CENSUS OF MARINE LIFE

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Experts are available for advance interviews. *High-resolution still images and video are available at www.coml.org/embargo/hardtosee*

Explorers Inventory Hard-to-See Sea Life: Tiny but Mighty Microbes, Plankton, Larvae, Burrowers -- Keys to Earth's Food and Respiratory Systems

Microbial mat the size of Greece found on oxygen-starved South American seafloor;
Scientists puzzle out Neptune's riotous diversity of tiny creatures;
"In no other ocean realm has discovery been as extensive";
Explorers yet to find any lifeless place on Earth below 150°C;
Release of historic global ocean Census: October 4, 2010

Ocean explorers are puzzling out Nature's purpose behind an astonishing variety of tiny ocean creatures like microbes and zooplankton animals – each perhaps a ticket-holder in life's lottery, awaiting conditions that will allow it to prosper and dominate.

The inventory and study of the hardest-to-see sea species -- tiny microbes, zooplankton, larvae and burrowers in the sea bed, which together underpin almost all other life on Earth -- is the focus of four of 14 field projects of the Census of Marine Life.

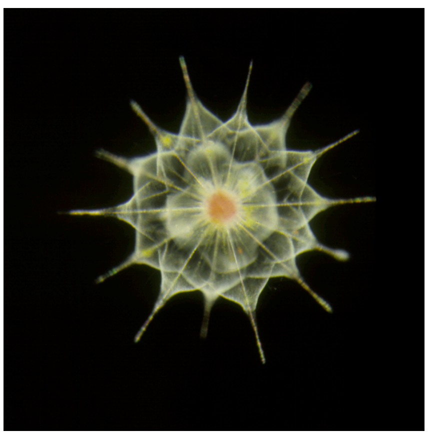
Identifying species within these hard-to-see groups, where they are and in what numbers, and the environmental role of each, is critical for understanding the size, dynamics and stability of Earth's food chain, carbon cycle and other planetary fundamentals.

At the other end of the hard-to-see scale: microbes form mats on the sea floor off the west coast of South America that explorers recently found. The mats cover a surface comparable in size to Greece and rank among Earth's largest masses of life.

The research will be showcased October 4 at ceremonies in London to conclude the Census and its historic decade of exploration, research, recording and logging of marine life past and present, with predictions of what will live in the ocean in the future. The Census involves more than 2,000 scientists from 80+ nations -- one of the largest global scientific collaborations ever undertaken.

Microscopic microbes: huge in diversity, abundance, importance

Microbial cells in the oceans' water column number roughly 10 to the 30th (called a nonillion; expressed another way: 1,000 x 1 billion x 1 billion x 1 billion) and collectively weigh the equivalent of 240 billion African elephants. That's 35 elephants of marine microbes per person.



Constituting 50 to 90 percent of all ocean biomass, marine microbes are the tiniest cogs essential to planetary functioning. Yet until technological marvels of this millennium (especially high-throughput DNA sequencing) revealed the stunning extent of this microscopic world, it remained largely hidden from humankind.

"In no other realm of ocean life has the magnitude of Census discovery been as extensive as in the world of microbes," says Mitch Sogin of the Marine Biological Laboratory in Woods Hole, Massachusetts, leader of the International Census of Marine Microbes (ICoMM).

"Scientists are discovering and describing an astonishing new world of marine microbial diversity and abundance, distribution patterns and seasonal changes."

After drawing ocean samples from more than 1,200 sites worldwide, ICoMM researchers have amassed a database that includes 18 million DNA sequences of microbial life spanning more than 100 major phyla (one of the highest ranks of life in taxonomy, phyla are groupings of organisms based on their general body plan).

Revelations about the microbial world within a single decade have led researchers to dramatically revise their estimates of diversity -- there may be up to 100 times as many microbial genera as previously thought. Genus is the category of life ranked between family and species.

During an 11 month study in 2007, scientists sequenced the genes of more than 180,000 specimens from the Western English Channel. Although this level of sampling "far from exhausted the total diversity present," they wrote, one in every 25 readings yielded a new genus of bacteria (7,000 genera in all).

Also surprising scientists -- and considered one of the foremost discoveries of the decade-long global Census: "the rare biosphere" of microbes.

Many rare species in a sample stand opposite to a few species predominating. Wherever Census researchers looked they found many species in a sample represented by less than one in 10,000 of all individuals, including one-off singletons. Evidently many candidates, now rare, lie in wait to become dominant species if changes favor them.

