold, nutrient-rich deep water to the surface. In the Northern Hemisphere, upwelling occurs on west coasts when winds are blowing north to south. Ekman transport and the Coriolis Effect make the coastal waters move, on average, 90 degrees to the wind. This means the water near the coast is being pushed west, away from the coast. This, in turn, pulls deep water up to the surface to replace the original surface water.

Upwelling can also occur at the equator. When the north and south trade winds meet, coming from opposite directions, they push water away from the equator, which pulls up the deeper water to replace it.

Downwelling can also occur, if the winds were to reverse. Ekman transport and the Coriolis effect would cause the water to basically "pile up" on the coast and eventually sink to the bottom.

Upwelling is important for coastal communities because deep water has more nutrients. Coasts with more upwelling usually have more phytoplankton and algae growth. The deep water brought up is also colder than usual surface water, which is why, for example, the west coast of North America has much colder water, as well as lots of fog, cooler weather, and no hurricanes.

Sources:

http://oceanexplorer.noaa.gov/explor...upwelling.html

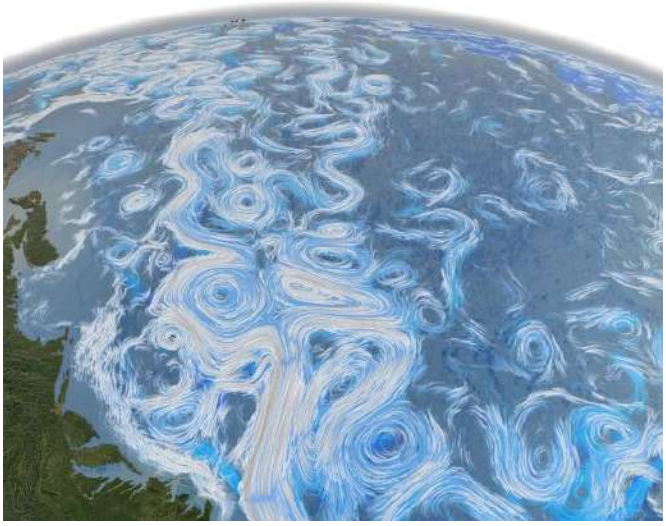
http://oceanservice.noaa.gov/facts/upwelling.html

Diagrams of upwelling and downwelling: http://oceanmotion.org/html/backgrou...ownwelling.htm

More information and a diagram for ekman transport: http://oceanmotion.org/html/backgrou...-in-motion.htm

7.4: Density Differences - Salinity and Temperature of Ocean

7.5: Summary



Gulf Stream flowing along East Coast

See http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=3879 for lots of very detailed and neat visuals to include about wind-driven currents (wind & ocean circulation layer)

7.6: Thermohaline Circulation

Circulation of water throughout the world's oceans occurs by one of two major modes: surface currents or thermohaline circulation. The former resides in the upper few hundred meters of the oceans and are predominantly controlled by winds. The latter is regulated by temperature (*thermo-*) and salinity (*-haline*). Together, these two physical parameters dictate particular ocean water mass densities, the driving force behind large-scale, deep circulation. In general, as a result, thermohaline circulation causes warm water to flow poleward near the surface; in turn, this warm water cools and becomes denser. The water mass then sinks and begins flowing south toward the equator.

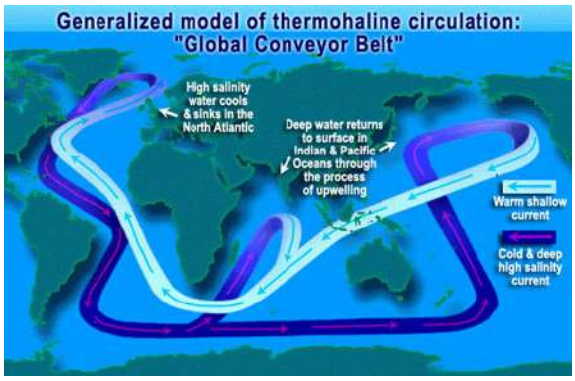


photo courtesy of http://nsidc.org/cryosphere/seaice/e...l_climate.html

Deepwater Formation

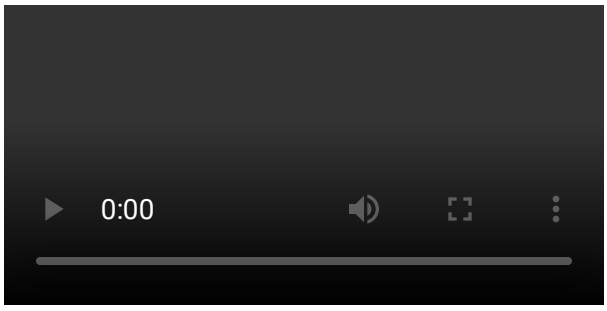
Where does it all begin? Thermohaline circulation is driven by the formation of North Atlantic Deep-Water (NADW), and Antarctic Bottom Water (AABW). Collectively these terms are referred to as deep water. Because the Earth is a sphere, the sun's energy warms the globe unequally, with most of the energy concentrated along the equator and the least amount of energy reaching the poles. The Gulf Stream facilitates the movement of warm equatorial waters through the tropics and subtropics north to the North Atlantic. Along this transit, the water becomes more saline due to evaporation. As the salty mass proceeds northward toward the sub-Arctic regions, it also cools. It can cool enough for sea ice to form, which leaves salt behind, causing the water to become even saltier and denser. Consequently, water jettisoned to the Norwegian Sea and the Arctic Ocean by the Gulf Stream becomes dense enough to sink out, and thus NADW is formed.

Kitchen Oceanography Experiment: Ocean Overturning Circulation [Link]

Try this easy-to-do at-home experiment shared by Dr. Mirjam S. Glessmer. It can potentially help you better understand how the temperature and salinity differences of water lead to North Atlantic Deep-Water circulation!

Transit Through the Ocean

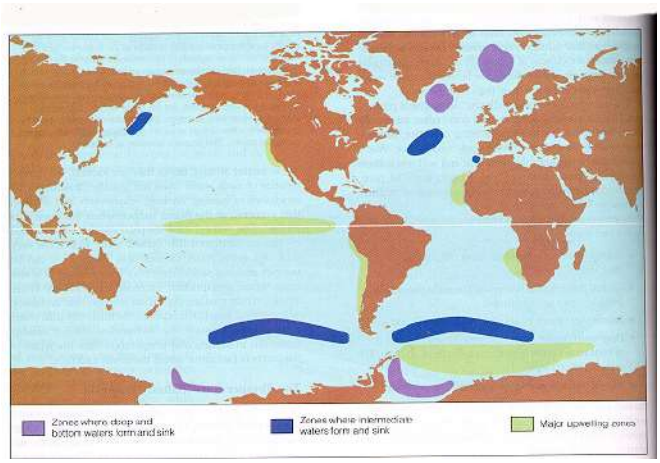
"This animation first depicts thermohaline surface flows over surface density, and illustrates the sinking of water in the dense ocean near Iceland and Greenland. The surface of the ocean then fades away and the animation pulls back to show the global thermohaline circulation," (Olsen et al 2013).



Thermohaline Surface Flow
http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=3658

Locations of Deep Water Formation

Deepwater is formed in several places around the world. As discussed above, most NADW forms in the North Atlantic, specifically in the Norwegian, Labrador, and Greenland Seas were the Gulf Current cools (also known as Atlantic Meridional Overturning Circulation). However, some NADW forms in the warmer waters of the Mediterranean. This water may not be as cold as polar sources but gains its density from its extremely salinity. Deepwater production sites in the Mediterranean include the Gulf of Lions, the Southern Adriatic Pit, and the Cretan Sea. Antarctic bottom water is formed during the production of large amounts of sea ice off the coast of Antarctica. The ice formation increases the salinity of the frigid surrounding waters, producing some of the densest seawater in the world. As its name implies, this water sinks right to the seafloor, displacing even NADW. This phenomenon occurs mostly in the Weddell and Ross Seas. Because of the proximity of these sites to large ice sheets, global warming could have strong effects on the rates of deep water formation. Freshwater runoff from melting glaciers can dilute surface salinity, decreasing density and stopping water from sinking. This in turn could slow global thermohaline circulation and have profound effects on how heat cycles on our planet.



Map illustrating upwelling zones and sinking zones

Image courtesy of education.nationalgeographic....r-belt/?ar_a=1

Further Resources

Flight Center Scientific Visualization Studio: Thermohaline Circulation - http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=3884

See Toggweiler and Key (2001) for an excellent introduction to thermohaline circulation www.researchgate.net/publication/242569649_Thermohaline_Circulation

NOAA: Thermohaline Circulation: http://oceanservice.noaa.gov/educati...conveyor1.html

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2. https://oceanservice.noaa.gov/education/tutorial_currents/05conveyor1.html
3. https://pangea.stanford.edu/courses/EESS146Bweb/Lecture%2013.pdf
4. https://www.nature.com/articles/990069
5. http://adsabs.harvard.edu/abs/2018EGUGA..2019128S

CHAPTER OVERVIEW

8: WAVES & TIDES

Tides have been studied and tracked for thousands of years since they are important to the livelihood of both merchants and fishermen. The force driving tides is a combination of the coriolis effect from the Earth’s rotation and the gravity fields of the sun and the moon.

8.1: Waves

In their simplest definition, waves can be described as energy and water. Every wave has a **crest**, which is the highest point of a wave, followed by a **trough**, the lowest point of a wave (NOAA). As seen in the diagram below, the distance between two waves is the **wave length**.

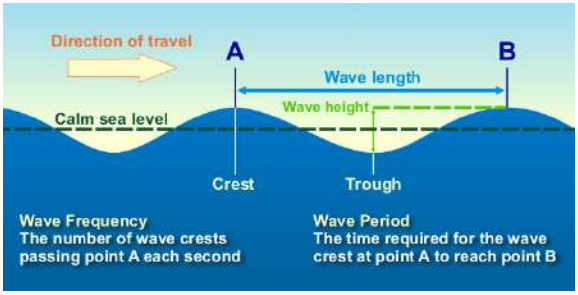


Figure: Anatomy of a wave. source: noaa

Waves can be caused by a number of things, such as: earthquakes, volcano eruptions and landslides but the most common ones are surface waves caused by winds (CoastalCare). When wind blows across the surface of the water, this creates friction between the air and the water causing a wave to form (NOAA). As the wave forms, it becomes easier for the wind to grip the water, creating larger waves. The size of the wave can depend on three things: wind strength, wind duration, and fetch. **Fetch** is the uninterrupted distance over which the wind blows with very little change in wind direction (NOAA). Larger waves are created by longer duration of winds; the stronger the winds, the higher the waves and the greater the fetch, the bigger the waves become (CoastalCare). As a wave approaches the shore, the wave direction can be changed due to the contour of the land (NOAA).

Rogue Waves

Rogue waves were originally thought to be a myth to cover the mistakes of sailors that wrecked at sea, but rogue waves are just regular waves of unusual height. Rogue waves occur when there are large swells that come from multiple directions and combine together to make one large wave (NOAA). There are three main characteristics of a rogue wave:

1. Their height is greater than twice the size of surrounding waves,
2. They often come unexpectedly from directions other than prevailing wind and waves, and
3. They are unpredictable. (NOAA)

A rogue wave was seen in 2005 when a 70-foot wave crashed into a norwegian cruise ship. The average height of waves were approximately 30 feet that day before the rogue one struck causing damage to this ships hull (NOAA).

What Causes Waves to Break?

When waves break on the beach or shoreline it is because of the decreasing water depth that the wave has to work with as it approaches the shore. When a set of waves approach the shore they begin to interact more with the bottom than they did in the deep ocean. This causes waves to slow down and bunch together, while the time between crests(period) remains the same. (Coastalcare.org) As this happens the wave height begins to increase while the wave continues to slow down via interaction with the sea floor. Eventually the top of the wave will be moving faster then the bottom and will cause the top to topple over the front, also called the break. (surfing-waves.com)

Waves can also break in the open ocean. This is caused by the same above water process as a shore break and happens when the top of the wave is moving faster than the bottom part of the wave. However, in the open ocean there is no interaction with the bottom causing this. For a wave to break in the ocean the winds forming it need to be strong enough to cause the wave to reach a height at which the water in different parts of the column are moving at different speeds due to gravitational interactions. If this happens then the wave can suffer a typical break just as seen on the shoreline. (marineinsight.com)

Awavebreakingoff theNorthShoreofOahu,Hawaii(www.surfingnews.com/wpconte...-surf-spot.jpg)

References:

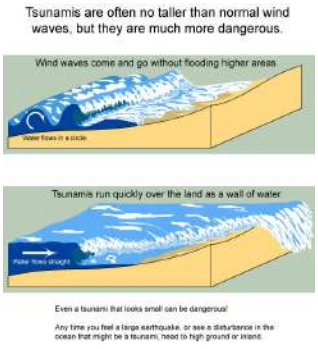
coastalcare.org/educate/waves/

www.surfing-waves.com/waves/h...aves_break.htmhttp://oceanexplorer.noaa.gov/edu/le...ing_waves.html

www.marineinsight.com/marine/...-of-sea-waves/

Tsunamis

Tsunamis are extremely large waves that can sometimes reach heights of over a 100 feet. These types of waves are caused from disturbances along the ocean floor from underwater landslides, volcanic activity, or earthquakes (National Geographic). They can have devastating impacts in the regions where tsunamis can occur. In the deep ocean, tsunami waves can appear to only be about a foot high and can travel at very high speeds of about 500 miles per hour (NOAA). As the wave approaches shore however, they slow down



and begin to gain energy and height. The trough reaches shore first, creating a vacuum effect, sucking the water away and exposing the shore line (National Geographic). This can actually be the first warning sign that a tsunami is approaching and it could arrive within 5 minutes. Knowing the signs of an approaching tsunami can help drastically reduce the damage.

Tsunamis are very large waves that can potentially reach 100 feet or more. Earthquakes, landside, volcanic eruption or meteorite can cause tsunamis and they occur along plate boundaries, this due to underwater disturbance. The waves are outward in all directions from where the tsunami originates. The topography of the coastline and ocean floor has a major significance to the size of the wave. The tsunami run up describes the height above sea level that the tsunami reaches. The process is very interesting, first the waves feel the bottom and then the wave becomes steeper and the wave then breaks. There can be more than one wave and the one after it may be larger than the one before. This is an example of a small tsunami at a beach resulting in a bigger wave a few miles away.

Tsunamis are known to be very dangerous even if they may not damage the coastline it hits. According to the International Tsunami Information Center it is said that the most destructive tsunamis have occurred along the coasts of California, Oregon, Washington, Alaska and Hawaii.

According to the North-Eastern Atlantic and Mediterranean Tsunami Information Centre, the wavelength is a factor, which depicts tsunamis from wind waves, (tsunami wavelength considered longer than a wind wave wavelength, it can be more than 200 km long). The wavelength is linked closely to the sea depth. As sea depth decreases, the wavelength decreases. And at the same time, the height of the wave increases.

Image:NOAA

8.2: Tides

Tides have been studied and tracked for thousands of years since they are important to the livelihood of both merchants and fishermen.

The Moon & and the Sun

The force driving tides is a combination of the gravity fields of the sun and the moon, with water motion influenced then by the Coriolis effect from the Earth's rotation. The gravitation influence of the moon is larger than the sun, since the moon is so (relatively) close to the Earth.

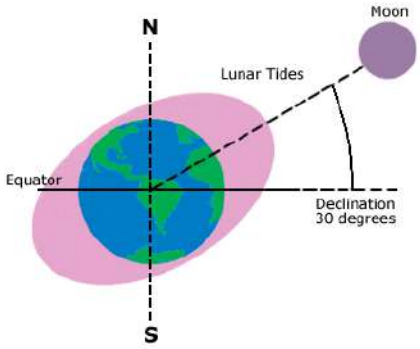


Figure: Image showing movement of the tidal bulges around the Earth in response to the rotation of the earth relative to the moon system. When the moon aligns with other celestial features, even more extreme water levels can result. (Public Domain; NOAA)

While the moon is the main reason for tide occurrence, the sun also plays a vital role. The sun is responsible for causing high-high tide (HHT) during new moons and full moons. Meanwhile, during ¼ moons, the sun causes lower-high tide (LHT).

There are three classifications of tides;

- Diurnal: One high tide and one low, per 24 hour
- Semidiurnal: Two high and two low tides per 24 hours, slightly different in level.
- Mixed Diurnal: Two high and two low tides per 24 hours, large difference in level. The result is what is referred to as High High Tide (HHT) and Low High Tide (LHT) as well as High Low Tide (HLT) and Low Low Tide (LLT).

Within the classifications are further extremes. Spring tides are extreme high and low tides and happen when the Earth, moon and sun are all in alignment and the gravitational pull from the sun and the moon are added together. King tides are extreme high spring tides, and occur only a few times a year.

