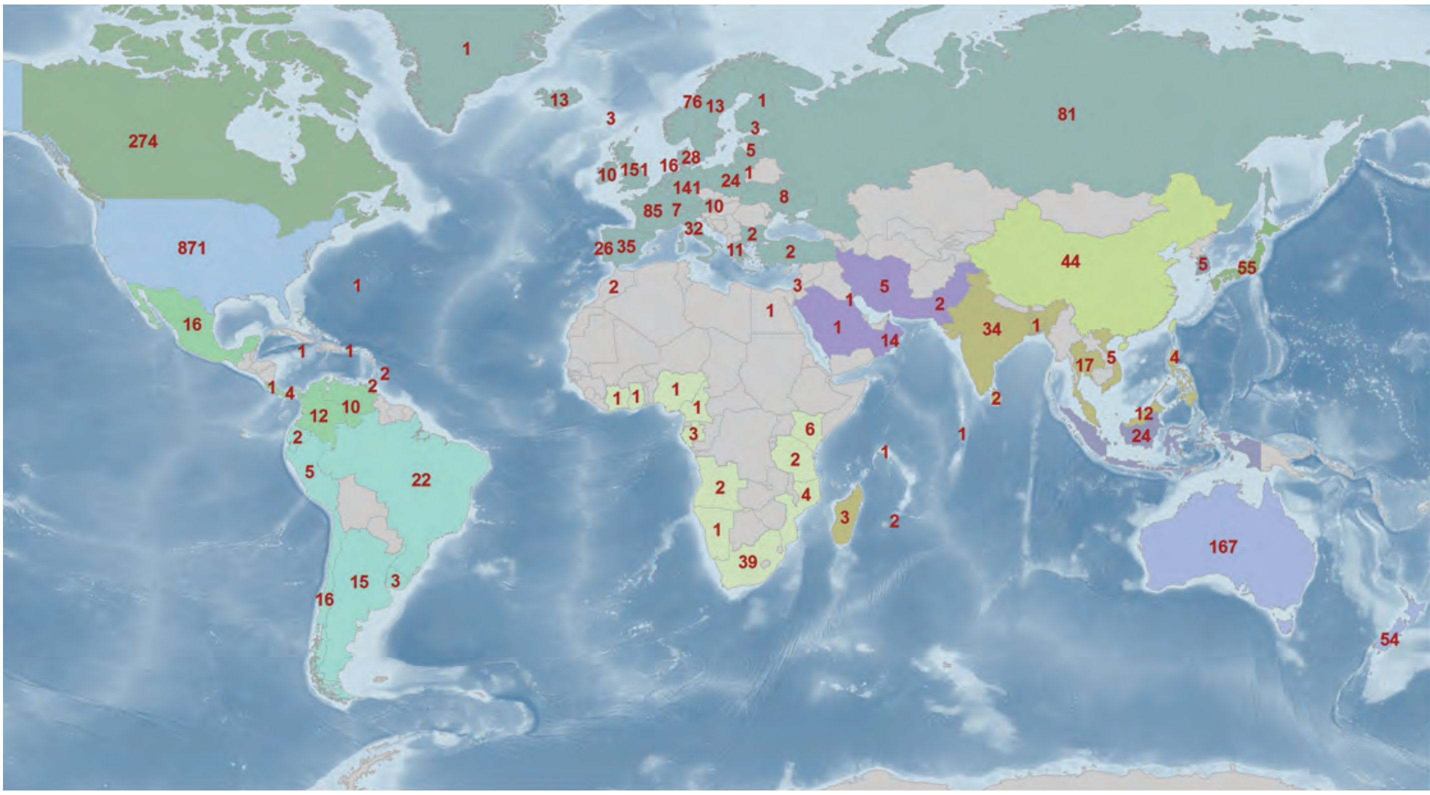
SCIENTIFIC RESULTS TO SUPPORT THE SUSTAINABLE USE AND CONSERVATION OF MARINE LIFE

A SUMMARY OF THE CENSUS OF MARINE LIFE FOR DECISION MAKERS

www.coml.org



1. Number of Census of Marine Life collaborators by country. Shaded regions indicate countries involved through its various national and regional committees. *Source: Jesse Cleary, Census of Marine Life Mapping and Visualization Team*

INTRODUCTION

Biodiversity is essential for the health of the planet and for humans because it underpins ecosystem functions that provide a wide range of goods and services to human societies. In the case of marine biodiversity, this means the use of marine life for food, energy, biomedical products, recreation, and climate regulating services, such as removal of carbon dioxide from and release of oxygen into the atmosphere. Some of these uses generate direct economic benefits to society, while the value of others, like climate services, is less tangible but no less important. Unwise use of the ocean, causing degradation and loss of biodiversity, negatively impacts its ecosystems functions, along with its ability to provide valuable goods and the invisible but necessary services.

Oceans cover more than 70 percent of the Earth's surface and sustain a much greater percentage of its biosphere. Despite their vast extent and their importance to planetary functioning and human society, the oceans and the life they contain are seriously understudied. Scientists estimate that humans have systematically explored only about five percent of the oceans. Recognizing this knowledge gap, the Census of Marine Life, a ten-year international research program completed in 2010, greatly enhanced what is known about life in the oceans while demonstrating that a global survey of ocean life was possible. The Census was a giant scientific partnership supported by the Alfred P. Sloan Foundation and over 500 other institutes and donors from more than 80 countries in Africa, Asia, Australia, Europe, North and South America, and Oceania. It brought together 2,700 scientists to establish a baseline of the diversity, distribution, and abundance of life in the ocean, against which future change can be measured. For policy makers and others who seek to sustainably use marine resources, the Census provides unprecedented scope, access to data and information, and tools and capacity for monitoring and study to better maintain, protect, and rehabilitate the oceans. The global overview provided by the Census also allows research managers and environmentalists to better prioritize conservation and research initiatives.

ACHIEVEMENTS OF THE CENSUS OF MARINE LIFE

The Census of Marine Life was a ten-year, $650 US million, scientific research and outreach program delivered between 2000–2010 by more than 2,700 scientists, supported by the Alfred P. Sloan Foundation and over 500 other institutes and donors from more than 80 countries [Figure 1]. Its achievements include:

• Established a baseline of marine life diversity, distribution, and abundance against which future change can be measured.

• Aggregated, as of January 2011, more than 30 million of species-level records obtained before and outside the Census and added millions more from its own field work, including 1,200 newly discovered and described species [Figure 2]. Another 5,000 or more await formal description.

• Created the Ocean Biogeographic Information System (OBIS), the world's largest online repository of geo-referenced data, which nations can use to develop national and regional assessments and to meet their obligations to the Convention on Biological Diversity (CBD) and other international commitments.

• Mapped migration routes and breeding areas that can be used to protect animals' oceanic transit routes.

• Identified well-explored areas and those where further exploration is warranted.