The theory recently gained steam thanks to an ICoMM study of microbes adapted to conditions inside cone-like carbonate chimneys in "The Lost City Hydrothermal Field." The field lies 15 km (9.3 miles) west of the Mid-Atlantic Ridge near the latitude of Florida and Morocco. Hydrothermal vents have been active for at least 30,000 years in the field.

When methane and hydrogen-rich fluids just below the boiling point emerge from deep within Earth and collide with frigid seawater they build the chimneys. Through genetics, scientists determined that rare microbes in young chimneys "were commonly more abundant than in older chimneys, indicating that rare members can become dominant members when environmental conditions change."

John Baross of the University of Washington, who chairs ICoMM's scientific advisory council, notes that with traditional methods so far experts have isolated and characterized about 20,000 marine microbes.

Census research suggests that, within a particular size interval, more than 20 million types of bacteria live in sea water. However, Dr. Baross notes: "The total number of species of marine microbes, including both bacteria and archaea, based on molecular characterization, is likely closer to a billion."

"ICoMM has studied relatively few of the oceans' microbial environments. And there are bacteria associated with each of hundreds of thousands of larger marine animals, all of which have a microbial flora in their guts and attached to their outer surfaces that have likely co-evolved with the animals. Marine animals alone may account for hundreds of millions of microbial species. This is a huge frontier for the next decade."

Scientists approximate diversity by clustering microbes according to their genetic similarity and assign them to "operational taxonomic units."

A study of sponges from Australia's Great Barrier Reef discovered one that was host to almost 3,000 operational taxonomic units of bacteria.

"Tracking and visualizing such complex populations was impossible 10 years ago," says Dr. Baross. "Sequencing allows us to give the equivalent of an Internet URL to millions of microbes, to which we can attach all kinds of other information, like their favorite temperature and amount of salt and light."

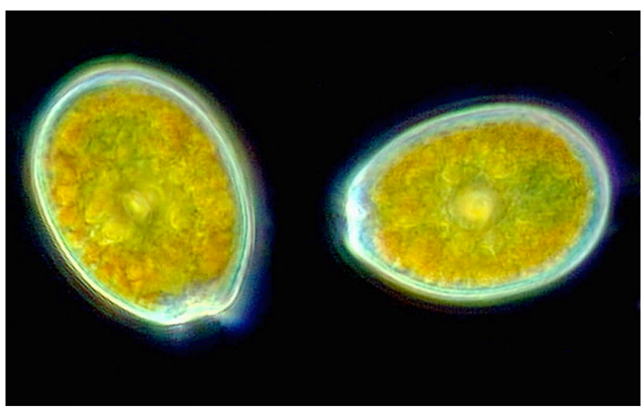
And the variety of marine viruses may rival that of microbes. "The first census of marine viruses should be a goal of the next decade," he adds.

Sensitive microbes power Earth's respiratory system

Responsible for more than 95 percent of respiration in the oceans, members of the microbe family maintain the planet's habitability. Their importance is hard to overstate.

By turning atmospheric carbon dioxide absorbed by the ocean back into carbon to be sunk to the depths (and doing likewise with nitrogen, sulfur, iron, manganese and more), marine microbes regulate the composition of Earth's atmosphere, influence climate, recycle nutrients, and decompose pollutants.

Scientists are testing the sensitivity of marine microbes to such changes as the creeping acidification of the seas by rising atmospheric carbon dioxide levels, and which microbes thrive in different environments.



With respect to abundance, scientists in the 1950s estimated about 100,000 microbial cells inhabit 1 liter of seawater. That was off by orders of magnitude. More likely estimates are now more than 1 billion microorganisms in a liter of seawater or a gram of seabed mud.

The vastness of the oceans, covering 70 percent of Earth's surface at an average depth of 3,800 meters (2.4 mi), challenges the science. So too do the contrasts between populations at both surface and deep sea levels and between temperatures, from polar ice to water around undersea vent that would melt lead.

"Only two of the 10 most common types of microbes in a bucket of Arctic water would be among the most common types at the Equator," says MBL scientist Linda Amaral

Zettler. "And there is enormous diversity on the sea floor we have only just begun to discover -- the deeper the depth, the less we know."

Last year, Casey Hubert of Germany's Max Planck Institute for Marine Microbiology and colleagues found that spores of bacteria typical in water warmer than 50°C (about 120°F) are also abundant in sediment under the Arctic Ocean. And they're replenished every year, leading scientists to speculate that warmth-loving "thermophile" bacteria originating in hot underwater crusts ride deep sea currents to the Arctic.

