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Policy Brief

Scientists warning on the interactions between ocean plankton and climate change

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Climate change is having a major impact on the largest and most widespread group of organisms on Earth: the ocean plankton.

The consequences of these changes for marine ecosystems and for human societies are currently understudied and underevaluated, but recent scientific results suggest they might be considerable.

In September 2019, more than a hundred scientists from 36 countries co-signed the IPCC Special Report on the Ocean and Cryosphere in Changing Climate. Based on the extensive study of more than 7000 scientific publications, their report highlights the urgency of prioritizing timely, ambitious and coordinated action to address unprecedented and enduring changes in the ocean and cryosphere and their impact on human populations. The report stresses that the combined effects of rising temperatures, ocean acidification and deoxygenation, with changes in nutrient availability, will have a strong negative impact on almost all forms of life in the ocean, from bacteria to fish, as well as viruses and algae.

Such changes can globally affect how the oceans contribute to the global ecosystem balance, as they underpin key ecosystem services, including the regulation of the carbon cycle and oxygen production. They can also have a strong and direct impact on coastal communities via, for example, the rising of sea levels, changes in salinity, or losses of coral reefs and mangroves. Further down the line, such widespread, profound, and rapid changes will impair the blue economy and challenge food security (via the loss of fisheries and possibilities for aquaculture).

The ocean is often said to be the only continuous ecosystem on the planet, and a foundation for its global health. The crucial role of the ocean doesn't only depend on its immense quantities of water, or on the fishes/fish stocks, but more importantly, on the billions of viruses, microbes, small animals and plants that drift with the currents and are collectively called « plankton ». They form the basis of marine food webs, capture a large fraction of the carbon in the atmosphere and generate oxygen via photosynthesis.

Despite their overwhelming importance and widespread presence, representing at least two thirds of marine biomass, the scientific knowledge on plankton, and its response to climate change, is still limited. The reasons for this situation are both financial and technical. Collecting a comprehensive collection of samples in the open ocean is an expensive challenge, but ensuring access to the necessary state-of-the-art infrastructure to study such microscopic organisms – DNA sequencing facilities, high throughput microscopy platforms, and computer servers able to store and process such large quantities of data – requires the collaboration of multiple scientific teams, across the planet. Those indispensable, yet complex and sophisticated analysis technologies were not available 10 years ago, and have only become accessible in recent years.

With the fall of technological barriers and the acceleration of developments in computer sciences, our capacities to analyse "big data" have increased dramatically. In parallel, the cost of DNA sequencing and high performance imaging tools have dropped significantly in the last 10 years, thus enabling more scientists and countries to take part in scientific projects aimed at understanding the multiple indispensable functions of plankton communities and how they might impact the climate as well as local fisheries.

Two examples[1] of these recent developments were published last November in the journal Cell. These studies analyse how microorganisms may respond to climate change and show that, first, the diversity of various planktonic groups is distributed unevenly between the equator and the poles and that, secondly, while adjusting differently to environmental, they appear to be mainly influenced by sea surface temperatures These findings could have strong ecological, environmental and economic implications, should the temperature of the oceans rise above a certain level.

« Our results clearly show that the diversity of most planktonic groups is more important around the equator, and decreases towards the poles » explains Lucie Zinger, co-lead author of one of the studies. Shinichi Sunagawa, Professor at the ETH, in Zurich, Switzerland, and his team complement this conclusion with slightly different data. « Analyzing which genes are actually expressed, rather than those that are just present, allowed us to study what ocean microbes actually do at a global scale, rather than what they are capable of doing in theory. We found the mechanisms that influence the community of bacteria and archaea, and hence their adaptation to new environmental conditions, to be very different in warmer waters and at the poles, » says Sunagawa.

[1] *Ibarbalz, F. M., Henry, N., Brandão, M. C., ... & Zinger, L. (2019). Global trends in marine plankton diversity across kingdoms of life. Cell, 179(5), 1084-1097; Salazar, G., Paoli, L., Alberti, A., ... & Sunagawa, S. (2019). Gene Expression Changes and Community Turnover Differentially Shape the Global Ocean Metatranscriptome. Cell, 179(5), 1068-1083.*

These two studies, using a unique and comprehensive set of multi-disciplinary data collected by the Tara Oceans consortium, show how marine science can evolve from empirical data and manual analysis to quantitative data and automated analysis.
These recent developments still need to be refined, but they open the door to a holistic understanding of the oceanic ecosystem. It is crucial to integrate our most recent knowledge about oceanic plankton and the biogeochemical cycles taking place in the oceans with knowledge from various other disciplines (oceanography, meteorology, physics, etc…), to develop more accurate predictive models, and anticipate changes.