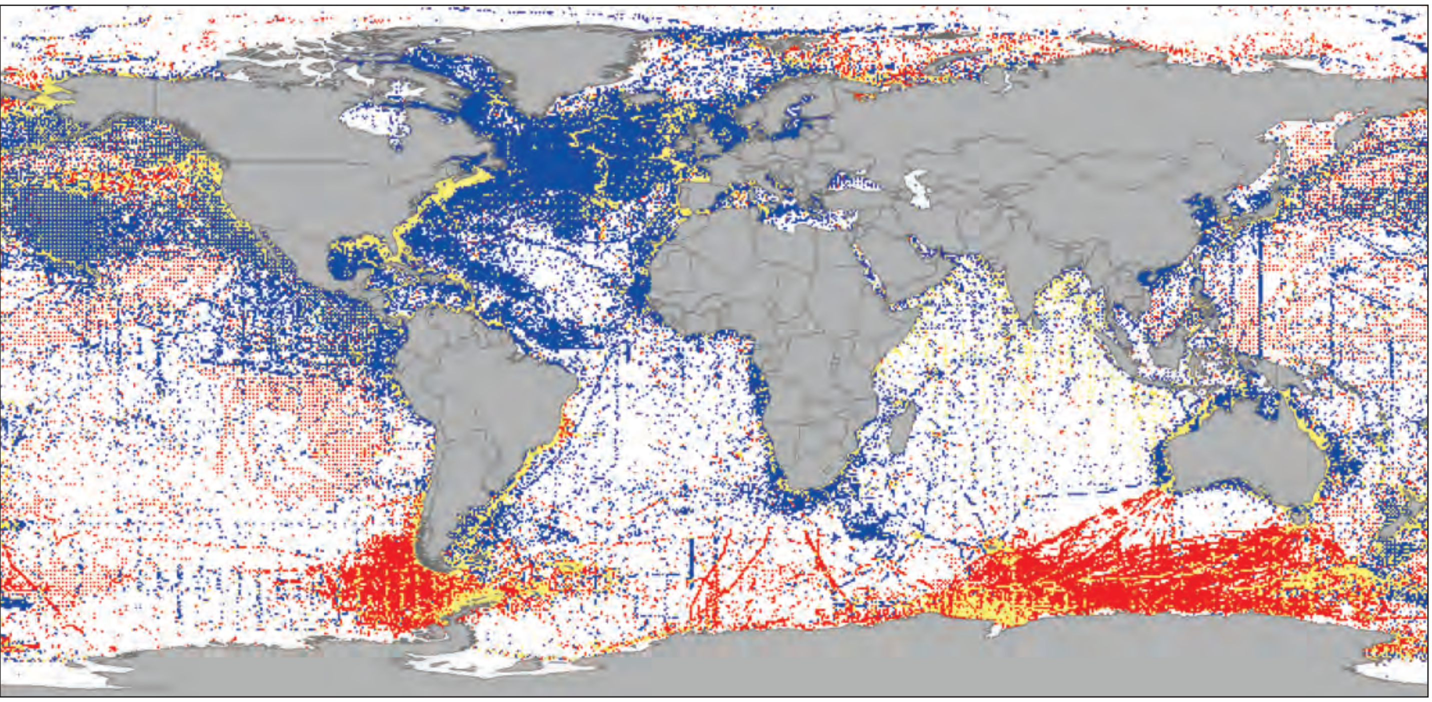
• Showed through studies of environmental history that some marine habitats and living resources have been impacted by humans for thousands of years. With protection recovery is slow but possible. Coastal and enclosed seas are the most impacted.

• Determined that past impacts in the deep sea were mainly from disposal of waste and litter. Today, fisheries, hydrocarbon, and mineral extraction have the greatest impact. In the future, climate change is predicted to have the greatest impact.

• Collaborated with the Encyclopedia of Life to complete ~90,000 marine species pages and continues to serve as the marine component of the Global Biodiversity Information Facility.

• Supported the World Register of Marine Species, which confirmed that, excluding microbes, approximately 250,000 valid marine species have been formally described in the scientific literature, with an estimated at least 750,000 more species remaining to be described.

• Built individual, institutional, national, and regional capacity. Through its young alumni, the Census will contribute to marine life knowledge for decades to come.



2. A global map of the nearly 30 million OBIS records of 120,000 species from more than 800 datasets shows the known and unknown ocean. In blue areas, the Census has aggregated data from before the Census began and from partner programs and institutions, often assembled by OBIS regional and thematic nodes. Yellow indicates regions with data both from Census partners and from the Census's own expeditions. Red indicates regions with data from Census expeditions where there were no prior data. Even with this decade-long global inventory, Census scientists could not conclusively determine how many species remain to be discovered, though they agree the number is at least 750,000. The gaps show that the inventory is as yet too incomplete even for first order estimates. New marine species, even large ones, are still found during almost every biological expedition. *Source: Ocean Biogeographic Information System*

The Census of Marine Life: A New Baseline for Policy

The Census global baseline of information about marine biodiversity focused on the species level of classification and also developed novel technologies relevant to studies below the species level.

While the Census discovered that ocean life is richer than imagined, it also found the ocean is more connected and more impacted than previously thought. Historic baselines of abundance, garnered from catch records, monastery records, fish bones, shells, and other credible documentation, show people began intensively exploiting and depleting marine life thousands of years ago.

The Census performed comprehensive regional and global analyses of marine species diversity. From the global synthesis of 13 taxa from zooplankton to mammals, two major patterns emerged: (1) in the open oceans, diversity peaked in mid-latitudes or in subtropical "strips" in all oceans; and (2) coastal species were most diverse in tropical areas such as Indonesia, Southeast Asia, and the Philippines. A Census review of all known marine biodiversity in 25 regions confirmed the coastal pattern. Sea surface temperature, which is significantly impacted by climate change, was the only environmental predictor highly related to diversity across all 13 taxa [Figure 3].

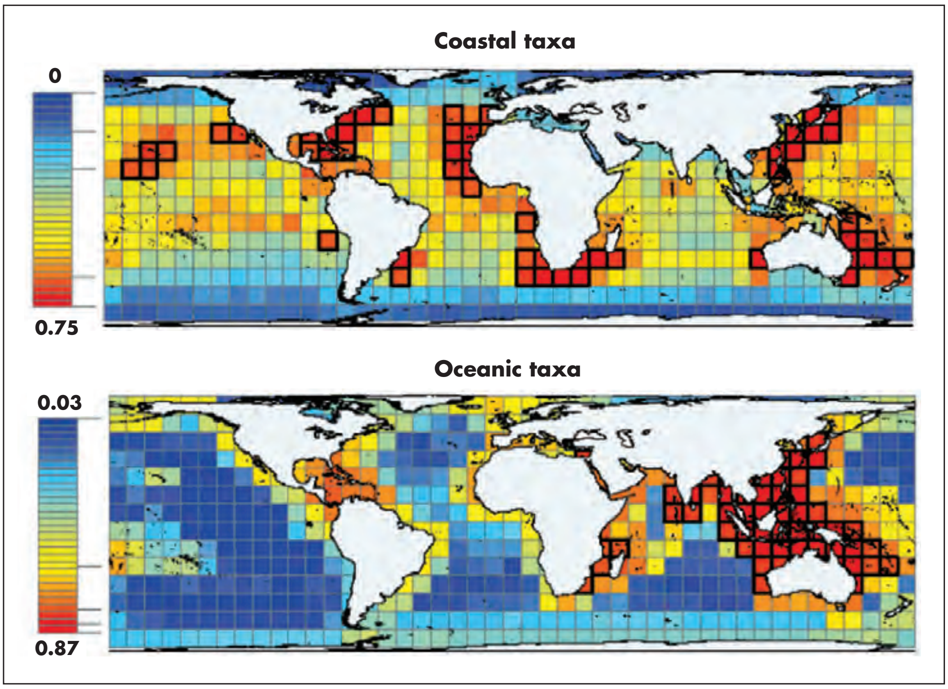
The Census supported the World Register of Marine Species, which confirmed that, excluding microbes, approximately 250,000 valid marine species have been formally described in the scientific literature. Scientists estimated at least 750,000 more species remain to be described. Little is known about the great majority of species. The best-known marine animals such as whales, seals, and walruses comprise only a tiny part of marine biodiversity. More than a billion types of microbes may live in the oceans. In the ocean, a small number of types dominate and thousands of low-abundance populations account for most of the observed diversity. Changes in this highly diverse "rare biosphere" may have profound impacts on the Earth's ecosystems.

