

# Mining the sea floor: Implications for biodiversity

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A sea cucumber (*Psychropotes longicauda*) rests on the seafloor of the Clarion Clipperton Zone, which has the largest known reserves of polymetallic nodules seen in the background. Photograph: ROV KIEL 6000, GEOMAR—Geomar Bilddatenbank CC BY 4.0

An air of urgency permeates the offices of the International Seabed Authority (ISA), the international agency in Kingston, Jamaica, tasked with regulating mining-related activities on the ocean floor. Overlooking the Caribbean Sea through their windows, representatives from the 168 member states are scrambling to finalize the Mining Code, a rule book that will govern the commercial extraction of deep sea minerals.

For over a decade, different organs of the ISA have been working toward framing regulations that support mining interests while also protecting the environment in the Earth's marine depths, a region we understand poorly. It is a painstakingly tough balancing act, and the COVID-19 pandemic has added further delay to finalizing the code, much to the anguish of some countries profoundly affected by climate change.

Some of them, such as the Pacific Island nation of Nauru, battered by rising sea levels, hope minerals mined from the deep sea can accelerate a switch from planet-warming fossil fuels to cleaner forms of energy. The years-long delay in developing the

Mining Code has led to frustrations. In 2021, Nauru triggered the 2-year rule—a provision that forces ISA to finalize the required regulations in 24 months.

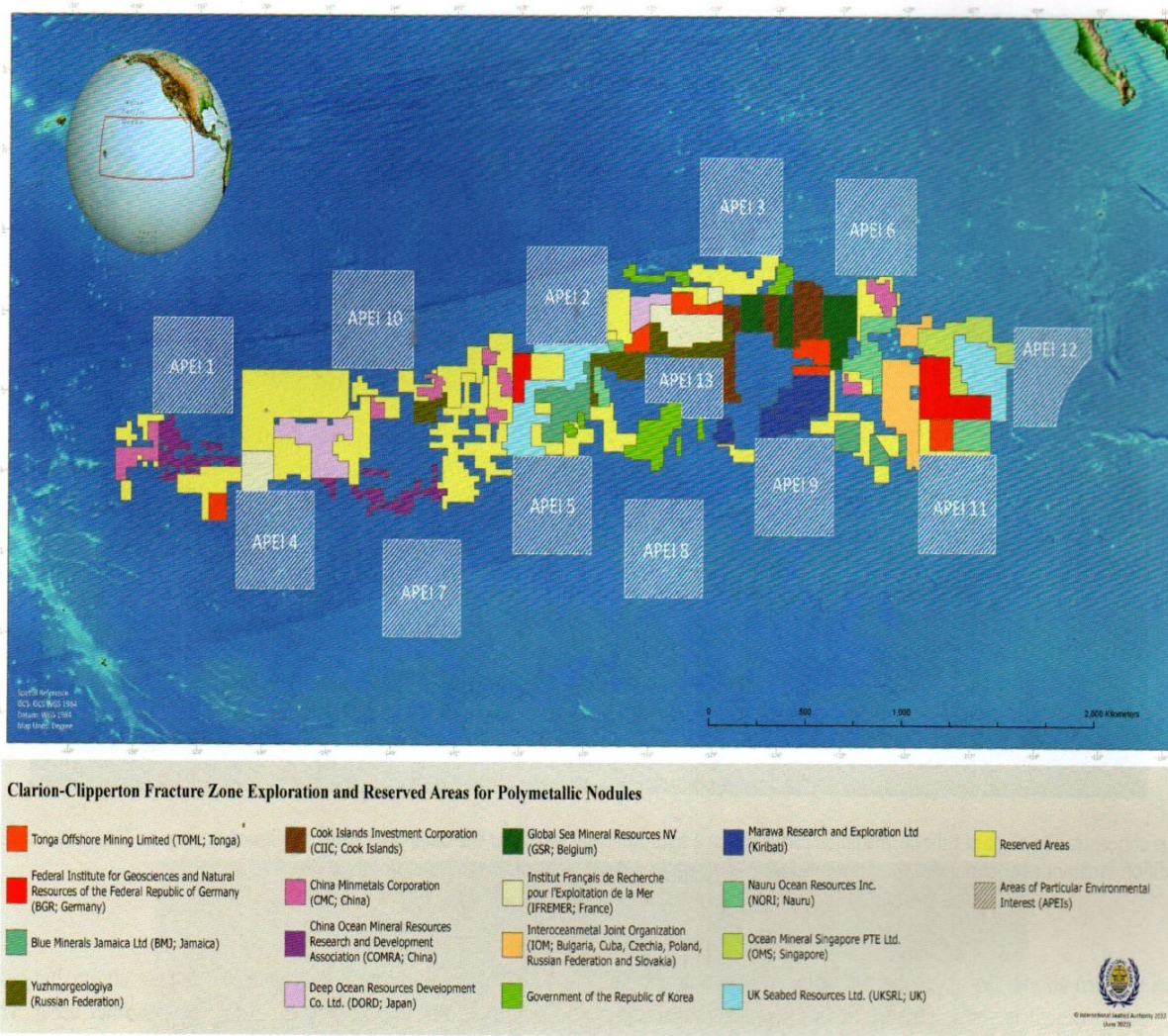
That means, by July 2023, the ISA Council, composed of 36 member states, must negotiate and decide on the exact text of the Mining Code. If this deadline is not met, Nauru can apply to mine the international seabed, and the ISA must consider and provisionally approve it, despite not having the governing rules in place.

