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Ocean

World map of the five-ocean model with approximate boundaries

The **ocean** (also the **sea** or the **world ocean**) is the body of salt water which covers approximately 71% of the surface of the Earth.[1] It is also "any of the large bodies of water into which the great ocean is divided".[1] A common definition lists five oceans, in descending order by area, the Pacific, Atlantic, Indian, Southern (Antarctic), and Arctic Oceans.[2][3]

Seawater covers approximately 361,000,000 km² (139,000,000 sq mi) and is customarily divided into several principal oceans and smaller seas, with the ocean as a whole covering approximately 71% of Earth's surface and 90% of the Earth's biosphere.[4] The world ocean contains 97% of Earth's water, and oceanographers have stated that less than 20% of the oceans have been mapped.[4] The total volume is approximately 1.35 billion cubic kilometers (320 million cu mi) with an average depth of nearly 3,700 meters (12,100 ft).[5][6][7]

As the world's ocean is the principal component of Earth's hydrosphere, it is integral to life, forms part of the carbon cycle, and influences climate and weather patterns. The ocean is the habitat of 230,000 known species, but because much of it is unexplored, the number of species in the ocean is much larger, possibly over two million.[8] The origin of Earth's oceans is unknown; a sizable quantity of water would have been in the material that formed the Earth.[9] Water molecules would have escaped Earth's gravity more easily when it was less massive during its formation due to atmospheric escape. Oceans are thought to have formed in the Hadean eon and may have been the cause for the emergence of life.

There are numerous environmental issues for oceans which include for example marine pollution, overfishing, ocean acidification and other effects of climate change on oceans.

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Terminology

The phrases "the ocean" or "the sea" used without specification refer to the interconnected body of salt water covering the majority of the Earth's surface.[2][3] It includes the Atlantic, Pacific, Indian, Southern and Arctic Oceans.[10] As a general term, "the ocean" is mostly interchangeable with "the sea" in American English, but not in British English.[11] Strictly speaking, a *sea* is a body of water (generally a division of the world ocean) partly or fully enclosed by land.[12] The word "sea" can also be used for many specific, much smaller bodies of seawater, such as the North Sea or the Red Sea. There is no sharp distinction between seas and oceans, though generally seas are smaller, and are often partly (as marginal seas) or wholly (as inland seas) bordered by land.[13]

The Atlantic, one component of the system, makes up 23% of the "global ocean".

World Ocean

The global, interconnected body of salt water is sometimes referred to as the "World Ocean" or global ocean.[14][15] The concept of a continuous body of water with relatively free interchange among its parts is of fundamental importance to oceanography.[16] The contemporary concept of the *World Ocean* was coined in the early 20th century by the Russian oceanographer Yuly Shokalsky to refer to the continuous ocean that covers and encircles most of Earth.[17] Plate tectonics, post-glacial rebound, and sea level rise continually change the coastline and structure of the world ocean. That said a global ocean has existed in one form or another on Earth for eons.

Surface view of the Atlantic Ocean

Etymology

The word *ocean* comes from the figure in classical antiquity, Oceanus (/oʊˈsiːənəs/; Greek: Ὠκεανός *Ōkeanós*,[18] pronounced [ɔːkeanós]), the elder of the Titans in classical Greek mythology, believed by the ancient Greeks and Romans to be the divine personification of an enormous river encircling the world.

The concept of Ōkeanós has an Indo-European connection. Greek Ōkeanós has been compared to the Vedic epithet ā-śáyāna-, predicated of the dragon Vṛtra-, who captured the cows/rivers. Related to this notion, the Okeanos is represented with a dragon-tail on some early Greek vases.[19]

Geography

Oceanic divisions

The major oceanic divisions – listed below in descending order of area and volume – are defined in part by the continents, various archipelagos, and other criteria.[7][20][21]

Oceans average nearly four kilometers in depth and are fringed with coastlines that run for 360,000 kilometres.[22][23]