Reason for Concern and Hope: Degradation and Rehabilitation of Marine Life

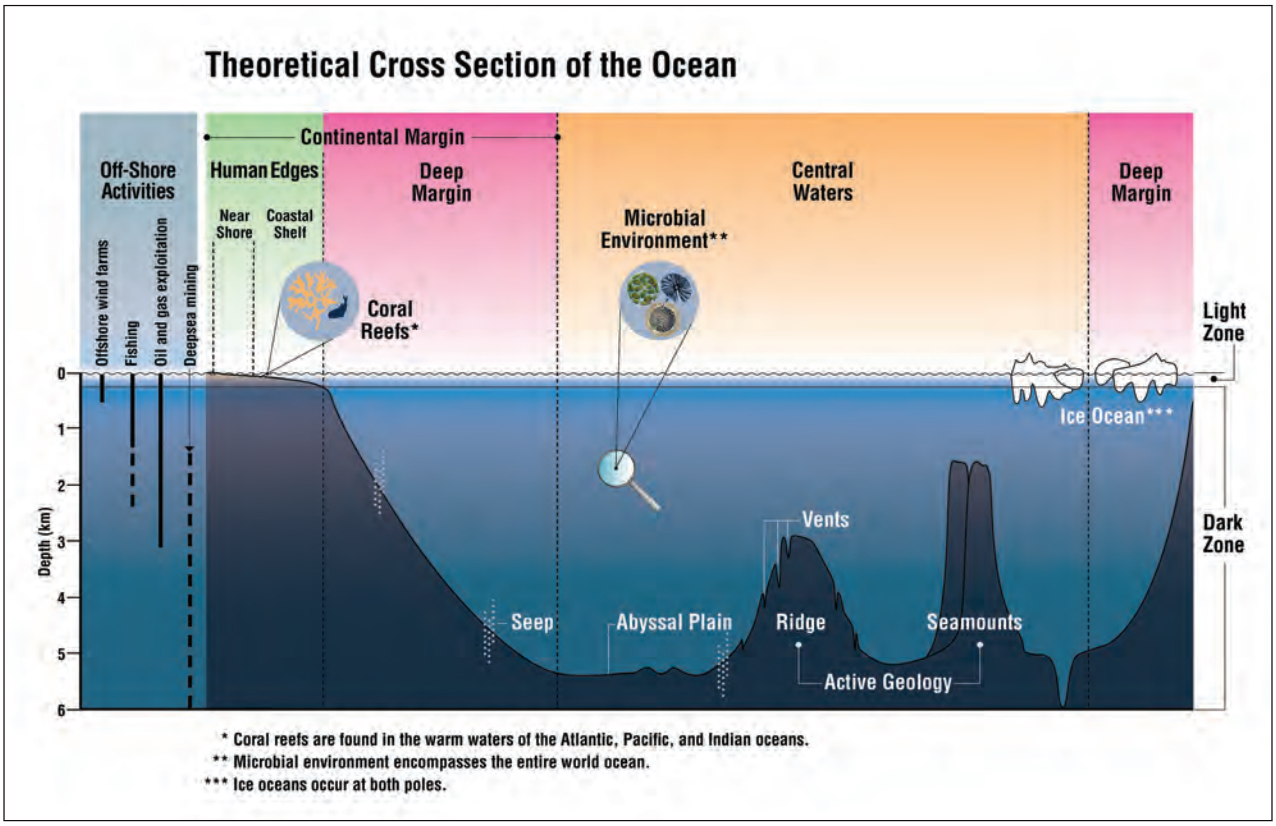
Biodiversity is under greatest threat in the enclosed seas and areas with high population density such as the Mediterranean, Gulf of Mexico, Baltic, Caribbean, and China's continental shelf. Marine industries and land-based pollutants are creating ever greater impacts on the health of ocean ecosystems, direct exploitation is reaching deeper depths, sectoral uses are overlapping [Figure 4], and passive dispersion and accumulation are contaminating all ocean realms [Figure 5].

The human footprint on the global ocean is not new. Research from the Census based on a study of 12 temperate coastal and estuarine ecosystems showed that over the centuries, human activities have eliminated 65 percent of seagrass and wetland habitat. Declines and range contractions were measured for the once abundant Atlantic bluefin tuna, *Thunnus thynnus,* off the coast of northern Europe, whose population was depleted in 40 years (1910 – 1950) and still remains rare there today. The numbers and sizes of exploited large marine animals have declined from their historic levels by, on average, 90 percent.

Census scientists estimated the global past, present, and future impacts of human-related activities on the deep sea, which harbors high biodiversity and is the largest and least known ecosystem on the planet. In past



3. Records of 11,000 marine species from tiny zooplankton to sharks and whales assembled in the Ocean Biogeographic Information System of the Census revealed hot spots of species diversity. The diversity of coastal species tended to peak around Southeast Asia, while the high diversity of open-ocean creatures spread more broadly across the mid-latitude oceans. Red indicates areas of high diversity. *Source: Tittensor DP, Mora C, Jetz W, et al. 2010. Nature 466, 1098–1101*



4. The Census of Marine Life created a baseline against which future change can be measured, which will be particularly useful as competing ocean uses continue to expand. Marine industries and land-based pollutants are creating ever greater impacts on the health of ocean ecosystems, direct exploitation is reaching deeper depths, and sectoral uses are overlapping—trends that are expected to continue.
Source: Williams MJ, Ausubel J, Poiner I, et al.

decades, disposal of waste and litter had the most significant anthropogenic impact on the deep sea. Presently, the biggest impact comes from exploitation (e.g. fisheries, hydrocarbon, and mineral resources). In the future, climate change is likely to bring more global effects, including warming, ocean acidification, and expansion of hypoxic and oxygen minimum zones.

Partly because evidence is more complete for larger species, the biggest changes and depletions in the ocean appear to be occurring in larger species that have been commercially fished and to species in coastal areas. Much less well known are the changes occurring in smaller organisms, as the historical records for these animals are almost non-existent. With the baseline information that the Census has provided on this segment of the ocean's population, future estimates of abundance and ways to protect them might be possible.

5. Looking for marine life, Census researchers instead collected a trawl of trash in the Eastern Mediterranean. *Source: Brigitte Ebbe/ Michael Türkay, Census of Diversity of Abyssal Marine Life*

Climate change predictions for marine life were investigated for coral reefs and the Arctic. Coral reefs are at high risk of extinction due to greenhouse gas emissions and the effects of ocean acidification. Reductions in Arctic sea ice are diminishing the substrate for ice-related flora and fauna, while increasing light levels and temperatures in regions previously covered by ice.

The good news is that recovery is possible if action is taken. Where conservation efforts were implemented, populations of some species, such as seals, whales, birds, and such bottom-dwelling fish as flounder and sole, recovered. In contrast to rapid depletion, however, recovery tends to be slow. Census researchers found that population increases were most notable for species whose exploitation ended at least 100 years ago and for some other species that became protected in the early to mid-twentieth century.

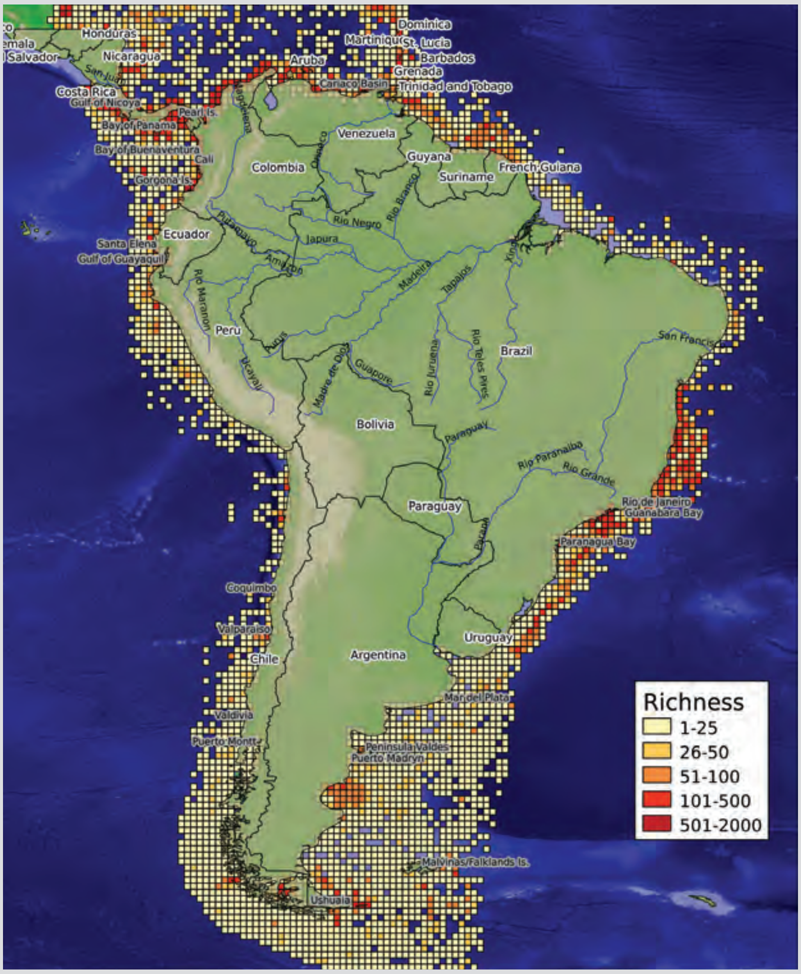
OBIS: MAKING MARINE LIFE DATA ACCESSIBLE TO ALL

