Critical Ocean Minerals Research Center

REPORT

A Deadly Moratorium

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Environmental organization, WWF, has attracted support from sovereign governments and large corporations for a moratorium on seabed mineral extraction. But the moratorium is forcing the world to double down on some of the deadliest mineral extraction practices known, in the most biodiverse ecosystems on the planet, directly adjacent to human settlements. It is bringing death, disease, and displacement to many vulnerable indigenous people each year that could be avoided. It is also impeding efforts to decarbonize while increasing our greenhouse gas emissions. This report is a call for signatories to the moratorium to reconsider their stance in the name of a more just energy transition and a healthier planet.

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Cover image: WWF flag at Policoro, Italy, July 17, 2011. WWF has called for a deep sea mineral moratorium that could have catastrophic consequences for wildlife, people, and our planet. (iStock/Angelafoto)

A young boy works among about 4,000 artisan miners dig for copper on December 13, 2005 in Ruashi mine about 20 kilometers outside Lubumbashi, Congo, DRC. Some children as young as eight work in the mine under dangerous conditions, where multiple miners die each month. Congo has one of the largest Copper deposits in the world and most of it is exported to China. (Per-Anders Pettersson/Getty Images)

About Deep Sea Polymetallic Nodule Collection

Polymetallic nodules, potato-sized rocks found in the deep ocean, are formed from dissolved metals that precipitate from the seawater and sediment, in remote, deep ocean waters (around 3 miles in depth). They contain a variety of critical energy minerals at high grades—manganese, nickel, copper, cobalt, rare earths, titanium, and more. Nodules grow over tens of millions of years under the extreme pressures and cold temperatures of the deep abyssal plains.

Despite WWF's efforts to paint all deep-sea extraction with a single brushstroke, the resources and the ecosystems in which they occur vary considerably. We have chosen to focus on nodules specifically because they can be extracted non-invasively and because they are found in a remote part of the ocean that hosts relatively little life and biodiversity (relative to where we mine the same minerals today). At the depths where nodules are found there is no light or plant life. The plains are lightly inhabited, with none of the sea life commonly known to man. Most organisms residing on the abyssal plains are found in the sediment and are microscopic or barely visible to the human eye (Rabone, 2023).

Nodules sit loose on the ocean bottom and can be picked up by remotely controlled vehicles. These machines, which are almost neutrally buoyant on the seafloor, move over the plains on tracks and gently pick up nodules by shooting a jet of water over them, creating a pressure differential that lifts the nodules from the sediment as the harvester passes (Jia, 2023). The design minimizes the amount of sediment that is mobilized in a plume. Once recovered and brought to port, nodules can be easily crushed and processed into mineral products that are useful for the energy transition or for other commercial applications.

About The Critical Ocean Minerals Research Center

The Critical Ocean Minerals Research Center ("COMRC") represents a group of stakeholders who have been studying seabed mineral extraction for the last decade. COMRC is run and funded by Scott Vincent, an investor in the industry. COMRC is also taking contributions from interested individuals but will not take money from contractors.

After careful and extensive due diligence, the group and our advisors, which include scientists, investors, mining professionals, offshore engineers, and other marine experts, concluded that research spanning six decades supports a precautionary and gradual start to polymetallic nodule collecting accompanied by careful monitoring, adaptive management, and prudent safeguards. Absorbing the relatively small risks inherent in this precautionary approach is justified given the severe costs to human health and to the environment which result from the extraction of these minerals from terrestrial locations today—these costs can be incrementally reduced or avoided as nodule extraction grows. Without switching to lower impact sources for many of these minerals, adverse effects will worsen as ore grades continue to decline.

Nodule collecting offers the world's inhabitants an immense and powerful decoupling opportunity. Decoupling is a term that Ecomodernists use to describe efficiencies gained through new technologies that allow for growth and development—in this case decarbonization development—at levels that exceed the growth in environmental impacts. Decoupling creates windfall gains for society, which benefits from increased living standards at reduced environmental costs.

COMRC operates independently of the contractors currently exploring polymetallic nodule resources; however, some of the organization's members hold investments in these contractors, providing COMRC with a unique perspective to evaluate contractor strategies and practices. COMRC strives to maintain objectivity, but like all stakeholders, it has biases. Unlike activists opposing nodule collecting, however, COMRC's biases are grounded in comprehensive research and critical thinking and are aligned with global goals of improving living standards while protecting our ecosystems.

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Democratic Republic of Congo, May 2009. "In the Democratic Republic of Congo around 1,500 people die every day over fighting to control the lucrative trade in minerals." Note that these figures tie to conflict conditions which vary from year to year. (Tom Stoddart/Getty Images)

Executive Summary

Imagine a vast source of energy transition minerals (ETMs) which could be extracted non-invasively from a remote region holding relatively little life and biodiversity. Tapping this resource could save many human lives per year, drastically cut the CO_2 footprint from ETM extraction, accelerate decarbonization, vastly reduce toxic mine tailings, reduce supply chain dependence on China, and protect the world's most biodiverse and endangered ecosystems. Such a breakthrough would be a monumental victory for both humanity and the environment. Fortunately, this isn't a distant dream. Polymetallic nodules on the deep ocean floor offer such a resource.

Polymetallic nodules are ETM-rich rocks formed from dissolved metals in the seawater and sediment in the deep ocean (~3 miles deep). Nodules grow over tens of millions of years and sit loose on the ocean floor. The plains are inhospitable, characterized by perpetual darkness, extreme cold, and immense pressure. Devoid of plant life, this environment is inhabited principally by microscopic organisms that are invisible or barely visible to the human eye. Nodules may be gathered in a non-invasive fashion by remote-controlled crawlers, specifically designed to minimize sediment disruption as they pass along the plains and send nodules to the surface (Jia, 2023).

While nodule collecting offers society an innovative solution to address our growing need for lower impact ETMs, WWF and other environmental non-governmental organizations (eNGOs) have called for a moratorium on the practice. These groups have chosen to ignore the science that firmly supports collecting's net benefits, and instead are steering us toward a path that exacerbates our

reliance on destructive strip mining in endangered tropical rainforests adjacent to human settlements.

The Critical Ocean Minerals Research Center ("COMRC") has spent years reviewing research and studying polymetallic nodules and their extraction—from collection and lift technologies to processing flows and financial projections to environmental considerations. COMRC occupies a well-informed position to consider the impacts from WWF's call for a moratorium.