Amphidromic points or nodes add complexity that is needed for tides to function properly, or as we know them to function. This is the point in water that has no tidal influence, as the distance from this point increases, the tidal range (amplitude) also increases. These amphidromic points occur due to the Coriolis effect and the interference within ocean basins or bays that cause a wave pattern called an amphidromic system, which means the tidal crests rotates around this point.

www.reddit.com or http://en.Wikipedia.org/wiki/Amphidromic_point (diagram 1)

Equilibrium Theory of Tides

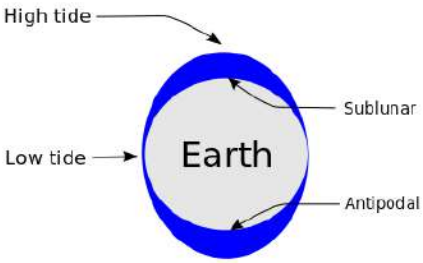
Isaac Newton first conceived the Equilibrium Theory of Tides, also called "static" tides. This is the theory that a hypothetical global ocean exists at unchanging equilibrium with the tide producing forces. The Equilibrium Theory of Tides is highly idealized, even to the point of altering the globe's shape to better align with the celestial body (sun and moon), and the theory ignores the continents.

web.vims.edu/physical/researc...ial/static.htm (diagram 1)

Tides and Sea Level Rise

The California King Tides Project uses this opportunity to envision Sea Level Rise by the help of citizen scientists who photograph areas where the high tide causes flooding. Neap tides are unusually low tides and occur when the sun and the moon are at 90 degrees to each other and the gravitational pull from each is partially canceled.

8.3: Shallow Water Processes



CHAPTER OVERVIEW

9: COASTAL PROCESSES

9.1: ESTUARIES

Estuaries are coastal bodies of water have mixed fresh and salty water. The water in estuaries is mixed because they are fed by rivers but also connection with oceans. Estuaries have a barrier to the sea, similar to lagoons, that protects them from ocean energy, but, unlike lagoons, estuaries still connect with the sea. Because of this connection with the sea, estuaries are strongly influenced by tides.

9.2 COASTAL EROSION

RESOURCES

9.3 SEA LEVEL

ESTUARIES & ESTUARINE CIRCULATION

9.1: Estuaries

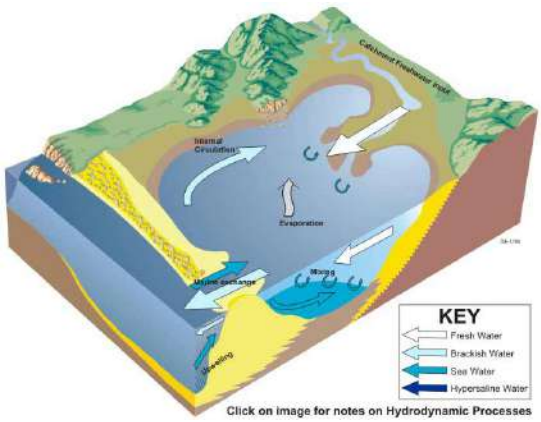
Estuaries are coastal bodies of water where freshwater from land sources, such as rivers, and salty seawater mix. Estuaries have a barrier to the sea, similar to lagoons, that protects them from ocean energy, but, unlike lagoons, estuaries still connect with the sea. Because of this connection with the sea, estuaries are strongly influenced by tides (NOAA).

Rio de Plata Estuary, https://upload.wikimedia.org

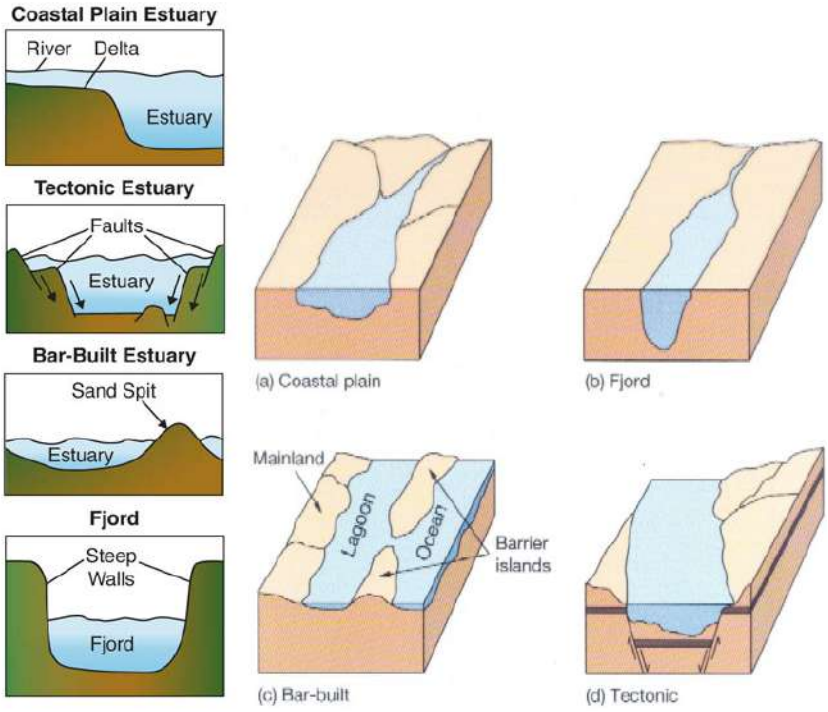
These tidal changes, along with seasonal changes in rainfall, cause estuarine environmental conditions, like water height and salinity, to fluctuate greatly (Nat Geo, NEEF). Having a wide range of conditions allows estuaries to be home to many different habitats and species (NEEF). Because the estuaries are mostly sheltered from fast-flowing waters, many small fish, shellfish, and migratory birds inhabit these waters. However, during storm surges, it is possible for ocean waves to enter estuarine habitats and disrupt the calm environment.

Estuaries' unique environment makes them a busy location for human and animal interaction. Humans benefit from the beauty of estuaries and the food and resources they provide. Estuaries make great tourist attractions or harbors and ports. The mix of fresh and saltwater makes a great feeding ground and habitat for many types of wildlife (EPA).

The mixture of fresh land water and salty seawater also results in a mixture of types of sediment. The input of sediments from both upstream and from the ocean floor makes estuaries nutrient-rich and able to support wide communities of plants and animals (Nat Geo). Though estuaries have sediment input from both upstream rivers and from the ocean, most of the sediment is relatively fine-grained (McNally, pg. 3). The type of sediment and the abundance of it affects human and animal involvement with estuaries. Too much sediment makes it hard for plants to photosynthesis and limits human use of the estuary because too much sediment makes the estuary unsuitable for ship traffic. On the other hand, if there is too little sediment in the estuary then the land surrounding may begin eroding away and increase predation rates in some species (McNally, pg. 2).



There are four main types of estuaries: coastal plain estuaries/drowned river valleys, tectonic estuaries, bar built estuaries, and fjords. Coastal plain estuaries form from rising sea level, which fills an already existing river valley with water, creating an estuary. Tectonic estuaries for on faults, where tectonic activity has created a space that can be filled in with water. The San Francisco Bay is an example of a tectonic estuary. Bar built estuaries are behind some sort of natural bar between the estuary and the ocean, such as a spit. Fjords are valleys that were, at one time, carved out by glaciers and were then filled in with water (ONA).



Because estuaries are located at or near 50% of the world's human population, they are vulnerable to a variety of threats from anthropogenic activities (Estuaries). Of these, the most pressing is pollution of the estuaries through the addition of human waste products as global populations expand. As the number of industrial processes, pesticides, herbicides, and synthetic fertilizer increases, it is inevitable that large amounts of these chemicals will end up in estuaries. 90% of pollutants that enter estuaries are from land-based sources, as opposed to marine dumping. These land-based pollutants such as sewage and fertilizers can contribute to organic loading can lead to depletion of oxygen levels in estuary waters. This can lead to death of fish and shellfish (Kennish 1994).

In addition to oxygen depletion, through the process of bioaccumulation, pollutants can build up in the tissues of living organisms. Heavy metals that enter the estuaries and enter the bodies of living organisms can hinder embryonic development and impede the function of numerous biological systems within the animal. Over time, this may cause irreversible changes to the ecosystem (Monserrat 2007).

Helpful Tools:

Visual Tools:

1. www.jht.com/icuf/202/YTMS-08B-135.htm: Visual depictions of the four types of estuaries
2. http://ozcoasts.org.au/conceptual-diagrams/science-models/geomorphic/wde/wde_pos_hydro/: An image depicting the hydrodynamic processes that govern estuaries

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9. Kennish, Michael J. “Pollution in Estuaries and Coastal Marine Waters.” *Journal of Coastal Research*, 1994, pp. 27–49. *JSTOR*, www.jstor.org/stable/25735588

9.2 Coastal Erosion

Coastal erosion is the loss or displacement of coastal lands and the subsequent landward retreat of the shoreline caused by the net removal of sediments or the underlying bedrock. There are two types of coastal erosion; **rapid-onset hazard erosion** occurs at a time scale of days to weeks, whereas **slow-onset hazard erosion** occurs at a time scale of decades to centuries. Both of these are caused by natural processes. For slow-onset hazards, common drivers of erosion include waves, currents, and **mass wasting processes**- which is the bulk movement of sediments and rock debris down slopes largely in response to gravity. Wind erosion also contributes to slow-onset hazards and is responsible for many of the horizontal and cross-bedding strata that are visible in some sand dunes and beaches. **Subsidence**, the gradual settling or sudden sinking of the Earth's surface, is another cause of slow-onset hazard erosion. The significant episodes of coastal erosion associated with rapid-onset hazards are often driven by extreme weather phenomena. An event such as a tsunami has an increased wave intensity that can flood and erode landforms that are not typically reached by normal coastal waves.

The effects of coastal erosion left evident marks on a cliff located in Jinshitan Coastal National Geopark, Dalian, Liaoning Province, China. (https://en.Wikipedia.org)

Beyond the natural drivers of coastal erosion, anthropogenic activities also have a strong influence. Construction of coastal structures often removes important sediments, as do processes like dredging and sand mining. Sediment supplies are also reduced through the damming of inflowing rivers, thus the coast on the opposite side of the dam is more susceptible to coastal erosion. On a global scale, climate change can lead to an increase in temperatures and heating. This has the opportunity to raise sea levels and create more intense winds and currents that increase coastal erosion rates.

Two primary solutions have been proposed to protect existing coastal developments from erosion: hard and soft coastal stabilization or reinforcement. Hard reinforcement refers to the construction of semi-permanent structures such as seawalls or groins, designed to trap sediments carried by long shore current and prevent further erosion of the location. However, hard reinforcement only acts as a temporary solution for coastal erosion. While seawalls and groins provide short-term benefits in the areas they are implemented, additional reinforcements are necessary to prevent further erosion downdrift.

Soft reinforcement attempts to maintain the current shoreline by imitating conditions that are naturally occurring. Examples of soft reinforcement include beach nourishment and dune stabilization, which requires transportation of sediments from elsewhere to support the coastline. Practices include bulldozing sediments from further down the beach or dredging to restore coastline. Drawbacks to this kind of reinforcement is that it is not recommended for high energy environments and is extremely costly to operate. Nature is dynamic and coastlines will continue to evolve, especially with the current coastal conditions. In many cases, the most effective approach to erosional shorelines may be to relocate or avoid building in these environments altogether.

Sea cliff erosion stems from erosion at the cliff base and leads to sloughing off of sea cliff material due to the increase in slope angle and shear strength. This debris then collects at the cliff base. This new debris temporarily halts the erosion of the coast until it is finally eroded away. Many different processes play a role in erosion. The dominant erosive process is dependent on the dynamics of the water system and the composition of the shore material. **Corrosion** affects rocks like limestone and calcium carbonates. Sea spray and wave splash, aided by rainwater and acidophiles, work to break down the rock. **Attrition** is the bombardment and scraping of particles against one another, and through this particle sizes decrease. **Corrasion** then takes over and rolls rocks and

particles over each other by wave-aided action. **Hydraulic action** is the final major erosional process, which is erosion caused by the force of the water body. The shock wave pressure breaks rocks free from their origin and pulls them toward the water.

Sea caves or **littoral caves** are formed when less resistant rocks are subjected to corrosion or scouring, and then caves are formed in the eroded niches. With enough erosion through the headland, sea caves can grow and extend into **sea arches.** Featured above are The Twelve Apostl.es in Australia. The image on top was taken before the 2010 collapse, while the one below that was taken after. (https://upload.wikimedia.org)

Common landforms of erosional coastlines include **stacks, sea caves,** and **sea arches**. **Sea stacks** form as water attacks the coast and manages to cut away isolated forms. The process of wave refraction around the headland reach works to separate the structure from the main body. They can also be created by erosion from wind and rain. These are The Twelve Apostles in Australia.

Coastal erosion is accentuated more as sea levels continue to rise. Research shows that rise affects sandy beaches the most, causing them to retreat at 150 times greater than the amount of water that rises (Leatherman et al., 2011). As beaches along the coast of America change, engineering and planning practices are forced to adapt in order to keep up with a decreasing volume of sand and smaller coastal area. In addition to the beaches, structures built along coasts are at high risk because the sediments they are built above are steadily decreasing (Zhang, 2004). Overall, the increasing effects of climate change could create drastic changes upon our coasts.

While the effects of coastal erosion are increasing, potential solutions are being discovered. An exciting solution is using ecological engineering initiatives. Two examples are: using ecological species to trap sediments and damp waves, and adhering hard substrates to surface to enhance the surfaces ecological function (Borsje, 2011). These frameworks provide potentials to create symbiotic relationships between ocean organisms and geologic change.

Helpful Tools:

Visual and Interactive Tools:

1. coastalchange.ucsd.edu/st3_basics/coasts.html: Animations of longshore drift
2. http://ccrm.vims.edu/gis_data_maps/interactive_maps/index.html: Interactive maps

More on Erosion: Additional sources on coastal erosion and general processes behind them:

1. coastalchange.ucsd.edu/st3_basics/budgets.html: More on sediment flux
2. http://oceanservice.noaa.gov/facts/s...-armoring.html: Preventing erosion
3. coast.noaa.gov/archived/beach...edirect=301ocm: Preventing beach erosion
4. http://www.seagrant.sunysb.edu/glcoa...nprocesses.pdf: Detailed information on coastal erosional processes
5. http://www.whoi.edu/main/topic/changing-shorelines-erosion: Short introduction that excellently summarizes erosion impacts → particularly useful for non-scientists/first-year science majors
6. http://www.ga.gov.au/scientific-topics/hazards/coastalerosion: Short introduction that explores the physical processes of the topic and explores coastal erosion in Australia

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3. www.popsci.com/how-sea-arches-form-collapse
4. https://coast.noaa.gov/digitalcoast/training/living-shorelines.html
5. www.e-education.psu.edu/earth107/node/1068
6. www2.gsu.edu/~mstnrhx/EnviroB...clamation.html
7. http://www.eurosion.org/
8. https://dukespace.lib.duke.edu/dspace/handle/10161/5182
9. Text, Process Geomorphology fifth edition, Dale F. Ritter, Chapter 13
10. Leaterman, et al., “Sea level rise shown to drive coastal erosion” *AGU 100*, 2011.
11. Zhang, K., Douglas, B.C. & Leatherman, S.P. Climatic Change (2004) 64: 41. https://doi.org/10.1023/B:CLIM.0000024690.32682.48
12. Borsje, et al., “How ecological engineering can serve in coastal protection” (2011). https://doi.org/10.1016/j.ecoleng.2010.11.027

Resources

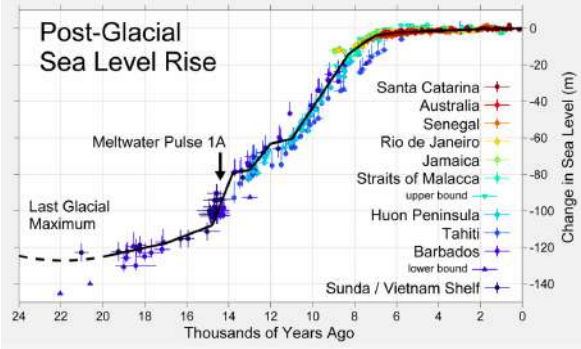
Coastal Erosion Resources (and some other general coastal processes resources encountered while researching):

1. oceanworld.tamu.edu/resources...talerosion.htm -- general information on the topic
2. coastalchange.ucsd.edu/st3_basics/coasts.html -- has some excellent animations of longshore drift etc. Other pages on the site would also be excellent sources of information, such as this page coastalchange.ucsd.edu/st3_basics/budgets.html about sediment flux.
3. http://instaar.colorado.edu/gallerie...astal-erosion/ video may be useful (haven't actually watched it, but it's supposed to include some time lapse sequences of coastal erosion)
4. csdms.colorado.edu/wiki/Coastal_animations collection of animations related to lots of different coastal processes, not just erosion
5. http://montereybay.noaa.gov/new/2012/erosion.html about erosion in Monterey Bay
6. coastalmanagement.noaa.gov/in...easements.html stopping erosion -- this source is more about policy than actual ocean science
7. http://oceanservice.noaa.gov/facts/s...-armoring.html methods of preventing erosion
8. coast.noaa.gov/archived/beach...edirect=301ocm lots more about preventing beach erosion
9. coastalmanagement.noaa.gov/in...finitions.html more stabilization, includes information on methods other than building crazy structures
10. www.seagrant.sunysb.edu/glcoa...nprocesses.pdf huge amount of information about coastal erosional processes in general

9.3 Sea Level

Sea level is the average level of the surface of a given body of water on the surface of the earth. **Water level** is the height of water relative to some reference point. [4] Sea level changes on short and long term scales. Over the short term periods, tides are the most significant change in sea level, but storms also short term influences of sea level. Coasts can be storm-dominated or tide-dominated, which affects the **relative sea level**. The relative sea level is the position of the sea relative to the land. [1] Land can emerge from or submerge into the crust, which affects how we view sea level. Emerging land makes it appear that the sea level is decreasing relative to the land while submerging land makes it appear that sea level is rising relative to the land [2, pg 222].