Oceans by size

#	Ocean	Location	Area (km^2) *(%)*	Volume (km^3) *(%)*	Avg. depth (m)	Coastline (km)
1	Pacific Ocean	Separates Asia and Australasia from the Americas[24]	168,723,000 *(46.6)*	669,880,000 *(50.1)*	3,970	135,663
2	Atlantic Ocean	Separates the Americas from Europe and Africa[25]	85,133,000 *23.5*	310,410,900 *23.3*	3,646	111,866
3	Indian Ocean	Borders southern Asia and separates Africa and Australia[26]	70,560,000 *19.5*	264,000,000 *19.8*	3,741	66,526
4	Southern Ocean	Encircles Antarctica. Sometimes considered an extension of the Pacific, Atlantic and Indian Oceans,[27][28]	21,960,000 *6.1*	71,800,000 *5.4*	3,270	17,968
5	Arctic Ocean	Borders northern North America and Eurasia and covers much of the Arctic. Sometimes considered a sea or estuary of the Atlantic.[29][30][31]	15,558,000 *4.3*	18,750,000 *1.4*	1,205	45,389
		Total	**361,900,000** ***100***	**1.335×10^9** ***100***	**3,688**	**377,412** [32]

NB: Volume, area, and average depth figures include NOAA ETOPO1 figures for marginal South China Sea. Sources: *Encyclopedia of Earth*,[24][25][26][27][31] International Hydrographic Organization,[28] *Regional Oceanography: an Introduction* (Tomczak, 2005),[29] *Encyclopædia Britannica*,[30] and the International Telecommunication Union.[32]

Oceans are fringed by smaller, adjoining bodies of water such as, seas, gulfs, bays, bights, and straits.

Ocean ridges

The mid-ocean ridges of the world are connected and form a single global mid-oceanic ridge system that is part of every ocean and the longest mountain range in the world. The continuous mountain range is 65,000 km (40,000 mi) long (several times longer than the Andes, the longest continental mountain range).[33]

World distribution of mid-oceanic ridges; USGS

Physical properties

Volumes and dimensions

It has been estimated that there are 1.36 billion cubic kilometers (332 million cubic miles) of water on Earth.[34] This includes water in liquid and frozen forms in groundwater, oceans, lakes and streams. Saltwater accounts for 97.5% of this amount, whereas fresh water accounts for only 2.5%. Of this fresh water, 68.9% is in the form of ice and permanent snow cover in the Arctic, the Antarctic and mountain glaciers; 30.8% is in the form of fresh groundwater; and only 0.3% of the fresh water on Earth is in easily accessible lakes, reservoirs and river systems.[34]

Three main types of plate boundaries

The total mass of Earth's hydrosphere is about 1.4×10^{18} tonnes, which is about 0.023% of Earth's total mass. At any given time, about 20×10^{12} tonnes of this is in the form of water vapor in the Earth's atmosphere (for practical purposes, 1 cubic meter of water weighs one tonne). Approximately 71% of Earth's surface, an area of some 361 million square kilometers (139.5 million square miles), is covered by ocean. The average salinity of Earth's oceans is about 35 grams of salt per kilogram of sea water (3.5%).[35]

The volume of water in all the oceans together is approximately 1.335 billion cubic kilometers (320.3 million cubic miles).[7]

Depth

The average depth of the oceans is about 3,688 meters (12,100 ft).[7] Nearly half of the world's marine waters are over 3,000 meters (9,800 ft) deep.[15] The vast expanses of deep ocean (anything below 200 meters or 660 feet) cover about 66% of Earth's surface.[36] This does not include seas not connected to the World Ocean, such as the Caspian Sea.

Map of large underwater features (1995, NOAA)

The deepest point in the ocean is the Mariana Trench, located in the Pacific Ocean near the Northern Mariana Islands.[37] Its maximum depth has been estimated to be 10,971 meters (35,994 ft). The British naval vessel *Challenger II* surveyed the trench in 1951 and named the deepest part of the trench the "Challenger Deep". In 1960, the Trieste successfully reached the bottom of the trench, manned by a crew of two men.

Color

The bluish ocean color is a composite of several contributing agents including the preferential absorption of red light by water, meaning that blue light is reflected back into the atmosphere. Prominent additional contributors to ocean color include dissolved organic matter and chlorophyll.[38] These aspects of ocean color can be measured by satellite observations and the assessment of chlorophyll provides a measure of ocean productivity (marine primary productivity) in surface waters. In long term composite images, regions with high ocean productivity show up in yellow and green colors, and low productivity ones in blue.

Season-long composites of ocean chlorophyll concentrations. These false-colored images make the data stand out. The purple and blue colors represent lower chlorophyll concentrations. The oranges and reds represent higher chlorophyll concentrations. These differences in color indicate areas with lesser or greater phytoplankton biomass.