This report demonstrates that WWF's call for delay and inaction is costing human lives and perpetuating suffering every day, while encouraging all manner of environmental destruction that is more damaging than the alternative. And while the list of harms from the moratorium is substantial, most stunning is the magnitude of those harms. The benefits of switching to nodule collecting are too profound to be ignored. The empirical data and scientific studies which back these statements are highlighted in detail later in this report.

The evidence will show the immense damage WWF's moratorium is having on people and our planet include the following:

- **Increasing human death, disease, and suffering in indigenous populations**
  - Terrestrial mining's toll on humanity is deadly. More than 15,000 miners are killed each year, but the indirect impacts are far more widespread and threaten death and disease for millions of people, most of them indigenous (World Counts, 2024). An estimated 23 million people live on toxic floodplains contaminated by mining (Macklin, 2023). Air pollution from mining is known to cause respiratory, cardiovascular, inflammatory, and neurological diseases in human populations (Silva-Rego, 2022).
  - There is no mechanism by which nodule extraction would negatively impact human health directly (outside the risks to workers inherent in commercial marine operations). The potential for indirect human health impacts from collecting is orders of magnitude lower than in terrestrial mining (Paulikas, 2020).
- **Increasing destruction of endangered tropical rainforests**
  - Many ETMs are strip mined from underneath rainforests. Research shows that deforestation associated with mines extends the mine footprint by ~12x (Sonter L. J., 2017). Minerals can be produced from nodules without any rainforest loss, and the observed damage to the ocean floor from non-invasive collecting is modest by comparison (O'Malley, 2023).
  - Scientists estimate approximately 4.35 million species inhabit rainforests, the vast majority of which are undiscovered, and these ecosystems are highly endangered (Mora, 2011) . Scientists estimate 8,000 metazoan species inhabit the abyssal plains, most also undiscovered, where nodule collection will take place (Rabone, 2023).
- **Displacing humans and loss of indigenous land rights**
  - Over half of ETM mining activities are based in or near lands of Indigenous people whose rights and protections are embedded in United Nations declarations (Owen, 2022).

- Tapping seabed nodule resources can relieve the pressure to compromise our ideals as we attempt to decarbonize. This will afford the Western world the opportunity to divest from mining companies who do not practice free prior and informed consent, and who abuse human rights.

- **Dramatically greater toxic waste streams and pollution of freshwater resources**
  - Terrestrial mines generate large quantities of toxic solid waste. That waste is dangerous, difficult to store or dispose of, and represents a significant and often deadly threat to human health. Terrestrial mine waste frequently contaminates freshwater resources (Macklin, 2023) (Lakshman, 2024).
  - Taking nodules avoids each of these consequences because nodules generate little/no solid waste (no overburden removal, 100% commercial material).

Open pit mine in Mindanao, Philippines with clearly visible tailings. (iStock/Mary Grace Varela)

- **Hindering efforts to decarbonize**
  - Efforts to decarbonize the world's economies require a large increase in the production of ETMs, and many analysts predict looming shortages. Recycling and innovation will help reduce some of the burden, but even with aggressive assumptions for these sources, experts believe we will still require significant production increases from the mining sector.
  - Artificially constraining the mineral supply of certain ETMs by imposing a moratorium on the largest and lowest impact resources in the world will result in higher mineral prices and slower clean energy adoption. Consumer backlash against high impact ETMs is already evident.
- **Dramatically more CO_2 emissions and sequestered CO_2 release**
  - CO_2 emissions from terrestrial mining are 20-74% higher than those from nodule collecting according to life cycle analyses (Benchmark Min Int, 2023) (Paulikas, 2020) (Alvarenga, 2022).
  - Life cycle analysis indicates that the amount of sequestered carbon dioxide released in nodule collecting is 94% below that which is released during land-based mining (Paulikas, 2020).
- **Increased threat to Western national security and strategic industries**
  - China dominates the world's production & processing of critical minerals and has introduced restrictions on these minerals nine times from 2009-2020 (Coyne, 2024).
  - Critical minerals are necessary for developing advanced defense systems and a variety of commercial applications. A moratorium increases our reliance on China's supply chain for these minerals just as it dims western commercial and economic prospects and thus represents a national security threat. It also provides great political and economic power to a country whose goals and values are not aligned with those of the west.

- **Reduction in opportunity for breakthrough medical therapies**
  - Investment in nodule exploration had driven increased access to deep-sea biological data, creating the opportunity for medical breakthroughs. Yet, the moratorium impedes this research by cutting off industry funding.
  - The moratorium risks the extinction of countless unknown plants and animals in rainforests due to the extremely high biodiversity found there, and therefore represents a far greater threat to the creation of novel therapies than does nodule collecting.

Figure E Impact Comparison

	Terrestrial Strip Mining	Nodule Collecting
Location[1]	Rainforests & Forests	Abyssal plains
Invasiveness[2]	Highly invasive	Non-invasive
Number of Species Present[3]	4,350,000	~8,000 (in CCZ)
Biodiversity impact[4]	~100% reduction	20% reduction
Biodensity impact[5]	~100% reduction	50% reduction
Human Impact[6]	Great loss of life, disease	Negligible
Solid Processing Waste[7]	Large quantities	Negligible
CO_2 Footprint[8]	Very large	Small
% Ecosystem Impacted[9]	10% to 33%	0.06% to 0.2%

In the following pages we delve into additional support behind each of the above bullet points. We offer more information, complete with references to a variety of scientific sources, on our website at COMRC.org. COMRC's website also includes a section on "Misinformation" where we debunk many of the false claims that WWF and other environmental groups make in their attacks on the industry.

Before exploring the details of our findings, we cover a few high-level points below.