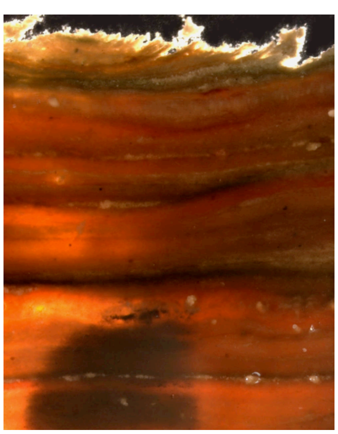
Marine explorers have yet to find any place on Earth cooler than 150°C (about 300°F) without life. Even the deepest mud ever recovered -- off the coast of Newfoundland 1,626 meters (about a mile) below the sea floor (and 4,560 meters, almost 3 miles below sea level) -- abounds in microbes. And spots hotter than 200°C (about 400°F) inside vents were found to have at least slimy biofilms -- a film of microorganisms sticking to each other.

Potential questions ahead for researchers into the distribution of marine microbes:
* Are the rarest species the newest species?
* Are all species everywhere in the oceans, albeit often in very low numbers?
* Did a rare species found in one place come from a larger population where it is native?

"The extreme diversity and curious distribution of deep sea microbes are among the great mysteries of nature, and begs questions about the evolution of life on Earth," says Dr. Sogin.

Microbial mats: Among Earths largest living structures; recognized only recently

Led by Victor Gallardo, Vice-Chair of the Census Scientific Steering Committee, researchers based in Chile have discovered offshore a massive, diverse microbial ecosystem thriving mostly on hydrogen sulfide. It resembles an ecosystem of the Proterozoic period 2.5 billion to 650 million years ago.



At mid-depths of the ocean are oxygen minimum layers (or OML) -- where little oxygen mixes down from the surface or up from the cold, oxygenated water that sinks at the poles and oozes like poured cream along the sea floor to other world regions.

At the bottom of the OML: extreme hypoxia and even anoxia (total lack of oxygen). Hydrogen sulfide, one of the primordial substances, reigns.

With so little oxygen, most life cannot survive. But certain microbes can, and where the OML meets the continental shelf they have formed mats of multicellular filaments -- towering Goliaths by microbial standards at 2 cm (the width of a penny's face) up to 7 cm (2.75 inches - the length of a side of a saltine cracker). The largest filaments are about half the width of a human hair, visible to the naked eye.

The microbial filaments form mats covering an underwater territory the size of Greece. Explorers found them off the central and northern parts of both Chile and Perú. The giant bacteria have been detected in sulfide seeps at the Galápagos Archipelago, Ecuador and off the Pacific coasts of Panamá and Costa Rica.

Investigators speculate that these microbial mats in low-oxygen layers may run from southern Chile to Colombia and may be present under all of the world's oxygen minimum layers.

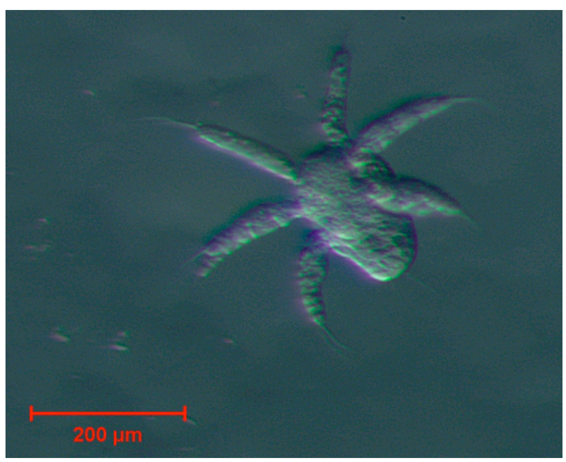
"Some things are unknown because they are too small to see, and some things are unknown because they are too big to see," observes Dr. Gallardo.

Human activities may foster the mats too: Similar mats have been found in marine dead zones where wastes accumulate, such as under unregulated aquaculture systems.

Censusing the diverse, spectacular world of sea bugs called zooplankton

Led by Ann Bucklin, head of the University of Connecticut Marine Sciences Department, the Census of Marine Zooplankton (CMarZ) has united the world's specialists to paint an unprecedented global picture of the abundance, diversity and distribution of tiny, often transparent sea "bugs" that form a vital link in both the food chain and Earth's carbon cycle.

Like microbes, plankton species are typically found in very low abundance in any given place, though there are exceptions. Census scientists sampling the Black Sea, for example, found blooms of tiny comb jellies (ctenophores) vacuuming up all available nourishment, while minute copepods (crustaceans) dominated parts of the North Atlantic.



When CMarZ began in 2004, scientists had described about 7,000 marine species that remain planktonic throughout their lives (called holozooplankton; another 26,000 known species are classified as plankton in their larval stage but change lifestyle as they grow larger).