Mariners and other seafarers have reported that the ocean often emits a visible glow which extends for miles at night. In 2005, scientists announced that for the first time, they had obtained photographic evidence of this glow.[39] It is most likely caused by bioluminescence.[40][41][42]

Oceanic absorption of light at different wavelengths[43]

Color (wavelength in nm)	Depth at which 99 percent of the wavelength is absorbed (in meters)	Percent absorbed in 1 meter of water
Ultraviolet (310)	31	14.0
Violet (400)	107	4.2
Blue (475	254	1.8
Green (525)	113	4.0
Yellow (575)	51	8.7
Orange (600)	25	16.7
Red (725)	4	71.0
Infrared (800)	3	82.0

Oceanic zones

Oceanographers divide the ocean into different vertical zones defined by physical and biological conditions. The pelagic zone includes all open ocean regions, and can be divided into further regions categorized by depth and light abundance. The photic zone includes the oceans from the surface to a depth of 200 m; it is the region where photosynthesis can occur and is, therefore, the most biodiverse. Photosynthesis by plants allows them to create organic matter from chemical precursors including water and carbon dioxide. This organic matter can then be consumed by other creatures. Much of the organic matter created in the photic zone is consumed there but some sinks into deeper waters. Life that exists deeper than the photic zone must either rely on material sinking from above (see marine snow) or find another energy source. Hydrothermal vents are a source of energy in what is known as the aphotic zone (depths exceeding 200 m). The pelagic part of the photic zone is known as the epipelagic.

The pelagic part of the aphotic zone can be further divided into vertical regions according to temperature. The mesopelagic is the uppermost region. Its lowermost boundary is at a thermocline of 12 °C (54 °F), which, in the tropics generally lies at 700–1,000 meters (2,300–3,300 ft). Next is the bathypelagic lying between 10 and 4 °C (50 and 39 °F), typically between 700–1,000 meters (2,300–3,300 ft) and 2,000–4,000 meters (6,600–13,100 ft), lying along the top of the abyssal plain is the abyssopelagic, whose lower boundary lies at about 6,000 meters (20,000 ft). The last zone includes the deep oceanic trench, and is known as the hadalpelagic. This lies between 6,000–11,000 meters (20,000–36,000 ft) and is the deepest oceanic zone.

The major oceanic zones, based on depth and biophysical conditions

The benthic zones are aphotic and correspond to the three deepest zones of the deep-sea. The bathyal zone covers the continental slope down to about 4,000 meters (13,000 ft). The abyssal zone covers the abyssal plains between 4,000 and 6,000 m. Lastly, the hadal zone corresponds to the hadalpelagic zone, which is found in oceanic trenches.

The pelagic zone can be further subdivided into two sub regions: the neritic zone and the oceanic zone. The neritic zone encompasses the water mass directly above the continental shelves whereas the oceanic zone includes all the completely open water.

In contrast, the littoral zone covers the region between low and high tide and represents the transitional area between marine and terrestrial conditions. It is also known as the intertidal zone because it is the area where tide level affects the conditions of the region.

If a zone undergoes dramatic changes in temperature with depth, it contains a thermocline. The tropical thermocline is typically deeper than the thermocline at higher latitudes. Polar waters, which receive relatively little solar energy, are not stratified by temperature and generally lack a thermocline because surface water at polar latitudes are nearly as cold as water at greater depths. Below the thermocline, water is very cold, ranging from −1 °C to 3 °C. Because this deep and cold layer contains the bulk of ocean water, the average temperature of the world ocean is 3.9 °C.[44] If a zone undergoes dramatic changes in salinity with depth, it contains a halocline. If a zone undergoes a strong, vertical chemistry gradient with depth, it contains a chemocline. Temperature and salinity control the density of ocean water, with colder and saltier water being more dense, and this density in turn regulates the global water circulation within the ocean.

The halocline often coincides with the thermocline, and the combination produces a pronounced pycnocline.

Ocean currents and global climate

Ocean currents have different origins. Tidal currents are in phase with the tide, hence are quasiperiodic; associated with the influence of the moon and sun pull on the ocean water. Tidal currents may form various complex patterns in certain places, most notably around headlands.[45] Non-periodic or non-tidal currents are created by the action of winds and changes in density of water. In littoral zones, breaking waves are so intense and the depth measurement so low, that maritime currents reach often 1 to 2 knots.

Amphidromic points showing the direction of tides per incrementation periods along with resonating directions of wavelength movements

The wind and waves create surface currents (designated as "drift currents"). These currents can decompose in one quasi-permanent current (which varies within the hourly scale) and one movement of Stokes drift under the effect of rapid waves movement (at the echelon of a couple of seconds). The quasi-permanent current is accelerated by the breaking of waves, and in a lesser governing effect, by the friction of the wind on the surface.

