A Census of Marine Life

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Although humanity has begun to explore Mars, we are still colonizing our home planet. The 70 percent of Earth beneath the oceans is twice the area of Mars and the moon combined, but it is not nearly as well mapped. Ninety-five percent of Earth's biosphere volume is in the oceans, where life has thrived for billions of years. At the genetic level, the oceans contain the vast majority of Earth's biodiversity. Although people have begun to recognize that biodiversity, particularly genetic diversity, is a valuable resource, the efforts to preserve it in the oceans lag far behind those for preservation of biodiversity on land. The number of known ocean species—about 200,000—contrasts sharply with the millions that could be known by applying modern technology (O'Dor 2003).

Implements of technology, such as factory trawlers and drilling platforms, are a permanent presence in the oceans, and developing technologies make exploitation of the full depth and extent of the oceans possible. Many economic sectors—food, energy, and international trade, for example—are significantly dependent on the sea. Society needs descriptions of the seas' resources, particularly the fragile, renewable ones. At present, the industrial sector knows more about the sea than does the scientific community, but by the end of this decade, scientists hope to have recorded the global scope of the ocean's resources.

What is the full scope of marine biodiversity? In 1997, the global marine science network began to tackle this challenging question, taking the first steps toward the Census of Marine Life (CoML). CoML's international scientific steering committee, formed in 2000, sponsored 20 workshops to delimit the known and the unknown, and it initiated a dozen major projects focused on the least-known parts of the ocean. Even the best modern technology cannot name and count every organism in the sea. Nor is that possible—some details are ever changing and unknowable. During its first three years, CoML has created the Ocean Biogeographic Information System (OBIS), which contains over a million records of 25,000 marine species. OBIS is projected to encompass 10 million records and all known marine species by 2005. Research organizations were initially reluctant to commit data to OBIS, but contributions are now coming in faster than they can be assimilated.

OBIS, which is open to the public at *www.iobis.org*, currently searches 20 databases worldwide to create maps of species distribution and lists of known species in an area. Maps can be overlaid on synoptic satellite or model information such as sea surface temperature or primary production. For some species, there are also time series—a few going back 400 years—based on biohistorical reconstructions from the History of Marine Animal Populations project (Holm et al. 2001). OBIS has modest modeling and predictive capacity now, but that capacity will grow as the database grows and as new applications are tested by the Future of Marine Animal Populations project (Worm et al. 2003). OBIS also has educational tools and lesson plans to build interest in ocean science and ocean life.

CoML divides the oceans into six operational "realms" of the unknown: human edges, hidden boundaries, central waters, active geology, ice oceans, and microscopic oceans. The realms are subdivided into "zones" that are based on the special technologies required to study them. By 2005, a dozen zonal CoML field projects will be creating large amounts of new information about species, including distributions and abundance. In the nearshore and coastal zones along the human edges, a high proportion of the macroscopic species are known, but distributions and abundance remain economically critical unknown factors that can be resolved with an integrated information system. In contrast, along the continental margins and abyssal plains that define the hidden boundaries, 80 percent of the specimens collected may be new to science. The goal of CoML is a global picture of marine life accessible through OBIS. Thus, although sampling must be done geographically, the projects focus on concepts and approaches that can be efficiently extended throughout the world. As climate change begins to affect ocean physics on a global scale, OBIS will be the key to translating physical patterns into biological ones.

Between 2005 and 2010, CoML will encourage additional sampling in all oceans, using protocols developed and tested in the initial zonal projects (Decker and O'Dor 2002). To this end, national and regional committees for the Census of Marine Life are forming around the world, including both scientists and stakeholders. National committees in countries with major research and industrial capacity at sea are identifying priorities and matching their capacity with CoML goals to implement sampling programs. Regional committees are forming where there is more ocean than capacity to encourage international collaboration and economies of scale in new sampling projects. These committees are also well placed to recognize and support new approaches and projects.

It is clear that the degree of resolution of the patterns of marine biodiversity developed by 2010 will vary both by realm and by region. The Japan-led nearshore project, NaGISA (acronym for Natural Geography in Shore Areas, but also Japanese for "coastline"), is relatively inexpensive, requiring only scuba divers to sample along a transect from the shore to a depth of 10 meters. Nearly

50 countries have committed to swim transects and record diversity in standardized ways, often using volunteers (Shirayama et al. 2002). The initial goal of a transect every 300 kilometers (km) along 15,000-km latitudinal and longitudinal gradients will be achieved, as well as some level of sampling along the millions of kilometers of coast globally. For this 2 percent of the ocean's area, some countries have already committed to monitoring transects for 50 years to record global change, giving the project a built-in fourth dimension.

At the other end of the spectrum, samples for the German-led abyssal plains project come from 4 to 5 km deep, a habitat that underlies 90 percent of the ocean. Each sediment sample takes hours to collect, using specialized vessels that cost thousands of dollars per hour to operate. Initial commitments are for a sampling gradient from the equator to the Antarctic in the South Atlantic, but so little is known about this habitat that we cannot even guess what sampling resolution will be necessary or possible. Similar vessels are required to reach the unique ecosystems at small geological zones of the seamounts, hydrothermal vents, and methane seeps. Work under the ice, Earth's fastest disappearing habitat, is even more expensive, and even less is known about the habitat being sampled.

In the light zone of the vast central waters above, large pelagic species are helping to map biological distributions in relation to ocean physics across the North Pacific by carrying satellite transmitters that locate them and record temperature–depth profiles. Acoustic tracking technology allows animals as small as sardines to chart their own migrations in the coastal zone. The technologies are not cheap, but they cost much less than vessels. Advanced acoustic fish-finding equipment on research and commercial fleets can count animals in both the coastal zone and the central water dark zones.

The challenges of collecting specimens throughout the ocean realms and recording them in a universally accessible and searchable database are large, but now essentially well defined and limited largely by financial commitment. The resolution of the picture of marine life that CoML will deliver in 2010 will depend on the investment society is prepared to make. The greatest challenge has in fact turned out to be describing all the new species being discovered. In recent years, approximately 2000 new species from the oceans have been described each year. A single CoML cruise to the abyssal plains off Angola recently recorded 400 new species. At this rate, five cruises per year will saturate the capacity of the world's museums and taxonomists to archive and describe new species. CoML already has more cruises than this scheduled for 2004. A new approach called the "bar code of life," which uses high-throughput DNA sequencing technology, holds great promise for accelerating this process, particularly in the microscopic realm (Stoeckle 2003). Yet it is clear that the Census of Marine Life remains a grand challenge for all parts of the marine biological community for the decade. It is also clear that this challenge offers great rewards for the inhabitants of the blue planet, who must learn to manage the ocean's bounty, having now proved beyond doubt that it is not an inexhaustible resource.

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