"[The] ISA member states have agreed to continue their work on the Mining Code with a view to reaching an agreement for the adoption of the exploitation regulations for July 2023, if possible," says Stefanie Neno, a spokesperson from the ISA in an email response, "However, the member states have also agreed that further work may be needed after this deadline to finalize their discussions."

Legal expert Catherine Blanchard, from the Netherlands Institute for the Law of the Sea, at Utrecht University, specializes

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Areas in the Clarion Clipperton Zone where exploratory licenses for polymetallic nodules have been issued so far. Image: Used with permission from the ISA.

in oceans governance, the law of the sea and international environmental law. She has been closely watching the negotiations transpiring in Kingston's office rooms. "The council has been extremely busy in light of this 2-year deadline," she says. "Are we going to meet that deadline? We'll have to see!" Her skepticism stems from the fact that in addition to the Mining Code, other documents, such as environmental management plans and standards and guidelines for exploitative mining, are still in the works.

Similar skepticism is shared by scientists who argue that our current understanding of deep sea ecosystems and biodiversity are too patchy to tinker with the seabed right away. It might be best for the environment, they argue, to adopt a precautionary approach until we know more. "It seems every time we go out to do a study, it results in a number of new species being described," says marine conservationist Rob Williams, from Oceans Initiative, a research nonprofit based in Seattle, Washington, in the United States. "If we don't know what they are, we couldn't possibly know what their response [to deep sea mining] will be."

Some ISA members, such as France, Chile, Germany, the Federated States of Micronesia, New Zealand, and Costa Rica, have urged the agency to delay granting commercial mining licenses in the international seabed, citing similar concerns. "We are not confident that a robust regulatory framework for deep sea mining beyond national jurisdiction, which ensures the effective protection of the marine environment, can be agreed by the required deadline," reads a statement from New Zealand's foreign affairs minister. New Zealand is in support of a conditional moratorium

on deep sea mining until a robust mining code is agreed on. In October 2022, it joined the list of countries calling for similar delays or bans.

Many environmental agencies and intergovernmental organizations, such as the World Wildlife Fund, Save the High Seas, and the International Union for Conservation of Nature (IUCN), have called for a moratorium on deep sea mining until certain conditions are met. "Deep seabed mining cannot and should not go ahead unless there is scientific evidence that it will not create any kind of irreversible damage" or until environmental impact assessments can be done adequately and in a transparent way, says Minna Epps, director of IUCN Ocean, based in Geneva, Switzerland. As an intergovernmental organization, the IUCN has been a permanent observer without voting rights at the ISA since its inception.

Although it is not clear whether these concerns are enough to keep the seafloor-mining bulldozers at bay, the next few months may see some action as proponents and opponents of deep sea mining come to the negotiation tables in a bid to finalize the Mining Code as soon as possible. As Blanchard puts it, "It's going to be a topic that will keep us lawyers, policy people, and scientists busy for many years to come."

