The green ocean — observations of marine biodiversity

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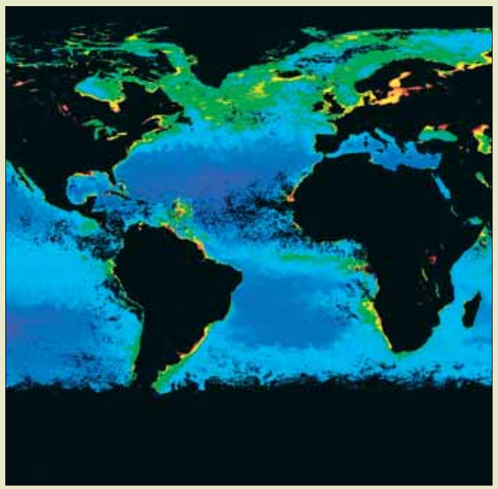
From space, a green ocean appears where the chlorophyll of plankton reveals productive areas. But most ocean life, although a vital and connected part of our living planet, is largely hidden from view. Observations of marine biodiversity — from the surface to the bottom of the ocean — are thus a central concern of GEO. Fish have been an essential food source since prehistoric times. Marine life provides much of the oxygen we breathe and removes a significant fraction of the atmosphere's greenhouse gases. Despite years of research on fish and marine mammals, their feeding, breeding and migration patterns remain a mystery to us today. Our ignorance is even deeper when it comes to non-commercial species including the abundant marine microbes and viruses, most of which have yet to be identified.

The Green Ocean



Chlorophyll concentration evident in northern seas and coastal regions (indicated by colours from green to red) as measured by the NASA satellite instrument MODIS on Aqua (1 May-1June 2007)

Courtesy NASA Goddard Space Flight Center

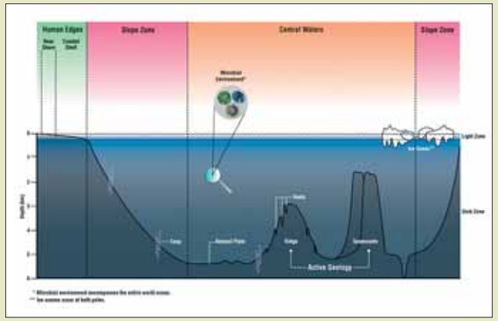
This ignorance contributes to deep uncertainty about human impacts on the ocean. Coastal pollution, the massive harvest of marine resources using modern techniques and, at ocean scales, the evolving chemical and physical properties associated with global warming, all affect the ocean and its life in unpredictable ways. We are only starting to learn about the interconnectedness of the marine web of life; but the more we learn, the better we understand that when something happens at one level or to one species, other species are impacted, throughout the food web. It is this interconnected character across the diversity of life that motivates our need to understand what lives in the ocean. Exploring and cataloguing this diversity is the central theme of the Census of Marine Life (the Census). The Census is a coordinated international effort to quantify what is known and to identify the unknown and the boundaries of what can be known about life in the world ocean.

The Census is the first international programme to systematically study the global ocean from a biological standpoint. It is providing information, technologies and approaches for critical understanding and management of marine ecosystems. The Census is identifying threatened species and important breeding areas and is helping authorities develop effective strategies for the sustainable management of marine resources. In short, it is both making scientific discoveries and helping society deal with the multiple threats to the ocean from human activity. The Census asks: what lived; what lives; and what will live in the oceans? By combining what we learn about historical trends with our knowledge of what lives there now, we can begin to formulate an answer to the core question of what will live in the ocean of tomorrow. Thus the Census scientific programmes and global database system are a critical contribution to the Global Earth Observing System of Systems (GEOSS).

What is the Census?

The Census of Marine Life is a growing global network of more than 2,000 researchers in more than 80 nations engaged in a ten-year initiative to assess and explain the diversity, distribution, and abundance of marine life in the oceans. The Census uses field projects, new technology, a data system, studies of historical data and future projections to understand the world of marine biodiversity. Since waters and animals move, the Census is organized by ocean realms. Each of the Census field projects focuses on a specific marine region, habitat, or oceanic community.

Theoretical cross section of the ocean



An ocean basin cross-section illustrating the realms and zones of the world ocean as defined by the Census of Marine Life.

Source: Census of Marine Life Communications Team, University of Rhode Island

The human edge, hidden boundaries and central waters
The coastal projects at the human edge of the ocean are providing databases, collections and expertise allowing developing countries to take a more active stance in reporting and defending the natural biology of their coastal waters. Beyond the coastal zone, the Census studies biological systems at the continental margins and in the sediments of the abyssal plains. This information will help to identify the historical causes and ecological factors regulating biodiversity and global change. Census field projects reveal the biology of the deep Mid-Atlantic, and study the unique biology of deep-water vents and seeps from the sea floor. The Census tracks Pacific salmon and other migratory species that move through the upper ocean where sunlight penetrates.