These relative changes affect storm and tide sea-level changes. The definitions of a storm or tide-dominated coasts are relatively straightforward: **storm dominated coasts** are controlled by storms and tide-dominated **coasts** are controlled by tides. Storms and tides control sea level, as well as other geologic processes such as sediment deposition. 80% of coasts on Earth are storm dominated, 17% are tide-dominated, and the remainder is dominated by ocean current [2, pg 217].



Post-glacial sea-level rise records throughout thousands of years allow us to see changes in sea levels across the globe (https://en.Wikipedia.org).

Recording sea level is important because that is how elevation and depth of the oceans are calculated. Scientists can also use sea level to keep track of how other climate factors are changing. Though natural global cycles contribute to sea-level rise over long timelines, anthropogenic activity is speeding up the process significantly. The burning of fossil fuels and other human activities contributes to an increased percentage of greenhouse gases in the atmosphere, which accelerates the ocean warming.

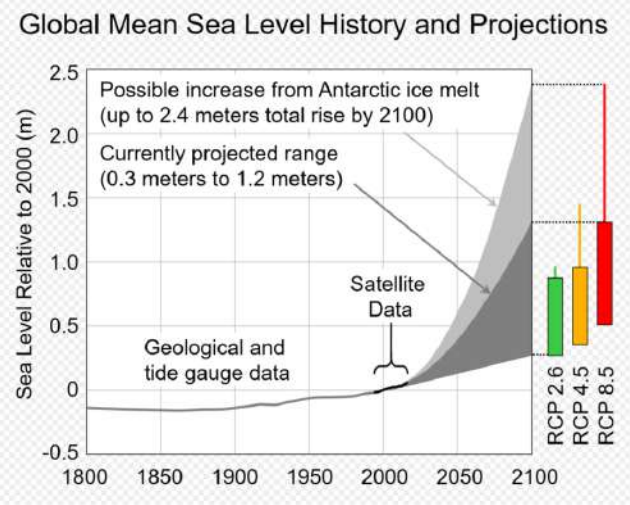
There are two main factors of global warming that contribute to sea-level rise:

1. Melting Ice

- While melting ice does add water to the ocean system, this only changes sea level when the ice was previously out of the water (i.e. landlocked ice, glaciers, ice caps) since ice takes up more volume than the water it contains.
- Ice also has a higher albedo (reflectivity) than water, meaning that it can reflect more light than the open ocean does. Once the ice melts into the water, there is less ice to reflect and more to absorb heat, this creates a feedback loop where the oceans get warmer and the ice continues to melt, causing the oceans to get warmer, and the cycle continues.

2. Thermal expansion of water

- When seawater warms, the particles become more spread out due to the higher kinetic energy, and this increased volume causes the sea level to rise.[4]



Global mean sea-level history and projections are depicted in the chart above using geologic tide gauge data and satellite data. (https://en.Wikipedia.org)

The mean sea level of the ocean is measured over a long period and may help identify the effects of global climate change and anthropogenic effects.

Since 1900, the sea level increase has been recorded to be between .04 and .1 inches per year, while the increase since 1992 has been measured at .12 inches per year. This seemingly slight increase is quite large due to the compounding effects. Global warming has been affecting so many things from agriculture to marine life and the rising of modern sea level will affect many of these factors of our lives. Sea level rise will lead to a drop in available land space for human habitation, and may eventually cause flooding of islands and coasts.

The History and Future of Sea Level Changes

Sea levels have changed drastically throughout history due to the changing temperature of the Earth. During glacial periods ice sheets were much more extensive than they are today. Conversely, interglacial periods are periods of warmer temperatures and less extensive ice sheets. We are currently in an interglacial period. Sea levels have risen and fallen hundreds of feet between the periods. During the last glacial maximum, the Late Glacial Maximum around 14,000 BCE, sea levels were 400 feet lower than they are today due to water freezing in glaciers and continental ice sheets. Currently, sea levels are rising faster than they have in the past 6,000 years. Sea levels have risen 5-8 inches since 1900, and the rate they are rising per year is increasing. As long as atmospheric carbon dioxide levels continue to increase at the rate they are and the Earth keeps warming, sea levels will continue to rise. The Intergovernmental Panel on Climate Change (IPCC) predicts that sea levels could rise to 1 meter by the end of the century. If they do rise 1 meter, New Orleans, Miami and many other cities on the coast will be completely under water[6].

Helpful Tools:

Risk Zone Maps: Interactive maps that simulate predicted sea rise levels:

1. https://ss2.climatecentral.org: Surging Seas, Risk Map Zones
2. https://vesl.jpl.nasa.gov/: Virtual Earth System Laboratory
3. https://coast.noaa.gov: NOAA: Sea Level Rise Viewer

Videos: further explore the basics of sea-level rise as well as causes, effects, and impacts:

1. https://www.youtube.com: AsapSCIENCE and the role of thermal expansion in rising sea levels.
2. https://www.youtube.com: “What If All The Ice Melted on Earth” ft. Bill Nye
3. https://www.youtube.com: “NASA’s Earth Minute: Sea Level Rise”

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5. http://oceanservice.noaa.gov/facts/sealevel.html
6. https://ocean.si.edu/through-time/ancient-seas/sea-level-rise

Estuaries & Estuarine Circulation

Estuaries are coastal bodies of water have mixed fresh and salty water. The water in estuaries is mixed because they are fed by rivers but also connection with oceans. Estuaries have a barrier to the sea, similar to lagoons, that protects them from ocean energy, but, unlike lagoons, estuaries still connect with the sea. Because of this connection with the sea, estuaries are strongly influenced by tides (NOAA).

Estuaries' unique environment makes them a great place for humans and animals. Humans benefit from the beauty of estuaries and the food and resources they provide. Estuaries make great tourism attractions or harbors and ports. The mix of fresh and saltwater makes a great feeding ground and habitat for many types of wildlife (EPA).

This water mixture also results in a mixture of types of sediment. Though estuaries have sediment from both upstream rivers and from the ocean, most of the sediment is relatively fine grained (McNally, pg. 3). The type of sediment, and the abundance of it, affects human and animal involvement with estuaries. Too much sediment makes it hard for plants to photosynthesis and limits human use of the estuary since sediment can be deposited, making the estuary unsuitable for ship traffic. If there is too little sediment in the estuary then the land bordering it may be eroded away and increase predation rates in some species (McNally, pg. 2).

There are four main types of estuaries: coastal plain estuaries, tectonic estuaries, bar built estuaries, and fjords. Coastal plain estuaries form from the rise of sea level. They rising sea level then fills an already existing river valley with water, creating an estuary. Tectonic estuaries for on faults, where tectonic activity has created a space that can be filled in with water. The San Francisco Bay is an example of a tectonic estuary. Bar built estuaries are behind some sort of natural bar between the estuary and the ocean, such as a spit. Fjords are valleys that were, at one time, carved out by glaciers and were then filled in with water (ONA).

Estuaries face many anthropogenic threats. Population growth is one of the main threats because 50% of the world's population lives on or in estuary systems. There are few policies in place to protect estuaries from population growth as more people seek the land and resources of estuaries. Another threat to estuaries related to population growth is sewage discharge and pollution runoff from urban areas. Since estuaries are fed by rivers and therefore streams,any pollutants that enter the system farther upstream end up in estuaries. An example of this is the annual "dead zone" that occurs in the Gulf of Mexico due to agricultural runoff (estuaries).

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CHAPTER OVERVIEW

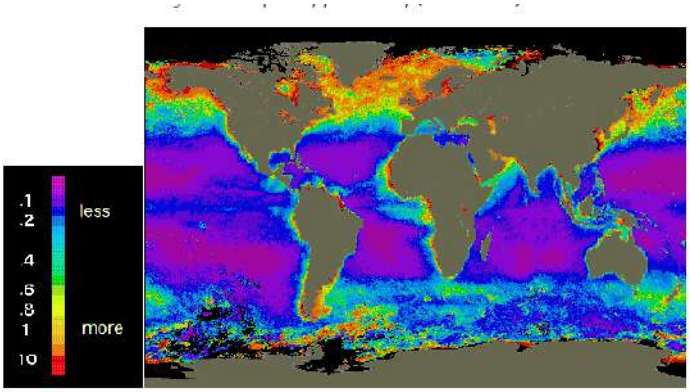
10: AN OCEAN FULL OF LIFE

DISTRIBUTION OF LIFE IN THE OCEAN
KINGDOMS OF LIFE IN THE OCEAN
PHYSIOLOGICAL IMPACTS OF SALINITY, TEMPERATURE, OXYGEN, PH

Distribution of Life in the Ocean

Global Distribution

Phytoplanktons are the major primary producers in Ocean, and the rest of marine animals rely on the primary productions for energy sources. Therefore, we can map the global distributions of marine life based on the distribution of chlorophyll and primary productions, see figures below [1]:



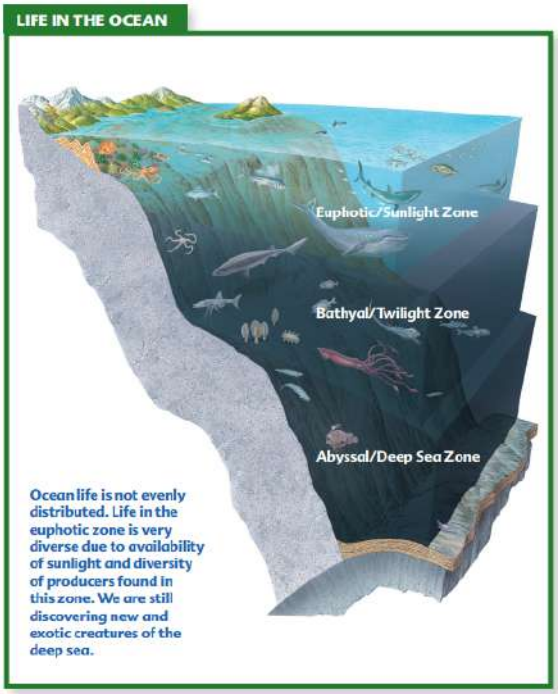
High primary productivity regions clustered in coastal regions where nutrients come from the lands, east side of ocean basins as well as polar regions where upwelling occur, and equatorial regions where surface water diverge and nutrient-rich deep water move upwards [1]. These are also likely to be the regions with most marine organisms.

To "assess and explain the diversity, distribution and abundance of life in the oceans"[2], the Census of Marine Life was formed as a global network with researchers in more than 80 nations[2], and the newly published map highlighting discoveries of ocean life in a decade's investigation could be found at www.comlmaps.org/oceanlifemap...tion-abundance [3].

Distribution In the Ocean

As with the global distribution of marine organisms, lives in the ocean are not evenly distributed throughout the ocean either, and are mostly controlled by the abiotic factors of marine environment such as temperature, salinity and light availability [4]. Therefore, oceans could be divided into three general zones which are euphotoic, twilight and deep sea zones[4].

- Euphotic Zone
- Twilight Zone
- Deep Sea Zone



The Deep Sea

The majority of biodiversity in the ocean in found in the photic zone where light permeates the water column making photosynthesis possible; however, even in the deep sea where little to no light is available, life has found a way. The deep sea is vastly different than shallow waters and riddled with physiological challenges. The water is frigid and pressure is immense in the dark depths. Because no photosynthesis occurs, there are very little nutrients in the water so meals are often few and far between. Animals that live in the deep sea have adapted to these challenging conditions stupendously. Many organisms have evolved bioluminescence, or the ability to create their own light. This is a very useful ability for attracting prey or finding a mate in the dark. In addition to bioluminescence, many deep sea predatory fish have evolved extremely large jaws, teeth, and eyes for finding and capturing prey while reducing other structures such as skeletons, muscles, and swim bladders to conserve energy and resist the effects of pressure. Since food is scarce in the deep sea, many of its inhabitants have extremely slow metabolisms so that they are capable of going up to a year without food in some cases. This host of adaptations has allowed life to not only survive, but to thrive in one of the most inhospitable environments on the planet.

The Euphotic zone is characterized by its many diverse ocean life. The ocean life in the Euphotic zone include sharks, jellyfish, sea turtles, coral, and zooplankton. The reason why there are so many various life in this zone is because of its access to sunlight. Direct sunlight causes photosynthesis, which allows many opportunities for life. The zone below this is the Bathyal zone, which is also known as the Twilight zone, because sunlight does not reach the Bathyal zone. The Bathyal zone is 1000 - 4000 meters below the surface of the ocean. Since there is no sunlight, a lot of the life in this zone don't have eyes. The marine life that do have life include squids, whales, and octopuses. It is difficult for fish to live in this zone, so they usually stay in the Euphotic zone. Lastly, the deepest ocean zone is the Abyssal zone. In this zone, the water pressure is so high that the marine life that live here need to be able to withstand the pressure. The marine life that live here aren't very typical. They are most commonly described as "abnormal", or sometimes even "scary". An example of marine life that lives in this zone is called the "Black Swallower", and it is a fish that has the capability of swallowing other fish that are bigger than its own body size.

http://www.exploringnature.org/db/de...D=44&detID=583

http://www.google.com/url?sa=i&sourc...26820199322229

Sources

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2. http://www.comlmaps.org/
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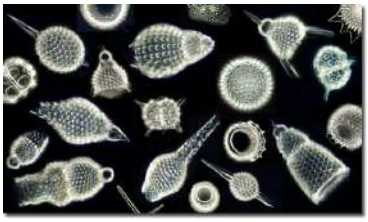
Kingdoms of Life in the Ocean

Most scientists agree that five kingdoms of life exist on Earth: animal, plant, bacteria, fungi and protist. And just as all five can be found across the continents, they exist and flourish in the sea as well. Here, life is adapted to various hazards including temperature, pressure, darkness, and salinity. The greatest depths are where the plant kingdom begins to show itself less while the other kingdoms exist in a quiet dark stillness. Their network of interactions changes with each type of ocean environment and results in a colorful diversity in life throughout the oceans.

Protista

Protists are single-celled or multicellular eukaryotic organisms, meaning they possess membrane-bounded nuclei. Protists cannot be classified as plants, animals, or fungi. They are found anywhere containing liquid water and exist in the oceans as plankton. Being phototrophs and organotrophs, marine protists provide a food source for the upper levels of the oceanic food web. Familiar marine protists include:

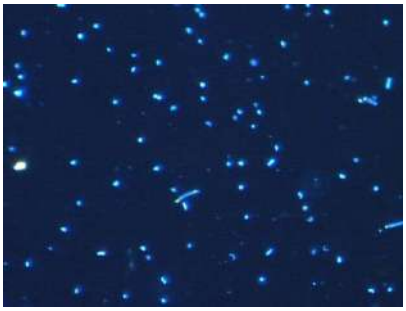
- red algae
- dinoflagellates
- diatoms
- euglena



Protists: Courtesy of UMD

Bacteria

Bacteria are single-celled organisms lacking membrane-bound nuclei. They are found all throughout the water column, some being aerobic and some anaerobic. They exist in the water, in sediment, and of course, in many organisms throughout the ocean. Marine bacteria play different roles when comparing with bacteria in other habitats. Some marine organisms harbor light-emitting bacteria, which forms a symbiotic relationship working to create an effect called bioluminescence, and the light produced could be used to hunt prey, defend against predators, and also find mates[1]. Other bacteria, like cyanobacteria, photosynthesize and are said to be the original source of oxygen on the early planet. They build stromalites, which also provide scientists with a key piece of evidence as to the Earth's past geological history. In addition to that, deep-sea bacteria that thrive on minerals from hydrothermal vents also develop important relationships with the surrounding communities, such as providing essential food sources.



Marine Bacteria: Courtesy of UCSB

Fungi

Marine fungi mainly have continental origins, many being transported out to sea by drifting organic matter from land. They exist largely as parasites on the other kingdoms of life. They can be found living within sand grains, inside coral, and in/outside plants

and animals. Many marine fungi have been found to originate from mangrove swamps in which floating pieces of driftwood harbor fungi that may disperse down the water column. Examples include:

- *Rhyzophydium littoreum*
- *Arthopyrenia halodytes*
- *Fusarium*
- *Candida albicans*

Salmon with fungal disease: Courtesy of Wikipedia

Plants

Underwater plants adapted to higher levels of salinity and some pressure are found all throughout the upper ocean. Here, plants are adapted in similar ways to their terrestrial counterparts. Both have developed ways to hold fast to their supports; one for wind, and one for currents. Whereas trees must grow tall to reach light, some plants develop air sacs to reach the sun. Plants exist in all shapes and sizes in the ocean ranging from the largest kelp to the phytoplankton found throughout the sea that generate a majority of the planet's oxygen.

California Kelp Forest: Courtesy of UCSB

Animals

The most visible kingdom of life in the oceans is the animal kingdom. Marine animals are adapted to a variety of hardships at all ranges across the ocean. The main food web lies between members of the animal kingdom, where the other kingdoms function mainly as food sources or recyclers. Marine animals are both predators and herbivores, creating a complex diversity in the way ecosystems must interact to sustain themselves.

