

The Deep Sea: new biodiversity in need of protection

The final frontier

Ironically less is known about the deep sea, one of our planet's last unexplored frontiers, than the moon surface. Of all the whole area covered by the deep sea (307 million km²), more than four hundred times larger than metropolitan France, Man has only explored *de visu* an area equivalent to the city of Paris. A census of the main "landscapes" of a huge section of the deep sea is still to be made, as well as an inventory of its biological wealth.

The deep sea adventure truly began in the 19th century with the advent of modern oceanography and the great pioneer expeditions.

Prince Albert I of Monaco (1848-1922) was opposed, like his professor Alphonse Milne-Edwards, to Forbe's theory maintaining that no life was possible beyond the aphotic zone¹, and between 1884 and 1915 he carried out 28 North Atlantic expeditions beyond the Arctic Circle, which greatly contributed towards showing that life indeed existed in the ocean's depths.

Up to the 1950s, it was assumed that the deep seabed consisted of vast monotonous expanses of sediment, interspersed with a few rocky outcrops on the periphery of the ocean. However, rapid technological progress in underwater exploration has changed this view, to such a degree that today we believe that in terms of environment, these landscapes are among the most heterogeneous and contain one of the richest biodiversities on the Planet.

Of the 5 to 30 million species that supposedly exist within the biosphere, the proportion in the abyssal zone is still poorly evaluated. American researchers have estimated, by extrapolating from certain studies, that the deep sea could be populated by approximately 10 million species. It is estimated today that we know of only between 1 and 15% of all species of marine fauna. Every year, over 1,600 new marine species are described and many of the species yet to be discovered live in these vast murky depths of the ocean.

Deep-sea diversity

What is defined as deep depends on the region and the institutional or research environment. As for the living organisms, they are not aware of such limits defined for management purposes. Thus certain species of fish such as the monkfish and the conger may live in coastal areas at depths of 1000 m and beyond. Generally speaking, the deep sea is often associated with the abyssal plain² and the continental margins, but the point at which the deep sea begins can also coincide with the aphotic zone. Certainly very little is yet known about the biodiversity at depths greater than 300 metres.

Indirect exploration (by sonar) and direct observation in a manned submersible vehicle or a ROV (Remote Operated Vehicle) have shown that the ocean bed is not just a vast plain covered in sediment. Rocky substratum is in fact much more widespread than we thought, including vast expanses on the borders of the steep continental margins³ and along the large mid-ocean ridge⁴ where the new ocean crust forms. The fauna housed by these rocky landscapes is totally different from that living in the large abyssal plains.

¹ Water layer beyond a depth of 300 m where there is almost no sunlight and where photosynthesis cannot occur.

² An abyssal plain is a flat area of the deep ocean floor, reaching depths of between 2,000 m and 6,000 m and lying between the continental rise and the mid-oceanic ridge on the borders of the continental shelf.

³ Area forming the transition between the continental rise and the oceanic area. The area consists of the shelf, the slope and the continental rise, which separates the continent from the abyssal plain or deep ocean floor. Also known as the continental shelf.

We also know today that the micro-topography, often very uneven, of these vast abyssal plains is generated by the diversity of the benthic organisms that populate them. This micro-topography contributes towards the heterogeneity and variety of the landscapes, which themselves are favourable to biodiversity. We therefore think that these ecosystems may be home to one of the most diversified biodiversities, with regard to the number of species, on our Planet, but that they are poor in biomass (a few grams of organic matter per m²), unlike other deep environments where the mass of living matter, or biomass, is high.

Life without light

Hydrothermal vents

In February 1977, when the American submarine *Alvin* dived at a depth of 2,500m onto the crest of the Galapagos ridge, at a longitude of 86° West off the coast of Ecuador, observers discovered, with great surprise, a profusion of life in what they had thought up to then was a desert: a community of large strange creatures with a surprising morphology gathered around the hot springs forming an exuberant population in contrast to the barrenness of the basalts of the mid-oceanic ridge. Corliss and Van Andel, the two geologists present in the submarine, continued their journey along the seabed and discovered a number of strange organisms close to the warm water springs (a dozen degrees above the ambient temperature of 2°C): “giant tube worms”, “giant clams” “spaghetti worms” etc.

