9. The vulnerabilities of the deep ocean's ecosystems

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The ocean's deep waters play a major role in alleviating the effects of global warming by storing a large proportion of the CO_2 produced by human activities and by absorbing the heat accumulated through the greenhouse effect. Today, an increase in dissolved CO_2 and in temperature has already been evidenced at a depth of more than 1,000 m in some ocean regions: the first signs that the disturbance already affects the entire water column.

Climate model projections predict that many deep-sea ecosystems rich in biodiversity and biomass will be exposed to disturbance by 2100. If these trends are confirmed, major changes in the functioning and services provided by these ecosystems are to be expected (cf. V.3). However, it is difficult to foresee the consequences without knowledge of natural fluctuations of these environments. Long-term observations are rare in the deep seabed, even relatively close to the coast, *i.e.* on continental margins or the surroundings of oceanic archipelagos – where numerous topographic features, such as canyons and seamounts, are key habitats for the conservation of exploited species. However, major risk factors can already be identified from our knowledge of mechanisms of interaction between marine species and their environment, along with a number of pioneer studies.

Warming and deoxygenation

The first of these threats is deoxygenation, amplified by ocean warming, which naturally affects intermediate waters (from a few hundred to about 1,000 meters deep) by reducing their 'ventilation'. Indeed, the warmer the surface water, the less it absorbs oxygen and the less it mixes with deep waters. Large areas of the tropical ocean - particularly the highly productive regions of the northern Indian Ocean, the west coasts of the American continent and West Africa – already encompass intermediate waters devoid of oxygen. Since the 1960s, these regions have lost more than 4% of their oxygen every 10 years and have expanded considerably. Many mobile species, including tuna or billfish, avoid these 'anoxic zones' and the seabed of these 'dead zones' only hosts microorganisms – with the exception of rare animal species on the fringes, where oxygen is still available. While reducing and fragmenting the habitable space of many marine species, these oxygen-depleted waters promote proliferation of predators that can survive low-oxygen conditions, such as Humbolt's squid, and consequently affect the whole ecosystem.

More subtle changes in water temperature can have equally dramatic consequences for ecosystems. The increase of a tenth of degree every 10 years in some polar regions gradually allows predatory crabs to expand their territory and to decimate species previously protected by very cold water (-1.5°C). In the Mediterranean Sea, warming raises the risk of irreversible damage to deep-sea coral reefs (Fig. 1), whose habitat's thermal limit is less than 1°C above the deep-water temperature (13.5-14°C) of this semi-enclosed basin.

Fig. 1 – **Coral assemblage at a depth of 500 meters in the Mediterranean Sea.** © UPMC / LECOB. ■

Acidification

In other areas, including the Gulf of Mexico, questions arise concerning degradation of the deep-sea reef on which many fish and crustacean species depend, due to the combination of acidification and deoxygenation. Deep-sea water is naturally more acidic than surface water. Carbon dioxide consumption by photosynthesis is no longer possible in the dark and, instead, deep layers are gradually enriched in CO_2 through the microbial degradation of sinking organic matter (*i.e.* remineralization). As a result, deep-sea corals are generally closer to the threshold of corrosive waters promoting carbonate dissolution than their tropical counterparts. While aquarium experiments revealed their adaptability to the high CO_2 levels mimicking the most pessimistic scenarios, the energy demand to form a calcium carbonate skeleton in such conditions is high. Associated with oxygen, nutritional conditions are another factor of vulnerability that is dependent on global change, and it is therefore difficult to extrapolate the response of deep-sea corals to water acidification without a better knowledge of their environmental conditions.

Deprived of light, most deep ecosystems are closely connected to surface water, where the organic matter that feeds them derives from photosynthesis. Rapid changes in the quantity and quality of these nutrients have already been reported, down to depths of several thousand meters on abyssal plains. Do they reflect extreme 'natural' events or global disturbance? Observation series covering 15 to 25 years are still too short to conclude, but they confirm that in-depth biodiversity changes very rapidly as resources become available.

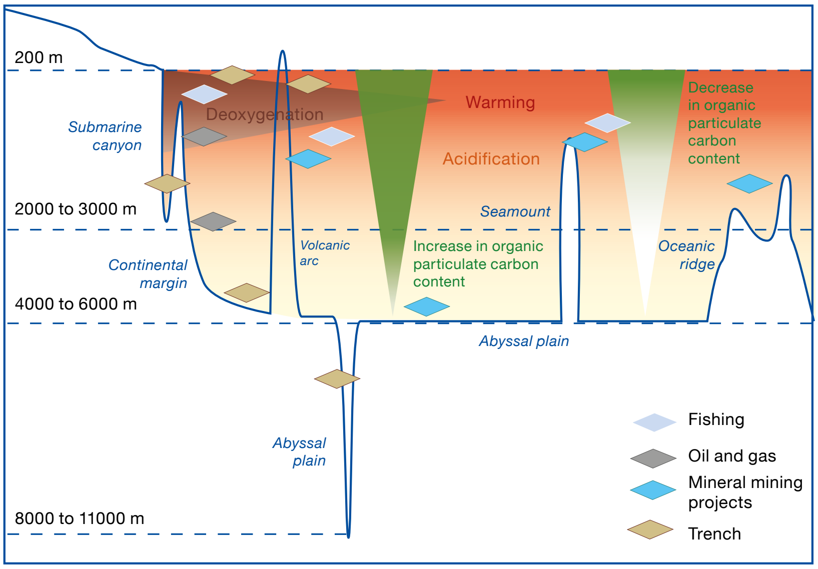

Fig. 2 – **Schematic diagram illustrating the combined pressures of human activities on various ecosystems at great depths.** Adapted from LEVIN and LE BRIS, 2015. ■

Maintaining ecosystem integrity

The rapid response of deep-sea biodiversity to changes calls for early consideration of such risks in order not to compromise the mitigation ability of ocean-induced climate disturbance and many other ecological functions guaranteed by the biodiversity of the ocean floor. Maintaining the integrity of deep-sea ecosystems under climate change is even more critical, as the exploitation of mineral, energetic or biological resources is rapidly expanding in deep waters, and it is extremely important to ensure that the environmental impacts of these activities are both controlled and minimized (Fig. 2). A significant effort is therefore needed to increase our knowledge of the sensitivity of deep-sea species and the synergistic effects that could affect other ecosystems, including those of the ocean's surface. However, we must admit that today, we only have a very limited view of the disturbances to be expected for these ecosystems. Deep sea ecology is a young science. Only 175 years ago, scientists considered marine life below a depth of 500 meters to be impossible. In this context, Marine Protected Areas are of great value, especially those that extend offshore. While integrating and protecting the most vulnerable components of these ecosystems, they constitute natural laboratories to better understand the effects of climate change at great depth and to ensure long-term surveillance of their consequences.

References

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