Blacktip Reef Shark, Courtesy of Tracking Sharks

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

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CHAPTER OVERVIEW

11: FOOD WEBS AND OCEAN PRODUCTIVITY

11.1: Primary Productivity

The oceans make up the largest habitat on the planet, stretching over approximately 71% of the Earth's surface and it contains 97% of the Earth's water. Subsequently, the oceans are home to a great diversity of living organisms that can be separated into two groups: autotrophs and heterotrophs. Autotrophs are organisms that use inorganic compounds (e.g. carbon dioxide) to produce organic products, (e.g. sugars and proteins). Heterotrophs consume the organic products produced by autotrophs and release inorganic compounds as a by-product. Phytoplankton are an example of marine photoautotrophs or autotrophs that obtain energy via photosynthesis. Whales are examples of heterotrophs. They consume plankton and releases carbon dioxide as a by-product of cellular respiration. This latter example illustrates the clear connection between the biological processes of autotrophs and heterotrophs through food webs.

Primary productivity is the process where inorganic substances are synthesized by organisms to produce simple organic materials. Primary producers, or autotrophs, are responsible for this phenomenon. Common examples of primary producers include diatoms, dinoflagellates, and coccolithophores. Primary producers can either be photoautotrophs, organisms that synthesize organic compounds using the sun as a source of energy, or chemoautotrophs, organisms that synthesize organic compounds from inorganic molecules found in the environment. Both photosynthesis and chemosynthesis contribute to the oceans' primary productivity, but photosynthesis is the dominant process with respect to the amount of carbon fixed and energy stored in organic compounds. Photosynthesis is used by autotrophs at the sea surface and high in the water column where light is abundant. Contrastly, chemosynthesis usually occurs in deeper water where little to no light is present.

There is a multitude of factors that determine the effectiveness of primary productivity. While the amount of water, carbon dioxide, inorganic nutrients, and sunlight all play a major role in how productivity, not all of these components act as limiting factors. Neither water or carbon dioxide act as limiting factors in the ocean, as they are abundantly available in the environment. For photoautotrophs, one of the greatest limiting factors is sunlight and light penetration into water columns. Consequently, most photoautotrophs are found near the ocean's surface (a zone aptly named "the photic zone") and few are found in the mixing zones at lower depths. Additionally, nutrients such as inorganic nitrogen, phosphorus, iron and/or silica are limiting on living organisms due to their scarcity in the ocean.

Primary production is the most basic building block for energy and the basis for food webs in all environments and ecosystems. In the ocean, autotrophs which are responsible for primary production consist of phytoplankton, marine plants, and macroalgae since they all perform photosynthesis. All photoautotrophs capture solar energy by utilizing the pigmentation such as Chlorophyll A, a pigment that is especially effective in capturing light energy in the blue and red wavelengths of light. There are various pigments used by the many different photoautotrophs in the ocean.

Primary production is often referred to in two ways: gross and net primary production. The entirety of the organic compounds produced by the primary producers is referred to as gross primary production. As with everything it is impossible to have 100% efficiency, the autotrophs require a part of the organic compounds that they produce for their own respiration processes. Net primary production is the measure of the organic matter that is produced by the autotrophs and available for consumption of the heterotrophs.

Resources

- cdn.intechweb.org/pdfs/28392.pdf
- http://www.globalchange.umich.edu/gl...nergyflow.html
- www.nature.com/scitable/knowl...ocean-70631104
- https://www.oceanicinstitute.org/aboutoceans/aquafacts.html
- https://www.ncbi.nlm.nih.gov/pubmed/28586682

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11.3: The Biological Pump

The biological pump is the exchange of carbon dioxide and other gas with surface water due to the respiration of biological activity within a water body, specifically the oceans of planet earth. Carbon dioxide and other gases like nitrogen are dissolved through the mixed layer of water and are utilized by photosynthetic phytoplankton. These phytoplankton fix the carbon dioxide into their tissues by means of photosynthesis, and they also produce carbon dioxide through cellular respiration. Another means of carbon fixation by plankton is the utilization of carbonate in the protective coatings of coccolithophores and foraminifora.The net carbon dioxide that is fixed into these organisms falls to the bottom of the ocean when the plankton die.

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11.4: Food Chains and Food Webs

Trophic Levels

A food chain follows one path of energy and materials between species. A food web is more complex and is a whole system of connected food chains. In a food web, organisms are placed into different trophic levels. Trophic levels include different categories of organisms such as producers, consumers, and decomposers. Producers are the basic trophic level while top predators are the peak level. Producers are autotrophs, meaning they produce their own food through photosynthesis or chemosynthesis. Consumers are animals that eat producers and are split into many different categories: primary consumers, secondary consumers, tertiary consumers, and more. Primary consumers are plant-eating herbivores; secondary consumers eat the herbivores; tertiary consumers can consume both the primary and secondary consumers. There may be more levels of consumers until eventually the top predator is reached. The relationship between trophic levels (e.g. primary producers, herbivores, primary predators, and top predators) is shown in Figure 1. It is important to note that consumers can be carnivores, animals that eat other animals, and also omnivores, animals that consume many types of food. Decomposers are also part of the food web and include organisms that feed on all varieties of dead plants and animals which are responsible for returning nutrients to the environment.

Figure 1: Diagram shows the hierarchy of consumption with each tier consuming species from the tier below them. The tapering of the pyramid indicates the highest quantity of biomass and energy located in the producers tier and the lowest quantities located in the top predator tier.

https://upload.wikimedia.org/wikiped...yramid.svg.png

Energy Transfer

The amount of energy that flows through the different trophic levels of a food web is usually displayed as a pyramid (see above). This pyramid shows much more information than just a diagram for the hierarchy between predator and prey. The amount of area in each trophic level displays the amount of energy present in the biomass. Producers clearly occupy the largest area on the pyramid, and therefore the largest amount of energy. Autotrophs convert solar and chemical energy into the biologically usable form, glucose. In the form of glucose, energy is able to be introduced into the food web system and which is then transferred through consumption. Since autotrophs are the source of energy into the food web it makes sense that they contain the highest quantity of energy within their biomass. Although the individual primary producer is relatively tiny in itself, the vast number of producers results in their combined biomass being the largest trophic group in the ocean. The combination of their vast biomass and retention of much of the energy they produce is what leads producers to occupy such a wide base of the energy pyramid. As you move up the trophic levels the amount of energy gained from consumption decreases by a factor of approximately 10 per level. This means that primary consumers only receive 10% of the energy from primary producers when consumed. The most shocking is that the apex predator in the example above represents the quaternary predator and therefore only receives .01% of the energy that was produced by the original primary producer. Energy, then, gets trapped in unusable forms (eg. fiber and bone) and is used in metabolizing material into useable forms, leading to an overall loss.

Figure 2: This figure illustrates the difference between a food chain and a food web. A food web depicts the complexity of interactions in a natural ecosystem. A food chain simplifies the interactions between selected organisms and can be used to better understand how changes in the populations of one species can affect the community as a whole.

https://upload.wikimedia.org/wikiped...TrophicWeb.jpg

Food Webs vs. Food Chains

Food webs are more complex than food chains, yet equally as useful in understanding the processes of ecological communities. Some food webs may be more complex than others but the concepts are always constant. A food web shows the flow of nutrients between different types of organisms which can help us understand the energy transfer as described before. Food webs begin with autotrophs and continue with heterotrophs, but due to their codependence, changes in abundance of one kind of organism may affect the others. For example, if the amount of phytoplankton were to suddenly decline dramatically, so would the number of heterotrophs that depend on the phytoplankton as a food source (known as 'bottom up' control of food webs).

When you examine a food web, you can observe how all the food chains interact in one community. When observing a single food chain, you can see the path in which energy and nutrients get passed along through a specific community. Since a food chain is much more simplistic than a food web, it can be used to predict the response of an ecosystem due to changes in population of a single species. Trophic cascades are one way in which a food chain can be used to predict changes in an ecosystem. A trophic cascade occurs when one species has a change in population size, resulting in changes in populations of other species within the food chain. A classic example of a trophic cascade is the example describing the relationship between orcas, sea otters, sea urchins, and kelp forests along the coasts of Alaska. It was found that an increase in killer whale predation was drastically reducing sea otter populations. Without a strong sea otter presence, sea urchin predation was low resulting in increased herbivory on kelp forests. With urchins free from significant predation, entire kelp forests were consumed resulting in urchin barrens which ultimately shifted the entire dynamic of these ecosystems. The use of food webs to predict changes in ecosystems through trophic cascades is essential to understand the full effects of humans on the natural world. They can help us better understand the best response to these cascades such as the one described above.

Types of Webs

In the ecological community there are two types of food webs: connectance webs and interaction webs: They are used to track the energy that flows within a community. Connectance webs use arrows that show the consumption of one species by another. These arrows are all of equal weight so there is no additional information about the strength of consumption between species (Atkinson et al. 2014). Interaction webs also use arrows to show the consumption of one species by another, but these arrows are weighted according to the interaction strength in the community. If one species is seen to regularly consume another then it will have a wide and dark arrow showing their connection. If it is observed that a species rarely consumes another then the connecting arrow will be very slim if present at all (Berlow et al. 2004).

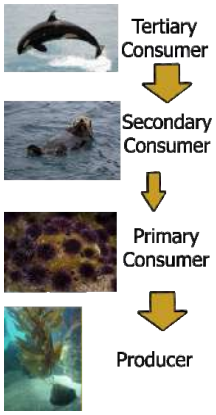

Figure 3: This figure revisits the idea of trophic cascades with an increase in orca populations causing an increase in urchin populations and a decrease in sea otter and kelp populations. This image also illustrates a foundation species and keystone species within the same food chain.

https://upload.wikimedia.org/Wikipedia/commons/e/e5/JumpingOrca.jpg

pixabay.com/static/uploads/p...76_960_720.jpg

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https://upload.wikimedia.org/Wikipedia/commons/3/34/CAS_Macrocystis_4.JPG

Foundation Species and Keystone Species

There are also organisms in a food web that are known as *keystone species* and *foundation species*. Foundation species tend to be primary producers and play a large role in the community due to their ability to build or provide a structure that other organisms inhabit (eg. mussels and kelp forests). These foundation species include organisms that impact a community by creating physical changes in the environment. Keystone species can be located anywhere in the food web, and play a vital role in the maintenance of the community. These organisms exert major influence over a community's structure by ecological roles or niches. Keystone species are defined as those that have a disproportionate impact on an ecosystem relative to their abundance. Sea otters do not have a very high biomass in a kelp forest but through predation of other species (such as sea urchins), they have a strong impact on the health and biomass of the kelp.

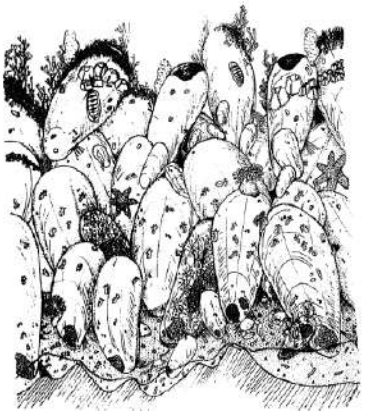

Figure 4: A cross-sectional diagram of *Mytilus californianus* mussel bed with the abundant community living within the matrix the mussels create. Aggregations of these foundational species can provide habitat for over 300 species of organisms.

Diagram modified from Schanek T.H. (1992)

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2. http://marinebio.org/oceans/biotic-structure/
3. education.nationalgeographic....od-web/?ar_a=1
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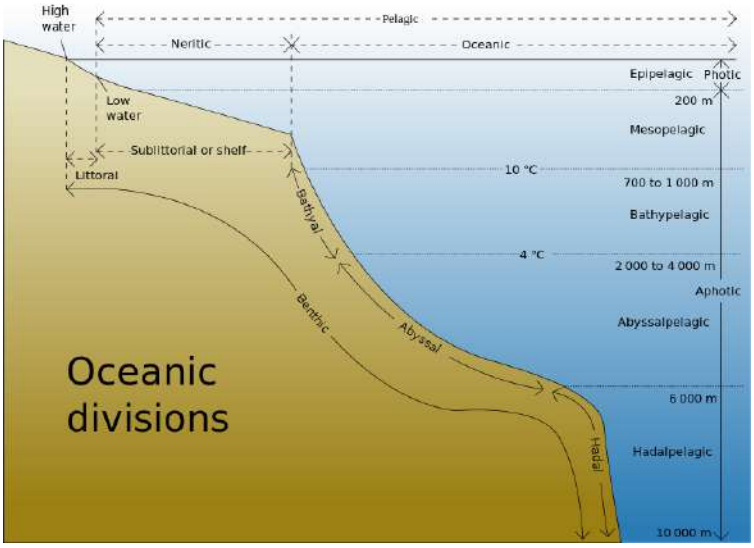
CHAPTER OVERVIEW

12: MARINE ENVIRONMENTS

[this page could use this site as a possible resource-- http://marinebio.org/oceans/marine-zones/]

12.1: Zones of Marine Environments



Profile view of ocean zones (WikiMedia)

Pelagic

This zone, also known as the open ocean, is comprised of oceanic water that is not in direct contact with the shore or sea floor. The pelagic zone is subdivided into vertical zones, based on factors such as sunlight amount. While these waters are known as the "deserts of the sea", a wide variety of organisms still call the open ocean their home.

Epipelagic

This zone, known as the "sunlit" zone, begins on the surface of the water and extends to the dark, sunlight-less area where photosynthesis ceases in production. This layer is heated by the sun and is mixed vertically downward by winds on the surface. This mixing allows for a distribution of heat in this layer around the world, from super warm in the Persian Gulf (97 degrees Fahrenheit) to super cold up at the North Pole (28 degrees Fahrenheit) (National Weather Service)!

At the bottom of this layer lies the thermocline. The thermocline is a region of rapidly decreasing temperatures with increasing depth. The depth of the thermocline varies in space and time and does not remain uniform across the globe as it is dependent on the season and year. The variability of this line can be altered by unusual weather patterns, like a monsoon, or local impacts (Pusparini et al., 2017).

Mesopelagic

The mesopelagic zone reaches 200-1000m in depth. Technical deep-sea divers reach the 300m mark (National Weather Service). The mesopelagic zone is home to some of the most diverse fishes and behaviors. It is estimated that around 90% of all global fish biomass occurs in this zone (Broad, 2015). The populations of these organisms are so large that WWII hydroacoustic researchers were not able to penetrate the zone because of the high biomass of organisms with swim bladders. Common fish of the Mesopelagic include hatchetfish, lanternfish, barreleye fish, and bristlemouth fish (Shields, 2017). Many of the fish in this region are on the smaller side, but the megamouth shark (*Megachasma pelagios*) stands out because of its unusually massive size (Oceana). Reaching up to 13-18 feet long, megamouth shark are large filter feeders that swim with their mouth open to collect food (Oceana).

Bathypelagic

The bathypelagic zone is known as the "midnight" zone for its characteristically lightless waters. At 1,000-4,000 meters below, no light is able to penetrate the ocean water this deep, preventing any primary production. The only source of light in this zone comes

from organisms using bioluminescence (National Weather Service). Bioluminescence is the ability for animals to glow in the dark, caused by the release of energy from chemical reactions in the form of light (Roberts).

Temperatures this deep are fairly constant and hover around 39 degrees Fahrenheit. This is only 7 degrees warmer than the temperature that freshwater freezes at! As a portion of the deep sea, there are no currents that affect this zone, rendering it as a relatively stable environment. The pressure this far deep would amount to 5,800 lbs per square inch, and it would be hard to believe life can withstand this much force (National Weather Service). However, there have been multiple soft-bodied organisms found this far below, as well as some bony fish (OceanScape)! Scientists have found that marine life in the bathypelagic zone can have a mass 10 times greater than predicted (Broad, 2015). The organisms that live in the Midnight zone survive off of fallen organic matter from the zones above (OceanScape).

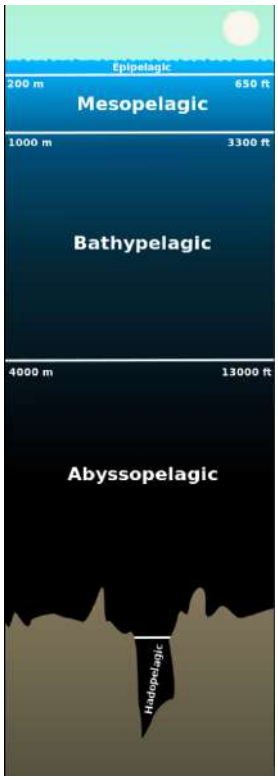
An organism that interacts with the Bathypelagic zone is the Sloane viperfish, who migrates to surface waters during the night from its location in the Bathypelagic

zone. (Wikimedia)

Abyssopelagic

The name for the abyssopelagic zone comes from the Greek word *abyss* which means “no bottom”. Early oceanographers believed that this zone did not reach the ocean’s floor. With the development of ocean floor mapping technologies, researchers know now that the abyssopelagic zone contains three-quarters of the ocean floor’s total area. Extending from roughly 4,000-6,00 meters, the abyssopelagic zone is pitch-black and home to many organisms that are specialized to live in high pressure, cold, and lightless conditions (National Weather Service).

