Ocean in danger:

Climate challenges and sustainable solutions

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Coral Bleaching in American Samoa, Before (Dec 2014) & After (Feb 2015). Credit: The Ocean Agency

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Protecting the ocean, the planet's number one climate regulator, is the *sine qua non* for maintaining life on earth. The ocean's resources are vast, diverse and essential, particularly in ensuring our supply of food. Our trade and communication both depend on the ocean. It is indispensable to our physical and social lives. It ensures that the planet remains habitable for all life, including humankind.

But human activities pose threats to the health of the ocean and its resources. If we fail to take appropriate, concerted and ambitious action, this tendency may quickly trigger famines, major population movements, and socio-economic inequalities, hampering our societies' aspirations for fair and sustainable development. How will the ocean behave tomorrow in the face of the pressures placed on it by humans and the uses we make of it? If we fail to remember this key element of our life on earth, we will alter how it functions and its health. This will inevitably affect our well-being, as our habitat depends on the ocean's vitality. How can we ensure the long-term future of this natural capital on an international scale? The ocean is a complex, dynamic and interconnected system, making it difficult to turn warnings from the scientific community into firm, actionable policy decisions. The Intergovernmental Panel for Ocean Sustainability (IPOS) is a project initiated by scientists that proposes the creation of an international body under the *aegis* of the United Nations to facilitate concerted reflections on the future of a sustainable ocean, and to take the necessary action.

INTRODUCTION

The ocean is essential to life on earth. It is the primary climate regulator, the largest carbon sink, and the number one generator of oxygen: since the oceans first formed, they have produced over 50% of the available oxygen that we breathe. Home to a considerable diversity of resources, the ocean feeds close to three billion people. It also plays an irreplaceable economic role as the vector for trade and communication between human societies. The ocean carries 90% of global freight and 99% of digital communications and data streams. This immense, much-coveted potential, particularly in terms of exploitable resources, makes the ocean a potential arena for future confrontation. Lying at the heart of vital environmental, social and economic challenges, the ocean must be protected to guarantee our health as well as that of the planet.

HUMAN ACTIVITIES, CLIMATE CHANGE, AND THE OCEAN

The Intergovernmental Panel on Climate Change (IPCC)[1] has been warning us for decades about the impacts of climate change. Although not often mentioned, the very first consequence of our greenhouse gas emissions is disruption to the role the ocean plays in regulating the climate. Since 1950, the ocean has absorbed over 90% of excess heat and 23% of the CO_2 generated by human activities, which has led to its acidification; a rise in water temperature, particularly at the surface, of 0.11°C per decade between 1971 and 2010; and a probable 3.5% fall in the amount of oxygen in the ocean by 2100.

The ocean today is experiencing record temperature rises, leading to widespread marine heatwaves that threaten emblematic ecosystems such as coral reefs. According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), close to a third of coral reefs have already disappeared. Another concern is increasing pollution of the oceans, which has also had a major environmental and economic impact. Every year, it is estimated that between five and twelve million metric tons of plastic find their way into the ocean, costing around €13 billion in annual clean-up costs and financial losses for a range of sectors, fisheries in particular. And approximately 90% of all plastic waste found in the ocean comprises single-use items, such as plastic bags, that take a very long time to break down.

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These changes are already having unwelcome consequences on marine ecosystems and human societies in the form of rising sea levels, an increase in extreme climate events, and intensification of coastal erosion. Regarding biodiversity, the IPBES[2] identified five primary drivers of its decline in 2019, ranked in descending order: direct exploitation of vagile species[3] through overfishing; changing uses of land and sea; climate change; pollution, and invasive exotic species. In addition, ocean-related tourism, which generates an estimated annual $134 billion and employs over a third of the labor force in certain countries, needs to be managed very carefully. If not, this form of tourism can be a major threat to the natural resources it relies on, as well as to local culture and industries. Our activities are thus a danger to the health of the ocean and the resources it is home to.