A hydrothermal site such as the one discovered on that day covers a limited area (a few hundred square metres). It consists of hydrothermal fields grouping together several sites situated at a short distance apart (several dozen metres) and whose “pipe system” is communal. Hydrothermal populations are therefore discontinuous in space and distributed in “clusters” along the ridge axis in a virtually linear manner. These sites have a relatively short lifespan, approximately several dozen years, as they appear and disappear depending on the number of emissions of deep high-temperature fluids from the terrestrial magma. Contrary to the whole of the deep environment, these oases are relatively poor in species but rich in living matter. Biomass can reach several dozen kilograms per square metre. However, they are linked to a transient resource and can quickly collapse.

Organisms are distributed depending on their ecological preferences and their capacity to resist the aggressive nature of this environment. These populations are generally restricted to the zone where an abnormality in temperature of more than one tenth of a degree compared to the ambient temperature (approximately 2°C) is detected, i.e. in the zone where the seawater mixes with the hydrothermal fluid, the temperature of which can reach or even exceed 350°C.

But how can we explain this explosion of life in an environment with no light and where the quantity of organic matter from the surface is unrelated to the biomass observed on hydrothermal vents? Where does most of the organic matter that feeds these extremely rich ecosystems come from?

On Earth and in the sunlit zones of the upper layers of the ocean, green plants and algae are able to synthesize their organic compound using carbon dioxide (CO₂) from the atmosphere or dissolved in the water by the photosynthesis mechanism. These organisms are *photoautotrophs* (*photo* – light – indicating that light is the energy source; *autotroph* – self-nourishment – indicating that the carbon source is CO₂). As for animals which are *heterotrophs* (*hetero* – another), they can only use organic matter that is synthesized by other organisms.

The fluids released from the hydrothermal vents and cold springs on the continental margins of the deep ocean floor contain various reduced chemical compounds (including hydrogen, methane, carbon dioxide, etc). In

⁴ Underwater mountain range, strung together over almost 60 000 km and situated at the boundary between two divergent lithospheric plates. Generally, they are located at depths of over 1,000 m; sometimes their summits emerge. A tectonic rift is usually observed in the centre. Its genesis can be explained by underwater basaltic volcanism at the point where the two plates separate.

the absence of light, another form of synthesis enables organic matter to be produced: micro-organisms and bacteria, which are at the bottom of this food chain, obtain their energy from the oxidation of mineral compounds (known as *chemiolithotrophs*) and use CO₂ or carbonates as a source of carbon (as such they are *autotrophs*) to produce their cell components. These are known as “chemiosynthetic” organisms.

C. Woese, based on the study of unicellular beings, showed the existence of seemingly extremely primitive bacteria, archaeobacteria. They obtain their energy from dissolved chemical compounds, resistant to high temperatures and an environment very similar to that of the hydrothermal vents, of the “black smoker” type. Genetic analyses gradually identified the common ancestor of cells in archaeobacteria. Life therefore would have emerged in a very hot environment, similar to that of the vents.

Ten years after these hydrothermal communities were discovered, communities of organisms around diffuse emissions and cold springs on the continental margins were uncovered.

The various types of hydrothermal vent

Black smokers

Hydrothermal flow originates in the network of fissures and crevices that form as the magma cools down. The seawater, dense and cold, penetrates the network up to several hundred metres deep and reacts with the hot rock in the “reaction zone” at temperatures exceeding 350°C. The transformed and less dense hot fluid rises to the surface and gushes forth on the axis of the mid-oceanic ridge in the form of a “black smoker”.

When undiluted, the fluid released is hot (typically 350°C), anoxic and acid (pH close to 3) and its salinity is variable. It is extremely rich in elements such as sulphides (in particular hydrogen sulphide), methane, carbon dioxide, helium, hydrogen and many other elements usually rarely found in seawater (Li, Mn, Fe, Ba, Cu, Zn, Pb, SiO₂). It contains only a very small amount of sulphate, nitrate, phosphate and magnesium.