In contrast to the epipelagic zone where photosynthesis provides the main food resources for many ocean organisms, the abyssopelagic marine life rely on detritus (dead marine organisms) to sink towards this deep layer for resources. Caused by increasing water pressure, the abyssopelagic zone is much less explored than the shallower ocean zones, and it is frequent that scientists discover new species when exploring this area. The most common characteristics of species that live in this zone include slow metabolic rates, slow consumption, flexible stomachs, large mouths, and bioluminescence. Interestingly, although these animals have unique adaptations to their environment, many belong to the same groups of continental shelf species (Brennan, 2018).



Epipelagic, Mesopelagic, Bathypelagic, and Abyssopelagic zones are depicted. (Wikimedia)

Benthic

Unlike its sister zones, the benthic (from Greek: “Depth of the sea”) zone is characterized not by its depth but by the body of water itself. The benthic zone is the lowest level of the ocean, encompassing the sediment surface and the water level right above it, starting from the shoreline and expanding to the deepest part of the ocean floor. Due to its large surface area, it is difficult to generalize the physical characteristics of the benthic zone; however, the most important and notable part of the zone lies with its ecological properties.

The benthic zone is home to a massive amount of oceanic life referred to as “benthos”, or bottom-dwellers. Out of all marine species, 98% of them can be found on the ocean floor, making the benthic zone the lifeblood of diversity in the ocean, comprised of mostly scavengers or detritivores, organisms that feed off of dead organic material. Benthic organisms found in the ocean floor itself, such as clams or macroinvertebrate, are called “infauna”. Stationary organisms or those that move along the ocean floor, such as polyps or sea stars, are called “epifauna”. Organisms like shrimp and flounders that move about freely in the water above the benthic zone but live at the bottom of the zone are called nektobenthos. Many organisms found in the benthic zone are highly attuned to life under deep-water pressure and little to no light availability, as these are the conditions found in the abyssal zone of the ocean. Due to their extreme adaptations, benthos do not travel far up the water column and use dead or decaying organic matter that drifts down from higher levels as a main energy source.

Helpful Tools:

Videos:

1. https://www.youtube.com/watch?v=UwVNkfCov1k: Just how deep does the ocean go?

More on the Benthic Zone: Helpful websites and reading sources

1. https://www.cabi.org/isc/datasheet/107788
2. https://watersheds.ca/wp-content/uploads/2016/02/Benthic-zone-Final.pdf

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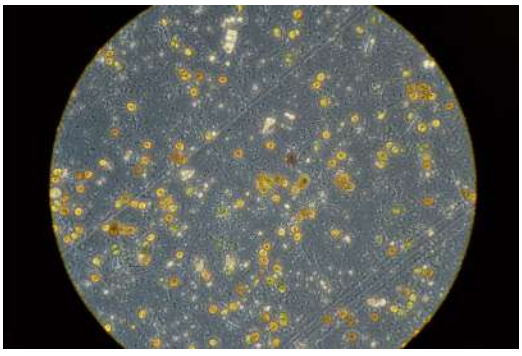
10. https://upload.wikimedia.org/Wikipedia/commons/c/cb/THERMOCLINE.png
11. https://en.Wikipedia.org/wiki/Oceani... divisions.svg
12. en.Wikipedia.org/wiki/Deep_s...dus_sloani.jpg

12.2 Coral Reef Ecosystems

Corals from Australia's Great Barrier Reef. (Wikipedia)

Coral reefs are characterized by the structures that provide habitat for the fish and invertebrate species that make up the ecosystem. Hard corals create the reef itself. They typically consist of a layer of colonial polyps that live on the surface of a calcium carbonate skeleton that is secreted by the coral polyps. Corals rely on a symbiotic relationship with the zooxanthellae algae which can be found in the gastrodermis, the "stomach," of coral polyps. Zooxanthellae photosynthesize while residing inside their host and provide the necessary nutrients and energy for the polyp, transferring 95% of the produced sugars (Muscatine, 1990). In return, corals supply zooxanthellae with nutrients essential for photosynthesis such as ammonia and phosphate from their waste metabolism. These nutrients seem to be essential for the survival of the zooxanthellae as the water column in the tropics is usually devoid of essential inorganic compounds (Trench, 1979).



Polyps of the coral *Eusmilia fastigiata* (Wikipedia) Zooxanthellae

https://commons.wikimedia.org/wiki/F...pistillata.jpg

Optimal Range for Coral Growth

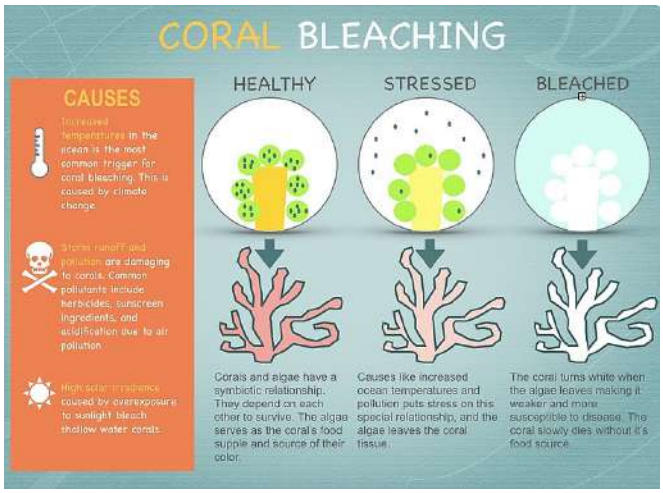
Shallow coral reefs are found in clear, tropical waters with temperatures around 70–85° F or 21–29° C. Temperature, salinity, nutrients, aragonite saturation state, and light are among the most important factors in controlling the geographic distribution of shallow-water coral reefs (Couce et al., 2012) (Kleypas et al., 1999). The global, annually-averaged tolerance limits for coral reefs are 21.7—29.6 °C for temperature, 28.7—40.4 psu for salinity, 4.51 μmol L-1 for nitrate, 0.63 μmol L-1 for phosphate, and 2.82 for aragonite saturation state. The averaged minimum light intensity in coral reefs is 450 μmol photons m-2 s-1 (Guan et al., 2015).

Shallow coral reef habitat flourishes in ample sunlight (Wikimedia)

Effects of Higher Temperatures on Corals

Coral reefs are one of the most vulnerable ecosystems to climate variation and change. Corals, the building blocks of carbonate reefs, have a restricted thermal tolerance. This results in 'bleaching' events (loss of symbiotic algae) when sea surface temperatures rise above a given threshold (Graham et al., 2008). Sea temperatures in tropical regions have increased by 1°C over the past century. These increases in temperature can exceed the thermal tolerance of corals and their photosynthetic symbionts, zooxanthellae, and cause more frequent and widespread bleaching. (Guldberg, 1999). Please see section X.X for additional information on coral bleaching.

Shown above is a reef where a significant number of corals have been bleached. (Wikimedia)



This graphic summarizes the processes behind coral bleaching (Wikimedia)

Corals and Macroalgae Phase Shifts

Other substantial influences for coral reef degradation also exist. Specific factors such as eutrophication, increased sedimentation, tourism, and increased fishing pressures may interact with climate change to produce negative synergistic effects (Wilkinson and Buddemeier, 1994). Degrading reefs undergo a phase shift in which the abundance of corals decline and switches to an increase in abundance of larger fleshy macroalgae (Done, 1992). The main drivers that have been cited to explain such a shift is primarily from eutrophication (Lapointe, 1997) and reduction in herbivory (Hughes, 1994). Eutrophication is mainly caused by high nitrogen and phosphorus runoff from agricultural lands that seep into the ocean. The increased nutrient load creates an optimal environment for the production of macroalgae, which is a direct competitor with coral reefs since they decrease the total amount of available light for zooxanthellae to photosynthesize. Intense feeding by herbivorous fish and sea urchins favor coral ecosystems by excluding the presence of macroalgae. Increased fishing pressure has reduced the number of herbivorous fish by orders of magnitude, estimated at around a 60 % decrease (Jackson, 1997) (Bellwood et al., 2004). Due to this reason it is essential to conserve species specializing in herbivory if our goal is to preserve coral ecosystems (Adam et al., 2015).

A healthy coral reef where no algae is present can sustain high amounts of biodiversity. (Wikipedia)

Helpful Tools:

1. https://www.youtube.com/watch?v=2aAfIlRjgk8: Parrotfish Keeping Macroalgae in Check Through Herbivory
2. https://www.youtube.com/watch?v=1aWoTGgVUkc: Jennifer Smith from Scripps Explaining The Basics of Coral Reefs

3. https://www.youtube.com/watch?v=60jof35WuAo: Coral Bleaching Explained
4. https://www.youtube.com/watch?v=rHHuq_COHZs: Heron Island Marine Research Station University of Queensland Coral Reef Climate Change Experiment

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12.3 Arctic Ecosystems

Featured above is a map of the Arctic Region created by State Department geographers of the U.S. Chairmanship of the Arctic Council. (Wikipedia)

Introduction to the Arctic

Farther north than any other ocean, average temperatures in the Arctic region range from -40˚C to 10˚C and can drop as low as -50˚C (-58˚F) in the coldest winters. The Arctic Ocean acts as the main body of water in the Arctic Circle. The fact that the Arctic ocean is largely covered in ice and relatively isolated from most of the other oceans makes this ocean incredibly unique.

Organisms in the Arctic must cope with Earth's harshest conditions, in terms of light and temperature. The Arctic has no shortage of daunting icebergs and snowcaps, freezing blizzards and winds, and sheer darkness during cold winters. Nonetheless, this ocean is teeming with life and is home to one of the most inaccessible, beautiful environments on Earth.

Featured above is a polar bear, a hyper carnivorous bear referred to by the Inuit as nanuq. (Wikipedia)

One of the top predators in the Arctic is the well known polar bear, which roams the Arctic ice and swims the Arctic seas. These predators feed on a variety of different organisms, including fish, birds, seals, walruses, and even certain types of whales. Other

animals would include the Bowhead Whale, Beluga whales, walruses, narwhals, harp seals, bearded seals, lion mane jellies, few species of fish, and krill. The main sources of primary productivity in the Arctic ocean are phytoplankton, algae, and diatoms.

Plant Life in the Arctic

When imagining the Arctic, most picture miles of icy and snow-covered land with little life around. However, this frozen environment is home to over a thousand plant species. Since the Arctic soil is mainly permafrost, the only plants that can grow here are small, short-rooted species. Permafrost is characterized as a thin, permanently frozen layer of soil containing decomposed matter. These conditions only allow plants that are low to the ground and adapted to the harsh, freezing conditions to grow and reproduce. It is a miracle that plant life has survived and thrived in the arctic, including species such as the Arctic willow and the Arctic poppy. The Arctic poppy is a fascinating plant because it has developed an adaptation in order to survive in the Arctic environment by having the head of its flower always turned towards the sun (Fries-Gaither 2009). Most of the other species of plants residing in the Arctic tundra are low-growing shrubs, grasses, and some flowering plants. With warming ocean temperatures and the extreme melting of polar ice caps occurring in the Arctic, these plant species will be at risk, as habitat availability is getting scarcer and the climate continues to rapidly change.

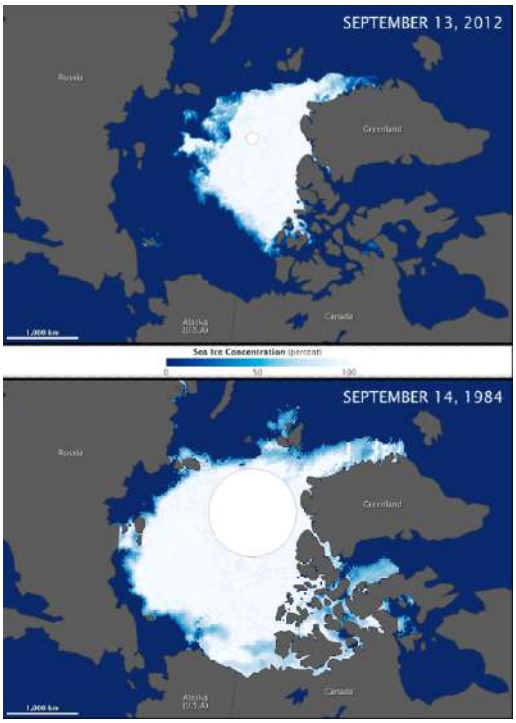
Arctic Poppies in bloom on Bathurst Island, which is part of the Canadian Arctic Archipelago (Wikipedia).

The Arctic and Climate Change

However magnificent this ecosystem may be, global warming is constantly changing the environment and threatening the stability of ocean life in the Arctic, putting it on thin ice. As the polar ice caps melt, the food web begins to change, and many species' feeding and migration patterns change as a result. Some marine species are becoming endangered (i.e. walruses and whales), and most organisms are slow to change and recover from disruptions or damage.

The melting of arctic sea ice is only exacerbated by the effects of albedo as seawater cover increases in surface area. Albedo is a measurement that quantifies the capability of a substance to reflect solar energy. Sea ice has a higher albedo and is able to reflect sunlight better than seawater. As ice continues to melt, the overall albedo is lower and less sunlight is reflected causing the temperature to increase and ice to melt faster. This creates a positive feedback loop resulting in an exponential increase in ice melt. This feedback is harmful, especially because it continues on past the initial disturbance, and temperatures are projected to only increase. Here is a short graphic video to visualize how albedo works: https://www.youtube.com/watch?v=P7r5AKYte00

There are several ways that melting sea ice can affect the organisms living there. For example, polar bears rely on sea ice to hunt, travel, and give birth to their cubs. If there is less sea ice present, polar bears are unable to hunt as effectively and lose valuable fat stores, resulting in lower reproductive success. Many sea birds also rely heavily on the ice by using the openings and surface to hunt and scavenge for prey. In addition, they use the rocky ledges to nest and breed. Smaller organisms like algae can also be affected. Algae that depend on ice as a habitat die out when the ice is no longer permanent. Overall, sea ice is invaluable, used by humans and animals alike for hunting, breeding, and traveling; losing the sea ice would be devastating to all species living there and could endanger many of them.



Arctic ice minimum extents are featured above. The top image is from 2012, while the bottom image is from 1984. (Wikipedia)

Ecological Importance of Sea Ice

As described above the Arctic Ocean is the home to many species of algae, microbes, and animals. We still lack a complete understanding of how Arctic ecosystems function due to the extremities of the environment and limited accessibility.

An important aspect of the Arctic Ecosystem is sea ice. Sea Ice covers about 7,000,000 km^2 of the Arctic surface during the summer which doubles in the winter. The Arctic is one of the only places with ice year-round and so with time many organisms have become specialized in living in or from the sea ice. A few of these organisms include bacteria, diatoms (algae), nematodes, copepods, amphipods, pelagic crustaceans, and Arctic Cod. They live in the pores and crevices in between the sea ice. Diatoms (algae) are speculated to be one of the most important primary producers in the Arctic. They will grow constantly starting spring and through the summer when sunlight is readily available for photosynthesis to occur. This algal bloom will allow for other species to feed including protists (single-celled organisms) and zooplankton. The algae produced will stick to ice which provides resources for other organisms but it will also sink to the bottom-feeding organisms in the water column and on the sea-floor.

These primary producers fuel life in the arctic. Every year when sea ice melts, more nutrients are introduced into the water and there is more mixing of the water due to the increased surface area of the open water for the wind to shift the surface water. In coastal zones of the arctic, this is resulting in an increase in upwelling (Arrigo, Dijken, & Pabi, 2008). As a result, some communities are experiencing increased photosynthetic activity. In the short term, this can provide more energy into the system and up the food chain. Over time, this increase in nutrient abundance can have an effect on the time window of primary productivity. Phytoplankton, in turn, can begin to bloom and decline sooner in the year. Populations of grazers, that over the years have adapted to this cycle, will be reaching a mature age to feed once the population of phytoplankton has begun to decline (Post et al., 2013). Many grazers will then have life cycles that may not align with that of the plankton; they would not be existing in the same place at the same time. This would result in unstable populations of grazers and furthermore result in a trophic cascade initially declining the populations of organisms directly feeding on the phytoplankton: arctic cod and other smaller zooplankton. These populations would suffer and as a result, large predators would not have a stable source of food. Large organisms such as killer whales and seals would unfortunately decline.

In another study, it was concluded that melting ice combined with the effects of run off of freshwater into the arctic resulted in the freshening of coastal waters. This freshening of the water favors smaller phytoplankton instead of larger diatoms (Li, McLaughlin, Lovejoy, & Carmack, 2009). The energy from a smaller plankton must pass through more trophic levels in order to support a large organism such as the arctic cod. This reduced the amount of energy that is actually transferred (refer to the Energy Transfer section

in 11.4 for more information). The less organisms (trophic levels) between the primary producer and the apex predator, the more efficient the food chain. Picoplankton dominated systems yield less effective feedwebs and can result in unsustainable ecosystems for large predators such as killer whales and polar bears.

The Arctic Cod, *Boreogadus saida*, is a key species to the Arctic environment. It has adopted a close relationship with the sea ice by using it as shelter from predators, as a feeding habitat, and a place to spawn. As discussed before, the arctic cod feed on organisms in the sea ice such as plankton and pelagic crustaceans, which are both abundant and have a wide distribution along the entirety of the Arctic. This abundance is key to the survival of much of the Arctic food chain since they are a primary resource for other fish, seabirds, seals, and whales. The melting of arctic sea ice would not only affect their physical habitat but reduce their food abundance which overall would have devastating effects on the ecosystem as a whole.