## Mineral wealth hidden in the deep sea

About 4000–6000 meters below the surface of the world's oceans lies a cold, dark, mysterious and muddy world that we have only



A large concentration of giant tubeworms (*Riftia pachyptila*) at a hydrothermal vent near the Galapagos Ridge, as viewed during the 2011 NOAA GALREX expedition. Anemones and mussels can be seen nearby. Photograph: NOAA Office of Ocean Exploration and Research.

begun to learn about. The abyssopelagic zone, as oceanographers call it, covers more than half of the Earth's surface. The water temperature here hovers just above freezing, between 2 and 3 degrees Celsius, and owing to very weak currents, this zone has some of the clearest waters in the sea.

However, the deep sea is not featureless. There are mountain ridges, volcanic peaks, plains, and canyons, just like on land. Hidden on the seafloor, attached to hydrothermal vents and on seamounts are huge mineral deposits in the form of polymetallic nodules, polymetallic sulfides, and cobalt-rich ferromanganese crusts. These mineral deposits contain critical elements, such as nickel, copper, cobalt, and manganese, needed to power batteries and run electric cars. As the mineral deposits on land diminish, the stash of underwater minerals is garnering the interest of mining countries and companies.

Although the three types of deep sea mineral deposits are found in all the major oceans of the world, their abundance and quality differ. "Not all minerals will be found everywhere in every ocean," says marine geologist Rahul Sharma, who retired from the National Institute of Oceanography, in Goa, India, and was associated with the Indian Deep Sea Minerals Program during his tenure. Each mineral deposit needs specific temperatures, salinity, pressure, and precipitation of minerals for its formation on the seabed.

Polymetallic nodules, first discovered in 1868 in the Kara Sea of the Arctic Ocean by a British scientific expedition on HMS *Challenger*, are the most well understood. These potato-size, half-buried rocks are found scattered on the seafloor in the abyssal plains, about 4–6 kilometers below the surface. They contain layers of iron and manganese hydroxide, with traces of nickel, cobalt, copper, and other elements. Currently, the Clarion Clipperton Zone (CCZ), located in the Pacific Ocean between Mexico and Hawaii, is considered to have the highest abundance of polymetallic nodules.

Rock formations called *polymetallic sulfides* sit on hot-water-spewing sulfide mounds, also called *hydrothermal vents*. These vents occur on underwater mountain chains, where the Earth's tectonic plates move. There, sea water seeps into the Earth's crust at depths of about 3700 meters and is heated by the magma. When the mineral-rich hot water, called *hydrothermal fluid*, meets cold ocean water, the dissolved sulfides precipitate onto the chimney-like vent structures. These sulfides are rich in lead, zinc, copper, and precious metals such as gold and silver.

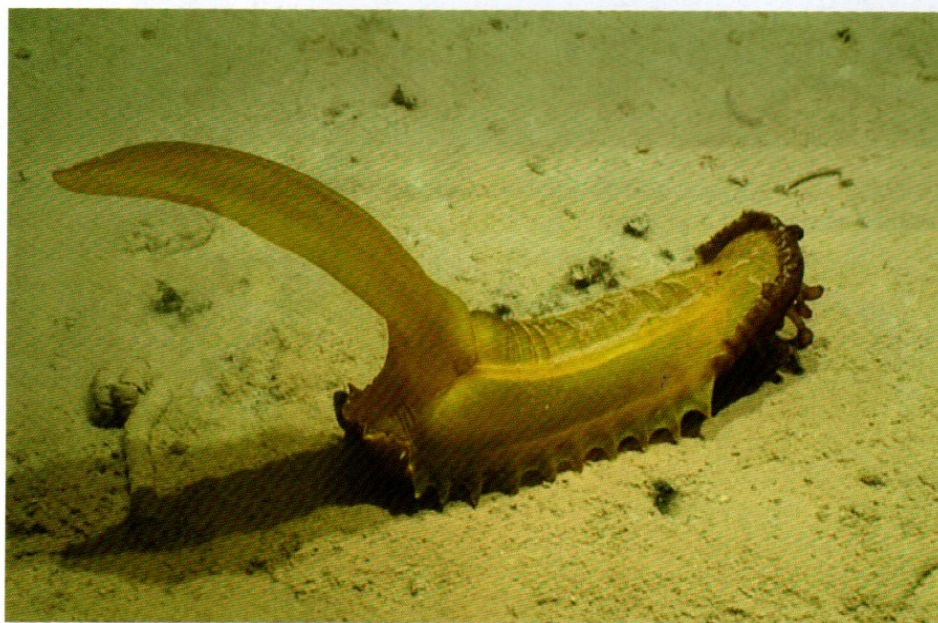
The least-studied mineral deposits so far are the cobalt-rich ferromanganese crusts found on seamounts—underwater mountains formed by volcanic activity. As the name indicates, they are rich in cobalt, iron, and manganese, but they also have small quantities of other rare earth elements such as titanium, cerium, nickel, platinum, manganese, phosphorus, thallium, tellurium, zirconium, tungsten, bismuth, and molybdenum. Nearly 2% of the ocean floor contains cobalt-rich crusts that estimates indicate could yield around 1 billion tons of cobalt.