A map of the global thermohaline circulation; blue represents deep-water currents, whereas red represents surface currents.

This acceleration of the current takes place in the direction of waves and dominant wind. Accordingly, when the ocean depth increases, the rotation of the earth changes the direction of currents in proportion with the increase of depth, while friction lowers their speed. At a certain ocean depth, the current changes direction and is seen inverted in the opposite direction with current speed becoming null: known as the Ekman spiral. The influence of these currents is mainly experienced at the mixed layer of the ocean surface, often from 400 to 800 meters of maximum depth. These currents can considerably alter, change and are dependent on the various yearly seasons. If the mixed layer is less thick (10 to 20 meters), the quasi-permanent current at the surface adopts an extreme oblique direction in relation to the direction of the wind, becoming virtually homogeneous, until the Thermocline.[46]

The wind blowing on the ocean surface will set the water in motion. The global pattern of winds or atmospheric circulation creates a global pattern of ocean currents driven by the wind and the effect the circulation of the earth or the coriolis force. Theses major ocean currents include the Gulf Stream, Kuroshio Aghulas and Antarctic Circumpolar Current. Collectively they move enormous amounts of water and heat around the globe influencing climate. These wind driven currents are largely confined to the top hundreds of meters of the ocean. At greater depth the drivers of water motion are the thermoahline circulation. This is driven by the cooling of surface waters at northern and southern polar latitudes creating dense water which sinks to the bottom of the ocean and moves slowly away from the poles which is why the waters in the deepest layers of the world ocean are so cold. This deep ocean water circulation is relatively slow and water at the bottom of the ocean can be isolated from the ocean surface and atmosphere for hundreds or even a few thousand years.

This circulation has important impacts on global climate and the uptake and redistribution of pollutants such as carbon dioxide by moving these contaminants from the surface into the deep ocean.

Ocean currents greatly affect Earth's climate by transferring heat from the tropics to the polar regions. Transferring warm or cold air and precipitation to coastal regions, winds may carry them inland. Surface heat and freshwater fluxes create global density gradients that drive the thermohaline circulation part of large-scale ocean circulation. It plays an important role in supplying heat to the polar regions, and thus in sea ice regulation. Changes in the thermohaline circulation are thought to have significant impacts on Earth's energy budget. In so far as the thermohaline circulation governs the rate at which deep waters reach the surface, it may also significantly influence atmospheric carbon dioxide concentrations.

Climate change could, via a shutdown of the thermohaline circulation, trigger cooling in the North Atlantic, Europe, and North America.[47][48]

The Antarctic Circumpolar Current encircles that continent, influencing the area's climate and connecting currents in several oceans.

Waves and swell

The motions of the ocean surface, known as undulations or wind waves, are the partial and alternate rising and falling of the ocean surface. The series of mechanical waves that propagate along the interface between water and air is called swell. These motions profoundly affect ships on the surface of the ocean and the well-being of people on those ships who might suffer from sea sickness.

Constructive interference can cause individual (unexpected) rogue waves much higher than normal.[49] Most waves are less than 3 m (10 ft) high[49] and it is not unusual for strong storms to double or triple that height.[50] Rogue waves, however, have been documented at heights above 25 meters (82 ft).[51][52]

The top of a wave is known as the crest, the lowest point between waves is the trough and the distance between the crests is the wavelength. The wave is pushed across the surface of the ocean by the wind, but this represents a transfer of energy and not a horizontal movement of water. As waves approach land and move into shallow water, they change their behavior. If approaching at an angle, waves may bend (refraction) or wrap rocks and headlands (diffraction). When the wave reaches a point where its deepest oscillations of the water contact the ocean floor, they begin to slow down. This pulls the crests closer together and increases the waves' height, which is called wave shoaling. When the ratio of the wave's height to the water depth increases above a certain limit, it "breaks", toppling over in a mass of foaming water.[49] This rushes in a sheet up the beach before retreating into the ocean under the influence of gravity.[53]

Weather and rainfall

Oceans have a significant effect on the biosphere. Oceanic evaporation, as a phase of the water cycle, is the source of most rainfall. Ocean temperatures affect climate and wind patterns that affect life on land.

One of the most dramatic forms of weather occurs over the oceans: tropical cyclones (also called "typhoons" and "hurricanes" depending upon where the system forms).

