Dark oxygen: A step towards increased climate and nature alignment?

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Virginie Derue
Head of RI Research
AXA IM

Key points

- A study published in July in Nature Science revealed that oxygen was not only consumed but also produced, without any sunlight, on the Pacific Ocean's seabed
- This so-called dark oxygen production could result from polymetallic nodules laying on the seabed and acting as 'geo-batteries', electrolysing seawater into hydrogen and oxygen
- The study highlights the extent of the knowledge gap around oceans and ultimately what could impact their role as carbon sink
- We believe there needs to be a ban or a moratorium on deep-sea mining activities until scientific research on its environmental impacts is completed
- This dark oxygen production discovery is further evidence of the need to align the climate and nature agendas of all stakeholders – making oceans the next focus for investors after deforestation

Deep-sea mining is at great odds with the vital role of oceans in the fight against climate change as it risks negatively impacting a vast ecosystem we do not yet fully understand. This is an issue we highlighted in a previous paper.[1]

In our view, recent discoveries[2] around so-called dark oxygen being produced on the sea floor of the Clarion-Clipperton Zone (CCZ) in the eastern Pacific Ocean have the potential to trigger a ban/ moratorium on deep-sea mining exploitation licences and support increased alignment of climate and nature goals - this is good news.

What have we recently learnt?

The oxygen cycle in oceans has been evidenced for many years, from the production of oxygen by photosynthetic organisms such as algae or plankton using sunlight, to the consumption of oxygen by deep-sea organisms.

The study published in July in the journal Nature Science[3] revealed that oxygen is not only consumed but also produced on the Pacific Ocean's abyssal seafloor. Its findings showed this might be attributed to polymetallic nodules – which appear to break down water and create dark oxygen - laying along the seabed.

This scientific research is striking as it challenges the long-held view that oxygen can only be produced through sunlight via photosynthesis - hence the notion of dark oxygen being produced without sunlight far below the ocean surface. Importantly, it illustrates the potential role of polymetallic nodules in this process, as a kind of 'geo-battery' that would electrolyse seawater in hydrogen and oxygen thanks to their high voltage potential.[4]

What are the implications?

Significant work remains to confirm what is still as of today a scientific hypothesis. While this dark oxygen production has been tested in situ e.g. at different locations on the ocean seabed since 2021[5], this study puts centre stage the role of polymetallic nodules, although in this case, demonstrated in laboratories. Further studies are hence required to confirm the polymetallic nodules' role as geo-batteries actually occurs on the ocean floor, and at scale. There are significant implications to this study.

- The first is quite straightforward - whether confirmed or not, it is a clear demonstration of how little we know about oceans. It is not new: scientists estimate that 91% of ocean species are still unclassified[6], with about 80% of ocean floors still unmapped to modern standards[7]. Crucially at a time when the world is starting to bear the brunt of global warming consequences and biodiversity loss, both socially and financially, it indirectly confirms the knowledge gap around what may impact the ocean's role as a carbon sink and biodiversity reservoir.

- The second implication relates to the renewed push to exploit the ocean floor for its metals and minerals needed for the transition to a low carbon economy. Preserving oceans, and at least avoiding disrupting their functioning, should lead to a ban or a moratorium on deep-sea mining commercial exploitation.

What is at stake with deep-sea mining?

There are different types of deep-sea mining currently envisaged, although still in an experimental stage: on the abyssal plains targeting polymetallic nodules; stripping seamounts (underwater mountains) of their outer layer of crust; and mining hydrothermal vents (cracks and fissures on the seabed which emits fluids seeming like black smoke, that are surrounded by rich biodiversity ecosystems).

Deep-sea mining targeting polymetallic nodules involves - depending on the processes used - removing or disturbing the top six-to-20 centimetres of the seafloor sediment, leading to the potential extinction of species living on or within it. Following exploration studies, scientists have warned that in these mined areas, biodiversity systems have not replenished, even more than 40 years after the tests[8]. As for the nodules themselves, they support complex ecosystems that would be entirely lost, causing species to become extinct[9].

Scientists have also warned about the indirect consequences that might be of wider impact, from the dispersion of sediment plumes created by the mining processes to the discharge of wastewater back into the ocean[10]. Their indirect effects on ecosystems, on carbon cycling and storage into marine sediments are still unknown.

What does it mean?

In our view, we must not open Pandora's box with any large-scale deep-sea mining activities which could significantly impact the role of oceans as a carbon sink. Specifically, we would urge declaring, both in national and international waters, a global moratorium on deep-sea mining exploitation activities until the impacts and risks are better understood. This is basically what is advocated by the Deep Sea Conservation Coalition (DSCC), which was founded in 2004 in response to international concerns over the harmful impacts of deep-sea bottom trawling[11].

Where do we stand today?