In decades to come, when all of the Census samples have been analyzed and described, Dr. Bucklin estimates the research will have roughly doubled to 14,000 the number of holozooplankton species known to science (of the estimated 15,000 to 20,000 thought to exist altogether).

"The Census has sampled more extensively, more intensively and more strategically than any previous project," she says. "The Census created an unprecedented opportunity for the fragmented international taxonomic community to look collectively for global patterns of diversity. Funding of such work by national or regional bodies typically limits the involvement of non-national investigators, which divides and partitions the research."

"The food web has a highly integrated structure; our research into it needs to be integrated too. The Census has helped develop a world view, and all of us who work in the field have treasured that."

Dr. Bucklin adds that functional biodiversity -- understanding the inter-relationships of species, and the unique (or replaceable) role of each species in an ecosystem -- is a frontier field of study. It will help determine the extent to which the food web is stable and resilient as species migrate if ocean temperatures change and if oceans acidify, impairing the formation of calcium carbonate shells grown by some planktonic species.

Like those studying microbes, zooplankton researchers use modern genetic identification techniques (DNA barcoding) to reveal "cryptic" species (which can be differentiated only through genetics), and to match larvae with adults.

Last year, CMarZ Steering Group member Tracey Sutton of the Virginia Institute of Marine Science and colleagues, led by the Smithsonian Institution's G. David Johnson, used genetics to correct a long-standing mistaken identity, an error in fish taxonomy.

Previously, the alien-like Mirapinnidae (tapetails), Megalomycteridae (bignose fishes) and Cetomimidae (whalefishes) constituted three different families in taxonomy based on their appearance, behaviour and other characteristics. Dr. Sutton and colleagues showed that they are, in fact, the larvae, males and females, respectively, of a single family, Cetomimidae.

Rare video of the red-headed baby of the family Cetomimidae, found down 1,450 m in the Gulf of Mexico, is available online at *www.coml.org/embargo/hardtosee* (along with many other images and videos of hard-to-see species).

Meanwhile, Colomban de Vargas, a CMarZ scientist from France, has called into question previous notions about climate conditions during the last ice age by revealing through DNA the hidden diversity of single-celled marine microorganisms called foraminifera (forams for short). The shells were associated with a particular temperature regime.

Thought at the time to be one species, fossil records of foram shells were advanced as evidence of ice age climate by the CLIMAP (Climate Investigation, Mapping, and Prediction) project of the 1970s and 1980s. Similar-looking shells may associated with different climates.

The new research shows there may be 20-50 times as many foram species as previously thought, potentially undermining CLIMAP conclusions.

"The discovery of this hidden diversity should encourage us to look back and re-examine previous studies," says Dr. Vargas.

Burrowers

The abyss -- the marine realm with least food -- may appear lifeless but is home to countless microscopic organisms smaller than 1 mm. Scientists with Census project CeDAMar use remotely-operated deep sea vehicles and other new technologies to study life in abyssal areas, many of them explored for the first time.

CeDAMar scientists say the most abundant multi-cellular organisms are roundworms (nematodes), which dominate the harsh abyssal conditions in numbers, biomass and diversity. In some places, more than 500,000 of them reside in a single square meter (1.2 square yards) of soft clay on the deep seafloor.

A tiny percentage of all roundworm species are now described and, with present techniques, the true extent of their diversity may never be known, experts say.

Another type of seaworms (polychaetes) may be just as species rich. Some 16,000 species are now known, with as many again thought to be awaiting discovery.

Questions about their role in the food chain, the significance of their high species diversity (perhaps related to living on diverse organic matter) and mysteries surrounding their reproduction and distribution likewise remain unsolved.

Loriciferans (affectionately dubbed “girdle wearers” due to characteristic hind shells resembling a corset) are among the smallest known multicellular marine animals, the average adult just 0.25 millimeters (1/100th of an inch) long.

They have a complex anatomy despite their minute size, with stiletto teeth and a head covered with delicate leaf or thorn-like appendages.

Soon after their first discovery in 1983 in shallow coastal waters, another loriciferan species was found at 8,260 meters (over 5 miles) depth. In the 1990’s, still more species were found on seamounts.

Several hundred more loriciferans species found during the Census now await formal description. But the real surprise has been the astounding complexity of the animal’s development, with nine stages distinguished, more than any similar creature in the deep sea.

Tiny copepod crustaceans form another group of deep sea inhabitants important because of both their species richness and sheer abundance.

Recent CeDAMar sampling astonished the specialists. On just two stops in the southeast Atlantic Angola Basin, they found almost 700 different copepod species (99 percent of them unfamiliar) in just 5.4 square meters (6.5 square yards), nearly twice the number of species described to date in the entire southern hemisphere.

