A DECADE OF DISCOVERY
CENSUS OF MARINE LIFE 2010

# Summary of the First Census of Marine Life 2010

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In the late 1990s, leading marine scientists shared their concerns that humanity's understanding of what lives in the oceans lagged far behind our desire and need to know. Some emphasized the question, "What kinds of life inhabit the oceans?" They pointed to opportunities to discover new kinds of life and to catalog and estimate the total diversity of life in the vast global ocean. Others asked, "What lives where?" They highlighted establishing addresses of marine life and drawing reliable maps of neighborhoods and travels. Still others asked, "How much of each lives?" and pointed to the human appetite for seafood. Everyone worried about changes in marine life and the need to improve management with sound knowledge.

In the year 2000, the scientists founding the Census of Marine Life converged on a strategy, a worldwide Census to assess and explain the diversity, distribution, and abundance of marine life. The founders organized the Census around three grand questions: What did live in the oceans? What does live in the oceans? What will live in the oceans? They designed a program to explore the limits to knowledge of marine life. They agreed to report in the year 2010.

Delving in archives, setting out on more than 540 expeditions in all ocean realms, and partnering with other organizations and programs, the 2,700 scientists from more than 80 nations who have become the Census community have assembled, augmented, and organized what is known about life in the oceans. They have drawn baselines for measuring changes of marine life after natural changes and human actions. Equally important, the Census has systematically delineated for the first time the unknown ocean.

Many books, papers, Web sites, videos, films, maps, and databases now form and report the Census. The following summarizes its findings, describe its legacies, and tell how it worked.

## Diversity

The Census encountered an unanticipated riot of species, which are the currency of diversity. It upped the estimate of known marine species from about 230,000 to nearly 250,000. Among the millions of specimens collected in both familiar and seldom-explored waters, the Census found more than 6,000 potentially new species and completed formal descriptions of more than 1,200 of them. It found that rare species are common.

With its collective digital archive grown to almost 30 million observations, the Census compiled the first regional and global comparisons of marine species diversity. It helped to create the first comprehensive list of the known marine species, already passing 190,000 in September 2010, and also helped to compose Web pages for more than 80,000 of them in the Encyclopedia of Life.
Applying genetic analysis on an unprecedented scale to a dataset of 35,000 species from widely differing major groupings of marine life, the Census graphed the proximity and distance of relations among distinct species, painting a new picture of the genetic structure of marine diversity. With the genetic analysis often called barcoding, the Census sometimes shrank seeming diversity by revealing that organisms had been mistakenly called separate, but generally its analyses expanded the number of species—and especially the number of kinds of different microbes, including bacteria and archaea.

After all its work, the Census still could not reliably estimate the total number of species, the kinds of life, known and unknown, in the ocean. It could logically extrapolate to at least a million kinds of marine life that earn the rank of species and to tens or even hundreds of millions of kinds of microbes.

## Distribution

The Census found living creatures everywhere it looked, even where heat would melt lead, seawater froze to ice, and light and oxygen were lacking. It expanded known habitats and ranges in which life is known to exist. It found that in marine habitats, extreme is normal.

With sound, satellites, and electronics, some- times carried by marine life itself, the Census tracking of thousands of animals mapped migratory routes of scores of species and charted their meeting places and blue highways across the interconnected ocean. The tracking measured animals' surroundings as they swam and dove and revealed where they succeed and where they die. The Census found temperature zones favored by animals and saw the immigration into new conditions such as melting ice. Now anyone can see the distribution of a species by entering its name at iobis.org, a Web site that accesses the names and "addresses" of species compiled in the Census's global marine life database.

With the names and addresses of species compiled in the database, the Census found and mapped the places of high and low diversity of marine life, globally. Coastal species showed maximum diversity in the tropical Western Pacific, whereas high diversity of species frequenting the open ocean peaked across broad mid-latitudinal bands in all oceans. In deep water and on the deep-sea floor, the Census discovered patterns of life on ridges, seamounts, abyssal plains, and the margins of continents and defined new provinces and classifications. The same Census data reveal where explorers have not yet looked, the unknown ocean. For more than 20 percent of the ocean's volume, the Census database still has no records at all, and for vast areas very few.