For now, no commercial mining operations have begun in any part of the international seabed. But exploratory mining projects are underway in the Pacific, Atlantic, and Indian oceans, which have given us a glimpse into underwater mineral wealth. Since 2001, the ISA has issued 31 exploratory mining licenses to member states and their sponsored contractors for feasibility studies. It is hoped that these efforts will reveal more about the environment and predict possible impacts of mining activities. The mining code for such small-scale explorations, along with standards and guidelines, has been in place since 2013.

As mining technologies evolve to enable the unearthing of vast deposits from the deep sea, the possibility of commercial mining is no longer a scene from a sci-fi movie. Mining companies are lining up for licenses to test the viability of operations. Most exploration licenses to date have been issued in the CCZ for



Polymetallic nodules from the South Pacific Ocean. Photograph: Hannes Grobe/AWI, CC BY-SA 4.0



Gummy squirrel (*Psychropotes longicauda*), a recently discovered sea cucumber found in the abyssal plains of the Clarion Clipperton Zone, is about 60 centimeters long. Photograph: DeepCCZExpedition.

mining polymetallic nodules, whereas those for polymetallic sulfides have been issued for the mid-Atlantic Ridge and the Indian Ocean. Licenses to explore cobalt-rich ferromanganese crusts have been approved in the Western Pacific Ocean and in the South Atlantic Ocean near Brazil.