More Resources:

Arctic | Exploring Oceans : https://www.youtube.com/watch?v=umAeFKF2uxA

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12.4 Deep Sea

12.4.1 Introduction

12.4.2 Life at Depths

12.4.3 Physical Adaptations

Introduction

The deep sea is an environment that is unfriendly to humankind. As a result, it represents one of the least explored areas on Earth. It has even been said that the deep sea is less explored than the surface of the moon. The deep sea region begins about 1000 meters beneath the ocean's surface, located between the thermocline and the seafloor (Gage 1991). Here, light is limited, and after a depth of 100-500 meters, it disappears completely. Temperatures in the deep sea can significantly drop -- nearing 0°C at the very bottom. However, its temperature typically ranges between 2-3°C. The salinity level is relatively stable, with concentrations ranging between 34-35 parts per thousand (ppt). On the other hand, its pressure steadily rises with depth, increasing approximately 10 atmospheric pressure per meter (Gage 1991; George 2013).

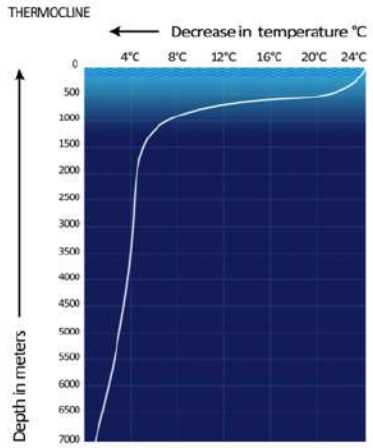

Figure 1. https://upload.wikimedia.org/wikiped...HERMOCLINE.png
This figure depicts the thermocline. Temperature of the surface water remains high until it reaches the thermocline where the temperature drops rapidly as the lack of heat from the sun dissipates. Temperature continues to decline, though much less rapidly, at lower depths.

Life at the Depths

While many scientists believed the deep sea was devoid of life due to its harsh conditions, multiple expeditions have demonstrated the opposite. They found that the deep sea possessed intricate and lively ecosystems, despite being thousands of meters below the surface. In the 1870s, the Challenger expedition revealed the existence of a variety of deep water species. More recently, in 1977, scientists aboard DSV Alvin discovered diverse deep sea communities around hydrothermal vents.

Caused by the absence of light, life in the deep sea faces multiple challenges, such as having difficulty producing energy, attracting prey, and finding mates. At these depths, primary producers can no longer rely on the sun for energy, so they use alternative sources, such as falling detritus from above. These falling particles are known as marine snow, consisting of dead or decaying plant, animal material, fecal matter, and other organic and inorganic particulate matter (Silver 2015). The continuous rain of marine snow provides food for many deep-sea creatures, giving them plenty of carbon and nitrogen to sustain the scavengers of the deep and fuel the rest of the ecosystem.

Physical Adaptations

The animals of the deep sea have adapted to survive in their habitats' extremely harsh conditions: no light, low amounts of food, low amounts of oxygen, high pressure, and cold temperatures. Advantageous physiological changes have developed to enable them

to survive in this kind of environment.

Many organisms in the deep sea have adapted a useful physiological trait to aid in the environment's low light conditions: bioluminescence. Bioluminescence is the production and emission of light by a living organism. The ability to produce their own light allows organisms to lure prey, attract mates, and find paths in the water. Additionally, it can be used for defense, mimicry, and counter-illumination (George 2013). Certain squid species can flash warning lights or secret bioluminescent ink in order to defend themselves and ward off predators. Mimicry can be used to match the light pattern of an otherwise fearsome or undesirable organism in order to fend off predators as well. Counter-illumination employs the use of lights on the underside of an organism to match the light coming from above, allowing an organism to appear dark from above (to match the dark water below it) and light from below (to match the light coming through the water above). A common example of attraction via bioluminescence can be demonstrated by angler fish. Angler fish have an appendage that extends from their head with a small light on the end. As they wave this appendage back and forth, they attract and lure prey towards their mouth (Gage 1991).

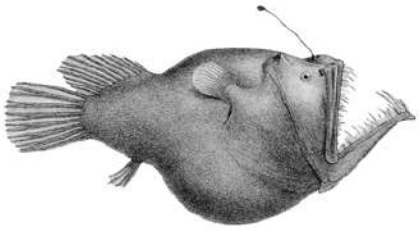

Figure 2. upload.wikimedia.org/wikiped...nglerfish).jpg
This image depicts the anglerfish with a light lure. This is a demonstration of the evolutionary adaptation bioluminescence.

Many deep sea fishes are either completely blind or have developed enlarged eyes, which enable them to detect the faintest of lights. To compensate for the loss of vision, they are well-equipped with a lateral line system, tactile organs, and other sensory structures (e.g. fin rays) (Pandev, 2007).

Body color also has become an adaptation for camouflage. Animals' bodies are often transparent, black, or red. The absence of red light at these depths keeps red-colored animals hidden from predators and prey.

Piezophiles are organisms that thrive in areas with high pressure. In order for them to inhabit such extreme environments, they evolved various mechanisms to counteract the effects of the elevated pressures. They are able to handle such pressure by remaining at a small size and eliminating excess cavities in their bodies that would otherwise collapse.

Many marine organisms have lost appendages and organs to conserve energy output, compensate for the extreme conditions, or because they simply do not use them anymore. The most common organ missing is the swim bladder; this is to escape the high stress of pressure present with extreme depth. In other cases, body parts have become enlarged and exaggerated (sensory organs, eyes, or mouths) in order to adapt to low light or scarce food (Pandey, 2007). An example of exaggerated and reduced body parts is the gulper eel, (*Eurypharynx pelecanoides*) which has tiny fins but also an enormous mouth, much larger than its body. Its mouth is loosely hinged and can open wide enough to swallow animals bigger than itself. Since food can be sparse in the deep sea, being able to eat whatever comes along, despite its size, is a huge advantage. The gulper eel has also adapted to having highly reduced pectoral fins because of their lack of use.

Figure 3. upload.wikimedia.org/wikiped...urypharynx.jpg
This image depicts the gulper eel with a large mouth and reduced fins.

To Learn More:

What's Hiding at the Most Solitary Place on Earth? The Deep Sea - Kurzgesagt Video

https://youtu.be/PaErPyEnDvk

Deep Sea Exploration Documentaries 1-3

https://www.youtube.com/watch?v=rCbJMtCdvMY

https://www.youtube.com/watch?v=jOIOXvU0_qk

https://www.youtube.com/watch?v=M9lXaThM5Vo

Marine Snow

https://www.youtube.com/watch?v=EF4IAGAXZsM

Angler Fish and Gulper Eel

https://www.youtube.com/watch?v=FswYwyke7cc

Hatchetfish

https://www.youtube.com/watch?v=XmjflLIB9J4

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12.5 Kelp Forest Ecosystems

Figure 1. depicts a kelp forest ecosystem commons.wikimedia.org/wiki/F...-_DSC06945.JPG

12.5.1 - Distribution

Kelp forests are mostly found in cool, shallow, nutrient-rich water near coasts. Kelp is a brown alga (*Phaeophyceae*), which requires access to light in order to photosynthesize - this is the reason for their abundance in shallow coastal waters (Sanctuaries.noaa.gov 2015). Kelp is one of the fastest growing organisms in the world, growing anywhere from 2 centimeter to 1 meter each day, depending on species and environmental conditions (Montereybayaquarium.org 2015).

Kelp can be found on the coast of every continent besides Antarctica (*Figure 1)*. Kelp forest ranges include areas of cold water, generally coinciding with coastal upwelling (Sanctuaries.noaa.gov 2015). The eastern Pacific Ocean along the west coast of North America, is an ideal area for kelp forests due to the presence of upwelling bringing cold water and nutrients to the surface from deep ocean water. Towards the poles, kelp forest development is limited by the availability of light at higher latitudes, while kelp towards the equator tends to be limited by the presence of warmer waters (Steneck et al. 2002).

12.5.2 - Characteristics

Kelp forests often draw comparisons to terrestrial forests, however the two ecosystems are distinct in that kelp is an algae - not a member of the Plant Kingdom. The structure of all kelp bears three universal morphological characteristics: holdfasts, stipes, and fronds (*figure 2*).

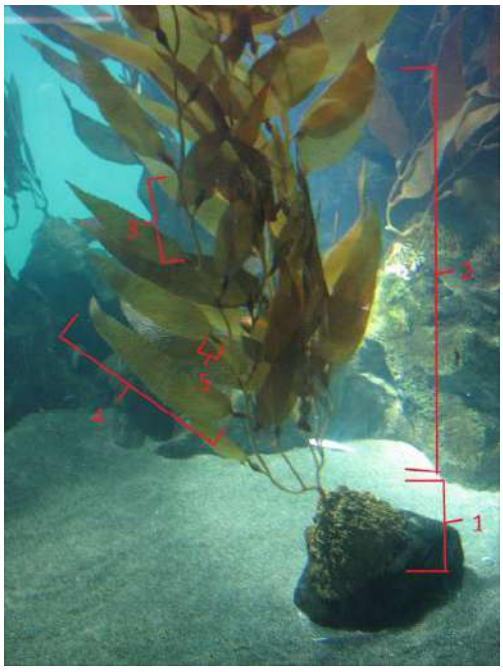

Figure 2. Diagram of kelp anatomy. Labels characteristics found in many species of kelp; 1. Holdfast 2. Frond 3. Stipe 4. Blade 5. Gas bladder. Note that gas bladders are not present in all species of kelp. upload.wikimedia.org/wikiped...rocystis_4.JPG

The holdfasts, which serve as an anchor for kelp, must be attached to hard substrates such as rocks or sand. Although they resemble roots on terrestrial plants, holdfasts do not transport water or nutrients through their stipe. The stipe, analogous to the stem, gives structural support to the algae. Fronds are blades extending from the stipe. The blades serve as the photosynthetic and nutrient uptake center for the organism (Connor and Baxter 1989).

Figure 3. Pictured above is bull kelp. The single pneumatocyst is clearly shown at the end of the stipe, with fronds extending from the end.
commons.wikimedia.org/wiki/F...eocystis_2.JPG

In addition to the universal characteristics of all kelp, many species have also developed pneumatocyst - also known as a "gas bladder" **.** Pneumatocysts are gas-filled bladders that provide the kelp with buoyancy that lifts the blades towards the surface, allowing for more photosynthetic productivity. The most common species of kelp found in Pacific forests are giant kelp (*Macrocystis pyrifera*) and bull kelp (*Nereocystis luetkeana*), both of which contain pneumatocysts.

Giant kelp is common in southern areas of the coast and bull kelp in the northern. The reason for this schism is due to giant kelp being perennial, meaning that the same organism will grow for multiple years – in this case, up to seven years – while bull kelp is an annual, which means it will complete its entire life cycle in one year. Winter storms farther north rip up kelp, washing it onto the shore, which makes bull kelp, and its one-year life cycle, much better suited to northern areas.

12.5.3 - Ecology

12.5.3a - Habitat

Kelp forests are an important foundation species , which provide large areas of habitat within the ocean (Oceanservice.noaa.gov 2015). Kelp forests have a wide variety of inhabitants within their boundaries: invertebrates frequently graze on the blades, fish find shelter in the fronds, and invertebrates - such as brittle stars, sea stars, anemones, sponges and tunicates - live in the holdfast (Connor and Baxter 1989). Kelp is also the single largest source of fixed carbon within their ecosystems (Graham 2004). Pieces of decomposing kelp sink deeper into the ocean, providing nutrients to deep sea organisms. Thus, kelp derived particulate organic matter (POM) is an important food source for fauna both within and outside the kelp forest (Norderhaug et al., 2003).

Since kelp is capable of attenuating waves and dampening their energy, many animals, such as mammals and birds, are able to seek refuge in the forests (Mork 1994). Various species of kelp tolerate ocean storms differently (Montereybay.noaa.gov 2015). In fact, along the California coast giant kelp has been known to dominate in years with less turbulent sea conditions, while bull kelp is more dominant in open waters and years of turbulent conditions (Harrold et al., 1988).

12.5.3b – Sea Otters and Urchin Barrens

Sea otter (*Enhydra lutris*) are one of the keystone species within kelp forests - meaning that they have a substantial impact within an ecosystem despite their relatively small population. Otters' diets consist mainly of invertebrates such as purple sea urchins (*Strongylocentrotus purpuratus*) which inhabit kelp forests along North America's west coast. Urchins feed on kelp and can potentially damage kelp forests by chewing through kelp holdfasts. Otters are the primary predator of urchins, keeping their populations at sustainable levels and maintaining the ecological balance of the kelp forest. Without otters a trophic cascade can occur; leading to destructive levels of grazing by urchin, causing a phenomenon known as an "urchin barren" (Sala et al., 1998, Siversten 2006). Due to kelp's role as a foundation species, significant populations of organisms that depend on their habitat are negatively impacted (Dayton 1985).

Fore more information:

Giant Kelp:

www.montereybayaquarium.org/a...ae/giant-kelp/

Bull Kelp:

www.montereybayaquarium.org/a...gae/bull-kelp/

Urchin Barren:

http://www.hindawi.com/journals/jmb/2012/492308/

Kelp Forests:

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

sanctuaries.noaa.gov/about/ec.../kelpdesc.html

Kelp Forest Ecosystems:

http://montereybay.noaa.gov/sitechar/kelp1.html

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12.6 Mangrove Ecosystems

Mangrove Ecosystems

Mangrove swamps are a complex and diverse compilation of resilient species that tolerate extremely challenging conditions of living in shallow seawater. There are approximately 70 species of mangrove trees that act as the foundation of the ecosystem, providing a habitat for numerous species in their branches above water and their tangled roots below water. Mangrove trees have adapted to living in high salinity conditions by developing a filtration system in their roots, and to stabilizing the soft sediments below by creating a complex root matrix to support their often massive weight above water. Many species of birds nest, roost, and feed in the canopy of the Mangroves. Various insects, snakes, lizards, and frogs make their homes in the branches, as well. Much like a coral reef or rocky intertidal shore, mangroves also provide habitat for many invertebrate and vertebrate marine species. Crabs, anemones, mussels, barnacles, oysters, and even juvenile reef fishes can be found clinging to or swimming through the complex system of roots. The mangrove provides shelter from predators as well as protection from physical forces such as high velocities of water flow for these small critters. It is important to protect this unique type of ecosystem because it provides shelter to an incredible diversity of marine and terrestrial species.

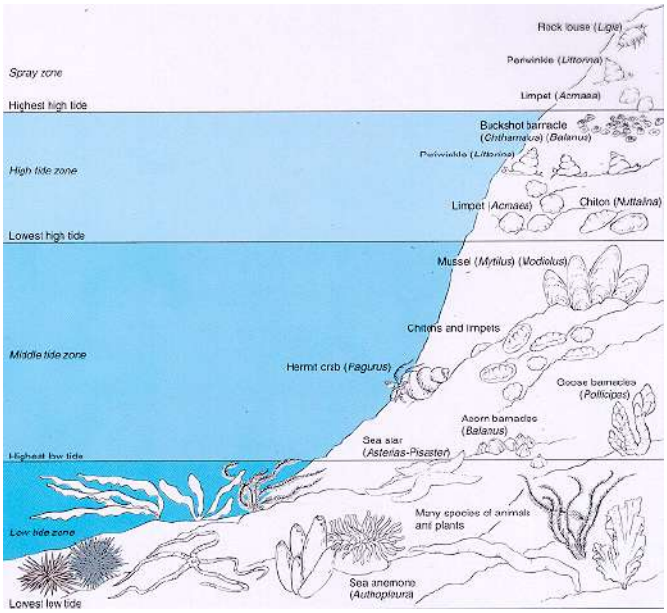
Mangroves provide billions of dollars worth of free services to humans. Through photosynthesis, they absorb a large chunk of carbon dioxide from the atmosphere, helping to reduce green house gas effects. They filter waste water and pollution along developed coastlines and provide clean water for numerous marine species. Additionally, their sturdy root system stabilizes shores from erosion or strong storms and can even create new land by trapping sediments. Mangroves also provide direct benefits to humans in the forms of medicines, seafood, fruits, fiber, and wood. However, in the past decade alone, over 35% of the world's mangroves have been destroyed largely due to human activity. Coastal development, climate change, and aquaculture have removed mangroves at an alarming rate that is more rapid than deforestation of tropical rainforests, yet have received far less attention from activists and media. Scientists estimate that all mangroves could be lost within the next 100 years if conservation efforts are not made. The loss of mangroves would cause a collapse of balance in many other ecosystems, especially coral reefs. Juvenile coral reef fish are raised within the mangrove root system, and without the mangroves, coral reef diversity will be adversely affected. Mangrove conservation should be one of the priorities of marine science in the near future.

online resources

- http://ocean.si.edu/mangroves
- www.mnh.si.edu/exhibits/ocean...e_removal.html

12.7 Rocky Shore

The incredibly diverse Rocky Intertidal Ecosystems are located on rocky shores ranging in the area of land that is exposed between high and low tide. This is a very extreme environment that has selected for organisms that are uniquely adapted to tolerate both exposure to air and high wave action, among other physical environmental factors. Frequent disturbance makes this a stressful habitat to live in, but intensity of stress varies among the high-, mid-, and low-intertidal zones. The high-intertidal zone, ending at the landward region of the intertidal zone, experiences the most extreme conditions and can be exposed to air and sunlight for long periods of time between high and low tide. Organisms that live in this region, including barnacles, limpets, chitons, and other encrusting species, are tough critters that have to withstand desiccation (loss of water) and sun exposure (over-heating). The mid-intertidal zone experiences the most frequent disturbance because it is submerged and exposed while the tide goes out and comes back in. In geographic areas that have semi- or mixed-diurnal tides, such as the western coast of the US, intertidal zones are exposed to two high and two low tides per day. This subjects organisms living in the mid-intertidal zone, including mussels and fucoid algae, to four periods of intense wave action per day. These organisms must develop strong attachment techniques to avoid dislodgment from the rocky shore, which would ultimately lead to death. The low-intertidal zone, the least stressful zone that is submerged in water for the majority of the day, is home to eel grass, sponges, and tunicates. Without the imminent threat of forceful waves, many delicate invertebrates thrive in the low intertidal.



