Encyclopedia of Earth

Marine biodiversity

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Table of Contents

1 What is Biodiversity?
2 Goods and Services Provided by Marine Biodiversity
2.1 Resistance and Resilience to Change
2.2 Resistance to Invasions
3 Marine Food Webs
4 Threats to Marine Biodiversity
5 Protection of Marine biodiversity
6 Marine Biodiversity Research
6.1 Technology and Data Information Systems
7 Further Reading
8 External Links

What is Biodiversity?

Biodiversity is now commonly defined as the variety of life in genes, species and habitats. According to the definition of the Convention on Biological Diversity, biodiversity is the variability among living organisms from all sources, including *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

The three domains of life, bacteria, archaea and eukarya are present in the marine environment. In addition there are viruses. About 230,000 species of marine plants and animals have been scientifically described and a few thousand bacteria and archaea. This known biodiversity only represents a small fraction of the number of species existing, except for the macrophytes and seagrasses which are living in coastal environments and, in general, for the pelagic environment.

Species diversity in the oceanic pelagic environment is extremely low. The number of species in the upper 200 meters (m) of the pelagic oceanic environment is well known for four groups of animals, the Euphausicacea, Chaetognatha, Pteropoda and Copepoda, which dominate the biomass everywhere. There are only 80 species of euphausiids, 50 of chaetognaths, about 40 of pteropods and less than 2000 for the most diverse group, the calanoid copepods. These data are based on more than 20,000 net tows and, although new species will certainly continue to be discovered, it is obvious that pelagic biodiversity is of another order than both terrestrial and marine benthic diversity.

This low number of (animal) species is in striking contrast with the diversity of animals in sediments. About 200,000 species are currently known from benthic environments. Most of them have been described from coral reefs, and only about 60,000 are known from soft bottom habitats that cover most of the Earth's surface. Benthic species from the temperate shallow waters of Europe are reasonably well known, especially in the larger macro- and megafauna. The smaller meiofauna (mm-sized animals) is less well described and, as an example, a survey of the benthos in the North Sea in 1986 yielded about 40% of benthic copepod species new to science.

For both animals and microbes, the exploration of environments that are difficult to access, such as the deep-sea floor or marine caves, and the application of new technologies, are constantly yielding new species and higher taxonomic categories, even up to phylum level. Especially the availability of rapid sequencing technologies has shown that variability in the microbial domain, including the small eukaryotes, is extremely high and that tens of thousands of 'species' may co-occur in a single liter of sea water.

Life originated in the sea and is much older in the sea than on land. As a consequence, animal and plant diversity at higher taxonomic levels are much greater in the sea where there are 14 endemic (unique) animal phyla whereas only 1 phylum is endemic to land. For plants the situation seems to be different—almost all algal groups have representatives in both fresh and marine waters and higher plants are nearly exclusively terrestrial. There is also a remarkable diversity of life-history strategies in marine organisms. The sum total of genetic resources and physiological diversity in the sea is therefore expected to be much more diverse than on land.

Habitat diversity and the number of marine habitats is difficult to define. Studies of zonation have typically demonstrated the existence of very narrow zones in intertidal areas, where direct observation is possible, and broader and broader zones as one goes deeper. However, it is recognized that this is due to our limited possibilities of observation and with increasing technological capability, finer discontinuities are revealed even in the water column. Besides zonation bands, a number of very specific habitats often linked to tectonic activities have been discovered over the last decades, starting with the hydrothermal vents in 1977 and followed in later years by cold seeps of gases and fluids, carbonate mounds, mud volcanoes, etc. Multibeam sonar has allowed much more detailed analysis of the sea floor showing fine-grained features in sediments that were previously thought to be rather uniform, or the very complex topology of marine canyons in the continental slope. With increasing potential of observation, the number of marine habitats on many different scales will certainly increase, and, as these habitats often contain species which are specifically adapted to their environmental conditions, so will species diversity.

Goods and Services Provided by Marine Biodiversity

Marine organisms play a crucial role in almost all biogeochemical processes that sustain the biosphere, and provide a variety of products (goods) and functions (services) which are essential to humankind's well-being. Goods include the production of food (about 100 million tonnes annually) and natural substances, ingredients for biotechnology and pharmaceuticals, and even land (e.g., the carbonate platforms that make up the Bahamas). These goods are mainly delivered by macroscopic organisms.