In fact, its composition varies depending on the rocks it passes through and its path.

When the fluid, released undiluted, comes into contact with the seawater, the polymetallic sulphides precipitate forming a hydrothermal structure. These chimney-like structures can exceed 30 m in height. The water released under pressure is limpid but colours with the precipitation of the metallic sulphites.

White smokers

They release calcium sulphate at lower temperatures (between 200 and 300 degrees), as their water does not penetrate the ocean crust so deeply. And in between the black and white smokers there are... a variety of shades of grey.

Diffuse emissions:

In this case there are no chimneys, but cold seeps. The fluids are extremely diluted and of a low temperature (3 to 50 degrees). In these conditions, their emissions are distinguishable by a mirror effect, like that of a mirage on a tarmac road in the midst of a heatwave! The temperature conditions are particularly conducive to life.

According to geological and biogeochemical studies, we already knew of cold seeps in several locations along the New Zealand coast but for the first time in 2006, on discovering cold seep communities in the South West Pacific, the biodiversity of the animal communities associated with these locations was directly observed and perfectly documented. The discovery of so many sites suggests that cold seeps can be found in abundance along the continental margin to the East of New Zealand.

Cold springs

We can no longer talk about hydrothermal vents in this case. But we can note a great similarity between them. In 1983, in the Gulf of Mexico, chemiosynthetic ecosystems similar to those found around hydrothermal vents, were discovered living around cold springs. This type of spring is found on the continental margins.

Deep coral reef

Thanks to new underwater technology, today researchers are discovering an increasing number of cold-water coral reefs in the seas and oceans of the entire globe, including the Atlantic, the Pacific, the Indian Ocean and the Mediterranean. These corals live at depths of several hundred metres along the continental margins. They serve as substratum, refuge and food for many invertebrates and fish, and are at the origin of a rich ecosystem the diversity and complexity of which is just starting to be studied. Despite their depth, they are subjected to the impact of human activities, in particular fishing trawlers which have already destroyed some of these “reefs” as well as the potential threat of oil exploration.

Other biodiversity hubs

Surface inputs

Over the past few years, underwater exploration has also shown the key role of organic waste (carcasses of large vertebrates, wood and plants) in the food supply for the deep sea ecosystems. We are therefore beginning to study a very specific deep sea fauna that draws its energy from whale carcasses and other large marine animals that have fallen to the seabed, masses of organic matter that also modify the marine landscape. Just like vegetation biomass inputs (wood, algae...), terrestrial inputs and planktonic “snow” (deposits of planktonic animals and plants dead on the seabed).⁵

Seamounts

Seamounts are mountains rising from the seafloor below sea level, usually of volcanic origin and reaching up to one kilometre in height. They can show on the surface but do not rise above it. These structures create unique tides and currents at their summit which encourage planktonic production. The plankton attracts a large number of fish and marine mammals. As seamounts are a rich source of food, they also encourage the growth of fixed living matter, such as corals. The concentration of fish stocks of commercial interest around these mounts makes these biodiversity rich areas attractive for fisheries.

Deep sea exploitation and its impact on biodiversity

Oil and mineral resources

The interest these deep sea ecosystems holds for mining minerals and extracting oil, as well as bio-prospecting activities have led to great concern vis-à-vis the rapid deterioration and the impact caused by this type of exploitation on deep sea biodiversity, as observed in areas that have already been exploited.⁶

Major technological and scientific innovations, such as recent progress in geology, in particular thanks to 3D seismic exploration, have led to extremely promising findings. New production methods and the unexpected quality of reservoirs (large volume and high yield) lead us to believe that there is great potential and more importantly production costs that justify the current enthusiasm for “deep sea oil”.

New potential sites are bound to be discovered in as yet non assigned areas, causing avarice. The deep offshore (500 – 3000 m) is one of the rare global areas, together with the Arctic, that is still very much unexplored and likely to give rise to major discoveries. Although in some cases, this phase of exploitation has already been reached, such as in Brazil (exploitation of the Marlim field at a depth of over 1,700 m), today there are four main geographical areas where oil exploration is at its height: the Brazilian margin, the Gulf of Mexico, the North-East Atlantic and the Gulf of Guinea.