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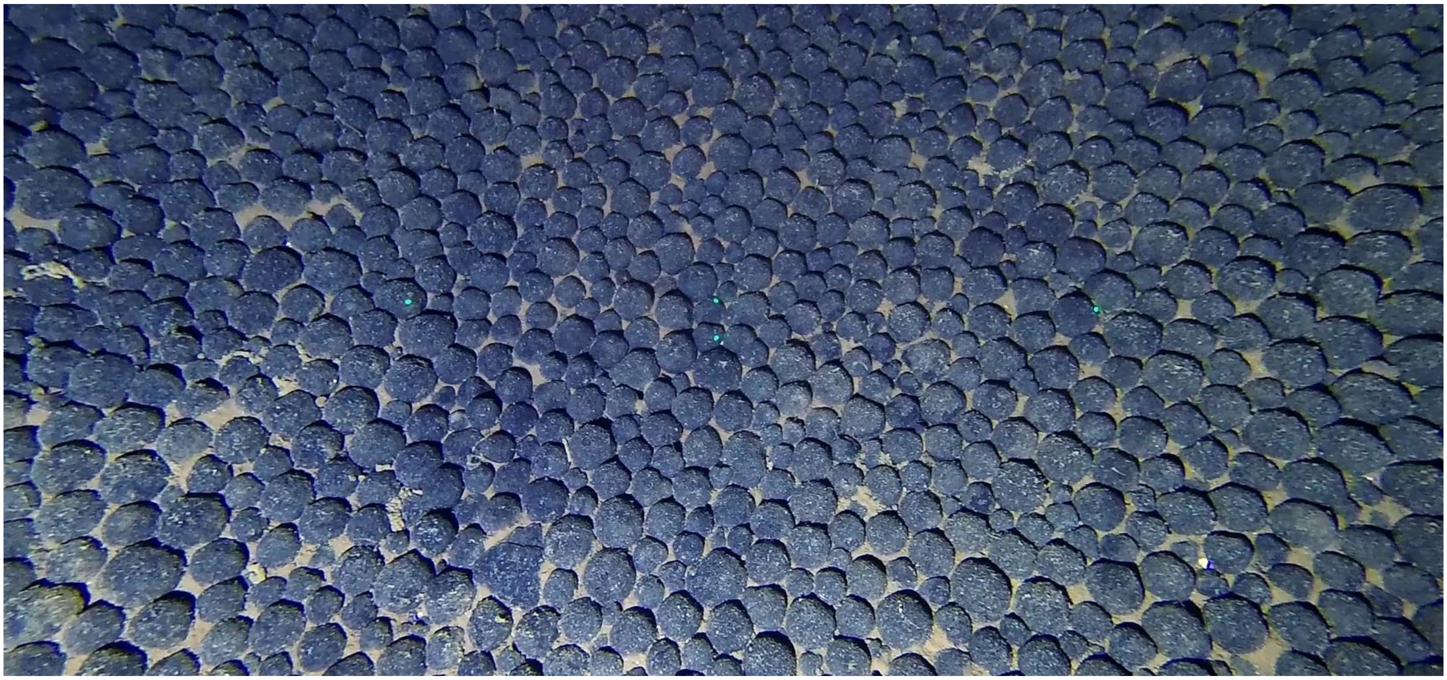
[1] Incremental supplies of nickel, cobalt, copper, manganese, and rare earths often (but not always) originate in tropical rainforest or forest ecosystems
[2] Nodule extraction requires no digging and is thus non-invasive
[3] (Pillay, 2021) (Mora, 2011) (Rabone, 2023)
[4] (O'Malley, 2023)
[5] (O'Malley, 2023)
[6] (World Counts, 2024) (Silva-Rego, 2022) (Macklin, 2023)
[7] (Tan, 2023), (Silva, 2023), (Bilgic, 2019) (Sullivan, 2017) (Paulikas, 2020)
[8] (Paulikas, 2020).
[9] Terrestrial mining figures reflect all mining – not just ETMs (Radwin, 2023); Nodules see quantitative analysis under rainforest impacts section



Deep sea polymetallic nodules in abyssal sea plains. Characterized by perpetual darkness, extreme cold, immense pressure, and devoid of plant life, this environment is inhabited principally by microscopic organisms that are invisible to the human eye.

A Precautionary Approach?

In their calls for a moratorium, or an outright ban on nodule collection, opponents often cite the need for precaution, referencing the lack of perfect knowledge about the impacts of the activity. The reality, however, is that their proposed approach is not precautionary at all. In fact, it is fraught with risk and fails to adhere to the precautionary principle's framework for decision making under uncertainty.

It is reasonable to approach polymetallic nodule collecting with caution as there is no precedent for commercial-scale extraction from the deep abyssal plains. Any new technology or process, such as nodule collection, inherently involves a degree of uncertainty, making precautionary measures necessary.

That said, it is crucial to recognize that a precautionary approach requires us, as a society, to weigh not only the risks associated with adopting a new technology or methodology, but also the risks associated with inaction related to the technology. Those risks can be measured in terms of avoided costs, or what we often think of as benefits of the new technology.

The European Union formally states this idea in its Communication from the Commission on the precautionary principle made in February of 2000:

> *Examining costs and benefits entails comparing the overall cost to the Community of action and lack of action, in both the short and long term. This is not simply an economic cost-benefit analysis: its scope is much broader, and includes non-economic considerations, such as the efficacy of possible options and their acceptability to the public. In the conduct of such an examination, account should be taken of the general principle and the case law of the Court that the protection of health takes precedence over economic considerations. (Commission of the European Communities, 2000)*

The concept of evaluating both the costs and benefits of a new technology might seem self-evident; however, those advocating for a moratorium or outright ban on nodule collecting almost exclusively focus on the technology's potential risks or costs. That is, they almost always ignore the benefits of implementing the practice (or the risks of inaction), and as a result, opponents lack a comprehensive framework for informed decision-making.

We assess both the costs and benefits of using a new technology because doing so provides a yardstick by which to measure the proposed technology's overall impacts. If we assessed new technologies solely by looking at their risks and costs, we would never adopt any of them. We never have scientific certainty surrounding the risks of adopting a novel technology, and we would never willingly expose ourselves to that uncertainty without the prospect of substantial benefits.

We would not have achieved advancement in medicine, transportation, electricity, or digital communication if we solely focused on the risks associated with their adoption and demanded near certainty in terms of understanding their risks prior to use. We continue to learn about the risks of these technologies long after their widespread use. We accepted these technologies because we measured the risks of their adoption against the costs we avoided in adopting them (the benefits, or the risks of inaction) and decided the net benefit justified it.

When opponents of nodule collecting publish work about the potential extraction method, they cite the risks of destroying the ocean floor, threatening biodiversity, releasing stores of CO_2, and poisoning the human food web. Yet, these risks are vastly overstated, in part, because of a failure to assess the costs of avoiding the activity. Without a benchmark, NGOs are unable to understand that the costs they cite are far lower than the alternative—sourcing the same minerals from terrestrial mines.