Besides goods, marine ecosystems deliver a series of services that are essential to the proper functioning of the Earth. These include the production and mineralization of organic material, the storage of carbon, the storage of pollutants and waste products from land, the buffering of the climate and of climate change, coastal protection (mangroves, dune-beach systems, coral reefs). Most of these services are delivered by microscopic organisms.

The rate and efficiency of any of the processes that marine organisms mediate, as well as the range of goods and services that they provide, are determined by interactions between organisms, and between organisms and their environment, and therefore by biodiversity. These relationships have not yet been quantified, and we are at present unable to predict the consequences of loss of biodiversity resulting from environmental change in ecological, economic or social terms.

The economic valuation of goods and services has been a subject of much research and debate recently. Although it is possible to attribute monetary value to many goods and services (and to show that this value can be extremely high) it is also important to recognize that non-use values such as intellectual interest, aesthetic pleasure and a general sense of stewardship towards the non-human life of our planet are important prerequisites for public support of the conservation and sustainable use of the marine environment

Resistance and Resilience to Change

The diversity-stability hypothesis suggests that diversity provides a general insurance policy that minimizes the chance of large ecosystem changes in response to global environmental change. Microbial microcosm experiments show less variability in ecosystem processes in communities with greater species richness, perhaps because every species has a slightly different response to its physical and biotic environment. The larger the number of functionally similar species in a community, the greater is the probability that at least some of these species will survive stochastic or directional changes in the environment and maintain the current properties of the ecosystem.

Even the loss of rare species may jeopardize the resilience of ecosystems. In the marine environment this is particularly relevant for species at the top of the food web, such as tuna and sharks, whales, sea lions and sea otters and perhaps some birds. Species diversity also reduces the probability of outbreaks by pest species by diluting the availability of their hosts.

Resistance to Invasions

Biodiversity can influence the ability of exotic species to invade communities through either the influence of traits of resident species or some cumulative effect of species richness. Early theoretical models and observations of invasions on islands indicated that species-poor communities are more vulnerable to invasions because they offer more empty niches. However, studies of intact ecosystems find both negative and positive correlations between species richness and invasions.

Marine Food Webs

The main marine primary producers are very small and often mobile. In the oceans cyanobacteria are the main primary producers: species from the genera *Synechococcus* and *Prochlorococcus*, about 1-2 µm in diameter, are responsible for about two thirds of oceanic primary production, i.e., one third of the total primary production of organic material on Earth.

Oceanic primary production is limited by nutrients, including iron in large areas of the oceans. A large part of the organic material produced is internally recycled. The microbial food web, based on dissolved organic matter, includes photoheterotrophic bacteria, using sunlight as an energy source but without the production of oxygen, and viruses which are responsible for control of the bacterial populations. The very small picoeukaryotes, both autotrophs and heterotrophs, many of which are grazers on bacteria, are extremely diverse but very poorly known. Marine food webs are very long in most areas and include many species.

The standing stock of grazers is higher than that of primary producers in the sea, which is the opposite of the situation on land. Ocean productivity is on average far lower than land productivity. In the largest part of the ocean, beneath the shallow surface layers, no photosynthesis occurs at all and the largest part of the Earth's biosphere is therefore dependent on external subsidies of organic matter.

High-level carnivores often play key roles in structuring marine biodiversity and yet are exploited heavily with unquantified but cascading effects on biodiversity and on ecosystem functions. This does not occur on land, where the ecosystems are dominated by large herbivores and, of course, increasingly by humans which monopolize about 40% of the total world primary production. Top down control of marine food webs implies that the fisheries of top predators have to be considered as a potential mechanism directly dependent on humans that may change the ecology of the entire ocean.

Threats to Marine Biodiversity

It is often argued that changes in biodiversity will be mainly restricted to land and consequently attention to biodiversity changes in the oceans is limited. However, humans do impact the oceans already to a considerable degree, especially in the coastal areas but increasingly in the open ocean as well.

The effects of fisheries, focusing on the top predators and herbivores of the food web, is globally visible in the disappearance of large fish, sharks, turtles, crustaceans and plants, and consequent increases in smaller fish species, sea urchins, etc., and their phytoplanktonic or macrophyte food. Global climate change is increasing sea-surface temperature and northward migrations of species have been documented from fisheries and the unique data from the Continuous Plankton Recorder. Increasing carbon dioxide (CO_2) levels reduce the pH of sea water and increase the solubility of calcium carbonate with potentially dramatic consequences for calcifying organisms, such as corals, mollusks, coccolithophorids, pteropods and forams.