One of the most important outcomes of the Census of Marine Life is the repository for its global inventory, the Ocean Biogeographic Information System (OBIS). OBIS is a gateway (www.iobis.org), to over 800 datasets containing information on where and when more than 30 million marine organisms have been recorded. OBIS is the world's largest online repository of geo-referenced data. Its datasets are integrated so they can be seamlessly searched by species name, higher taxonomic level, geographic area, depth, and time. OBIS allows users to identify biodiversity hotspots and large-scale ecological patterns, analyze distributions of species over time and space, and plot species' locations with temperature, salinity, and depth.

At its 2009 General Assembly, the UNESCO Intergovernmental Oceanographic Commission adopted OBIS as one of its programs under the International Oceanographic Data and Information Exchange (IODE). With the support of policy makers and nations it serves, OBIS will continue to grow and thrive under IODE, remaining a permanent legacy of Census collaboration.

OBIS is a powerful tool for many management applications, including assisting nations to meet their obligations to the Convention on Biological Diversity to report on the biodiversity in their exclusive economic zones. OBIS builds capacity for countries with limited resources to meet national reporting requirements and makes data and information management more efficient through shared data, tools, and standards across different organizations and countries [Figure 6].

Before posting, OBIS data undergo a rigorous vetting process, including confirmation of its source, with quality control completed initially and at regular intervals thereafter. Data providers retain ownership of the data and are informed of any discrepancies and possible errors that may occur. OBIS benefits from user peer-review and feedback that identify technical, geographic, and taxonomic errors in the data served. Although errors will exist in such a large data collection, the data in OBIS are the best available in electronic form.



6. Map showing the distribution of marine biodiversity around the South American continent using data from the OBIS database. *Source: Eduardo Klein, Universidad Simón Bolívar*

In the coastal environment, researchers documented that the fastest path to recovery was achieved by mitigating the cumulative impacts of human activities. Seventy-eight percent of documented recoveries occurred, for example, when at least two human activities, such as resource exploitation, habitat destruction, and pollution, were reduced. Likewise, for top predators, recovery was noted for seals, whales, birds, and some bottom dwelling fish, such as flounder and sole, when actions were taken to protect their numbers.

Improved Knowledge of Biodiversity for Sustainable Use and Conservation

The Convention on Biological Diversity (CBD) recognizes the complex nature of biodiversity and aims to protect it at three levels: within species, between species, and at the ecosystem level. Relevant to marine biodiversity protection and management, the Census provides considerable scientific knowledge on marine biodiversity, particularly at the species and ecosystem levels. Measurement of the diversity within species for larger organisms, which is essential to maintaining species capabilities to adapt, remains a challenge for the future.

INNOVATIVE TOOLS ADVANCE FINDINGS

While the Census focused on species-level biodiversity, tools such as tagging technologies and low-frequency acoustics for estimating the large-scale distribution and abundance of pelagic species, can assist management of marine life populations at a stock or sub-species level, such as through tracking stocks of salmon and tuna. Enhanced capacity to track population components of commercial species, combined with genetic information on individual fish and their pedigrees, is improving information for managing specific and intra-specific marine resources and genetic biodiversity.

The information and technologies developed or adapted by the Census are tools that can be used now and in the future to increase confidence in decisions for achieving sustainable use of marine life.

1. Tools, Technologies, and Methods for Ecosystem Management Approaches

Since the 1972 Stockholm United Nations Conference on the Human Environment, governments have recognized that protecting and improving the environment from deleterious human activities needs integrated approaches. Reconciling the demands of different ocean uses has become urgent. Slowly, countries and international bodies have strengthened their commitments to integrated management by adopting marine spatial planning and ecosystem approaches to management. Some examples include the 2002 World Summit on Sustainable Development's International Plan of Implementation, decisions by the 2010 Committee of the Parties of the Convention on Biological Diversity, and national bioregional planning schemes in Australia, Canada, Korea, Norway, the United States, the United Kingdom, and the European Union Marine Strategy Framework Directive.

Preserving the structure and natural resilience of an ecosystem requires greater scientific information than does a traditional sector or species-based approach. The additional costs of this process should be shared across all sectors, and new legislation, management, and consultative processes are needed.

Many management decisions are constrained by a lack of adequate data. The Census has been involved in three significant ways in helping to overcome such data constraints: consolidating existing information, developing tools for rapid collection of new and detailed data, and piloting ecosystem-based approaches to management.

• ***Consolidating existing information, creating baselines.*** Typically, different ministries, museums, industries, science agencies, and even individual scientists collect and maintain biodiversity data. Sharing data is a challenge. The Census was committed to open access data, information and knowledge and through OBIS and its National and Regional Implementation Committees initiated the first, or most, comprehensive consolidations of biodiversity information across all databases and other sources (e.g. Antarctica, South America, Australia, Canada, Japan, New Zealand, South Africa, United States, Western European Margins, and the Baltic, Mediterranean, and Caribbean Seas). Furthermore, as a legacy of the Census, OBIS has become part of a fully intergovernmental process, guaranteeing open and free access to ocean biodiversity data (see sidebar: *OBIS: Making Marine Life Data Accessible to All*).

Such consolidations offer both scientific and management value. In the Gulf of Mexico in 2009, for example, researchers completed a comprehensive regional assessment of the species that live in the Gulf of Mexico, providing a baseline prior to the BP oil spill in 2010 [Figure 7]. This information will be valuable as scientists and managers attempt to understand the magnitude of the spill and its effects on marine life in the coming years to improve management and industry practices.

• ***Efficient data collection and monitoring technologies.*** New genetic, sensing, animal tracking and information technologies, and their combinations can rapidly and comprehensively collect, manage, and make accessible new data for ecosystem approaches. The Census helped to advance molecular genetics tools for easy and rapid identification of marine species. DNA barcoding and 454-pyrotag sequencing, for example, use very short genetic sequences from a standard part of the genome to identify each unique species or type of

ECOSYSTEM APPROACH ADOPTED TO PRESERVE BIODIVERSITY

The CBD defines the "ecosystem approach" *as Ecosystem and natural habitats management... to meet human requirements to use natural resources, whilst maintaining the biological richness and ecological processes necessary to sustain the composition, structure and function of the habitats or ecosystems concerned.* Similar to land and urban planning, marine spatial planning has arisen to provide order and predictability to multiple ocean uses at scales smaller than those provided by global bodies, such as the United Nations Convention on the Law of the Sea and the Convention on Biological Diversity.

microbe. As new tools in taxonomists' toolboxes, these will become increasingly important if the current shortage of taxonomists persists.

Complementing the genetic advances, a project on coral reefs developed Autonomous Reef Monitoring Structures, 500 of which are now deployed in the Pacific and Indian oceans and the Caribbean. These structures collect specimens and ecological data that are used to monitor tropical coral reef biodiversity. Collected specimens are analyzed using DNA barcoding techniques, which gives an overall picture of the biodiversity in an area [Figure 8].