1 IPCC: https://www.ipcc.ch/.

2 IPBES: https://www.ipbes.net/.

3 Aquatic animals living and moving in the overall aquatic habitat (fish, mollusks, etc.).

CLIMATE CHANGE AND SPECIES DISTRIBUTION

Variations in temperature, pH and oxygenation in the ocean also influence species distribution by modifying their habitat.[4] Additionally, these disruptions can alter the physiological functions of organisms or engender phenological[5] changes that impact the seasonality of individual lifecycles. These pressures lead to a potential alteration in the geographical distribution of species that will, because of rising temperatures, migrate to cooler regions. This results in a gradual shift by certain species toward zones where organisms will find more favorable habitats. Modelling changes in species ranges makes it possible to predict the probability that a species will be present in 2100. We are already often seeing changes in the distribution ranges of fish species that bring them closer to the poles. Every year it is estimated that marine species move six kilometers nearer to the poles to find cooler water. But although the available models make it possible to predict movements of certain vagile species such as fish, the phenomena are sometimes more complex for benthic species that live on the seabed without moving location, such as corals, algae and oysters. Scallops, for example, are forecasted to disappear from the English Channel but this has yet to happen. The origin of these differences remain unclear, but it may, but it may lie in a failure either of the models used or of the appropriate management measures.

Acidification of the ocean as a consequence of climate change leads to a fall in the availability of carbonate ions,[6] with significant repercussions for the marine biosphere. This reduction affects the growth of organisms with calcareous structures such as phytoplankton, zooplankton, mollusks, and corals. Once over a certain threshold of acidification, we note a weakening of coral structures, greater fragility of mollusk shells, and a trend for large phytoplankton[7] to be replaced by smaller species. These consequences may have a snowball effect on climate change by limiting CO_2 absorption by the biological carbon pump,[8] whose absorption capacity correlates to the abundance of certain plankton species.

4 Euzen, A., Gaill, F., Lacroix, D., & Cury, P. (2019). *L'océan à découvert* [*The Ocean Revealed*], CNRS éditions.

5 Phenology is the study of natural cyclical and seasonal events in biological lifecycles. Phenological changes are changes in the calendar of species' biological cycles.

6 Carbonate ions enable numerous marine species to form their skeletons and shells. They also help maintain pH balance in the ocean.

7 Microscopic algae present in water.

8 Two mechanisms make the ocean the planet's primary carbon sink: the physical pump that carries surface water rich in CO_2 to greater depths, and the biological pump that absorbs CO_2 thanks to the presence of phytoplankton.

Copepod (zooplankton) under microscope

THE WATER COLUMN AND PLANKTONIC ECOSYSTEM

The ocean is often considered in geographical terms: exclusive economic zone, territorial waters, and ocean coastlines, all refer to a horizontal division of this common good. However, the ocean is characterized above all in terms of its verticality, or its immense depth, extending from the surface water all the way down to the seabed. This depth, essential to understanding oceanic dynamics, is known as the water column. The processes for capturing CO_2 from the atmosphere and storing it in the depths of the ocean occur in the water column. The water column is at the heart of the ocean's physical and biological processes, yet, along with the deep ocean, it remains one of the least-known zones. The water column is also where we find plankton, a term used to designate an infinite number of species that sit at the bottom of food chains. Despite being mostly microscopic, plankton represent incredible genetic wealth, as demonstrated during recent Tara Ocean expeditions.[9] The planktonic ecosystem is the cornerstone of oceanic biodiversity, supplying half of the oxygen that we breathe via photosynthesis during the world's evolution. Lastly, the majority of species that provide food and ensure the survival of human societies live in the water column. However, the riches and benefits it provides to humanity are inexorably shrinking.

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Water color provides a very good indicator of the local populations of microscopic algae (phytoplankton) it contains. Phytoplankton species proliferate very rapidly and can alter the ocean's characteristics in a short number of days. Dark green water is, for example, home to diatoms surrounded by their silica cell walls while white and foamy water is caused by the presence of choanoflagellates. Dinoflagellates turn the water a pronounced green-yellow, and the red waters of Brazil are the result of a predator dinoflagellate species.