Chemical composition of seawater

Salinity

Salinity is a measure of the total amounts of dissolved salts in seawater. It was originally measured via measurement of the amount of chloride in seawater and hence termed chlorinity. It is now routinely measured by measuring electrical conductivity of the water sample. Salinity can be calculated using the chlorinity, which is a measure of the total mass of halogen ions (includes fluorine, chlorine, bromine, and iodine) in seawater. By international agreement, the following formula is used to determine salinity:

Salinity (in ‰) = 1.80655 × Chlorinity (in ‰)

The average ocean water chlorinity is about 19.2 ‰ , and, thus, the average salinity is around 34.7‰.[43]

Salinity has a major influence on the density of seawater. A zone of rapid salinity increase with depth is called a halocline. The temperature of maximum density of seawater decreases as its salt content increases. Freezing temperature of water decreases with salinity, and boiling temperature of water increases with salinity. Typical seawater freezes at around −2 °C at atmospheric pressure.[54] If precipitation exceeds evaporation, as is the case in polar and temperate regions, salinity will be lower. If evaporation exceeds precipitation, as is the case in tropical regions, salinity will be higher. Thus, oceanic waters in polar regions have lower salinity content than oceanic waters in temperate and tropical regions.[43] However, the formation of sea ice at high latitudes excludes salt from the ice and thereby increases salinity in the residual waters in some polar regions.

Surface

Generalized characteristics of ocean surface[55][56][57][58][59][60][61]

Characteristic	Oceanic waters in polar regions	Oceanic waters in temperate regions	Oceanic waters in tropical regions
Precipitation vs. evaporation	P > E	P > E	E > P
Sea surface temperature in winter	−2 °C	5 to 20 °C	20 to 25 °C
Average salinity	28‰ to 32‰	35‰	35‰ to 37‰
Annual variation of air temperature	≤ 40ªC	10 °C	< 5 °C
Annual variation of water temperature	< 5ªC	10 °C	< 5 °C

Oxygen concentrations and other dissolved gases

Ocean water contains large quantities of dissolved gases, including oxygen, carbon dioxide and nitrogen. These dissolve into ocean water via gas exchange at the ocean surface, with the solubility of these gases depending on the temperature and salinity of the water. The increasing carbon dioxide concentrations in the atmosphere due to fossil fuel combustion lead to higher concentrations in the ocean waters and ocean acidification. The process of photosynthesis in the surface ocean also consumes some carbon dioxide and releases oxygen which may then return to the atmosphere. The subsequent bacterial decomposition of organic matter formed by photosynthesis in the ocean consumes oxygen and releases carbon dioxide. The sinking and bacterial decomposition of some organic matter in deep ocean water, at depths where the waters are out of contact with the atmosphere, leads to a reduction in oxygen concentrations. This decrease in oxygen increases with the amount of sinking organic matter and the time the water is out of contact with the atmosphere. However, most of the deep waters of the ocean still contain relatively high concentrations of oxygen sufficient for most animals to survive, but there are some ocean areas with water with very low oxygen.[43][62][63]

Concentrations of dissolved gases in the ocean[64][65]

Gas	Concentration of seawater, by mass (in parts per million), for the whole ocean	% dissolved gas, by volume, in seawater at the ocean surface
Carbon dioxide (CO_2)	64 to 107	15%
Nitrogen (N_2)	10 to 18	48%
Oxygen (O_2)	0 to 13	36%

Solubility of oceanic gases (in mL/L) with temperature at salinity of 33‰ and atmospheric pressure[66]

Temperature	O_2	CO_2	N_2
0 °C	8.14	8,700	14.47
10 °C	6.42	8,030	11.59
20 °C	5.26	7,350	9.65
30 °C	4.41	6,600	8.26

Residence times of chemical elements

The ocean waters contain all of the chemical elements as dissolved ions, but the concentration in which they occur range from some with very high concentrations of several grammes per liter, such as sodium and chloride, to others, such as iron, with tiny concentration of a few ng (10^{-9}) g/l. The concentration of any element depends on its rate of supply to the ocean from rivers, the atmosphere and via mid ocean ridge vents, and the rate of removal. Hence very abundant elements in ocean water like sodium, have quite high rates of input, reflecting high abundance in rocks and relatively rapid weathering, coupled to very slow removal from the ocean because sodium ions are rather unreactive and very soluble. By contrast some other elements such as iron and aluminium are abundant in rocks but very insoluble, meaning that inputs to the ocean are low and removal is rapid. Oceanographers consider the balance of input and removal by estimating the residence time of an element as the average time the element would spend dissolved in the ocean before it is removed, usually to the sediments, but in the case of water and some gases to the atmosphere. These cycles represent part of the major global cycle of elements that has gone on since the Earth first formed. The residence times of the very abundant elements like sodium in the ocean are estimated to be millions of years, while for highly reactive and insoluble elements, residence times are only hundreds of years.[43]

A few elements such as nitrogen, silicon and phosphorus are essential for life and major components of biological material, sometimes called “nutrients”. The biological cycling of these elements means that this represents an important removal route from the ocean as some of the organic material sinks to the ocean floor and is buried. These elements have intermediate residence times.