## Abundance

After establishing historical baselines from sightings, catches, and even restaurant menus, the Census documented declining numbers and sizes, too, even within a human generation. In enough cases to encourage conservation, the Census documented the recovery of some species. History shows people began catching ma- rine life long ago, and their extractions are far broader in scope than once thought. Historically, overfishing and habitat destruction lead the ranking of threats to marine life associated with human activities. With sound, the Census observed tens of mil- lions of fishes assembling swiftly and swimming in coordinated schools as large as Manhattan island, and also saw hosts of animals commuting at regular hours, moving back and forth to the surface from hundreds of meters below.
The Census affirmed that by weight most marine life is microbial, up to 90 percent. The weight of Earth's marine microbes equaled about 35 elephants for every living person.

Analyzing indirect observations from oceangoing vessels since 1899, Census researchers discovered that the food-producing phytoplankton near the surface has declined, globally. The Census maps of the global seafloor showed that the delivery of food in a "snow" from water above controlled the mass of living things on the floor. On the seafloor, the quantity of life peaks toward polar regions, along continental margins where cool currents well up toward the surface, and where equatorial currents diverge. On the deep-sea margins, the Census unexpectedly
discovered mats of bacteria and reefs of coral extending hundreds of kilometers.
While patchy evidence from the phytoplankton near the bottom of the food chain and more extensive evidence from large animals at the top of the food chain suggest decline, whether the total weight of life in the ocean is changing remains unknown.

## Legacies

At the end of its decade, the Census bequeaths legacies of knowledge, technology, and work habits. Regarding knowledge, the Census recorded its findings in more than 2,600 papers, many freely accessible online. The Census built the largest repository of data about marine species by compiling observations and adding its own, and then made it a publicly accessible infrastructure for future research, which governments have committed to sustain. The Census drew baselines to help nations and the international Convention on Biological Diversity select areas and strategies for greater protection of

marine life. Its baselines will help assess habitat changes such as warming water or damage from oil spills.

Regarding technology, the Census proved new technology, such as DNA barcoding for the identification of marine life. It arrayed microphones from California past Canada to Alaska to pioneer a global ocean tracking network for animals, invented Autonomous Reef Monitoring Structures to standardize global assessment of reef life, and fostered acoustic systems to measure abundances over tens of thousands of square kilometers. Together, these technologies show that the incipient Global Ocean Observing System can observe life as well as water temperature and waves.
Regarding work habits, the Census brought scientists with different interests from different nations together under one umbrella, to use standard proto- cols for sampling marine life from the deep sea to the near shore, to speed the adoption of good techniques, to build capacity economically, and to jump start initiatives in marine research. It strengthened partnerships of scholars in the humanities and natural and social sciences to use archival research to build the picture of life in oceans past and assess changing diversity, distribution, and abundance.
As it worked, the Census found that the causes separating the known, unknown, and unknowable about marine life fall into five categories: the invisibility of the lost past, the vast expanse of the oceans, difficulties of assembling knowledge of parts into knowledge of a whole, blinders we put on ourselves by choosing not to learn or spend, and unpredictable disturbances such as tsunamis.

The Census showed that we know less about the small than the large and that generally knowledge is inversely related to size. But some patterns exceed our field of vision, and for these the Census devised “macroscopes,” tools to make sense of very large regions or datasets, to overcome limits to knowledge. The Census encountered an ocean growing more crowded with commerce and transparent through technology. Setting out to draw baselines of the diversity, distribution, and abundance of species, the first Census of Marine Life documented a changing ocean, richer in diversity, more connected through distribution and movements, more impacted by humans, and yet less explored than we had known. The Census has multiplied the qualified experts, developed and spread technologies for discovery and monitoring, improved access to data, and informed decisions about conserving marine species and regions. The legacies of the Census—the baselines of knowledge, the cascade of new technology, the collaboration across borders—promise more benefits for humanity and the oceans.