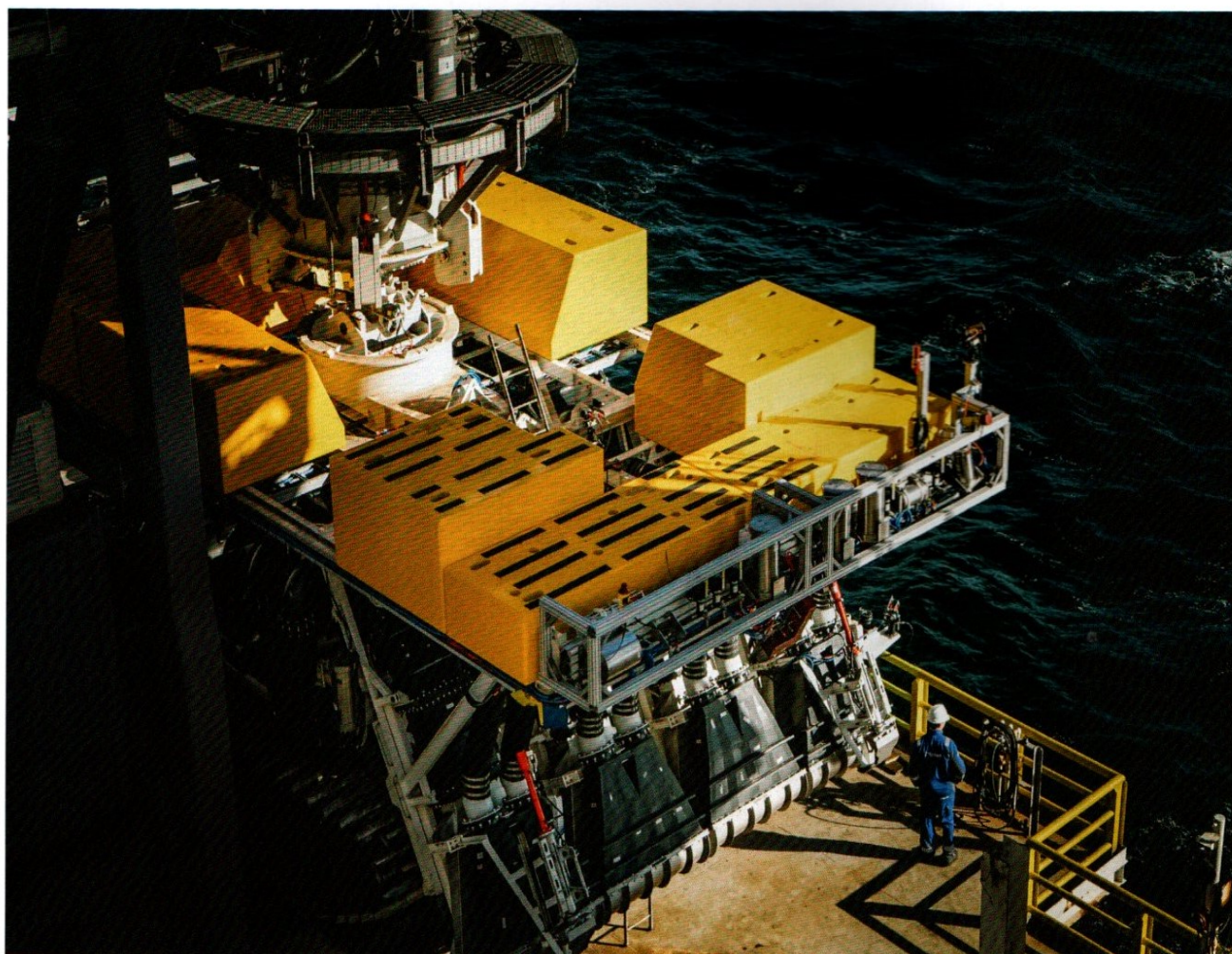
In November 2022, Nauru Ocean Resources Incorporation, sponsored by Nauru and holding an exploration license in the CCZ, concluded its pilot mining operation, bringing over 3000 tons of polymetallic nodules from the seafloor to the surface vessel *Hidden Gem*. The pilot collector vehicles involved in the trial drove across 80 kilometers of the ocean bed, collecting about 4500 tons of nodules—the largest recent operation since work began in the 1960s.

The other expected outcome of exploratory mining is gathering data about the deep sea environment, which ISA and other

organizations could use to inform regulations such as the Mining Code. So far, however, this information is scant because not all exploratory mining entities have made such data available to science, and the rush to mine the seabed without understanding the risks is raising concerns among scientists.

### Deep sea mining threats to biodiversity

Bringing the wealth of deep sea minerals to the surface is an intensive operation involving remotely operated vehicles that scrape the seafloor to pick up polymetallic nodules or dig up sulfides and crusts stuck to hydrothermal vents and seamounts. The next step is to crush this extracted material. Riser pipes with noisy pumps then send these powdered ores to a big processor ship on the ocean surface. Smaller vessels aid the



Polymetallic nodule collector vehicle being deployed from the *Hidden Gem* vessel during the 2022 exploratory trial in the Clarion Clipperton Zone. Photograph: TMC/The Metal Company Inc.

processing operations. After extracting the necessary minerals, the mining waste from the ore is released into the ocean, piped back part way down to the depths.

Scientists are worried about the scale of such operations and their impacts in a connected ocean when multiple commercial mining projects are greenlit. A 2018 study published by an international consortium of marine biologists suggested that deep sea mining is impossible without a net loss in biodiversity, because these environments are understudied and vulnerable to mining impacts and because we currently lack technologies that can minimize harm (<https://doi.org/10.3389/fmars.2018.00053>). “We just don’t know enough about the intricate connections that biodiversity provides in terms of important ecosystem services of these regions,” says marine social scientist Holly Niner, the study’s lead author and a research fellow at the University of Plymouth, in the United Kingdom.