The Census has contributed much to advancing the biological components of the incipient Global Ocean Observing System, from serving as a prototype for the Ocean Tracking Network , a growing global network of seafloor-mounted microphones to track salmon and other migrant animals, to developing new sonar devices that make it possible to observe how marine life assembles over huge areas, forming shoals in a matter of seconds, to creating a legion of "bio-logger" animals that transmit data about oceanographic conditions in which they travel. In addition, the Census has worked to standardize the way global data is collected, allowing for comparisons between regions.

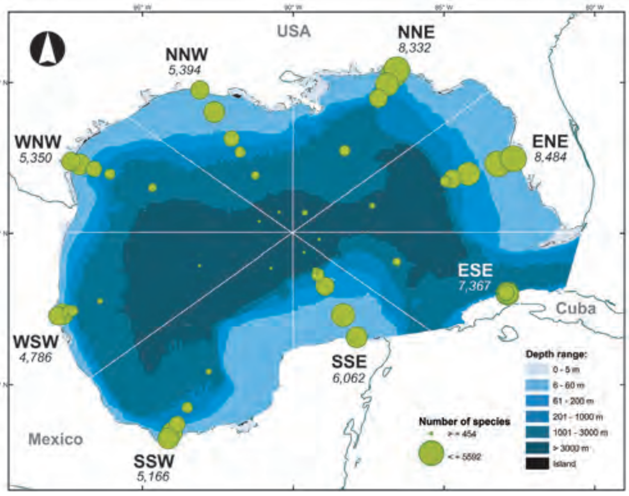
• ***Piloting ecosystem-based management.*** The Census helped pioneer work on the ecosystem approach to management through a pilot study making use of the well-researched Gulf of Maine ecosystem. The project used new technologies and an ecosystem approach to go beyond species information to learn about populations, their habitats, and animal interactions with one another and their environment. The findings have enhanced the capacity to track the abundance of the population of commercial species and provide improved indicators of ecosystem health.

2. Information for Marine Protection Decisions at the Ecosystem Level

Already, Census of Marine Life technology, tools, and data have been used in governance and management for protecting marine life. In the future, such uses will increase.

• ***Deep-sea ecosystems.*** The *Global Biodiversity Outlook 3*, published in 2010 by the Convention on Biological Diversity, noted increasing concern for deep-water habitats, such as seamounts and cold-water corals. These slow-growing marine life communities can be vulnerable as new fisheries resources are discovered, then exploited. Providing for precautionary protection before exploitation is a challenge, especially in areas beyond national jurisdictions, such as beyond the 200 nautical mile limits of countries or outside jurisdictional areas of regional fisheries management organizations. Several Census projects have been at the forefront of working with industry, policy makers, and conservationists to help provide data upon which decisions can be based.

Even where data are scarce, indicator species of certain ecological assemblages can be used as proxies to suggest which areas to protect. Through modeling, Census scientists have predicted the likely distribution of deep-sea corals that not only are indicator species, but also highly vulnerable to impacts from fishing and mining. Regional fisheries management organizations, such as the South Pacific Regional Fisheries Management Organization, have used Census information on indicator species to predict where habitats sensitive to fishing might occur.



7. The Harte Research Institute, a Census affiliate, published the first baseline of marine life in the Gulf of Mexico in 2009 and made it available online shortly thereafter. The assessment listed 15,419 species, 8,342 of which were recorded in the area of the BP oil discharge. *Source: Harte Research Institute*

8. Artificial Reef Monitoring Structures are small boxes made out of PVC with many tiny holes for invertebrates such as crabs, and mollusks to inhabit. They are designed to mimic the reef environment, and after a year or two the boxes are removed from the reef and studied to see what organisms settled inside and on top of them. *Source: Andy Collins, National Oceanic and Atmospheric Administration*

The deep-sea projects of the Census that investigated vents and seeps, seamounts, and abyssal plains gave definition to previously hinted-at links between biodiversity and the occurrence of valuable living and non-living resources. The Census greatly expanded the knowledge of (1) cold water corals along margins and seamounts associated with commercial fish stocks, (2) luxuriant chemosynthetic communities of large worms, mussels and clams, as well as bacterial mats associated with cold seeps on continental margins that are rich in methane and are linked to oil reservoirs and gas hydrates, and (3) highly productive ecosystems, rich in life due to chemosynthetic bacteria living in symbiosis with large organisms (e.g., worms and molluscs), and found on oceanic ridges associated with hot vents rich in sulphides, methane, and minerals like copper, gold, silver, and zinc.

Based in part on Census work on deep-sea coral associations with seamounts, the North East Atlantic Fisheries Commission in 2009 voted to close more than 330,000 sq km to bottom fisheries on the Mid-Atlantic Ridge, an area larger than the United Kingdom and Ireland combined. At the Oslo-Paris Commission, several proposals for high-sea marine protected areas were submitted and endorsed at the ministerial level, again using Census information from the mid-Atlantic. In late 2008, the Commission for the Conservation of Antarctic Living Resources protected two Vulnerable Marine Ecosystems from long-line fishing, based on images and samples of large red seaweed assemblages from Census Antarctic researchers.

The Census chemosynthetic vents project helped conduct an environmental impact assessment of possible biodiversity impacts of deepwater mineral extraction for deep-sea mining companies in Papua New Guinea and worked with the International Seabed Authority to develop *Codes for the Environmental Management of Marine Minerals*. Census data fed into designing a Preservation Reference Area network of the International Seabed Authority to manage potential mining for polymetallic nodules in the Clarion-Clipperton Fracture Zone of the central Pacific Ocean.

• ***Identification of ecologically or biologically significant areas and vulnerable marine ecosystems.*** Census information was pivotal in helping parties to the Convention on Biological Diversity (CBD) identify areas of potential future value that should be protected until they can be properly managed. The Census assisted the CBD in defining potential ecologically or biologically significant areas (EBSAs) in areas beyond national jurisdiction. In 2008, the CBD agreed on scientific criteria for EBSAs. These criteria were then tested by pilot illustrations for 15 different areas or species. Working with members of the Global Ocean Biodiversity Initiative (GOBI) and other researchers, Census researchers demonstrated the importance of organized, publically accessible data portals, such as OBIS, that could deliver the results of over 800 existing quality-controlled data collections, including all data gathered by Census projects.

This information was then used in a decision by the CBD at its 10th Conference of the Parties to effectively establish a repository and a process for identifying candidate EBSAs, emphasizing the use of the Census data through OBIS and GOBI. Once candidate EBSAs are identified, the United Nations General Assembly or other competent governing body could use them to implement management measures helping to conserve biodiversity, including the establishment of marine protected areas.

Input from Census researchers was also important in the United Nation's Food and Agricultural Organization discussions on management of deep-sea fisheries on the high seas, providing background information to national delegates formulating the final set of international guidelines for these vulnerable marine ecosystems.

• ***Tracking trans-boundary fisheries species.*** Many marine ecosystems are connected by ocean currents and shared stocks, thus trans-boundary issues are critical to decision makers in conservation, industry, and government. The Census used advanced tagging technologies on iconic trans-boundary fished species. For Pacific salmon, for example, individual fish were tracked from their home rivers in Canada along the British Columbia coast to Alaska. Atlantic bluefin tuna were tracked from the Gulf of Mexico to the Mediterranean and back again. These data reveal previously unknown information about species habitat such as natal homing of the tuna or ecosystem connectivity through the long-distance movement of animals. Tagging and tracking technology also documented that, in some parts of the ocean, species congregate, pointing to hotspots and migration corridors.

The Ocean Tracking Network, a Census legacy project supported by the Government of Canada and covering 14 ocean regions off all seven continents, is now applying advanced acoustic and tagging technologies. The project tags a wide range of marine species and records their location as they swim over "listening lines," lines of acoustic receivers situated on the ocean floor. Through the network, thousands of commercial and endangered marine animals will be tagged to increase understanding of what lives where and when in the oceans. Knowing where fish actually travel makes it easier to designate new marine protected areas, set shipping routes, and site oil and gas exploration.