TaraPolarCircle-banquise-Tara behind ice ©François Aurat

Polar regions
will be impacted first

The two papers published in Cell also indicate that the impact of climate change on the distribution and quantities of planktonic species would be greater in the polar regions - the Arctic Ocean and the Antarctic-Southern Ocean. Based on the most recent and accurate IPCC models, the study led by Zinger predicted how the diversity gradient of species between the equator and the poles could evolve. Although their predictions need to be refined and validated, they clearly suggest that higher oceanic temperatures would lead to what one usually calls a « tropicalisation » of the temperate and polar oceanic regions, with higher water temperatures leading to an increased diversity of planktonic species.

Oceanography and climate science can currently predict some effects of temperature on bigger organisms, however no model can precisely predict how entire ecosystems could adapt to climate change. The research from Sunagawa and his team gives us clues on which mechanisms will play a role where, at least for planktonic bacteria and archaea.

Globally, these communities can adapt to environmental changes in two different ways: first, by adapting their metabolism, and hence their gene expression patterns to make the most of the new conditions (dominating in warm waters). Secondly, they can replace their less adapted member species by better adapted ones (dominating in cold, polar, waters). This is an important step forward in understanding how biochemical processes contribute to the global environmental balance, and better model changes. The “tropicalization” of polar regions would lead to biodiversity changes, and have a strong impact on the functioning of global ocean ecosystems.

Temperate and polar waters are currently crucial for numerous environmental and economic reasons: they play a crucial role in capturing carbon and storing it out of the atmosphere, they harbor large fish stocks on which intense economic activities rely on, and an important fraction of them are protected to provide shelter for endangered species.
Since the most important changes in diversity are projected to occur in these areas, they may alter permanently these ecosystems and have serious consequences.

TaraPolarCircle-banquise-Tara behind ice ©François Aurat

The Unseen Majority

Nearly in parallel, a group of 34 scientists published a consensus statement in the journal Nature Reviews microbiology, to raise the alarm about the consequences of climate change on the unseen majority, the billions of microscopic organisms that support life everywhere in the biosphere (both in the oceans and on land). “To understand how humans and other life-forms on Earth (including those we are yet to discover) can withstand anthropogenic climate change, it is vital to incorporate knowledge of the microbial ‘unseen majority’[2] into our models.
We must learn not just how microorganisms affect climate change (including production and consumption of greenhouse gases) but also how they will be affected by climate change and other human activities”[3], warn the authors. “The impact of climate change will depend heavily on the responses of microorganisms, which are essential for achieving an environmentally sustainable future”[4].
Their warning echoes the conclusions of the IPCC Special Report on the Ocean and Cryosphere in Changing Climate: the need for a better understanding of oceanic ecosystems, and for more robust prediction models on how climate change will affect them and the ocean microbiome is urgent.

In the context of the Paris Agreement Rulebook, and the upcoming development of the, hopefully ambitious, objectives for each country (called NDC, or Nationally Determined Contributions), the next ten years can be crucial for climate sciences and the ocean. The scientific community, together with decision-makers and the civil society, need to join forces to enforce a real change for the planet.

The UN Decade of Ocean Science for Sustainable Development

2021-2030 will be the UN’s Decade of Ocean Science and Sustainable Development, and will provide the perfect platform to gather forces towards such ambitious goals at a planetary level. With regards to climate change and ocean, more data and analysis will be key to generate robust models and predictions on the global impact of climate change on oceanic ecosystems.

As underlined by the global assessment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the above-mentioned IPCC report, climate change has an increasing impact on marine biodiversity, and can have synergistic consequences when associated with anthropogenic activities. In the last decades, we have understood that the main threats to maintaining the balance of the oceanic ecosystem were the direct exploitation (in particular overexploitation) of fish, shellfish and other organisms, the pollution of the land and sea, and how mankind changed and intensified its use of land and sea.
Thanks to new engines, cheaper energy, engine that consumes less, new techniques, new tools, high seas and deep sea exploitation have recently become easier and cheaper, opening up the last preserved areas to anthropogenic changes.

Climate change is now coming as an additional stress-factor. The cumulative effects of all these threats to the oceans’ sustainability cause changes in the ecosystem’s properties, altering habitats, species distributions, food webs, and the oceans’ circulation and biogeochemistry.
While the oceans’ good health is critical to achieve a sustainable development of human societies in general, their productivity, adaptive capacities and their role in climate regulation are now being altered.

The actions taken until now at a global level have failed to put us back in a safe operating space, on a sustainable trajectory. In the current context of a global ecological crisis, science and innovation-driven policies represents our best and most effective options towards identifying operational, sustainable, and transformative actions. From a local to a global scale, we need scientifically informed policies that can have a strong changing impact on societies.