Mean oceanic residence time for various chemical elements[67][43]:225–230

Chemical elements	Residence time (in years)
Iron (Fe)	200
Aluminum (Al)	600
Manganese (Mn)	1,300
Water (H_2O)	4,100
Silicon (Si)	20,000
Carbonate (CO_3^{2-})	110,000
Calcium (Ca^{2+})	1,000,000
Sulfate (SO_4^{2-})	11,000,000
Potassium (K^+)	12,000,000
Magnesium (Mg^{2+})	13,000,000
Sodium (Na^+)	68,000,000
Chloride (Cl^-)	100,000,000

Marine life

Life within the ocean evolved 3 billion years prior to life on land. Both the depth and the distance from shore strongly influence the biodiversity of the plants and animals present in each region.[68]

As it is thought that life evolved in the ocean, the diversity of life is immense, including:

- Bacteria: ubiquitous single-celled prokaryotes found throughout the world
- Archaea: prokaryotes distinct from bacteria, that inhabit many environments of the ocean, as well as many extreme environments
- Algae: algae is a "catch-all" term to include many photosynthetic, single-celled eukaryotes, such as green algae, diatoms, and dinoflagellates, but also multicellular algae, such as some red algae (including organisms like Pyropia, which is the source of the edible nori seaweed), and brown algae (including organisms like kelp).
- Plants: including sea grasses, or mangroves
- Fungi: many marine fungi with diverse roles are found in oceanic environments
- Animals: most animal phyla have species that inhabit the ocean, including many that are only found in marine environments such as sponges, Cnidaria (such as corals and jellyfish), comb jellies, Brachiopods, and Echinoderms (such as sea urchins and sea stars). Many other familiar animal groups primarily live in the ocean, including cephalopods (includes octopus and squid), crustaceans (includes lobsters, crabs, and shrimp), fish, sharks, cetaceans (includes whales, dolphins, and porpoises).

In addition, many land animals have adapted to living a major part of their life on the oceans. For instance, seabirds are a diverse group of birds that have adapted to a life mainly on the oceans. They feed on marine animals and spend most of their lifetime on water, many only going on land for breeding. Other birds that have adapted to oceans as their living space are penguins, seagulls and pelicans. Seven species of turtles, the sea turtles, also spend most of their time in the oceans.

Human uses of the oceans

Humans have been using the ocean for a variety of purposes, for example navigation and exploration, naval warfare, travel, shipping and trade, food production (e.g. fishing, whaling, seaweed farming, aquaculture), leisure (cruising, sailing, recreational boat fishing, scuba diving), power generation (see marine energy and offshore wind power), extractive industries (offshore drilling and deep sea mining), freshwater production via desalination.

Many of the world's goods are moved by ship between the world's seaports.[69] Large quantities of goods are transported across the ocean, especially across the Atlantic and around the Pacific Rim.[70] Shipping lanes are the routes on the open ocean used by cargo vessels, traditionally making use of trade winds and currents. Over 60 percent of the world's container traffic is conveyed on the top twenty trade routes.[71] A lot of cargo, such as manufactured goods, is usually transported within standard sized, lockable containers, loaded on purpose-built container ships at dedicated terminals.[72] Containerization greatly increased the efficiency and decreased the cost of moving goods by sea, and was a major factor leading to the rise of globalization and exponential increases in international trade in the mid-to-late 20th century.[73]

Oceans are also the major supply source for the fishing industry. Some of the major harvests are shrimp, fish, crabs, and lobster.[4] The biggest commercial fishery globally is for anchovies, Alaska pollock and tuna.[74]:6 A report by FAO in 2020 stated that "in 2017, 34 percent of the fish stocks of the world's marine fisheries were classified as overfished".[74]:54 Fish and other fishery products are among the most widely consumed sources of protein and other essential nutrients. Data in 2017 showed that "fish consumption accounted for 17 percent of the global population's intake of animal proteins".[74] In order to fulfill this need, coastal countries have exploited marine resources in their exclusive economic zone, although fishing vessels are increasingly venturing further afield to exploit stocks in international waters.[75]