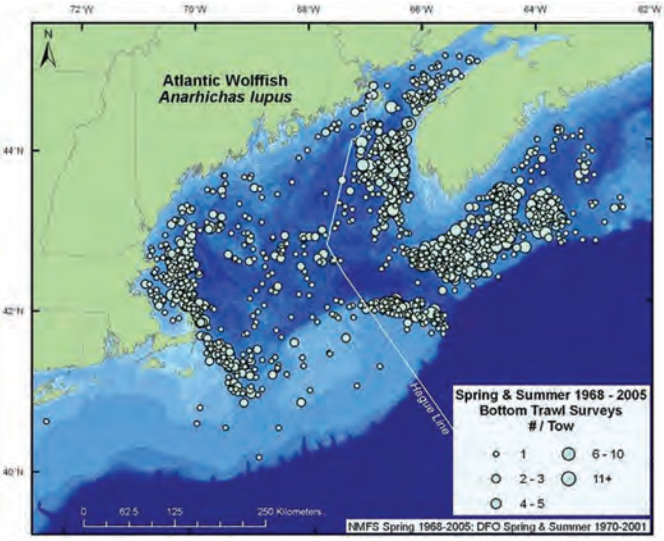
3. Information for Protecting Marine Species

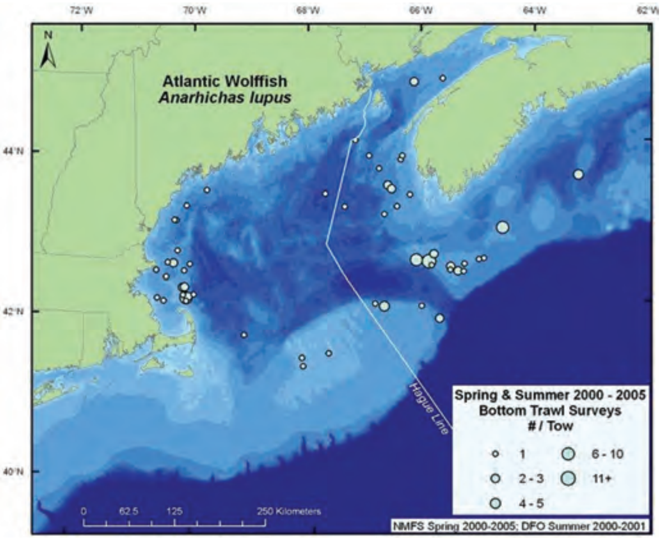
In addition to ecosystem-wide information, the Census, via OBIS, provided data for making species conservation decisions. OBIS provided geo-referenced global datasets on vulnerable and other species, which will aid in determining the species distributions. The history project of the Census also provided valuable perspectives on natural and anthropogenic changes in abundance in a geographic area over time and the effectiveness of management intervention. The likely historic abundance levels of key resources were reconstructed based on interpretation of datasets from early periods of marine fisheries, providing an improved objective basis for establishing targets for species recovery and improved understanding of recovery of a few species.

• ***Protecting species within national borders.*** The project studying the Gulf of Maine in the northeastern U.S. documented the spatial and temporal decline of the wolffish, *Anarhichas lupus*, over the past 20 years, and the data were used by petitioners who wanted the species listed as threatened or endangered under the Endangered Species Act. While the U.S. National Marine Fisheries Service reviewed the case and determined that there was not justification for listing, it did conclude that the fish should remain on the species of concern list. The maps show the decline of the wolffish in fishery-independent surveys from 1968 to 2005 [Figure 9].

• ***Discovering habitat and life cycle patterns of vulnerable species.*** Another Census project used bottom-based listening lines to create a database that contributed to the designation of a critical habitat area for threatened green sturgeon, *Acipenser medirostris*. Similarly, another Census project mapped the travels of 23 different species, including Atlantic bluefin tuna, *Thunnus thynnus*, great white sharks, *Carcharodon carcharias*, leatherback turtles, *Dermochelys coriacea*, and Northern elephant seals, *Mirounga angustirostis*, and Sounthern elephant seals, *Mirounga leonina*, that revealed breeding spots, migratory corridors and feeding areas, providing data for consideration of areas warranting designation as protected areas [Figure 10].

• ***International trade in endangered species.*** A fundamental aspect of the Convention on International Trade in Endangered Species (CITES) process is the correct identification and naming of species proposed for listing. OBIS and DNA "barcoding" techniques provide support to taxonomists proposing to list a species. Once such technology is easily accessible, it could also provide officials with a quick and inexpensive way to monitor and enforce the trade of endangered species.



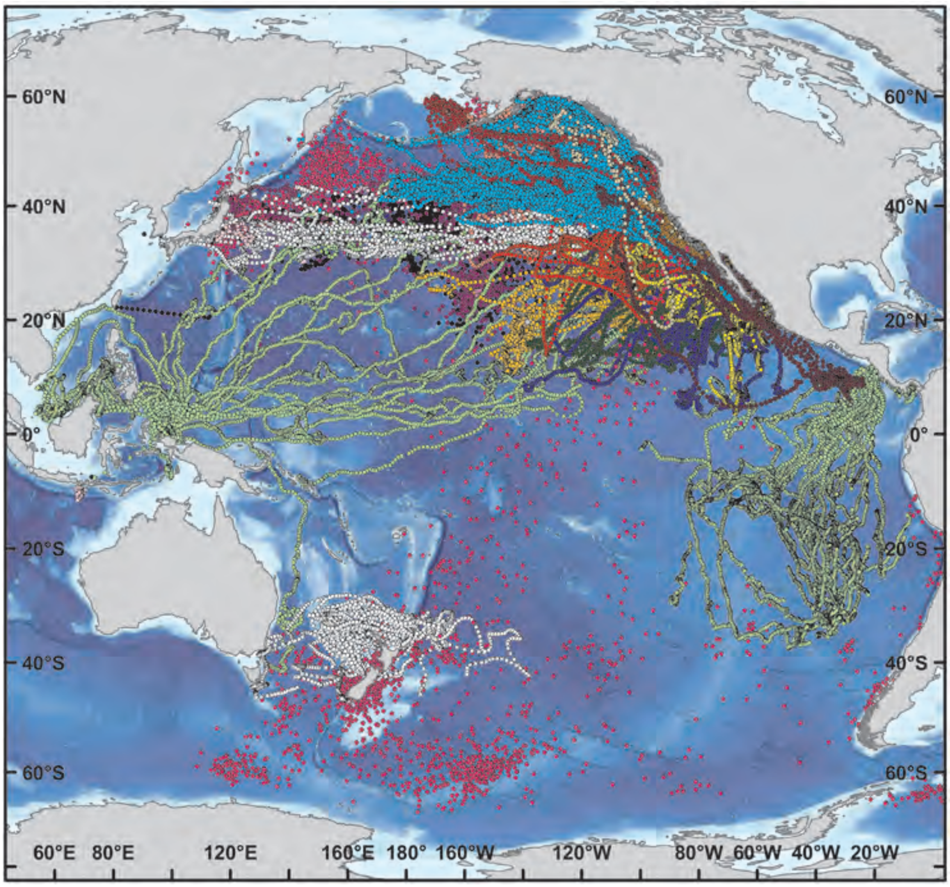


9. These maps show the decline of wolffish in U.S. National Marine Fisheries Service fishery-independent surveys from 1968 to 2005.
Source: Gulf of Main Area Project using data from the U.S. National Marine Fisheries Service and Department of Fisheries and Ocean, Canada, 2008