⁵ Paul Tyler, National Oceanography Centre, Southampton, Deep sea Biology symposium – October 2005

⁶ Source : Daniel Desbruyères - : news from Ifremer, June 2006

Polymetallic nodules⁷, concretions on the sea bottom, generated a great deal of interest among many countries in the 70s-80s⁸. Important progress made recently in deep sea oil exploitation, has largely enabled us to develop technology which is adapted to harvesting these ores. Furthermore, the prices of commodities, including those found in the nodules (manganese, nickel, copper, cobalt, phosphate...) have increased significantly following worldwide economic growth, in particular in Asia. However, the environmental aspects still need to be examined and taken into consideration, the importance of which is a determining factor. Scientific studies are being conducted on the abyssal floor in order to gain a better understanding of these environments and to endeavour to assess the consequences of such exploitation.

Diamonds are currently mined off the coast of Namibia and South Africa at a depth of up to 300 m; their exploration is currently conducted up to depths of 2,000 metres.

Waste and discharge

In addition to deep sea deterioration caused by current or future exploitation, we should not forget the damage caused to the seabed and the impact on its biodiversity by waste dumped by man. Submerged discharge, household and industrial waste, waste that forms sediment... the sea and ocean floors are polluted by millions of tons of waste, 80% of which is of terrestrial origin and 20% of marine origin.

Deep sea fishing

Although still widely unknown by researchers, the deep ocean has already been exploited on an industrial scale for over thirty years. The bottom trawling fishing method is unanimously considered today as the most destructive. It consists of towing huge fishing nets weighing several tons to catch fish living close to the seabed (grenadier, hoki, oreo dory, emperor...). This non-discriminatory method also catches non targeted species such as sharks (up to 40% of the catch). In 2006 a study⁹ published in Science showed that all commercial fisheries will have collapsed by 2048 if fishing pressure remains at its current level. For deep sea fish, which are slow growing and long-lived, the collapse is expected to occur by 2025.

The expedition conducted in 2006 along the coast of New Zealand in deep cold seep locations also revealed to what extent these communities are endangered and impacted by human activities. In every seep location observed, there were signs of the damage caused by fisheries such as traces of trawl nets or lost fishing gear as well as large areas covered by the remains of deep coral.¹⁰

What can be done?

Klaus Toepfer, Executive Director of UNEP, recently declared: "We are only beginning to understand where these life forms are and what their role is in, for example, replenishing deep sea fish stocks and nurturing other marine living organisms. Cold-water corals may also harbour important compounds and substances that could be the source of new drugs or novel industrial products."

Mr Toepfer also pointed out: "All these benefits could be lost if we mismanage this newly emerging resource. *The biggest threat to both cold and warm-water corals is coming from unsustainable fishing. So it is incumbent upon us to not only better manage deep sea fisheries, but all fisheries so that there is less pressure on the deep and shallow parts of the seas*".

The solutions should first and foremost focus on sustainable and controlled consumption and a change of mentality...

⁷ Guy HERROUIN : DCNS, strategic project manager, former director at Ifremer

⁸ These ores turned out to be a resource of major interest, both for the developed countries for their metal supply and for the developing countries that shared the income derived from their exploitation.

⁹ Impacts of biodiversity loss on ocean ecosystem services by B. Worm et al., 2006

¹⁰ http://www.ifremer.fr/comarge/fr/Gallerie_NZexpedition.html

From a global point of view, four types of recommendation, among others, can be highlighted in order to protect this new biodiversity of the deep sea:

- ✓ **Support the assessment of the impact of deep sea fisheries on the replenishment of the species**
- ✓ **Support the coordinated implementation of marine protected areas in proximal deep ocean areas**
- ✓ **Encourage projects aimed at identifying and establishing an inventory of deep sea species and biodiversity hubs**
- ✓ **Promote the application and implementation of international agreements**

Today the discovery of the deep sea is a challenge that is comparable to that of the conquest of space. Countries must now pool their projects and unite their efforts to achieve a common goal – to save this biodiversity and use such resources whilst respecting the natural balance.

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