Online resources

- oceanspaces.org/monitoring/ec...dal-ecosystems
- http://montereybay.noaa.gov/sitechar/rock3.html
- http://dusk.geo.orst.edu/oceans/intertidal.html
- www.bbc.co.uk/nature/habitats/Intertidal_zone

12.8 Sandy / Mudflat

Mudflats (tidal flats) are areas in which coastline shores are separated from the destructive forces of the ocean's waves. They are created through the deposit of sediments originating from the oceans and rivers. These calm environments, also known as estuaries, are commonly susceptible to the ever changing sea levels, otherwise known as the ocean tides, which consists of low and high tides. During the event of a high tide, sea water level rises to engulf the entire area bringing in nutrients from the oceans. As the sea water extracts during the low tide, a vast amount of nutrient is left behind making the mudflat a rich feeding ground for a plethora of organisms that it hosts. The ecosystem that exists within the area heavily revolves around this nutrient delivery system. The abundance of nutrients make mudflats one of the world's most productive ecosystems, and as such, produces one of the most diversified range of living organisms.

The notorious sand bubbler crab is a specie that depends on the mechanism that brings in nutrients from the sea. They only emerge during periods of low tide, right after the sea water has retreated back into the ocean, to feed. They sift rapidly through the fine sediments (sand) for food and throw aside the rest in the form of a small ball. The entire surface of the area in which these crabs inhabit can be covered in these balls just as the high tide is about to come in, to which now the crabs are the ones retreating back underneath the sands.

www.marinebio.net/marinescien...gy/mfindex.htm
https://www.youtube.com/watch?v=6XJtq2d_lFs
http://www.mbgnet.net/salt/sandy/mudflats.htm
http://en.Wikipedia.org/wiki/Tide
http://en.Wikipedia.org/wiki/Mudflat

12.9 Antarctic Ecosystems

The Antarctic ecosystem varies significantly due to the polar opposite conditions of summer and winter. In the summer, there is plentiful light and sunshine to power photosynthesis for algae, which transforms the ocean into a very productive ecosystem. This phytoplankton is consumed by krill, which are a key food source for many larger animals such as whales, seals, fish, and penguins. Depending on the year, gelatinous organisms called salps may dominate the lower trophic levels by competing with krill and consuming phytoplankton. Salps are not nutrient-rich, and therefore do not nourish larger animals the same way krill do.

In the winter, the Antarctic remains in near darkness. The surface of the ocean freezes over around Antarctica, providing more breeding and hunting ground for large animals like penguins and polar bears. Algae partially freezes up in the ice, while some can grow on the underside of ice sheets and provide food for hungry animals who depended on photosynthetic phytoplankton. Juvenile krill take cover under these ice sheets and feed on the ice algae to survive, while larger krill can still make it in the open ocean. These krill provide protein and fats for their predators and sustain the delicate ecosystem that has adapted to the freezing waters.

As the ocean is warming and ice is melting, the ecosystem will be changing. Whether or not some of these species will be able to adapt to the loss of ice and potential influx of invasive species is unpredictable.

Interactive Ecosystem:

http://polardiscovery.whoi.edu/antarctica/winter.html

Antarctic is separated by Southern Ocean from other land masses. The extreme minimum temperature has been recorded as low as -86.9 degrees Celsius and because of this extreme cold condition and windiness, the terrestrial biome is not as rich in biodiversity as the marine biome. Antarctic is surrounded by a continuous sea with relatively fast circumpolar currents. And some of the circumpolar deep water is carried to the surface which comes from eddies of the Antarctic Divergence zones. These eddies are upwelling areas where phytoplankton flourish on the additional nutrients and along with Antarctic Krill, a dominant herbivore in Southern Ocean, they serve secondary and tertiary production level.

Fauna of the Southern Ocean is not significantly rich in diversity; however, it is distinctive. Fish fauna is found to be composed of 120 species, belonging to 29 families, and the dominant fish species being Nototheniiformes. These fish are adapted to oxygen-rich and cold water. The importance of preserving the Antarctic ecosystems become important because they provide information about global system: heat budge, magnetism, atmospheric electricity, plate tectonics, ocean currents, and ocean chemistry.

Sources:

1. polardiscovery.whoi.edu/antar...ecosystem.html
2. www.divediscover.whoi.edu/ecosystem/
3. vishnu.whoi.edu/services/comm...3n2/wiebe.html

CHAPTER OVERVIEW

13: HUMAN IMPACTS ON THE OCEAN

13.1: POLLUTION - SOURCES & TYPES

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

13.2: NOISE IN THE OCEAN

13.3: DISEASES AND PATHOGENS

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.

13.4: OVERFISHING

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. In some cases, the end result of overfishing is a permanent collapse in fish supplies. It is important that we move to a more sustainable fishing method that will both maintain a steady food source for coastal communities and reduce the negative effects on marine ecosystems.

13.5: INVASIVE SPECIES

13.6: CLIMATE & CARBON CYCLE

The carbon cycle can be described as the flux of carbon between the Earth's sediments, life, and the atmosphere. The amount of carbon present in the earth is always the same but its presence in the various parts of the environment may vary. Humans have been burning fossil fuels and pumping more CO2 into the atmosphere leading to serious alterations to the carbon cycle.

13.7: 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 ou

13.1: Pollution - Sources & Types

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

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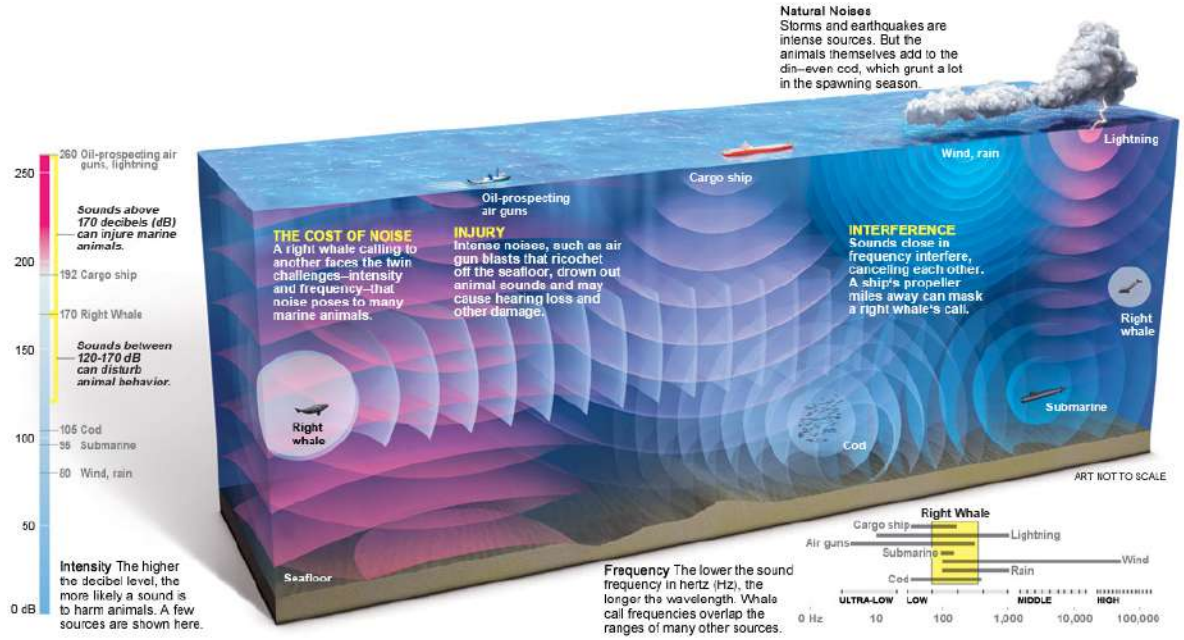
13.2: Noise in the Ocean

[this page is missing info on levels of noise and how this can impact animals. It is also missing a broad picture of how human made noise affects smaller organisms and the ecosystem as a whole]

The ocean is a noisy place. A lot of this sound is natural, but over the past 100 years anthropogenic ocean noise has greatly increased. Sources of these sounds include increased ship traffic, use of sonar, research surveys using high power sound, and oil extraction. Sound moves faster and further in the ocean, meaning its affect on animals is amplified. Ocean noise caused by humans impacts sea life immensely. Commercial shipping is disruptive to large animals, such as cetaceans (whales, dolphins, and porpoises), who rely on sound for communication and migration. Sonar is especially damaging because its frequency overlaps the frequencies of marine animals and causes confusion, which may lead to beaching, as a form of escape from the noise. Noise pollution has also led to traumas such as cerebral hemorrhages and bursting ear drums in several marine mammals. There have also been many digestive issues noted due to chronic stress from these animals.



Source: http://ngm.nationalgeographic.com/20...ea/noisy-ocean

Noise pollution interferes with sea life's ability to move freely in the ocean.

Source: guardianlv.com/wp-content/upl...ic-air-gun.jpg

Seismic Air Gun: commonly used in deep ocean seismic surveys.

These air guns produce sounds louder than military active sonar and are commonly used to survey the ocean floor for oil and topography.

13.3: 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.

13.4: 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

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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13.5: 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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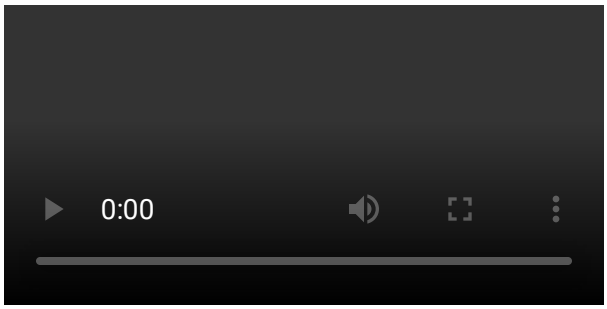
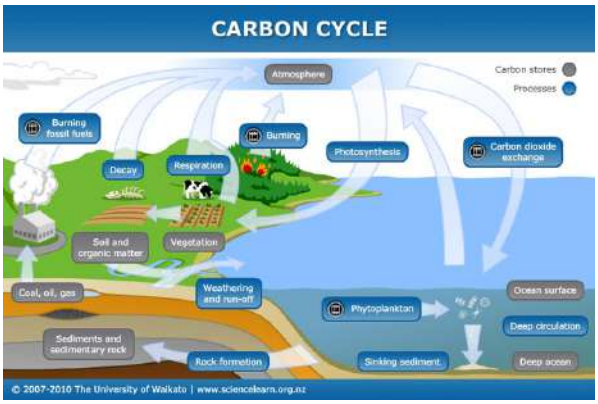
13.6: Climate & Carbon Cycle



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.

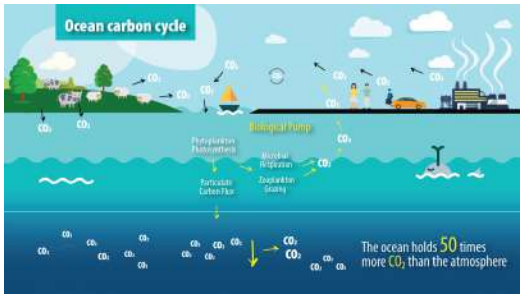


The Carbon Cycle: a map illustrating how carbon moved thought the environment.

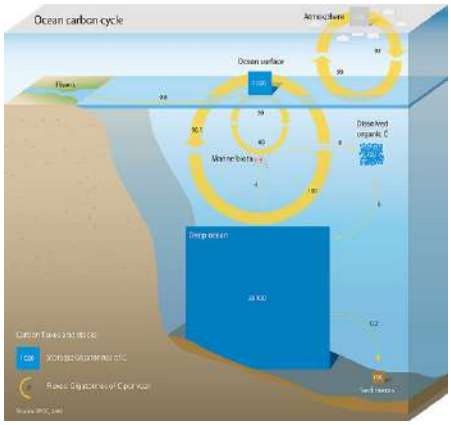
https://www.sciencelearn.org.nz/resources/689-the-ocean-and-the-carbon-cycle

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

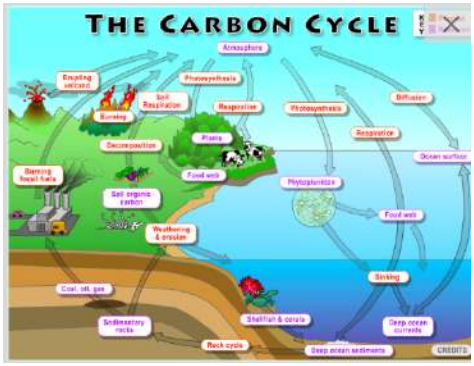


Diagram showing the physical, biological, and chemical processes affiliated with the Carbon Cycle. https://serc.carleton.edu/eslabs/carbon/index.html

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

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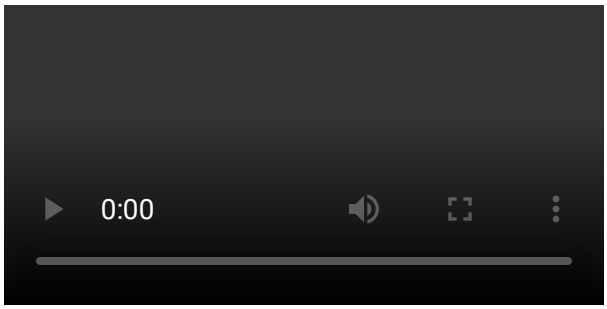
13.7: Eutrophication

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.

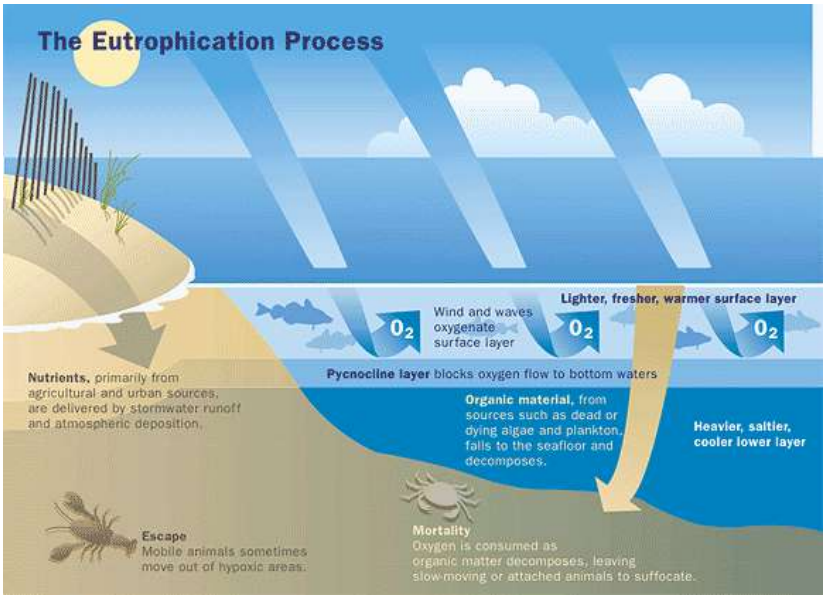


This video by NOAA explains Eutrophication

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

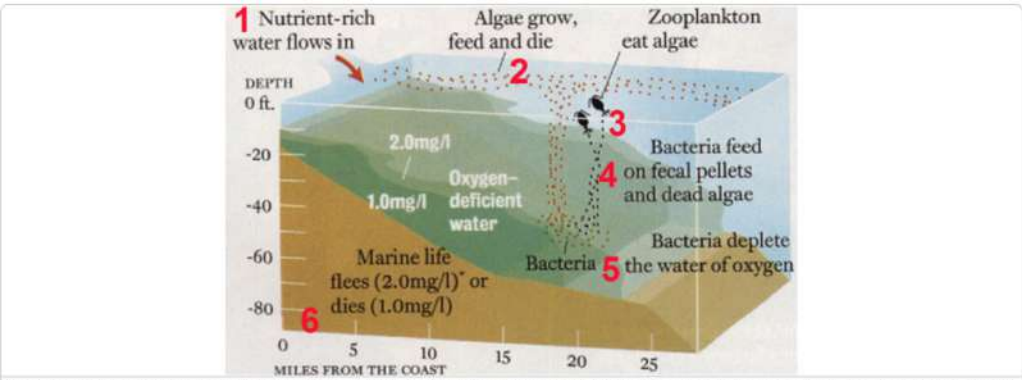
A point source pollution is one that is directly identifiable and can be traced back to a singular distinguishable source. Factories and sewage treatment plants are the most common types of point sources that cause eutrophication. Some factories discharge their waste, called effluent, directly into a 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.