History, future, data and technology
Current Census projects study microbes, plankton, coral reefs, continental margins, seamounts, and the Arctic and Antarctic to increase understanding of all factors influencing marine biodiversity. The Census also supports the study of historical records, projects through modelling and data analysis what the future is likely to hold, and maintains a major data system — the Ocean Biogeographic Information System (OBIS) — that brings together in an accessible format all of the data collected. New technology is being developed: advanced acoustic methods have been tested for tracking and mapping fish populations instantaneously over thousands of square kilometers, as have optical imaging of small and microscopic life forms, telemetric technologies for identifying and characterizing ocean hotspots for large predators and quantitative tracking approaches for global use. The Census also uses natural DNA labels to keep track of known and newly found species.

Photo: Larry Madin, Woods Hole Oceanographic Institution, US

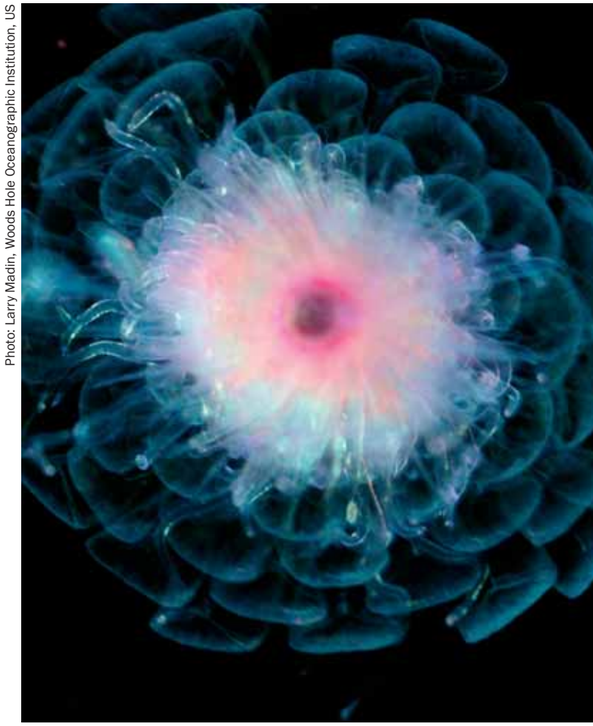


Image of newly discovered species: *Athorybia rosacea*, an animal that looks like a flower, flapping its petal-like appendages to swim

In summary, the Census of Marine Life focuses on providing a representative, quantitative record of biodiversity of organisms from microbes to large marine mammals through the 1.5 billion cubic kilometres of the ocean, looking back five hundred years through historical records and forward fifty years using forecasts of ecosystem patterns.

Management
The Census is coordinated by a Secretariat in Washington, DC and governed by an international scientific steering committee as well as several national and regional committees. Support for the Census comes from government agencies concerned with science, environment and fisheries in a growing list of nations as well as from private foundations and companies. The Census is associated or affiliated with a number of intergovernmental and non-governmental organizations.

Census achievements

The Census began in 2000 and its first comprehensive report on findings will be released in 2010. It has achieved several goals that will contribute to this.

Photo: US National Oceanic and Atmospheric Administration (NOAA)

A dense bed of hydrothermal mussels and shrimp covering the slope of the Northwest Eifuki volcano near the Mariana Arc in the western Pacific ocean

Comprehensive assessment of the state of estuaries and coastal ecosystems
Scientific assessments of the changing environment provide the foundation for sustainable management of resources. A Census study of human impact on ecological change traced changes from historical times to the present in species, species invasions, habitats and water quality in twelve estuaries and coastal seas in the US and Canada. This assessment determined how the decline of coastal seas accelerated in the last 150-300 years. This is the most comprehensive quantitative assessment of the state of estuaries and coastal ecosystems to date.

Basin-wide observations of migration patterns and ocean properties
As of 2007, researchers had tagged more than 2,000 animals and birds in the Pacific Ocean, providing unprecedented information on their behaviour. Tags attached to the animals transmit their positions and other information, revealing migration routes and areas where the animals gather to feed and breed. The data will help protect endangered species and help society better manage fisheries that are at risk of collapse.

An extraordinary and largely unexpected bonus of this programme is the transmission of important information about water properties. Temperature and salinity profiles, normally acquired at great cost from ships, are acquired by these 'animal oceanographers,' yielding a rich cache of data of interest to biologists as well as information sought by the oceanographic community — and the Global Ocean Observing System.

Establishment of the Ocean Biogeographic Information System
The Ocean Biogeographic Information System (OBIS) is an online, user-friendly system for absorbing, integrating, and assessing data about life in the oceans. OBIS is aimed at stimulating research generating new hypotheses concerning evolutionary processes, species distributions, and roles of organisms in marine ecosystems. Today, OBIS contains more than 13.4 million records of 82,000 species of marine life from 222 databases. All data are freely available over the Internet and interoperable with similar databases. Software tools are available for data exploration and analysis. Any organization, consortium, project or individual may contribute to OBIS. Given its strengths and global role, OBIS will be a key data management contribution to the overall framework of GEOSS.

How the Census contributes to GEOSS
The Census of Marine Life contributes to GEOSS by laying the groundwork for global biological monitoring in several GEO societal benefit areas.