Eutrophication is a problem created by the accumulation of algae biomass in far greater quantity than the local ecosystem can manage. It disrupts the food chain by depleting oxygen in the water, suffocating organisms. Inflows of elements such as nitrogen, phosphorous and nutrient pollution from farming can have damaging consequences. The accumulation of organic material leads to bacterial decomposition on the seabed, beginning with an aerobic situation (bacteria multiply and decompose excess organic material by consuming oxygen in the water) which then becomes an anoxic[10] situation owing to depletion of the oxygen. Under these conditions, the population of anaerobic bacteria will increase thanks to sulfates in the seawater, releasing sulfides that are toxic to humans and animals. This very situation occured in Brittany with the green algae tides. This phenomenon is at the origin of the dead zones we have seen growing in size and number over the past two decades.

THE CHANGING OCEAN CLIMATE AND HUMAN HEALTH: THE OCEAN AS MOLECULAR RESERVOIR

In addition to issues relating to disturbance to the food chain, these environmental variations have other consequences that will have a direct impact on human populations.[11] An increase in marine temperature will lead to major repercussions on the pathology of certain species of marine bacteria, and there are critical temperature thresholds above which these bacteria can become toxic. This toxicity may also affect other marine species, such as the *Vibrio harveyi* bacteria which at temperatures above 17°C will infect abalones, crustaceans and marine mammals. Toxins from microalgae are secondary metabolites[12] whose varied modes of action can lead to diarrheal, amnesic and neurotoxic illnesses.[13]

The ocean is also a well of potentiel new resources, both for health and for other fields ranging from energy to food and materials. Close to twenty thousand new secondary metabolites have been observed in marine organisms over the past 40 years.

Pathogens also progress far faster than on land, and it is impossible to isolate the contaminated areas. Almost 15 million food infections in the USA are caused by eating contaminated seafood. The toxic effects of certain unicellular algae are all the more severe when they are displaced because of climate change and human activities. For example *Ostreopsis ovata*, which is usually found in warm

9 Tara Ocean Foundation (2024b, August 5th). *Defend Life. Protect the ocean.* https://fondationtaraocean.org/en/home/.

10 An anoxic environment no longer contains oxygen.

11 Zhivkoplias, E., Jouffray, J. P., Dunshirn, P. A., Pradndinti, A., & Blaziac, R. (2024). Growing prominence of deep-sea life in marine bioprospecting. Nature Sustainability, 7(11), 1027–1037.

12 Compounds produced by organisms and that play crucial roles in defense against predators, competition with other organisms, and attracting pollinators. They include substances that are often responsible for the medicinal and toxic properties of plants.

13 Landrigan, P. J., Stegeman, J. J., Fleming, L. E., Allemand, D., Anderson, D. M., Backer, L. C., ... & Rampal, P. (2020). Human health and ocean pollution. Annals of Global Health, 86(1), 151.

tropical waters, is now present in the Mediterranean where it provokes respiratory illnesses via aerosol inhalation without direct contact with the sea.

But the ocean can also provide solutions. At the present time, almost twenty medicines of marine origin are available on pharmaceutical markets in the EU and USA as well as Australia and China. Most of them are anti-cancer agents, although other molecules are used for pain relief or to treat viral infections. Moreover, new antibiotics should appear during the decade ahead. For instance, one of the emblematic organisms found in hydrothermal vents in the Pacific, *Alvinella pompejana*, is a thermophile animal that exhibits remarkable behavioral, cellular and molecular adaptations.[14] A new antimicrobial peptide, *Alvinellicin*, has been patented, and exploring the therapeutic potential of this type of antibiotic in lung environments infected by Gram-negative pathogenic bacteria is expected to lead to beneficial applications.[15]

Florida beach covered with toxic Atlantic sargassum algae known as red tide

PROTECTING HUMAN HEALTH AND THE HEALTH OF THE OCEAN: WHAT ACTION CAN WE TAKE?