"Freedom of the seas" is a principle in international law dating from the seventeenth century. It stresses freedom to navigate the oceans and disapproves of war fought in international waters.[76] Today, this concept is enshrined in the United Nations Convention on the Law of the Sea (UNCLOS).[76] The safety of shipping is regulated by the International Maritime Organization.[77]

The ocean offers a very large supply of energy carried by ocean waves, tides, salinity differences, and ocean temperature differences which can be harnessed to generate electricity.[78] Forms of sustainable marine energy include tidal power, ocean thermal energy and wave power.[78][79] Offshore wind power is captured by wind turbines placed out on the ocean; it has the advantage that wind speeds are higher than on land, though wind farms are more costly to construct offshore.[80] There are large deposits of petroleum, as oil and natural gas, in rocks beneath the ocean floor. Offshore platforms and drilling rigs extract the oil or gas and store it for transport to land. Offshore oil and gas production can be difficult due to the remote, harsh environment.[81]

Threats

Human activities affect marine life and marine habitats through overfishing, habitat loss, the introduction of invasive species, ocean pollution, ocean acidification and ocean warming. These impact marine ecosystems and food webs and may result in consequences as yet unrecognized for the biodiversity and continuation of marine life forms.[83]

Global cumulative human impact on the ocean[82]

Marine pollution

The impact of pollutants depends on their mode of interaction with biota and also their concentration. Hence many marine pollution problems are greater nearer to input sources. Since most inputs come from land, either via the rivers, sewage or the atmosphere, it means that continental shelves are more vulnerable to pollution.

A particular concern is the runoff of nutrients (nitrogen and phosphorus) from agriculture and untreated sewage. These nutrients stimulate phytoplankton growth, which can provide more food for other marine life, but in excess can lead to harmful algal blooms (eutrophication) which can be harmful to humans as well as marine creatures. Such blooms are naturally occurring but may be increasing as a result of anthropogenic inputs or alternatively may be something that is now more closely monitored and so more frequently reported.[84] A second major concern is that the degradation of algal blooms can lead to depletion of oxygen in coastal waters, a situation that may be exacerbated by climate change as warming reduces vertical mixing of the water column.[63]

Marine pollution occurs when harmful effects result from the entry into the ocean of chemicals, particles, industrial, agricultural and residential waste, noise, or the spread of invasive organisms. Eighty percent of marine pollution comes from land. Air pollution is also a contributing factor by carrying off iron, carbonic acid, nitrogen, silicon, sulfur, pesticides or dust particles into the ocean.[85] Land and air pollution have proven to be harmful to marine life and its habitats.[86]

Marine debris

Marine debris, also known as marine litter, is human-created waste that has deliberately or accidentally been released in a sea or ocean. Floating oceanic debris tends to accumulate at the center of gyres and on coastlines,[87] frequently washing aground, when it is known as *beach litter* or tidewrack. Deliberate disposal of wastes at sea is called *ocean dumping*. Naturally occurring debris, such as driftwood and drift seeds, are also present.

With the increasing use of plastic, human influence has become an issue as many types of (petrochemical) plastics do not biodegrade quickly, as would natural or organic materials.[88] The largest single type of plastic pollution (~10 %) and majority of large plastic in the oceans is discarded and lost nets from the fishing industry.[89] Waterborne plastic poses a serious threat to fish, seabirds, marine reptiles, and marine mammals, as well as to boats and coasts.[90] Dumping, container spillages, litter washed into storm drains and waterways and wind-blown landfill waste all contribute to this problem. This increased has caused serious negative effects such as ghost nets capturing animals, concentration of plastic debris in massive marine garbage patches, and concentration of debris in the food chain.

Microplastics

Due to their ubiquity in the environment, microplastics are widespread among the different matrices. In marine environments, microplastics have been evidenced in sandy beaches,[92] surface waters,[93] the water column, and deep sea sediment. Upon reaching marine environments, the fate of microplastics is subject to naturally occurring drivers, such as winds and surface oceanic currents. Numerical models are able to trace small plastic debris (micro- and mesoplastics) drifting in the ocean,[94] thus predicting their fate.