“Such findings make us look at the deep sea from a new perspective,” says CeDAMar leader Pedro Martinez Arbizu. “Far from being a lifeless desert, the deep sea rivals such highly diverse ecosystems as tropical rainforests and coral reefs. As tiny burrowers crawl around they help oxygenate sediments and interact with microbes to cycle nutrients and carbon on the ocean floor. Once again, the tiny play a mighty role.”

“The inventory of life in the deep sea has only just begun, and much more remains to be done,” he adds. “Sediment-covered seafloors cover more than 60 percent of Earth’s surface. And, given these new insights, we cannot possibly use the deep-sea floor as a waste dump or subject it to unlimited resource extraction without massively impacting the marine communities living there.”

The scientific chair of the entire Census, Ian Poiner, concluded: “The Census of Marine Life takes immense pride in recognizing the hidden majority.”

Census of Marine Life: Final summaries and reports

Started in the year 2000, the Census of Marine Life has been a decade-long international research program uniting thousands of scientists worldwide with the goal of assessing and explaining the diversity, distribution and abundance of life in the seas. It has been supported by private sources and government agencies the world over, listed online at www.coml.org/support.

The final reports of the Census of Marine Life will be presented and discussed in London in October. Three books will be launched. Many of the results described above will be documented in *Life in the World's Oceans: Diversity, Distribution and Abundance*, A.D. McIntyre, ed., Wiley-Blackwell, in press).

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Censusing the hard to see:

Some 300 scientists collaborate on the four Census projects focused on hard-to-see sea species: ICoMM, CMarZ, CeDAMar and ChEss. By the time the 10-year Census concludes in October 2010, the projects will have collectively fielded almost 300 expeditions (ICoMM: 66, CMarZ: 122, CeDAMar: 18, ChEss: 80).

Microbes (ICoMM)

The International Census of Marine Microbes is a collaborative effort between the Royal Netherlands Institute for Sea Research in Texel, The Netherlands and the Marine Biological Laboratory (MBL) in Woods Hole, MA, USA. It has galvanized the microbial oceanographic community to catalogue all known diversity of microbes - single-cell organisms including bacteria, archaea (no cell nucleus), protista (unicellular, or multicellular without specialized tissues), and associated viruses - determine their relative numbers and the range of their genetic diversity at sampling sites throughout the world's oceans.
http://icomm.mbl.edu.

Zooplankton (CMarZ)

The Census of Marine Zooplankton (CMarZ) is producing a global assessment of zooplankton species diversity, biomass, geographic distribution, and genetic diversity, focusing on the roughly 7,000 described species of animals that drift with ocean currents throughout their lives.
CMarZ focuses on the deep sea, under-sampled regions and biodiversity hotspots, using integrated morphological and molecular (DNA barcodes) approaches to analysis and assessment of species diversity. Education, professional training, and capacity-building efforts will increase the number of taxonomic experts.
The CMarZ database contains species-level, specimen-based, geo-referenced entries; data and information are accessed via the CMarZ and CMarZ-Asia websites, as well as the Ocean Biogeographical Information System (OBIS).

www.cmarz.org

Abyssal Plains (CeDAMar)
Started in 2003, project CeDAMar (Census of the Diversity of Abyssal Marine Life) has sampled abyssal plains and major basins in all the world's oceans, particularly the equatorial Pacific, southern Atlantic and Southern Ocean, and:
* Described nearly 500 new abyssal species, from unicellular animals to large squid;
* Provided first insights into the feeding biology of abyssal organisms;
* Identified bathymetric and geographic distributional patterns of deep-sea organisms;
* Compiled data essential for establishment of protected areas on the seafloor outside national jurisdiction.

www.cedamar.org

Vents and Seeps (ChEss)
Since it began in 2003, project ChEss (Biogeography of Deep-Water Chemosynthetic Ecosystems) has enhanced knowledge of the biogeography of deep water chemosynthetic ecosystems, and:
* discovered the deepest (4100m / 2.5 miles), hottest (407°C), most northerly (73°N, Arctic) and most southerly (60°S, Antarctic) hydrothermal vents known to science. Scientists expect this record to be extended to about 5000 meters (3.1 miles) next year (having found plumes in the Cayman trough below 4500 meters (2.8 miles), their sources must be deeper still);
* explored the largest known cold seep in the world covering about 180,000 square meters (215,000 square yards);
* described > 170 new species, including a new family of "Yeti Crabs";
* pioneered groundbreaking new robotic techniques; and
* provided leadership on global hydrothermal vent conservation.

www.noc.soton.ac.uk/chess/