Biodiversity
One of the goals of GEOSS is to develop a biodiversity observation network on land and for the ocean. The Census, through its various ocean realm projects, provides the information that will guide the development of such a global network. The Census work can facilitate the establishment of monitoring systems and help achieve consensus on data collection protocols and interoperability.

Another goal of GEOSS is to capture historical data on biodiversity from natural history collections in databases and museums as well as from field programmes — data that is critical to the design of observational systems and predictive models. The Census project on the History of Marine Animal Populations aims to improve our understanding of ecosystem biodiversity by focusing on long-term changes in stock abundance and the ecological impact of large-scale harvesting. It helps to answer the question 'what lived in the oceans?'

Agriculture and fisheries
Salmon provide an important economic and protein resource in some parts of the world, but little is known about their migration and life history. The use of acoustical tags is yielding new insights on the marine life history of Pacific salmon as well as promoting the application of new tagging technology. The tagging of an increasing variety of other valuable species is contributing to our understanding of their life history. An international exploration of the macrofauna of the northern mid-Atlantic Ridge ecosystem is revealing comprehensive information on the processes controlling their distribution and the community structures.

Ecosystems and habitat documentation
Through its work on ecosystems of coral reefs, oceanic ridges, the open ocean and the polar regions, the Census is defining potential protected areas related to fish habitats, deep sea corals and predator hotspots and helps to answer the question, 'what lives in the oceans?' The ecosystem data collected through the Census is being used, for example, to establish areas of reduced fishing in the Northeast Atlantic. Coral reef information helps gauge the impacts of rising temperatures and ocean acidity on this habitat. Studies of past oceanic biodiversity and abundance provide information useful for management on the status of stocks prior to or in early stages of exploitation.

The ecosystems on shallower oceanic features such as seamounts and hotspots, both of which have become targets for unregulated over-exploitation, are also being studied by the Census. The UN Convention on the Law of the Sea is still dealing with defining regulations for the shallower parts of the open ocean. Census projects are providing crucial information and technologies to recognize and manage these ecosystems.

Forecasting what is likely to happen to ecosystems — what will live in the oceans — is being carried out by a network of statisticians and mathematical modellers. Models will focus on sampling design and assimilate data in order to understand the transformation of marine life in earlier times to present conditions, and to forecast the likely future.

Climate
Marine life is sensitive to climate change over a wide range of latitudes; the database developed through Census activities will contribute to charting its response. The Census has research programmes in both polar regions that will guide long-term biological monitoring beyond the International Polar Year. The Census is surveying the Southern Ocean to understand the biological diversity of this unique and poorly understood environment. Global warming is transforming the Arctic sea: the year-round ice realm may cease to exist within the next 50 to 100 years. The Census includes an international collaborative effort to inventory biodiversity in the Arctic sea ice, water column and sea floor.

Status of the Census today; plans for the future
Having begun in 2000, the Census of Marine Life is now in its seventh year of studying life in the sea. Each of the projects is mature and providing new insights and information, and OBIS is collecting and disseminating information as required. Because of its very nature, this work must continue well beyond the end of currently planned field and ocean realm projects.

The principal goal of the Census in 2010 is to have a representative record of global marine biodiversity patterns, available through OBIS, that can be used to enable commercial, legal and conservation interests to deal sustainably with ocean biodiversity. For example, the data in OBIS is proving valuable as nations develop Marine Protected Areas to preserve biodiversity and increase sustainability of fisheries. In addition to this information, the Census will provide legacies of proven technology and science input to management principles and international cooperation. Especially important is the legacy of demonstrating that a coordinated, multifaceted effort to explore ocean biodiversity can make real inroads on this seemingly overwhelming but vitally important task.

In 2010, the Census fieldwork will end and its first comprehensive report on the status of knowledge of marine biodiversity will be released, with a focus on integration, synthesis and visualization. The work of the Census will have provided both the knowledge and technology for future marine biological monitoring systems.

The UN General Assembly has called for regular Global Marine Assessments, and the Census intends that its realm projects and OBIS will become standards for these. Similarly, agencies around the world have called for an 'ecosystem approach' to sustainable fisheries management within their Exclusive Economic Zones. What could be more important to managing an ecosystem than knowing what lives there?

It is important to note that the Census has been funded as a research programme. Long-term monitoring of ocean biodiversity will depend on long-term support within an operational GEOSS framework. By emphasizing the societal benefits of global systematic biodiversity measurements and associated data systems, GEO can bring awareness at the ministerial level of the green ocean and all life in the sea, and the critical need for long-term stable funding for these observations. At the same time, the breadth of GEO will encourage collaborations among the Census and related biodiversity programmes to identify and fill remaining gaps so that the societal benefits of GEO can be met.

Looking beyond 2010, the Intergovernmental Oceanographic Commission of UNESCO has initiated discussions with the Census to develop a strategy for building a long-term biological monitoring programme. Such a programme will eventually be an integral part of GEOSS, and will provide it with the marine biodiversity data essential to society's needs.

Photo: Dan Costa, University of California, Santa Cruz

An elephant seal with a satellite tag attached