Marine biologist Craig Smith, from the University of Hawaii, has led seven expeditions to the CCZ, a biodiversity hotspot that has surprisingly diverse life forms for such depths. “When you dive down or take a remotely operated vehicle to the seafloor, you see very strange creatures on the seafloor and in the water column,” he says, citing the example of sea cucumbers nicknamed *gummy squirrels*, because “they look like a gummy worm, but they’re like a squirrel, with a big tail sticking up.”

There are also many species of worms, crustaceans, anemones, and brittle stars. Scientists have only recently begun to catalog the species that live there, ranging from microscopic bacteria all the way up to megafauna such as whales and fish. “Nowhere has it been sampled enough to know even close to what the total species

richness is,” Smith says, adding that, at this point, we may know just over half of what might exist deep underwater. In the CCZ, for example, scientists have documented over 600 species of large fish and invertebrates and over 10,000 species of foraminifera—a family of protozoans related to amoebae—on the seafloor. Most of these species are endemic to these zones—found here in these depths and nowhere else.

Polymetallic nodules are also home to over a hundred endemic species. “They require nodules to live, and, if the nodules are removed or buried by mining, then their habitat will be gone,” says Smith, adding that these species could be wiped off the face of the planet if large-scale mining begins.

When autonomous vehicles descend to the seafloor to mine polymetallic nodules, they remove the nodules, disrupting the sediment around the area and creating a sediment plume on the seafloor, causing turbidity. The footprint of such a disturbance, Smith warns, is projected to be around 45,000 square kilometers or more from a single mining operation conducted over 30 years—far greater than the footprint of a single land-based mining operation.

In the CCZ, simulations of small-scale mining operations have shown that mined areas take over 30 years to recover. Even after recovery, the ecosystems showed changes: The sediment structure had altered, and the composition of life forms had changed. “We know that nodules themselves have been deposited over timescales of millions of years,” says Smith, “If you mine tens of thousands of square kilometers, it’s extremely likely that it will take a century or more for the soft sediment communities to recover,” he speculates.



A new species from a new order of Cnidaria, found at 4100 meters in the Clarion Clipperton Zone. This organism lives on sponge stalks attached to polymetallic nodules on the seafloor. Photograph: Craig Smith and Diva Amon/ABYSSLINE Project.

Hydrothermal vents have bacteria that produce energy that attract a special community of organisms, including crabs, shrimps, mussels, and other crustaceans. Depending on how deep the vents are and the chemical composition of their fluids, each field can have uniquely adapted organisms. For example, the scaly-foot sea pangolin (*Chrysomallon squamiferum*) is an endemic snail species recorded exclusively from only three sites in the Indian Ocean within an area equal to two football fields. Two of these three sites are under explorative mining licenses. Considering the risk deep sea mining poses to this species, scientists have recently added it to the IUCN Red List as Endangered.

Vent fields are patches of the seabed where hydrothermal-fluid-filled active vents occur close to inactive vents lacking fluid. "What's fascinating is that every vent field is different from the others," says marine biologist Sabine Gollner, from the Royal Netherlands Institute for Sea Research. Gollner's research is focused on hydrothermal vent ecosystems in the mid-Atlantic Ridge.

For the mining industry, inactive vents are more attractive because they hold many minerals. But because the vents are geologically connected, digging up inactive ones may cause their reactivation, disturbing the connectivity in the vent fluid systems. When you dig up active vents, Gollner warns, you could start messing up system processes. "If you basically destroy one [through mining operations], the chances are very high that it probably will not recover because it is unique," she says. Compared with their active counterparts, inactive vents are also the most understudied vent systems in terms of biodiversity.