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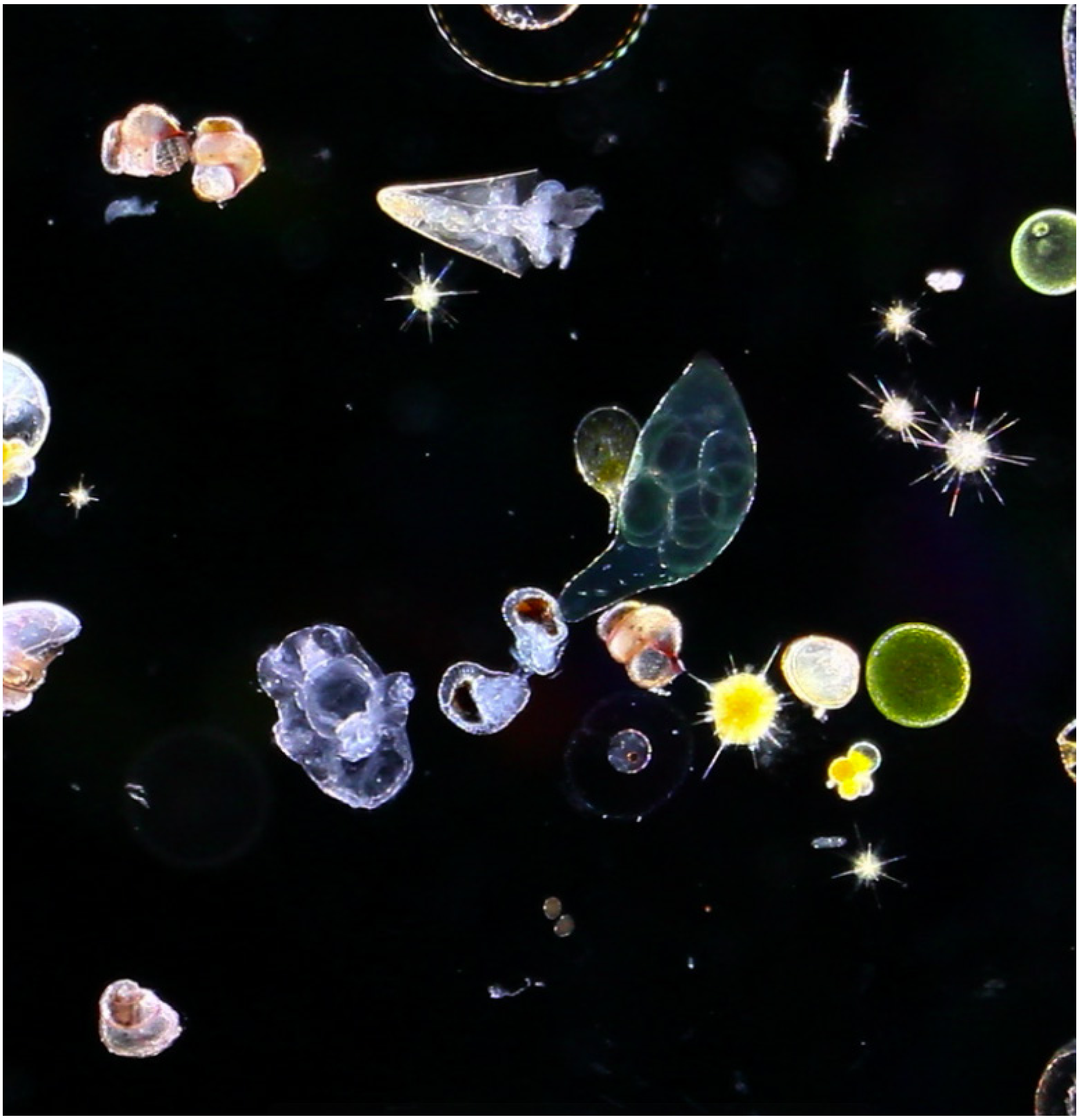
[2] *Scientists Warning to Humanity : Microorganisms and climate change, Nature Reviews, June 2019*
[3] *idem*
[4] *idem*

To reach that goal, several challenges need to be addressed. More specifically, there is an urgent need for:

- a stronger integration of social, natural and physical sciences and more interconnected ocean observing systems
- scientists to be more solutions-driven to solve sustainability problems
- policies to be better informed by science
- and overall, increased political action

This requires improved science/policy interfaces where research questions are co-designed and research itself is co-produced with scientists and policy-makers together. To ensure that these policies are meaningful to people and impactful for society, the involvement private sector and the civil society is crucial. A way to foster stakeholders' engagement and appropriate change in social norms is to establish new partnerships, supported by a new ocean-climate finance system and improved ocean literacy and education. It is imperative that we change course before the end the UN Decade of Ocean Science for Sustainable Development with a new way of doing marine science: multi-disciplinary, financially sustainable and meaningful for society.



Tara in Arctic 3 © Anna Deniaud

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