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Two ocean studies look at microscopic diversity and activity across entire planet

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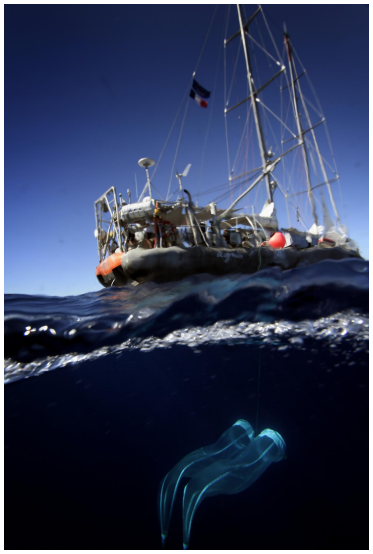

IMAGE: THIS PICTURE SHOWS A BONGO NET UNDERWATER WITH THE TARA IN THE BACKGROUND. **view more** ›

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- Two papers publishing in the journal *Cell* use samples and data collected during the Tara Oceans Expedition to analyze current ocean diversity across the planet, providing a baseline to better understand the future impacts of climate change on the oceans.
- Ibarbalz et al. report that most planktonic groups follow a gradient of diversity along latitudes, with the lowest level of diversity closest to the poles.
- Salazar et al. find that microbial diversity and microbial gene expression play different roles in how ocean microbial communities respond to environmental change in different geographies.
- In a Perspective publishing in the journal *One Earth*, Claudet et al. examine the barriers that have prevented ocean sustainability policy changes so far and suggest strategies for leveraging the UN Decade of Ocean Science for Sustainable Development to overcome these challenges.

In an effort to reverse the decline in the health of the world's oceans, the United Nations (UN) has declared 2021 to 2030 to be the Decade of Ocean Science for Sustainable Development. One key requirement for the scientific initiative is data on existing global ocean conditions. An important trove of data is already available

thanks to the Tara Oceans expedition, an international, interdisciplinary enterprise that collected 35,000 samples from all the world's oceans between 2009 and 2013. The samples were collected by researchers aboard one schooner, the Tara, at depths ranging from the surface to 1,000 meters deep.

Two papers being published November 14 in the journal *Cell* are the latest to use samples and data collected during the Tara Oceans expedition to analyze diversity across the entire planet of plankton, microscopic organisms that drift on oceanic currents that are key for the well-being of our oceans. One study focused on the diversity of plankton across Earth's oceans, whereas the other study assessed gene expression among microbial communities as a way to predict how these communities might adapt to changing environmental conditions.

Plankton Diversity across Different Latitudes

"Everything in the ocean is connected, which means it has the potential to move around," says Chris Bowler, a National Center for Scientific Research (CNRS) scientist at the Institut de Biologie de l'Ecole Normale Superieure (IBENS) in Paris and a co-senior author of the plankton study. "This makes it important to assemble everything on a global scale. Doing deep analysis also allows us to catch the rare organisms in the biosphere in addition to those that are more abundant."

"Our study focused on plankton because it's a major contributor to marine ecosystems in terms of biomass, abundance, and diversity," says co-senior author Lucie Zinger of IBENS. "All types of life have representatives in the plankton--bacteria, archaea, protists, animals and plants, as well as viruses. But the large majority of this diversity is invisible to the naked eye."

The paper reports that the large majority of planktonic groups, from giant viruses to small animals, follow a gradient of diversity along latitudes, with the lowest level of diversity closest to the poles. "Ocean temperature is mainly responsible for this pattern," Zinger notes. "Ocean warming due to climate change is likely to lead to a 'tropicalization,' or increase, of plankton diversity in temperate and polar waters. The consequences of this are still unclear, but we know these geographic areas are currently very important for different ecosystem services, including fisheries and carbon sequestration."

One innovative aspect of this study was that it combined both imaging and DNA-based techniques to assess plankton diversity. "We know a lot about how to process information from DNA sequences," Bowler says. "But images are much more complicated. We observed many different morphologies and different behaviors of these organisms. There are many new organisms and new kinds of interactions between them still to be discovered."