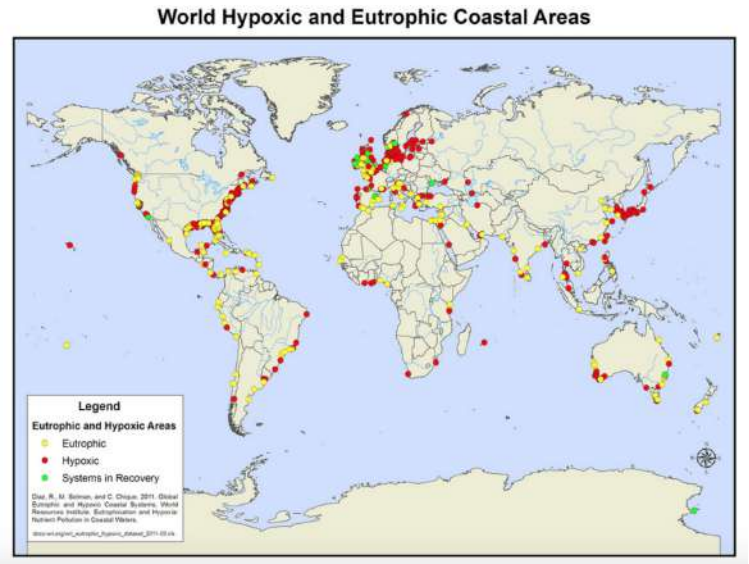
The Gulf of Mexico is essentially a large drain for the network of rivers known as the Mississippi-Atchafalaya River Basin (MARB), which includes major rivers such as the Mississippi and Missouri. MARB passes through 31 states, and agriculture is the dominant industry in several of those states, which 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/



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

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2. www.globalpartnershipforocean...black-sea-blue
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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
11. http://www.wri.org/resource/interact...cation-hypoxia
12. http://www.lenntech.com/eutrophicati...on-effects.htm
13. http://www.lenntech.com/turbidity.htm

CHAPTER OVERVIEW

14: SPECIAL TOPICS - THE OCEAN IN A WARMER WORLD

This page will provide a summary of impacts on the ocean from rising temperatures and carbon dioxide concentrations. Please see "articles" tab above for subheadings if they do not appear here.

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Impacts: Biological, Environmental, Social, Economic

- Biological Impacts
  - Species Distribution
  - Changes in Oxygen Levels
  - Effects on Coral Reefs
- Environmental Impacts
  - Rainfall and Winds
  - Ocean Acidification
  - Sea Levle Rising
- Other Impacts (Social, Political, Economical)

Impacts on Ocean Circulation and Weather

The ocean encompasses over seventy percent of the Earth and is a primary regulator of heat through ocean currents . Ocean currents move vast amounts of heat across the planet via the great ocean conveyor belt and is driven by both temperature and salinity . As the water is transported so does the heat along with it, so tropical waters moving along the currents toward Northern Europe releases heat causing those areas to be warmer (Sverdup 204) . The problem is Greenland and the Artic is losing ice so there is more available freshwater which can cause the great conveyor built to slow down . It slows because it will take longer for the water from the tropics to mix and sink below to become deeper current with the new addition of freshwater from melted ice . This slow down can have great effects on both northern Europe and the tropics . For Europe they would experience cooler temperatures which can devastate crops in these regions, and as for the tropics they would experience warmer climates due to warmer water not moving up north to cool .

Weather has become more extreme due to the changes in climate causing heat waves, disastrous floods, and hurricanes . Sixty years ago the United States temperature record highs and lows were roughly equal to one another, however, now records highs are twice as much as lows (Overview) .This data is significant because it is a sign of a warming climate and can be correlated to the recent heat waves and droughts we have today . Especially in the southwest of the United States experiences high temperatures and droughts which can be detrimental to farmland and natural systems . Not only droughts, but with sea level rising in the east they are more susceptible to flooding due to heavy rain or tropical storms . Tropical storm activity in the Atlantic Ocean has also increased during the past 20 years and is closely related to variation in sea surface temperature in the tropical part of the Atlantic (Climate Change) . Risings sea surface temperatures increase the probability of hurricanes occurring, but there is no correlation to strength of storm to the sea surface temperature (Micheals) . However, with the rise in sea level these tropical storms can run through the coastline because there is less of a buffer between the sea and land causing more damage to be done by the storms .

Sverdrup, H . U . , Martin W . Johnson, and Richard H . Fleming . The Oceans, Their Physics, Chemistry, and General Biology . New York: Prentice-Hall, 1942 . Print .

Michaels, Patrick J . , Paul C . Knappenberger, and Robert E . Davis . "Sea-surface Temperatures and Tropical Cyclones in the Atlantic Basin . " Geophysical Research Letters 33 . 9 (2006): n . pag . Web .

"Overview." Climate Communication. N.p., n.d. Web. 17 Mar. 2015. <https://www.climatecommunication.org...ther/overview/>.

Ocean Acidification

Ocean Acidification

Ocean acidification is the change in pH of seawater due to the oceans absorbing carbon dioxide emissions to the atmosphere.

Why does ocean acidification happen?

- Impacts on ocean life & ecosystems
  - Examples of impacted organisms
    - Invertebrates
      - Corals
      - Pteropods
      - Oysters, Mussels, Clams
      - Urchins
    - Fish
    - Foraminifera
  - Examples of ecosystem scale responses
  - Interactions with other stressors (multistressor)
    - hypoxia
    - changes in salinity

Multimedia Sources:

www.teachoceanscience.net/tea...t_coral_reefs/ (Coral acidification)

Excellent, general introductory video:

http://youtu.be/Wo-bHt1bOsw (source: Alliance for Climate Change, youtube)

OA pH Graph: www.pmel.noaa.gov/co2/file/pH+Time+Series

www.whitehouse.gov/sites/defa...march_2014.pdf

http://ocean.si.edu/ocean-acidification Videos in the news section for multimedia - bml.ucdavis.edu/research/rese...acidification/ Video - https://m.youtube.com/watch?v=9j8KEhpEg0s Maps - www.sciencedirect.com/science...04420314001042

CHAPTER OVERVIEW

15: SPECIAL TOPICS - FISHERIES MANAGEMENT

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15.2 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

http://oceanservice.noaa.gov/ecosystems/mpa/

marineprotectedareas.noaa.gov...effectiveness/

marineprotectedareas.noaa.gov.../mpainventory/

15.3: 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.

References

1. http://us.whales.org/wdc-in-action/whaling
2. https://iwc.int/whaling
3. http://www.ifaw.org/united-states/ou...ruelty-whaling
4. education.nationalgeographic....haling/?ar_a=1

15.4 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

2. www.nmfs.noaa.gov/aquaculture...uaculture.html

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

4. http://www-tc.pbs.org/emptyoceans/ed...s-and-Cons.pdf

15.5 Human Factors

What can we help you find?

Search

Help resources

Recommended links

15.6 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(CO2) 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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15.8 Population Dynamics

What can we help you find?

Search

Help resources

Recommended links

16: Special Topics - 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

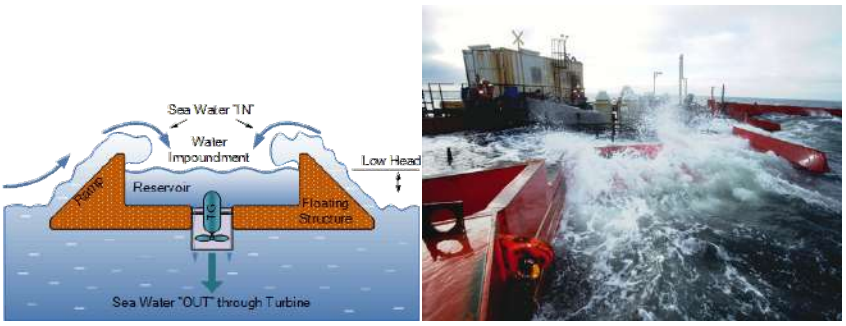
Point Absorbers

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).

CHAPTER OVERVIEW

17: SPECIAL TOPICS - MAJOR ENVIRONMENTAL EVENTS

17.1: 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

References

[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

17.2: 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

17.3: 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.

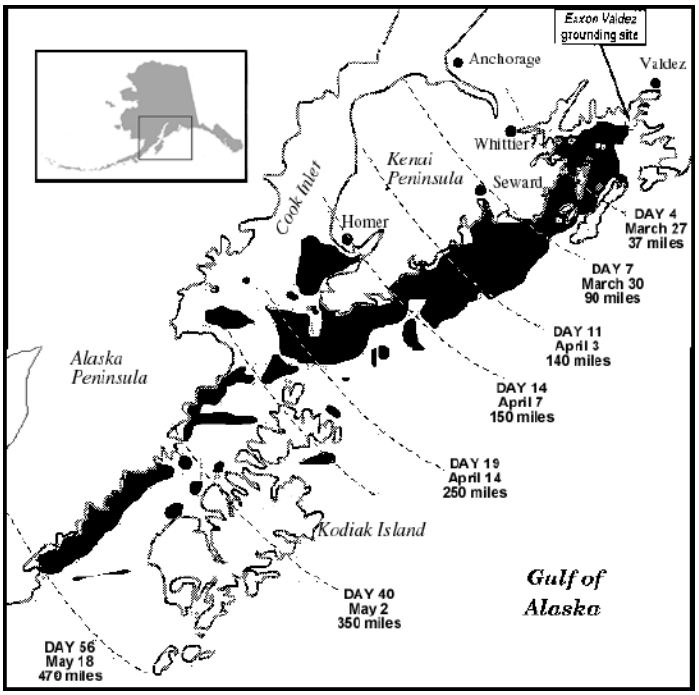
Aerial view of 1969 Santa Barbara Oil Spill

References

- 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

17.4: 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

17.5: 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

17.6: 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

17.7: 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)

17.8: 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.

17.9 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

CHAPTER OVERVIEW

18: SPECIAL TOPICS - OCEAN ENGINEERING

Welcome to the Geosciences Library. This Living Library is a principal hub of the LibreTexts project, which is a multi-institutional collaborative venture to develop the next generation of open-access texts to improve postsecondary education at all levels of higher learning. The LibreTexts approach is highly collaborative where an Open Access textbook environment is under constant revision by students, faculty, and outside experts to supplant conventional paper-based books.

Campus Bookshelves

Bookshelves

Learning Objects

ROV's, AUV's, and cool technology

Many organizations utilize several different methods of environmental monitoring. The U.S. Navy, Military, NOAA, USGS, and organizations/companies involving oceanography, fishing, civil engineering, security, and mineral prospecting all currently work with remotely operated underwater vehicles (ROV's), autonomous underwater vehicles (AUV's), and other new or developing sensor and monitoring technologies.

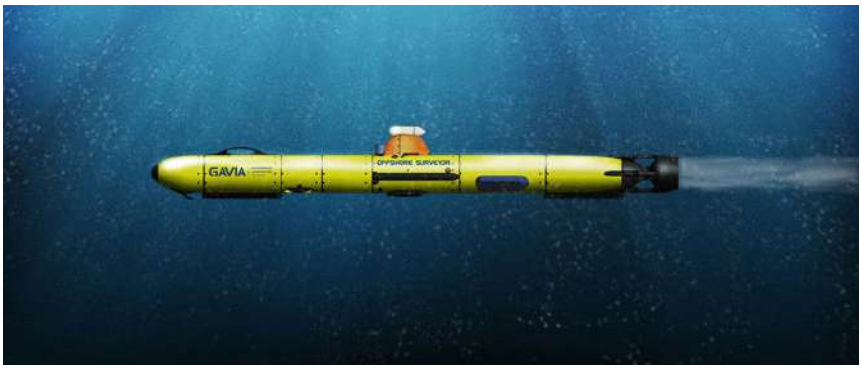
A remotely operated underwater vehicle, or ROV, is an underwater vehicle that completely functions underwater. It is operated by a crew, either located above or below the surface. Unoccupied and highly maneuverable, a ROV is linked to a ship by either a tether or a load-carrying umbilical cable is used along with a tether management system if working in rough conditions or deep waters. This tether or cable serves as the connection between the ROV and the ship. It provides the ROV with electric power and control commands, while providing the crew with video data.

A ROV's main functions are: searching/recovering, inspection, equipment repairing, dredging, trenching, cable-laying, and surveying. Most ROVs are equipped with at least a video camera and lights. Additional equipment is commonly added to expand the vehicle’s capabilities, such as sonars, magnetometers, still cameras, manipulators or cutting arms, water samplers, and/or other instruments that measure water clarity, water temperature, water density, sound velocity, light penetration, or temperature.

Image: nurn.eng.usm.my/imagesnurn/bu...4_nov/p7_1.jpg

Remotely operated underwater vehicles (ROV's)

Autonomous underwater vehicles (AUV's)



Cool Technology and Sensors

Sources:

List of NOAA ROV's: oceanexplorer.noaa.gov/techno...subs/subs.html

ROV definitions/overview/history: http://www.rovexchange.com/mc_rov_overview.php

www.marineinsight.com/tech/wh...r-vehicle-rov/

ROV and AUV definition: ocean.si.edu/ocean-news/subma...ing-deep-ocean

Cool ROV video: http://www.offshoreenergytoday.com/r...to-life-video/

19: Special Topics - International Cooperation and Managment

International Policy and Management

Several international and intergovernmental organizations have been founded in order to protect and manage our world's oceans. These organizations aim to control different aspects of human's interactions and use of the oceans. The duties of these organizations range from the management of vessels and maritime transport, to the education and limitation of human activities in different countries. The following serves as an overview of the duties and scope of these organizations, as well as examples of national policy that require international cooperation:

- **International Maritime Organization**

  The International Maritime Organization (IMO) is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships.[1]

- **Intergovernmental Oceanographic Commission**

  The Intergovernmental Oceanographic Commission (IOC-UNESCO) [was] established in 1960 as a body with functional autonomy within UNESCO, is the only competent organization for marine science within the UN system. [2]

  The ICO is recognized through the United Nations Convention on the Law of the Sea (UNCLOS) [3]

- **United Nations Convention on the Law of the Sea**

  Referred to as "The Constitution of the Oceans" [4], the United Nations Convention of the Law of the Sea (UNCLOS) is an international and multilateral agreement on the use and protection of the world's oceans. It was ratified on 10 December 1982.[5] It sets forth the principles and limitations that allow member countries to make use of the diverse ocean resources including fishing, trade and transportation. It also outlines the policies to help protect the oceans from anthropogenic misuse. It further outlines the creation of the Intergovernmental Oceanographic Commission under Section XIII as the competent body in the fields of Marine Scientific Research, as well as Transfer of Marine Technology under Section XIV. [6]

- **United States Commission on Ocean Policy**

LAW OF THE SEA: a multilateral consortium

LOSC and Maritime Zones

Maritime zones are established through the LOSC and International Maritime Laws. These zones are marked in relation to the land's furthest extent into the ocean. A country's maritime zone extended 12 miles off the coast from it's shoreline. The laws that govern the area within the 12 mile territory are established through *Trace Parallele*, which establishes "internal waters" where countries may exercise their own economic ventures and conduct their laws in these territories. There exists a " Contiguous zone " that extends 12 additional miles beyond the internal waters where a country may monitor or police for such activities as drug running. Countries must allow for "innocent passage" through their waters so long as a vessel does not contain weapons materials, fishing gear, or other resource extraction equipment. Military ships blur the extent of which innocent passage can be applied such as U.S. vessels patrolling waters off the coast of North Korea or the Persian Gulf.

In addition to the 12 miles off it's coastline every country is entitled to to practice internal waters law, there is an Exclusive Economic Zone that extended 188 additional miles off a country's coast. The EEZ was proposed by President Reagan to investigate deep water and open ocean resource extraction. This comes in the form of oil drilling, wind energy, and energy production. However the seabed is considered *Res Communis* or "public domain". To extract resources from the seafloor, a country must pay a fee to the Seabed Authority, an entity established by international maritime law.

Resource extraction has become a driving factor in the construction of maritime policy as countries aim to collect oil and precious natural resources. China and Japan debate which nation has access to resources in parts of the South Pacific Ocean near islands that are geographically closer to China but Japan has held control over for decades. Japan claims that control of these islands entitle them to an EEZ thousands of miles beyond that of Japan's main island. The Arctic is another hotly contested area of maritime law and resource extraction. Russia, Canada, the U.S., Sweden, and Denmark all have laid claim to EEZ's in the Arctic hoping to find petroleum or other non-renewable resources under the melting ice.

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

Resources

1. [1] United Nations International Maritime Organization: http://www.imo.org/About/Pages/Default.aspx
2. [2] Intergovernmental Oceanographic Commission-UNESCO: http://www.ioc-unesco.org/index.php?option=com_content&view=article&id=14&Itemid=100062
3. [3] Ibid
4. [4] http://www.ioc-unesco.org/index.php?...&Itemid=100030
5. [5] Ibid
6. [6] Ibid

Index

Glossary

Sample Word 1 | Sample Definition 1