Great Pacific garbage patch — Pacific Ocean currents have created three "islands" of debris.[91]

Microplastics enter waterways through many avenues including deterioration of road paint, tire wear and city dust entering the waterways, plastic pellets spilled from shipping containers, ghost nets and other synthetic textiles dumped into the ocean, cosmetics discharged and laundry products entering sewage water and marine coatings on ships degrading.[95]

Overfishing

Overfishing is the removal of a species of fish from a body of water at a rate that the species cannot replenish, resulting in those species becoming underpopulated in that area. Overfishing can occur in water bodies of any sizes, such as ponds, rivers, lakes or oceans, and can result in resource depletion, reduced biological growth rates and low biomass levels. Sustained overfishing can lead to critical depensation, where the fish population is no longer able to sustain itself. Some forms of overfishing, such as the overfishing of sharks, has led to the upset of entire marine ecosystems.[96] Types of overfishing include: Growth overfishing, recruitment overfishing, ecosystem overfishing.

Climate change

The effects of climate change on oceans include the rise in sea level from ocean warming and ice sheet melting, and changes in ocean stratification and circulation due to changing temperatures leading to changes in oxygen concentrations. There is clear evidence that the Earth is warming due to anthropogenic emissions of greenhouse gases and leading inevitably to ocean warming.[97] The greenhouse gases taken up by the ocean (via carbon sequestration) help to mitigate climate change but lead to ocean acidification.

Physical effects of climate change on oceans include sea level rise which will in particular affect coastal areas, ocean currents, weather and the seafloor. Chemical effects include ocean acidification and reductions in oxygen levels. Furthermore, there will be effects on marine life. The consensus of many studies of coastal tide gauge records is that during the past century sea level has risen worldwide at an average rate of 1–2 mm/yr reflecting a net flux of heat into the surface of the land and oceans. The rate at which ocean acidification will occur may be influenced by the rate of surface ocean warming, because the chemical equilibria that govern seawater pH are temperature-dependent.[98] Increase of water temperature will also have a devastating effect on different oceanic ecosystems like coral reefs. The direct effect is the coral bleaching of these reefs, which live within a narrow temperature margin, so a small increase in temperature would have a drastic effects in these environments.

Global mean land-ocean temperature change from 1880–2011, relative to the 1951–1980 mean. The black line is the annual mean and the red line is the 5-year running mean. The green bars show uncertainty estimates. Source: NASA GISS (http://data.giss.nasa.gov/gistemp/)

Ocean acidification

Ocean acidification is the ongoing decrease in the pH value of the Earth's oceans, caused by the uptake of carbon dioxide (CO_2) from the atmosphere.[99] The main cause of ocean acidification is the burning of fossil fuels. Seawater is slightly basic (meaning pH > 7), and ocean acidification involves a shift towards pH-neutral conditions rather than a transition to acidic conditions (pH < 7).[100] The concern with ocean acidification is that it can lead to the decreased production of the shells of shellfish and other aquatic life with calcium carbonate shells, as well as some other physiological challenges for marine organisms. The calcium carbonate shelled organisms can not reproduce under high saturated acidotic waters. An estimated 30–40% of the carbon dioxide from human activity released into the atmosphere dissolves into oceans, rivers and lakes.[101][102] Some of it reacts with the water to form carbonic acid. Some of the resulting carbonic acid molecules dissociate into a bicarbonate ion and a hydrogen ion, thus increasing ocean acidity (H^+ ion concentration).

Extraterrestrial oceans

Extraterrestrial oceans may be composed of water or other elements and compounds. The only confirmed large stable bodies of extraterrestrial surface liquids are the lakes of Titan, although there is evidence for oceans' existence elsewhere in the Solar System.

Although Earth is the only known planet with large stable bodies of liquid water on its surface and the only one in the Solar System, other celestial bodies are thought to have large oceans.[103] In June 2020, NASA scientists reported that it is likely that exoplanets with oceans may be *common* in the Milky Way galaxy, based on mathematical modeling studies.[104][105]

See also

- Blue carbon
- Borders of the oceans
- Brackish water
- European Atlas of the Seas
- International Maritime Organization
- List of bodies of water by salinity
- List of seas
- Ocean general circulation model
- Ocean governance
- Oceanography
- Polar seas
- Sea ice
- Sea in culture
- Seven Seas
- Superocean
- United Nations Convention on the Law of the Sea
- Water distribution on Earth
- Water hemisphere
- World Oceans Day
- World Ocean Atlas

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External links

- NOAA – National Oceanic and Atmospheric Administration – Ocean (http://www.noaa.gov/ocean.html)
- Origins of the oceans and continents (https://web.archive.org/web/20070915012040/https://www.oceansatlas.com/unatlas/about/howoceanswereformed2/originsofoceans/originofocean2jte.html)". *UN Atlas of the Oceans (http://www.oceansatlas.com/).*
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