While the IPCC and IPBES play a major role in influencing policy decisions relating to the climate and the erosion of biodiversity and natural resources, neither body is primarily focused on the sustainability of the ocean, and no equivalent body exists to plan on how to keep the ocean healthy. Although the World Ocean Assessment regularly issues summaries of the current state of the ocean, and despite a plethora of international organizations and initiatives that seek to inform ocean policymaking, most initiatives in this domain concentrate primarily on specific topics. Several UN agencies have special-interest mandates relating to the oceans: the International Maritime Organization for maritime transport, the Food and Agriculture Organization for food issues that concern the ocean, the International Seabed Authority for deep-water mining, and the UN Environment Programme for the treaty on plastics. Other efforts concentrate on specific themes, such as the High Level Panel for a Sustainable Ocean Economy or the High Ambition Coalition for Nature and People, which targets ocean conservation and Agenda 30x30.[16]

Acting to ensure that the ocean is recognized as a “common good of humanity”[17] so that it can be kept healthy and managed sustainably is the aim of the International Panel for Ocean Sustainability (IPOS) that we have set up with scientists, experts, representatives from civil society and all the oceans' stakeholders.[18] The IPOS seeks to act as a cross-disciplinary interface to promote knowledge-sharing between science, society and policymakers to help map a path toward solutions for the future of the oceans. It aims to bring together all available knowledge that will be of use in determining future ocean behavior and provide tools to support decision-making. The range of challenges affecting ocean territories create a diversity of problems that we have to get to grips with, whether they are social, economic, health-related, or environmental in a more general sense. Thanks to Towards IPOS,[19] a program financed by private partners and the European Commission, the characteristics, operation, cost and mechanism for incorporating IPOS into the constellation of UN bodies will be presented at the third UN Ocean Conference (UNOC3) in Nice, France, in June 2025.

CONCLUSION

Faced with growing threats posed by climate change, it is more important than ever to adopt a coordinated cross-cutting approach to protecting the ocean, the planet’s largest lung. This vital ecosystem absorbs a large part of the impacts of climate warming and plays a crucial role in regulating the climate. However, its ability to absorb is not unlimited, and the consequences for marine ecosystems and human societies are already visible: rising sea levels, increase in marine heatwaves, acidification, and species migration to cooler regions. Deterioration of the ocean also impacts human health, including with the emergence of diseases of marine origin, increasing toxic emanations, and disruption to food chains. Nevertheless, the ocean is also a well of resources with lasting positive impacts on our health, where we can find molecules that can heal us. The urgency of the current situation requires the creation of a global governance process for ocean health. This is why the IPOS seeks to act as an interface for dialogue between science and knowledge, society and policymakers, aiming to promote sustainable management of the ocean and guarantee that it is protected for future generations. We cannot wait before taking action to preserve the ocean because the ocean’s timescales far exceed human lifespans, stretching from centuries to millennia.

14 Gaill, F. (2017). The Pompeii worm or how to adapt to extreme conditions [Le ver de Pompéi ou comment s'adapter à des conditions extrêmes]. In A. Euzen, B. Laville, & S. Thiebault (Eds.), Adapting to climate change: A question for our societies (pp. 175–182). ediSens.

15 Tasiemski, A. et al., (2014). Characterization and Function of the First Antibiotic Isolated from a Vent Organism: The Extremophile Metazoan Alvinella pompejana. *PLoS ONE, 9*(4),

16 Agenda 30x30 is a global initiative that seeks to protect 30% of the planet by 2030.

17 Gaill, F., Riblier, E., Chabaud, C., et al. (2021). L’océan bien commun de l’humanité: Séminaires de la task force océan du CNRS [The Ocean as a Common Good of Humanity: CNRS Taskforce Seminars]. La Revue Maritime, 5, 37.

18 Gaill, F. et al., (2022). An evolution towards scientific consensus for a sustainable ocean future. *Npj Ocean Sustainability, 1*(1). https://doi.org/10.1038/s44183-022-00007-1.

19 *Towards an Intergovernmental Panel for Ocean Sustainability (IPOS)* (August 2023). European Climate, Infrastructure and Environment Executive Agency. https://cinea.ec.europa.eu/funding-opportunities/calls-tenders/towards-intergovernmental-panel-ocean-sustainability-ipos.