Critics also claim there are too many unknowns around nodule collecting to carefully begin the activity, conveniently ignoring the fact that we have been researching the impacts of nodule collecting for over 50 years (Jones, 2017) (NOAA, 1995). Data from studies indicates the extent of damage associated with nodule collecting is highly manageable when compared with impacts from terrestrial mining (O'Malley, 2023) (McLachlan, 2023).

Notably, far greater uncertainties surround the principal alternative to nodule collecting—strip mining in tropical rainforests. These critical and endangered ecosystems harbor millions of unidentified organisms (approximately 86% of rainforest species are unknown and uncharacterized), and the consequences of the damage or extinctions we may cause individual species as we expand terrestrial mines is largely unknown (by contrast, scientists believe there are approximately 8,000 unidentified metazoan species in the Clarion Clipperton Zone—an area that is half the size of the world's rainforests) (Mora, 2011) (Rabone, 2023) (Lamb, 2024).

Regardless, the risks of the unknowns around nodule collection will persist, no matter how small. One thing we can say with high confidence is that even if we were to study collecting impacts for another 50 years, activists would continue to demand more research, oblivious to the harm they do with these demands.

This report demonstrates, through scientific studies and empirical data, that the risks associated with *not* collecting nodules significantly outweigh the potential risks of nodule extraction in terms of human suffering and environmental damage. While uncertainties exist regarding the impacts of nodule extraction (as in terrestrial mining) there is considerable certainty surrounding the fact that related impacts are not as damaging as those associated with terrestrial mining. The non-invasive nature of nodule extraction, the limited biomass & biodiversity found in abyssal plains ecosystems relative to terrestrial settings, the lack of human presence on the abyssal plains, and the relatively small footprint of impacts from collecting compared to the size of nodule rich plains, together place limits around potential damage from collecting. Those limits are well within the bounds of environmental and human damages defined by terrestrial mining as will be developed later in this report.

In particular, it is the death and disease in human populations which could be avoided if we harvested nodules, that demands a careful start to nodule collecting. The EU report on the precautionary principle is explicit in stating that human health must take precedence over other considerations when making decisions about adopting and using a novel technology. **The evidence is unequivocally clear that we will save many lives and considerable pain and suffering among indigenous populations as we transition from terrestrial strip-mining to nodule collection. A truly precautionary approach necessitates a clear acknowledgement of this reality.**

It is worth noting that we currently engage in a number of maritime activities, such as bottom trawling, construction, and dredging, which are more invasive than nodule collecting, and which occur across far larger areas annually. For instance, each year bottom trawling covers an area almost 30x times greater than we would cover in 20 years of nodule collecting if we sourced ***all*** of the cathode minerals required under the IEA's Stated Policies Scenario from the seafloor (IEA, 2021) (Graham, 2024). Unlike nodule collecting, these activities typically occur close to humans, at depths that could impact the human food web, and in places that are far more inhabited and biodiverse than the abyssal plains. In addition, we subject the ground to these activities repeatedly, despite the negative consequences (nodule collecting would not subject the ground to repeated exposure).

Large companies and sovereign governments have been misled by environmental activists to join calls for a moratorium. They've been told they are endorsing a precautionary approach when the reality is that eNGOs are advocating a risky strategy that is causing large-scale damage to humanity and the environment.


Low-impact sources of key minerals are urgently needed to accelerate the transition to a clean energy economy that benefits our planet and all of its inhabitants. (iStock/nrqemi)

Deception by WWF and other eNGOs

Before moving on to the detailed consequences of a moratorium, we would like to dispel a few of the many myths that WWF and other eNGOs have used in their campaigns against nodule collecting. We provide a more detailed analysis of the misinformation provided by these groups on our website.

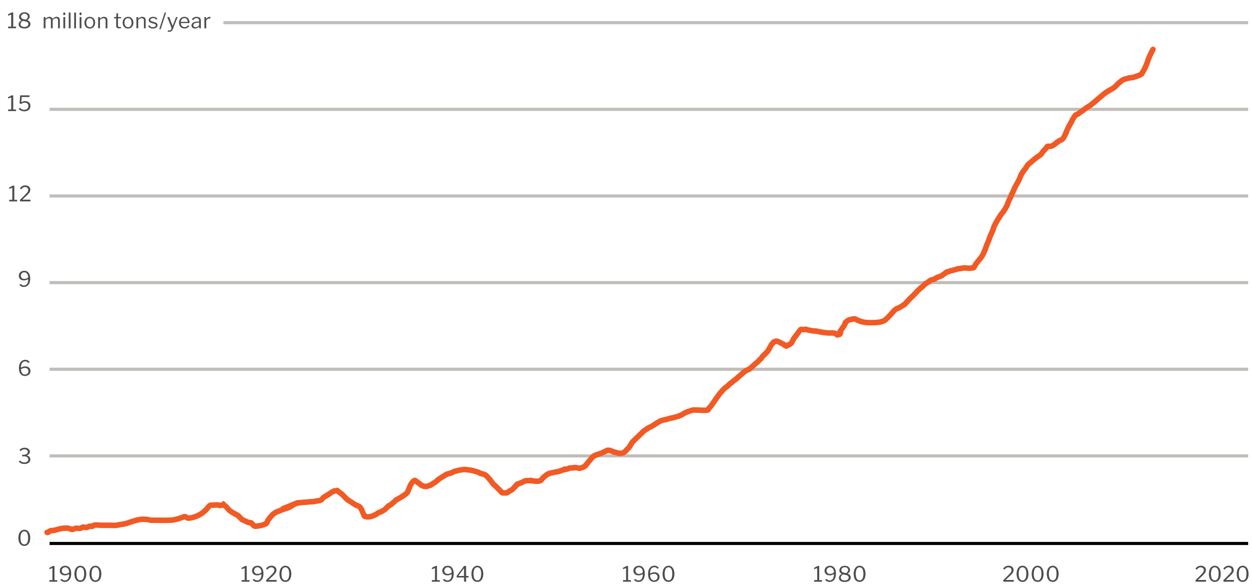
WWF and other eNGOs deploy a range of deceptive tactics in their campaigns against nodule collecting. Their strategies range from simple exaggerations about impacts and fabricated stories, to fearmongering, to misleading analyses, pictures, and graphics that deviate considerably from reality. However, the most egregious deception is actually an omission of critical fact: if we do not source minerals from the seabed, we must obtain them from alternative sources. The absence of this consideration in anti-deep sea mining campaigns shows blatant disregard for rational decision-making.