The oceans' role as a major carbon sink, absorbing up to 30% of human-induced carbon dioxide emissions is well documented[12]. Accordingly, oceans have been the focus of various global agreements, from the United Nations Convention on the Law of the Sea (UNCLOS) in 1982 – a multilateral treaty codifying the standards and principles of international maritime law - to the adoption of the High Seas Treaty in 2023. The latter, also known as the agreement on Biodiversity Beyond National Jurisdictions (BBNJ), is an international agreement on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdictions[13].

One of the BBJN's aims is to establish large-scale marine protected areas (MPAs) - all the more at stake as only about 1% of the high seas is currently protected[14] - setting up rules to conduct environmental impact assessments and establishing the sharing of benefits from marine genetic resources[15].

The focus on the high seas outside of national jurisdictions is key, as they cover two-thirds of the ocean surface and 95% of its volume[16]. Quite crucially, given the reported fracture between the Global North and the Global South, it entails the notion of fairness and equity. This aspect was tackled in the United Nations General Assembly as early as 1967, when the exploitation of polymetallic nodules seemed to promise substantial economic benefits that were proclaimed "the common heritage of mankind"[17]. The High Seas Treaty now formalises this aspect[18], in a context of increasing demand for marine resources, whether food, minerals or biotechnologies. Treaties and agreements require ratifications though, and some are still needed before it can enter into force.

As seen above, and somehow surprisingly, the focus on deep-sea polymetallic nodules is not recent. However**,** it was many years later, in 1994, that the International Seabed Authority (ISA) was established, as an organisation through which states that are parties to UNCLOS organise and control all mineral resources-related activities in the area[19]. The ISA has accordingly the mandate to ensure the effective protection of the marine environment from harmful effects that may arise from deep seabed-related activities, and to advance scientific knowledge and understanding of deep-sea ecosystems[20]. Through its council, it seeks to draft a mining code to regulate the exploitation and extraction of polymetallic nodules on the ocean floor, before mining activities begin.

Deep-sea mining rules: No deal is good news

The ISA's 29th session, concluded on 2 August 2024, was not able to reach a consensus on deep-sea mining rules, delaying for another year the potential start of deep-sea mining commercial exploitation projects.

This delay is positive in our view, as it gives scientists more time to better assess the impact of deep-sea mining on ecosystems and foster a balanced picture of the potential risks and opportunities.

Indeed, we find it striking that there are still some deep-sea mining supporters, arguing there are fewer direct social impacts from deep-sea mining than land-based mining, which is criticised for its high fatality and injury rate and child labour. But in our view, this is just the tip of the iceberg given that, as mentioned, some key environmental impacts are just not assessed at this stage.

Other supporters may leverage on global concerns over tense geopolitics and critical minerals security to advocate for deep-sea mining exploitation as a way to break China and Russia's grip on certain critical minerals[21]. We would argue, as already highlighted[22], the geographical concentration of processing and refining capacities is even more topical than supply, meaning that the latter might be equally important to increase critical minerals security.

In that context, the election of Leticia Carvalho as the new ISA Secretary General for 2025-2028, seems to us positive news. Her appointment comes at a time of intense debate over deep-sea mining's future, and her oceanographer background could give the ISA a new perspective, with a greater focus on science and the environment.

Next events to watch

Overall, we do not expect the recent news flow on dark oxygen production to trigger significant announcements at the upcoming United Nations Biodiversity Conference, COP16, which is set to follow up on COP15's adoption of the Kunming-Montreal Global Biodiversity Framework and its goal to conserve and restore 30% of terrestrial and marine ecosystems by 2030[23].

By contrast, we would expect the topic to advance scientific research ahead of the June 2025 UN Ocean Conference, that will be held in Nice, France. Occurring right in the middle of the UN's Decade of Ocean Science for Sustainable Development (2021-2030), the conference could turn out to be the "Summit of Ocean Action" [24], tackling the sensitive topic of deep-sea mining alongside plastic pollution and biodiversity beyond national jurisdictions. Deep-sea mining is set to rise up investors' agendas and stewardship efforts, including the downstream part of the value chain, starting with the automobile sector.

More broadly, we believe this dark oxygen production discovery, whatever the need to confirm scientific hypothesis around its source and scale, is just more evidence of the need to align the climate and nature agendas of all stakeholders. After deforestation, oceans must be the next battle for investors, with a first, essential step being to not contribute to deep-sea mining. Policy advocacy, research financing and engagement are key levers which must be activated in that regard, extending to other effective actions in the field of plastic pollution and overfishing, implementable in various sub-sectors.

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[21] Norway defends deep-sea mining as a necessary step into the unknown (cnbc.com)
[22] Understanding and responding to the human cost of the green energy transition | AXA IM Corporate (axa-im.com)
[23] COP15 ends with landmark biodiversity agreement (unep.org)
[24] Consultation – United Nations Ocean Conference 2025 (ocean-climate.org)

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