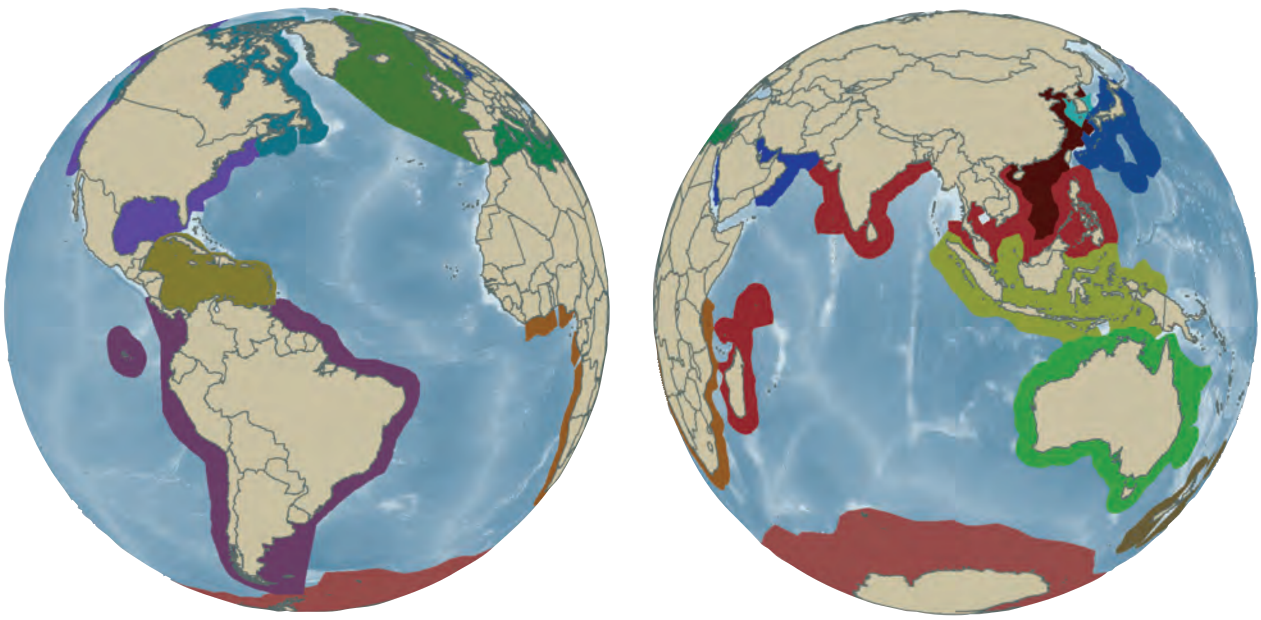
4. Building capacity

From the beginning, the Census sought and inspired global collaboration among scientists and stakeholders, essential to developing a good assessment of life in the oceans. The 2010 *Secretary-General's Report on Oceans and the Law of the Sea* (A/65/69) underlines the continuing "essential need for cooperation" to ensure that all States are able to implement the Convention on the Law of the Sea and participate in forums and processes regarding the oceans. As a global program that enhanced the capacity for marine research in all of its participating countries, including 50 developing countries, the Census of Marine Life served as a model for how this mandate might be met.

The Census built human, technological, and institutional capacity at the global, regional, national, institutional, and individual levels. At the national and regional levels, 13 networks were created [Figure 11] to



10. Reports from birds, fish, whales, and other animals carrying small tags reveal highways and neighborhoods of the vast Pacific. Census biologgers followed bluefin tuna, *Thunnus orientalis,* traveling between Japan and California and leatherback turtles, *Dermochelys coriacea,* between Borneo and Mexico. Traveling animals connect all the oceans. *Source: McIntyre AD, ed. 2010. Blackwell Publishing, Ltd.*



11. National and Regional Implementation Committees of the Census applied their expertise about nearby waters to compile a roll call of known species, estimated unknown species, and ranked threats to diversity. The numbers of species, the currency of diversity, ranged up to 33,000 in Australian and Japanese waters. Even in familiar waters, undiscovered species and microbes will swell the future number. *Source: Census of Marine Life Mapping and Visualization Team*

identify research targets in countries and enhance local support for marine biodiversity projects. Some support was financial, such as providing the means to build bridges between marine researchers and government and intergovernmental initiatives (such as Large Marine Ecosystems projects), and some was "in kind," such as the use of local scientists, vessels, and laboratories to accomplish Census research.

OBIS' open access to data from existing sources, regardless of location, enables countries to make the best use of limited data and strengthen the datasets through pooling from all possible sources. This may facilitate the repatriation of data, such as historical data collected pre-independence by colonizing countries.

The Census provided a framework for cooperation and, in some cases, seed funding to develop proposals for more marine biodiversity research. For example, the Census helped support the development of a successful Global Environment Facility proposal involving Indonesia, Timor-Leste, Papua New Guinea, and Australia including surveys of marine biodiversity and facilitating an integrated, cooperative, sustainable, ecosystem-based management of the Arafura and Timor Seas.

The Census also created educational opportunities [Figure 12], facilitated networking, and supported hundreds of up-and-coming marine scientists. Thus, through its young alumni, the Census will contribute to the generation of marine life knowledge for decades to come. Program funding largely flowed through universities and research institutions, creating opportunities for learning at all levels, from the work of dozens of post-doctoral fellows to graduate and even high school students, who participated in the nearshore monitoring project. Some projects sponsored early career professional development programs, such as training awards for new scientific investigators. Most of the Census projects also held taxonomic workshops to train young scientists in specialist skills and knowledge for particular taxa and ecosystems. These workshops, which contributed to the Global Taxonomic Initiative, were led by world experts who, in most fields, are increasingly rare, as recognized by the parties to the Convention on Biological Diversity.

The Census projects shared technologies and approaches across countries, resulting in increased institutional and personal capacity, shared data standards, and complementary sampling and data collection for regional and global analysis. In the coastal (tidal and intertidal) zone, where the nearshore project served as an ambassador project, international cooperation and capacity building were encouraged for inventorying and monitoring coastal biodiversity and linking Census goals with local interests.

Although the Census has helped to build capacity and awareness in new places, the needs are still great. With the help of its many partners, the capacity that has been built will continue on as one of the legacies of the Census.

12. The Census of Marine Life created many different types of educational opportunities—for grade school children to the post-doctoral level. *Source: Megan Moews, Census of Coral Reefs Ecosystems*

5. Partnerships that maximize impact

A primary goal of the Census was to generate knowledge of marine life and, therefore, its main partnerships were among scientists and their institutions. As the Census and its projects evolved, potential uses of the results began to emerge. To maximize the utility of its findings for management and policy applications, the Census built complementary relationships with other key partners and worked to raise public awareness of marine life.

Program-wide, the Census partnered with many, including the International Union for Conservation of Nature (IUCN), and the Convention on Biological Diversity. Both recognized the Census and OBIS as sources of unbiased scientific information. Led by IUCN, the GOBI initiative and partnership will continue to provide important services in translating scientific information into useful forms for open ocean policy makers.

The Census projects each worked with many international agencies to provide scientific input, including the International Seabed Authority, the Commission for the Conservation of Antarctic Living Resources, and the Food and Agriculture Organization of the UN, as well as various national regulatory agencies.

In 2009, the United Nations Environment Programme and the UNESCO Intergovernmental Oceanographic

CENSUS ENCOURAGED CAPACITY BUILDING

The Census created learning opportunities at all levels and provided advancement opportunities for young researchers such as Eva Ramirez Llodra (Spain) and José Antonio Faría (Venezuela).

Eva Ramirez Llodra
After earning a PhD in marine biology from the University of Southampton, Eva became involved with the Census as a post-doc at the National Oceanography Centre Southampton, where she agreed to coordinate the Census deep-sea project on biogeography of deep-water chemosynthetic ecosystems. Eva has since led the first global Synthesis of Biodiversity, Biogeography and Ecosystem Function in the Deep Sea, and is presently a co-principal investigator that will carry on the Census work in the deep sea called the International Network for Scientific Investigations of Deep-Sea Ecosystems Program.