On the occasions when eNGOs acknowledge society's need for minerals, they often argue that we shouldn't need to mine any new minerals if we rely on recycling, innovation, and behavior change instead. They also frequently argue that adding nodule collecting capacity will not reduce the need for terrestrial mining. However, these arguments run counter to both economic history and fundamental supply and demand dynamics.

All natural resource extraction imposes costs on society. Yet, as much as we wish we could stop extracting resources to eliminate these costs, society depends on these resources for its survival.

Consequently, mine production has steadily increased throughout history. Recycling, reuse, repair, changing consumer behavior, and innovation have yielded some progress over the last half-century, yet they have only slightly impacted the ***growth*** in annual mining production, they have not begun to satisfy ***base mineral demand.***

Figure 1 Copper – World Production Trend



Source: Wikimedia Commons

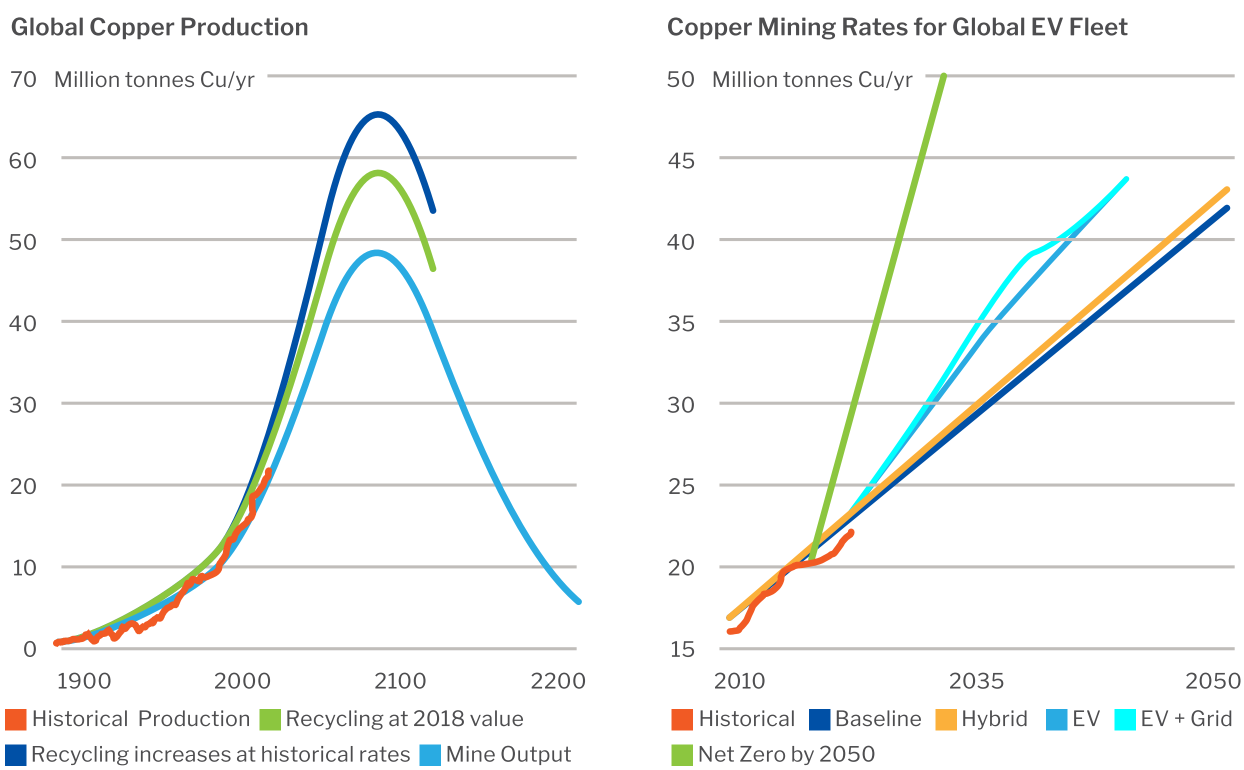
Industry analysts from the International Energy Agency, the World Bank, The Breakthrough Institute, Benchmark Minerals Intelligence, and others concur that even with substantial advancements in resource efficiency and behavioral changes aimed at reducing our carbon footprint, significant mineral production from new mines will remain essential (IEA, 2021) (World Bank Group, 2020) (Wang, 2024) (Moerenhout, 2023). This is especially true in light of the fact that we are now trying to electrify and decarbonize large parts of the global economy—an effort that is highly mineral intensive. The mathematics behind the idea that recycling, reuse, and innovation can fulfill the needs of a growing, urbanizing, decarbonizing, global population, do not work.

> *"While the recycling and reuse of minerals can play a key role in reducing emissions, mining will still be required to supply the critical minerals needed to produce these low-carbon technologies, even with large future increases in recycling rates." "Technology and subtechnology choice, material substitution, and technological improvements will shift the demand for individual minerals under different low-carbon scenarios. Still, any lower-carbon pathway will increase the overall demand of minerals" (World Bank Group, 2020)*

A recent study published by authors from the University of Michigan and Cornell University noted that we will use more copper between 2018 and 2050 than we have in all of human history—and this is before accounting for the energy transition (Simon, 2024). To suggest that we can stop mining and dismantle every single home and building in the world, as well as all infrastructure that embeds copper, for reuse, is simply irresponsible. It is also dangerous, as these claims can lead to complacency and a belief that we don't need to invest in mining. This attitude, after all, is what created the dangerous situation in which we now find ourselves (Runde, 2023).

As a thought experiment, we might cast logic and historical data aside for a moment and compare the pathways implied if eNGOs are correct about mineral usage versus if they are incorrect.

Figure 2 Global Historic and Projected Copper Production versus Copper Mine Production Requirement Scenarios



The report referenced earlier from the University of Michigan asserts that copper cannot be mined quickly enough to keep up with current U.S. policy guidelines to transition electricity and vehicle infrastructure to renewable energy (U. Mich, 2024).