A greater variety of species at a higher trophic level is exploited in the sea than on land: humans exploit over 400 species as food resources from the marine environment; whereas on land only tens of species are harvested for commercial use. Exploitation of marine biodiversity is also far less managed than on land and amounts to the hunter-gatherers stage that humans abandoned on land over 10,000 years ago, yet exploitation technology is becoming so advanced that many marine species are threatened to extinction. Insufficient consideration has been given to the unexpected and unpredictable long-term effects that such primitive food-gathering practices engender.

Most if not all pollution (air, land and freshwater) ultimately enters the sea. Marine biodiversity is thus most exposed to and critically influences the fate of pollutants in the world. Yet marine species are probably least resistant to toxicants. The spread of pollutants in marine food chains and therefore the quality of marine food is uncontrollable by humans.

Protection of Marine biodiversity

Human attention rightly focuses on the decline of biodiversity on land, but this should not happen at the expense of the oceans—attention to marine biodiversity is also urgently needed if we want to maintain a stable relationship between humans and the sea. The oceans have no owner and no single nation or international organization is liable for their health. As a consequence, the seas are under increasing pressure. Humankind is destroying the coastline and its protection against flooding, polluting coastal waters and critically changing the oceanic food webs by overfishing of the top predators over large parts of the world. Marine Protected Areas and Nature Reserves are now being established rapidly but not in areas beyond national jurisdiction which remain vulnerable to uncontrolled exploitation. This includes most of the open ocean and deep-water habitats on Earth and so, in fact, most of the planet.

Marine Biodiversity Research

We know more about the Moon than about the oceans and more money is spent on space research than on exploration of the deep sea, the last unknown habitat on Earth and one where exciting discoveries can still be made. As an example, since 1980 two new animal phyla have been discovered that are endemic to the marine environment and a whole series of new habitats have been found and explored in the last ten years. Even more recently is the exploration of the vast genetic and microbial diversity. The need for extended exploration is exemplified by programs such as the Census of Marine Life, a worldwide effort to explore and understand the biodiversity of the oceans.

An important product of marine biodiversity research should be the necessary knowledge and tools for adequately managing and protecting marine biodiversity. This requires knowledge on genetic and ecological mechanisms that control biodiversity (gene flow, dispersal, adaptive value of genetic polymorphisms, determination of dispersal and recruitment, species interactions including invasions, sediment transport, natural and human-induced catastrophes, etc.). It also requires knowledge on the functional role of biodiversity: what is the variability in genes, species and communities that is required for 'normal' or desirable ecosystem functioning; and models on dispersal of genes and organisms, species interactions and food webs, the interaction between food webs and biogeochemical fluxes, and impact assessment of diffuse and point source pollution, coastal constructions, mass tourism and global climate change.

Technology and Data Information Systems

Support of conservation and sustainable exploitation of biodiversity will require development of rapid assessment techniques for monitoring marine biodiversity (genes, species and biotopes), including the use of molecular techniques, rapid identification techniques, assessment of difficult species (microbes, sibling species, multispecies complexes), pictural taxonomic and identification keys accessible on the World Wide Web and CD-ROM, remote sensing techniques (Satellite Imagery, Side Scan Sonar, multibeam, LIDAR, etc.). It must also provide for the development of data bases and Geographic Information Systems (GIS) for genes, species and habitats.

Further Reading

- Marine Conservation Biology Institute, Elliott A. Norse and Larry B. Crowder (Editors), 2005. Marine Conservation Biology: The Science of Maintaining the Sea's Biodiversity, Island Press, 470 pp. ISBN: 1559636629
- Ormond, Rupert F. G., John D. Gage, and Martin Vivian Angel (Editors), 1997. Marine Biodiversity: Patterns and Processes, Cambridge University Press, New York, 449 pp. ISBN: 0521552222
- Thorne-Miller, Joyce and John G. Catena, 1993. Living Ocean: Understanding and Protecting Marine Biodiversity, Island Press. ISBN: 1559630647

External Links

- Census of Marine Life
- Diversitas
- European Census of Marine Life
- EU Network of Excellence Marine Biodiversity and Ecosystem Functioning

- International Council for the Exploration of the Sea
- UNESCO Man and Biosphere Programme

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