Apart from the physical disturbance in the deep sea ecosystems, noise from mining activities, expected to propagate throughout the water column, poses an additional threat. Bulldozers clank on the seafloor. Kilometers-long riser pipes, fitted with pumps, rattle along their entire length as they move rocks and

water to the surface. The propellers of the surface ships whirl. Although noise levels in air cannot be compared directly with those underwater, in a 2022 study, a team led by Williams estimated that mining noise from a single operation in the CCZ will create a cylinder of noise up to 500 kilometers around it, including in areas earmarked for conservation. "It's not just that we're concerned that noise can have an impact," he says, "It's that proposed monitoring programs will be incapable of detecting impact, because both the mining sites and the preservation reference zones will be exposed to noise."

For the many underwater creatures, especially those living in the quieter parts of the ocean, this noise isn't music. Although oceans undisturbed by humans are not entirely quiet, "these are organisms that have evolved in an area that is free of anthropogenic noise," says Williams. "We think it's worth pointing out that we don't know how those species will respond to a new noise source." For marine organisms, noise is known to have both acute and chronic negative effects.

To minimize any known and unknown harm to the marine environment, the ISA says it requires mining contractors to conduct mandatory environmental baseline studies while also promoting scientific research on deep sea ecosystems and biodiversity. In the CCZ, the ISA has established an environmental management plan where no mining will be allowed in 13 designated areas, covering 1.97 million square kilometers. "This is, in effect, one of the largest networks of marine protected areas today," says Neno, from the ISA, indicating that similar plans are underway for the mid-Atlantic Ridge, the Indian Ocean, and the Northwest Pacific Ocean.

But until large-scale mining operations begin, it's hard to know the exact impacts they have on the diverse ecosystems in the deep sea. "It's a little bit of a catch-22 situation," says Smith. "You'd like to know what's going to happen before you allow full-scale mining, but, probably, we can't really [understand the



Three populations of *Chrysomallon squamiferum*, also known as the sea pangolin, found in the Indian Ocean (Kairei, Longqi, and Solitair vent fields). The species has unique iron-infused scales as a layer of protection. Threatened by deep sea mining, the species has recently been designated Endangered on the IUCN Red List. Photograph: Chong Chen, CC BY-SA 3.0.

full impacts] until a mining operation has been up and running for some period of time.”

With a generous dose of caution, however, there may be a way out of this dilemma.

### A cautious step into the future

Proponents of deep sea mining, such as Nauru, cite the existential threat posed by climate change and the environmental impacts of land-based mining as reasons to mine the deep sea to satisfy the world's hunger for energy and minerals. The accelerated switch to renewable sources of energy, they argue, may be a worthy trade-off for some deep sea biodiversity loss.

The first step toward striking a good balance is accepting that there will be major habitat destruction and disturbance from mining operations for over tens of thousands of square kilometers, says Smith. The next would be to stagger mining operations, where the ISA could approve one license instead of multiple licenses in a region, then carefully watch the environmental impacts. “If it's too big an impact, then we stop,” he says.

To minimize the impact of mining noise, Williams urges that the industry should share the noise-related data they have collected so far during exploratory operations. “We need high-quality recordings from real-world pilot projects,” he says, including low-frequency noise that are inaudible to human ears. He also suggests they could test noise-dampening techniques such as

bubble curtains or “whatever works to quiet that sound source.” Experimenting with such techniques might provide global benefits, because shipping-related noise levels are doubling every decade. But with deep sea mining, it's challenging to measure noise levels, because both the mining sites and the preservation reference zones, with which the impacts are compared, will be exposed to noise.

In an area where science advances with every scientific expedition, designing regulations that incorporate dynamic knowledge is challenging. It may take years or decades for knowledge to translate into policies. Drawing from her experience with other international laws, Blanchard suggests that the ISA could future-proof the Mining Code by including provisions that allow swift modifications in response to new developments, knowledge, and scientific discoveries. In other words, says Blanchard, the aim is to “make the regulations as adaptable as possible to these changes.”

However one looks at it, with the looming dangers of climate change and potential ecological havoc of ramping up deep sea mining, there is a lot at stake for the future of life on planet Earth. When it comes to the fate of the bottom of the sea, much rests on ongoing discussions in Kingston. Making an informed choice with multiple fallback options may be the smartest move to balance economic, political, and environmental aspirations. As humans, our track record in striking such a balance is not great. However, as Sharma notes, the human mind is ingenious at finding solutions.