If environmental groups are accurate, and people curtail their use of cars, the world widely adopts degrowth strategies, decarbonization happens without need for additional minerals, and technologies appear that make recycling highly profitable, logistically feasible, and not very damaging to the environment, then the mineral extraction industry will cease to exist due to market forces. Thus, if they have confidence in their thesis, eNGOs should spend their time protesting other activities and leave nodule extraction to die under its own weight. Instead, their continued fervent protests raise questions about the sincerity of their arguments, implying that these campaigns may be driven by factors other than genuine environmental concerns (such as fundraising).

In the likely event that activists are wrong, and we continue to require primary mineral production, as we have throughout human history, then eNGOs will have artificially limited the supply of minerals and left the western world almost totally dependent on China, just as we approach the greatest acceleration in mineral demand we've experienced in modern human history.

Limiting supply in a manner such that we are forced to lean into the most costly forms of mining in terms of damage to the environment and to humanity, just as we are accelerating our usage of these minerals, would not only impose greater threats to the environment and human lives, but it would also make the minerals extracted more expensive. Restricting supply in a time of burgeoning demand, while holding all else equal, will cause mineral prices to be higher than they would be in a non-supply-constrained market, thereby undermining the push to decarbonize and fight climate change.

> *Many have expressed concern that the lack of critical mineral resources may not allow full electrification of the global vehicle transportation fleet, and the vehicle electrification resource demand is just a small part of that needed for the transition. By displaying both demand and mine production in full historical context we show that copper resources are available, but 100% manufacture of EVs by 2035 requires unprecedented rates of mine production. The 100% EV target not only requires significant extra copper for battery manufacture, but also more copper for grid upgrades to support charging, while hybrid electric vehicles do not require extra grid capacity. Under today's policy settings for copper mining, it is highly unlikely that there will be sufficient additional new mines to achieve 100% EV by 2035.* (Simon, 2024)

The notion, often expressed by eNGOs, that extracting minerals from the seabed will not reduce the need for terrestrial mining contradicts economic history, economic theory, and common sense. In a market with stable or low demand growth, introducing substantial new supply of a commodity to market lowers the price of that commodity. Higher cost producers are put out of business as they can no longer make a profit, effectively replacing their output with the new, more cost-effective supply.

We are seeing evidence of this today in near real-time, as many western nickel producers are closing their mines because cheap Chinese-sponsored supply from Indonesian rainforests has come to market (Bloomberg News, 2024) (Climate Rights International, 2024).

In a scenario of high demand growth, new supply might not cause closure of high-cost mines because commodity prices would not necessarily decline as new supply enters the market. In this case, incremental demand is met by incremental supply. Nonetheless, the new nodule supply would obviate the need for incremental supply from new, more damaging, terrestrial mines.

Some eNGOs argue that nodule collecting operations are too high cost to operate. If they're correct then they have nothing to worry about, and there is no need for a moratorium. A high-cost mining operation will not survive. It is worth understanding that nodule collecting companies are burdened with a high cost of capital because the industry is in its infancy, and investors demand venture-like returns. The only way that those return demands can be met is with healthy forecasted margins. In other words, with a high cost of capital, nodule collecting operators must show relatively low costs of operations to be funded by objective investors in arms-length transactions.

If nodules are being produced it is because they are produced at low enough cost that operators are making a profit. If nodules are being produced at low cost, then those nodules are either replacing other mine production (in a fixed demand environment) or they are incrementally adding to supply to meet rising demand and replacing new terrestrial mines that would otherwise have to be built to meet demand. Either way, because nodules are produced at lower costs to humanity and the environment than alternatives, we should aim to meet as many of our mineral needs as possible through the extraction of nodules, as doing so means we are sparing human lives, the environment, and our remaining global carbon budget in the process.

On the rare occasion when eNGOs have attempted to compare the impacts of nodule collecting to terrestrial mining, their work has been fraught with basic errors and logical inconsistencies. We highlight the only substantial example, a report from an activist group called Planet Tracker on our website under Misinformation (Planet Tracker, 2023).

The Planet Tracker report tried to measure the volume of ocean that could be impacted by collecting as compared to the volume of impacts from terrestrial mining, but the group significantly miscalculated plume dynamics (vs. empirical data) and underestimated the area affected by land-based operations. Most important, the group failed to account for damages related to impacts. Planet Tracker overlooked the human toll of strip mining, including increased mortality and disease rates, which nodule collecting could help mitigate. The group also failed to consider the fact that collecting disturbs the ocean floor while strip mining removes and destroys tropical rainforests.

Planet Tracker's premise that we should prefer strip mining in tropical rainforests, overlapping or adjacent to human settlements, rather than picking up rocks from the bottom of the remote deep ocean, is awkward for a group that is supposed to be dedicated to stopping planetary collapse. But it is the logical consequence of avoiding critical and objective thinking.

eNGOs often argue that we don't need nodules to fuel the energy transition. Whether this is true or not is a matter for academic debate, but the reality is that the argument is irrelevant. Even if the energy transition never happens, we should source our minerals in a manner that does the least amount of damage to humanity and to the environment. Based on the empirical data, we can show that nodule collecting accomplishes these goals.

Most recently, in an effort to further justify the moratorium, eNGOs have promoted a study, authored by scientist Andrew Sweetman, claiming that polymetallic nodules are powering electrolysis on the ocean floor, converting water into oxygen (Sweetman, 2024). Yet the study has been questioned by many in the scientific community. In an article published in *Science*, geochemist, Kentaro Nakamura noted that, “There is a high possibility that the paper is wrong.” The *Science* article goes on to question Sweetman for selectively publishing certain data, and excluding data that contradicted his work (Voosen, 2024). Three independent studies have found no evidence of oxygen produced by nodules, and a fourth is getting ready for publication. There is no evidence of increased oxygenation in waters above nodule dense regions, nor is there an increase in acidity from the production of hydrogen as a byproduct of electrolysis. Adepth Minerals published a review of this work on its website which further questioned the validity of the hypothesis (Trellevik, 2024). While many are skeptical of the hypothesis, we acknowledge that sometimes nature surprises us, just as we agree that we cannot accept or reject the hypothesis without further independent research.

Yet, even if the study’s conclusions are confirmed by future independent experiment, the amount of oxygen produced per square meter is exceedingly small - far less than 100x the amount of oxygen produced by rainforests, which provide the additional utility of capturing CO_2 (COMRC, 2024). Notably, those figures assume constant oxygen production from the nodules which Sweetman acknowledges (and the data confirm) is not the case. Thus, when it comes to oxygen production, CO_2 sequestration, and ecosystem function, the empirical data suggest that even if Sweetman’s hypothesis has merit we are still far better off extracting nodules than taking ETMs from terrestrial forested locations.