Understanding the Activity of Microbial Life at Different Ocean Depths and Geographies

The transcriptome study combined metagenomic and metatranscriptomic data, allowing the team to analyze the analyze which genes were present, as well as which genes were turned on, in ocean microbial communities across gradients of both depth and latitude. Previous studies on the diversity of marine microbial life have focused primarily on genomes. This was the first to look at transcriptomes on a global scale.

"Looking at transcriptomes is important for determining not just which microbes are present, but what those microbes are actually doing with regard to activities like photosynthesis and nutrient uptake," says senior author Shinichi Sunagawa of the Institute of Microbiology and Swiss Institute of Bioinformatics at ETH Zurich. "One of our goals was to learn whether microbial communities adjust to environmental and temperature variations with changes in their composition relative to each other or with changes in the gene expression patterns within these communities."

The investigators found that in terms of taxonomic, genomic, and transcriptomic composition, there are distinct ecological boundaries separating both surface water from deep water and polar from nonpolar regions. They expected to see some of these changes--such as differences in the levels of photosynthetic organisms relative to water depth. But some other observations were rather unexpected.

"We did not expect to find biogeographic patterns for the underlying mechanisms of metatranscriptomic composition variation. Specifically, we found differences in polar communities to be dominated by changes in organismal composition, while in nonpolar waters, the differences were dominated by changes in the expression of genes," Sunagawa says. He adds that his team was also surprised to find genomic and transcriptomic evidence for a nitrogen-fixing bacterium in deep Arctic waters.

"Every drop of marine water is full of microbes, which play a central role in many processes relevant to life on Earth," he notes. "Understanding the ecological factors that determine the diversity, composition, and activity of these organisms is essential to better model and predict future deviations, especially in light of climate change."

One limitation of the data to come from the Tara Oceans expedition is that the samples were collected over a relatively short period of time, less than four years. This makes it difficult to observe any measurable trends in today's oceans related to climate change. The researchers say that longer-term studies are needed to account for changes in factors like acidification, deoxygenation, and pollution.

A Call for Ocean Science in the Face of Climate Change

Researchers examine the barriers that have prevented ocean sustainability policy changes so far and suggest strategies for overcoming these challenges in a Perspective publishing November 14 in the new *Cell* Press journal *One Earth*.

"As revealed by the releases of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services global assessment and of the Special Report on the Ocean and Cryosphere of the IPCC, both in 2019, there is now an urgency to engage into sustainable pathways," says corresponding author Joachim Claudet of the CNRS. He adds that the main threats on the ocean's sustainability are overexploitation of fish, shellfish, and other organisms; land- and sea-based pollution; and land/sea-use change, including coastal development for infrastructure and aquaculture; and climate change.

"We need science to develop evidence that can better inform policies to implement viable solutions, as well as operational and transformative actions that can better impact societies, from local to global scales," he says. "The Tara expeditions have multiple values. They allow us to collect local natural, chemical, and physical in situ

data at the ocean scale. These data can feed into both basic and applied research. Tara's outreach programs can also be a driver of the most needed change in perception that the ocean is both highly valuable and vulnerable."

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This work was primarily funded by the Tara Ocean Foundation and 23 supporting institutes (https://oceans.taraexpeditions.org/). For additional funding information, please see individual papers.

Cell, Ibarbalz et al.: "Global Trends in Marine Plankton Diversity across Kingdoms of Life" https://www.cell.com/cell/fulltext/S0092-8674(19)31124-9 DOI: 10.1016/j.cell.2019.10.008

Cell, Salazar et al.: "Gene Expression Changes and Community Turnover Differentially Shape the Global Ocean Metatranscriptome" https://www.cell.com/cell/fulltext/S0092-8674(19)31164-X DOI: 10.1016/j.cell.2019.10.014

One Earth, Claudet et al.: "A Roadmap for Using the UN Decade of Ocean Science for Sustainable Development in Support of Science, Policy, and Action" https://www.cell.com/one-earth/fulltext/S2590-3322(19)30093-4 DOI: 10.1016/j.oneear.2019.10.012

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