José Antonio Faría
José Antonio holds a degree in Biology at Universidad Simón Bolívar, Venezuela. He became involved with the Census as an undergraduate student working in the Census nearshore project and works for the Miranda State Government, serving on the committee for education, science, and technology, which coordinates educational activities between the government and universities, research institutes, civil associations, and private companies.

Commission jointly published a survey of global and regional assessments and related marine activities, in response to the UN General Assembly (Resolution 57/141) and heads of states and governments at the World Summit on Sustainable Development, to establish a regular process for the global reporting and assessment of the state of the marine environment. This report (*UNEP*) noted the Census was one of few activities in the high and deep seas, which could help address new and emerging issues regarding the threats facing the deep sea. The report also cited the Census as a case study for lessons learned in undertaking a broadly scoped initiative.

Recognizing the need for public engagement and awareness, the Census partnered with National Geographic to produce videos and maps for the general public. These videos have reached millions of viewers around the globe via YouTube, Facebook, Twitter, and the Census portal, piquing the interest of Internet users who would otherwise be unaware of what lives below the waves. Additionally, news releases, reported on average by 24 global newswires and 321 online news sites (at least once in some 31 languages and from media sites spanning 95 countries) over the course of the Census, also helped to build public awareness. The Census collaborated with Galatee Films in the production of its *Oceans* movie, which brought marine life to millions of viewers around the world. In addition, Census projects have informed their local publics through museum and aquarium displays, school visits, art, and other outreach activities.

The Future of the Census of Marine Life and Marine Biodiversity Research

Marine biodiversity research has come a long way in the last decade, but, to continue to be useful to managers and policy makers, it needs to continue to grow and adapt to new challenges and questions that arise. Several of the Census of Marine Life projects will continue, and some have joined together to form new research programs, such as the International Network for Scientific Investigations of Deep-Sea Ecosystems. On the policy and managerial side, GOBI, spawned in part by the Census, will continue to use the Census network and data as it works towards protection of the open ocean and deep seas.

The marine biodiversity community will meet at the World Conference on Marine Biodiversity in Aberdeen in September 2011 to discuss the next phase of research and consider the big scientific questions that remain and how they fit into societal needs. However, much can be done with the information that is already available. On the next page are recommendations for how this information can be used to help maintain, protect and rehabilitate marine life.

CENSUS OF MARINE LIFE RECOMMENDATIONS FOR APPLICATIONS OF MARINE BIODIVERSITY RESEARCH IN THE NEXT DECADE

FOR GOVERNMENT AND INTERGOVERNMENTAL AGENCIES

• Use and adapt Census-developed national and global research partnerships (National and Regional Implementation Committees), information systems (OBIS), and methods and technologies to help meet biodiversity reporting and monitoring commitments.

• Develop further and make use of Census' National and Regional Implementation Committee, technologies, and OBIS for national and regional marine biodiversity protection and monitoring, such as in the designation of Marine Protected Areas, Vulnerable Marine Ecosystems, and Ecologically or Biologically Significant Areas.

• Support further development of OBIS in the International Oceanographic Commission-UNESCO through data contributions, expertise, and funding.

• Ensure that marine life monitoring is included in ocean observing systems under Group on Earth Observations Biodiversity Observation Network (GEO-BON).

FOR INDUSTRIES USING AND EXPLOITING THE MARINE ENVIRONMENT

• Contribute to marine life conservation and knowledge by supporting research, depositing marine biodiversity data in OBIS or linking company inventories with OBIS.

• Work with governments and researchers to create plans for sustainable ocean use, including national and regional marine spatial planning efforts and in open ocean areas beyond national jurisdiction here governance arrangements are still being built.

FOR DEVELOPMENT ASSISTANCE AGENCIES AND CONSERVATION FUNDING BODIES

• Build on the foundation laid by the Census to develop human and institutional capacity, infrastructure and technology in developing countries so that they are better able to better sustain their valuable marine biodiversity.

• Support opportunities to coordinate research and information in the deep seas, one of the most understudied, but potentially valuable, areas on the earth.

• Support initiatives that bring high quality, unbiased science to policy makers and managers.

FOR CONSERVATIONISTS, RESEARCHERS, AND EDUCATORS

• Make use of the results of the Census to inform and prioritize conservation and research activities.

• Support the sharing and enrichment of global, national and local information bases, especially OBIS and those linked to it. Update campaign, educational and public information materials about marine life, for example, local wildlife guides, in light of the results of the Census.

FURTHER READING

Cooke, Steven J., Scott G. Hinch, Anthony P. Farrell, *et al.* 2008. *Fisheries*. 33(7): 321-338.

Costello, Mark J., Marta Coll, and Roberto Danovaro, *et al.*, 2010. *PLoS ONE* 5(8): e12110.

Fuller, Erica and Les Watling. Petition for a rule to list the US Population of Atlantic Wolffish *(Anarhichas lupus)* as an endangered species under the Endangered Species Act, 2008.

Hoegh-Guldberg, Ove, Peter J. Mumby, Anthony J. Hooten, *et al.* 2007. *Science* 318, 1737-1742.

Lotze, Heike K, Hunter S. Lenihan, Bruce J. Bourque, et al. 2006. *Science* 312: 1806–1809.

Lotze, Heike K., Boris Worm. 2009. *Trends in Ecology and Evolution* 24(5): 254-262.

MacKenzie, Brian R. and Henn Ojaveer, editors. 2007. *Fisheries Research*, 87(2-3): 101-262.

McIntyre, Alisdair D., editor. *Life in the World's Oceans: Diversity, Distribution, and Abundance.* 2010. Blackwell Publishing Ltd, Chichester, 361 pages.

Ramirez Llodra, Eva, Paul Alan Tyler, Maria C Baker *et al. Deep diverse and definitely different, unique attributes of the world's largest ecosystem.* Submitted to *PLoS ONE*.

Schlacher, Thomas A., Ashley A. Rowden, John F. Dower, *et al. Marine Ecology:* Special issue: Recent advances in seamount ecology. September 2010. Volume 31, Issue Supplement s1: 1–241.

Secretariat of the Convention on Biological Diversity (2010) *Global Biodiversity Outlook 3*. Montréal, 94 pages.

Sinclair, Michael, Serge M. Garcia, and Meryl J. Williams. September 2010. Intecol e-Bulletin. Vol 40, No. 3, 30.

Tittensor, Derek P., Camilo Mora, Walter Jetz, *et al.* 2010. *Nature* 466, 1098–1101.

UNEP and IOC-UNESCO. 2009. *An Assessment of Assessments, Findings of the Group of Experts. Start-up Phase of a Regular Process for Global Reporting and Assessment of the State of the Marine Environment including Socio-economic Aspects.* ISBN 978-92-807-2976-4.

Williams, Meryl J., Jesse Ausubel, Ian Poiner, *et al.* 2010. PLoS Biol 8(10): e1000531.

ACRONYMS

CBD Convention on Biological Diversity
EBSAs Ecologically or Biologically Significant Areas
GOBI Global Ocean Biodiversity Initiative
IODE International Oceanographic Data & Information Exchange
IUCN International Union for Conservation of Nature
OBIS Ocean Biogeographic Information System
UNESCO United Nations Educational, Scientific and Cultural Organization

Acknowledgements

This document was prepared by Meryl Williams, Heather Mannix, Kristen Yarincik, Patricia Miloslavich, and Darlene Trew Crist with contributions by members of the Census of Marine Life Scientific Steering Committee—Vera Alexander, Patricio Bernal, Serge Garcia, Pat Halpin, Poul Holm, Ian Poiner, and Myriam Sibuet—which endorses its content.

Graphic design by Darrell McIntire.

Census of Marine Life International Secretariat
Consortium for Ocean Leadership
Suite 420
1201 New York Avenue, NW
Washington, DC 20005 USA

www.coml.org
coml@oceanleadership.org
+1 202 232 3900

Printed in the United States of America

March 2011

Caranx sexfasciatus
Bigeye trevally
Coco Island, Costa Rica
Galatée Films
Roberto Rinaldi, 2006