Finally, WWF’s blithe assertion that “there’s no rush” to produce minerals by picking up nodules is a callous and ignorant position (Alberts, 2022). Perhaps the group’s concern for humanity is limited to wealthy donors, but the rest of us –particularly the indigenous who are dying and falling ill every day due to WWF’s moratorium– deserve consideration. WWF should be put on notice that there is, in fact, a rush to save human lives, reduce our CO_2 footprint, decarbonize our economies, and rescue western nations’ security and commercial interests which are now compromised by a reliance on non-aligned countries for critical energy minerals. WWF’s misinformation campaign, and its push for a moratorium, are restricting sovereign governments from encouraging industry development and choking-off investment in the industry. **This moratorium represents an existential threat to humanity, and it demands immediate widespread condemnation.**

Please visit our website section entitled Misinformation for more rebuttals to the deception and misinformation provided by WWF and other eNGOs about deep sea nodule collection.

WWF and environmental NGOs like Greenpeace (vessel pictured) have called for a moratorium on nodule collecting without considering the comparatively large costs connected with alternative sources of energy minerals. (Unsplash/Steve Sharp)

Why have large companies and sovereign governments signed the moratorium?

Large corporations and sovereign governments have signed the moratorium. They each have different reasons for doing so, but they have all done so after being supplied with misinformation by WWF and others. Society should be concerned when we have created a circumstance where powerful commercial interests and sovereign governments evaluate claims of eNGOs non-critically and find themselves in a situation where they have been misled to support measures that run counter to society's interests. Shareholders should be concerned when their interests are not being adequately represented by their appointed management teams.

Brands and countries that have signed the moratorium may be unaware of the extent to which they have been misled by eNGOs. Understandably, they are busy managing their own affairs, are not deep-sea science experts, and have implicitly trusted these organizations to provide accurate information. In some cases, company executives and supply chain professionals are unaware of their company's involvement in the moratorium and would oppose it if consulted.

We know that some of these brands and sovereign nations are conducting their own research to better understand the issues around polymetallic nodule collecting, as they do not feel they have gotten an objective account from WWF and other eNGOs. We are working to help them in that endeavor, and we ask that any others who have signed the moratorium, as well as those interested in understanding the science and data that supports careful polymetallic nodule collecting, to contact us.

COMRC will distribute this report to all entities that have signed WWF's moratorium and to those the group may have targeted. We encourage these entities to meticulously review our materials and references, and to do their own independent research. By following the empirical data and scientific studies in this field, they will reach conclusions similar to ours.

It is important that supporters of the moratorium ***publicly*** revoke their backing. Without the benefit of a public display, stakeholders will be left to assume these entities remain in support of WWF's dangerous moratorium. Stakeholders will understand that companies and sovereigns who have supported the moratorium in the past are now armed with the data and research that demonstrate the high human toll and environmental consequences associated with their support for the moratorium, and they will look for public acknowledgement from these institutions as to their ongoing stance. If it is more appealing to revoke support through COMRC—allowing us to notify stakeholders—then contact us to do so.

WWF's intents with respect to the moratorium are fundamentally misaligned with the objectives of shareholders in most of the corporate entities who have signed the moratorium. This circumstance is likely to create liability for management teams within companies who have signaled support.

A number of companies who have signed the moratorium have put out statements that, in effect, endorse a pause until science demonstrates that extraction can be undertaken without inflicting serious harm to the ocean. These objectives are redundant with respect to those of various regulatory bodies around the world who have oversight of the industry and are thus unnecessary. Yet, by allowing WWF to use their logos in conjunction with the moratorium, these companies have aligned themselves with WWF's wording, which effectively closes the door to seabed extraction, going so far as to suggest that mining will no longer be needed. Some will no doubt argue that management teams are breaching their fiduciary duty to shareholders by shutting the door to a massive source of low-impact critical minerals. Being cut off from large sources of critical minerals can erode shareholder value, as the US and European auto sectors are experiencing right now.

WWF's website states that, "Opening up this new frontier for extraction would destabilize delicate ocean ecosystems and fatally undermine the foundations of a circular ocean economy…. a combination of innovation, recycling and repair can satisfy industries' need for raw materials without opening the seafloor to mining….The journey to a more sustainable future begins with a simple decision: **No deep seabed mining**." (WWF, 2024) And while the site also says that, "Extraction must not go ahead until the environmental, social and economic risks are understood, and all alternatives to deep sea minerals have been explored," the open-ended nature of these qualifications creates an indefinite timeframe to commercialization, and few investors will fund projects with no visibility to revenue (WWF, 2024). Thus, the moratorium denies industry the financing required to continue scientific inquiry and lift the moratorium, effectively shutting down operators for good, consistent with WWF's stated goals.

Management teams who have signed the moratorium risk losing access to a robust, pro-human rights, low impact supply chain, while they simultaneously feed a system that is killing people and destroying the most biodiverse ecosystems on the planet. **Corporate signatories to the moratorium find themselves in a lose-lose situation. They are harming shareholders' interests while also doing immense damage to humanity and the environment.**

In six months, if any corporates or sovereign nations remain in support of this destructive moratorium, we are likely to update our work and reference them. We will press these groups to explain their motivation for supporting an approach that is clearly damaging the world. Some groups have economic motivation to support the moratorium, and they are unlikely to revoke their support, even if their position endangers human lives.

A terrestrial nickel mine in Sulawesi, Indonesia–August 09, 2021. Terrestrial ETM mines often displace critical habitats with profound environmental and social costs to inhabitants. (iStock/Adhitya Nur)

Detailed discussion on impacts of moratorium

Below we dive deeper into the specific costly impacts of a moratorium. We include references to reports, studies, and data in any instances where the information is not generally known. For more comprehensive information, please visit our website.

Increased death, disease, and suffering especially among indigenous populations

This point alone should bring an immediate end to the debate around a moratorium. Likewise, it should encourage a careful start to nodule collecting. Terrestrial mining is extremely dangerous to human health. It causes widespread death and disease, and it impacts many millions of lives each year. By contrast, nodule collecting has very limited pathways to negatively impact human health.

The differences in human health impacts between the two forms of extraction are vast (90%+ reduction in impacts across a variety of categories per lifecycle analyses (see table below)). To the extent that we reduce future terrestrial mining by collecting nodules instead, we will spare human lives and reduce mining-related sickness and disease. Every single life lost due to WWF's moratorium is significant. ***Supporting the moratorium, and the death and disease it perpetuates, is an irresponsible affront to humanity.***

The casual observer will not be surprised to learn that using a non-invasive extraction process to retrieve minerals from the remote ocean bottom, far from where any humans live, has dramatically fewer negative human health impacts versus strip mining directly adjacent to human settlements (most often next to indigenous populations) (Alhaddad, 2023) (Jia, 2023). Yet rather than bring to light the dramatic reduction in death and disease that will accompany the substitution of nodule collection for terrestrial strip mining, WWF and other eNGOs have instead focused their efforts on speculating about the potential, however faint, for indirect impacts to human health from nodule collecting.

People from the Mura tribe are pictured in a file photo at a deforested area in unmarked Indigenous lands inside the Amazon rainforest near Humaita, Brazil. Bishops working in the Amazon are opposing a bill they say threatens Brazil's rainforest by allowing illegally deforested federal lands to become private holdings. (Reuters/Ueslei Marcelino)

We will start by looking at some of the human health impacts that result from terrestrial mining and then move to nodule collecting.

There is no debating the fact that terrestrial mining leads to human casualties (Entwistle, 2019) (Stewart, 2019). Approximately 15,000 people die each year directly in mine related accidents (World Counts, 2024). But the indirect impacts to human health from mining are far more widespread and likely cause many more deaths.

One recent study noted that 23 million people are exposed to mine contamination as they live on flood plains known to host toxic mine contaminants (Macklin, 2023) while another study found that the people impacted by mine pollution (specific to energy transition minerals) are the most vulnerable. Indigenous populations are more likely than those in industrialized societies to rely on the land and water around them for sustenance, meaning that they are even more likely to suffer disease from the mining contamination where they live. Researchers estimate that nine million people die each year from air pollution, and mining & metals processing is cited as one of the largest contributors to air pollution (Earthworks, n.d.) (Fuller, 2022).

> *Mining operations are understood to have some of the highest concentrations of potential harmful contaminants derived through anthropogenic activities, along*

with the highest particulate emissions and the highest risk to both human and environmental health (Csavina, 2012) (Meyer, 2015) (Stewart, 2019)

Diseases stemming from mining activities are severe. Mine dust (plumes) and other effluent carries toxic emissions and can travel thousands of kilometers (Entwistle, 2019) (Does, 2018). That effluence is known to cause cancer as well as respiratory, cardiovascular, inflammatory, and neurological diseases in human populations (Silva-Rego, 2022). Mine effluence carried by wind and water is known to spread over wide areas and can linger in the soil and water long after mines close, even in well-regulated economies (Baeten, 2018).

The human impacts from terrestrial mining are worsening due to declining ore grades and growing demand for minerals from urbanization, industrialization, and the energy transition. Nodule collection will not eliminate all of those costs, but to the extent we source minerals from the remote abyssal plains instead of from terrestrial sources, we can reduce the human toll. If we operate under the assumption that every human life counts, this harm reduction can be highly meaningful to the world.

The human health impacts from nodule collection are dramatically less consequential by comparison.

Nodule extraction does not involve a pathway that would bring negative health consequences to humans directly (outside the normal risks present for workers in commercial marine operations) (extraction is distinct from processing - processing nodules can follow some of the same pathways used for terrestrial minerals though it is less dangerous as it creates far less waste and often involves hydrometallurgical processes rather than pyrometallurgical approaches). Nodule collection creates indirect impacts that could cause harm to humans, but the scale of those impacts is orders of magnitude lower than the alternative.

WWF and other eNGOs argue that humans can be impacted indirectly by nodule collecting in that the activity would “compromise the ocean carbon cycle” (WWF, 2021), ostensibly this would be dangerous in that it would result in an increase in threats from climate change. Yet, WWF’s claim is disingenuous. Multiple lifecycle analyses note a stunning reduction in CO_2 emissions and sequestered CO_2 release when we substitute nodule collecting for terrestrial mining of the same minerals (Paulikas, 2022) (Benchmark Min Int, 2023). In fact, sequestered CO_2 release is ~16x lower in a nodule collecting operation than in a terrestrial mine for the same minerals, while we reduce CO_2 emissions by some 20-70% when we extract nodules rather than terrestrial minerals. In addition, seafloor sediments host less than 5% of oceanic carbon, and less than 1.5% in abyssal plains and rises (Dunne, 2007). The amount of disturbance that could be caused to sequestered carbon dioxide in the abyssal sediment is almost terribly minimal in scale (Gronewold, 2019).

Figure 3 Environmental, social and economic impacts

	Land	Nodules	*% Change*
Climate change			
GWP – CO_2 equivalent emissions, Gt	1.5	0.4	-70%
Stored carbon at risk, Gt	9.3	0.6	-94%
Nonliving resources			
Ore use, Gt	25	6	-75%
Land use, km^2	156,000	9,800	-94%
Incl. Forest use, km^2	66,000	5,200	-92%
Seabed use, km^2	2,000*	508,000	+99.6%
Water use, km^3	45	5	-89%
Primary and secondary energy extracted, PJ	24,500	25,300	+3%
Waste streams			
Solid waste, Gt	64	0	-100%
Terrestrial ecotoxicity, 1,4-DCB equivalent Mt	33	0.5	-98%
Freshwater ecotoxicity, 1,4-DCB equivalent Gt	21	0.1	-99%
Eutrophication potential, PO4 equivalent Mt	80	0.6	-99%
Human & wildlife health			
Human toxicity, 1,4-DCB equivalent Mt	37,000	286	-99%
SOx and NOx emissions, Mt	180	18	-90%
Human lives at risk, number	1800	47	-97%
Megafauna wildlife at risk, trillion organisms	47	3	-93%
Biomass at risk, Mt	568	42	-93%
Biodiversity loss risk	Present	Present	
Economic impact			
Nickel sulfate production cost, USD per tonne Ni	14,500	7,700	-47%
Jobs created (non-artisanal), worker-years	600,000	150,000	-75%

Source: (Paulikas, 2020)

We discuss, in greater detail, the remarkable reduction in CO_2 footprint as we substitute nodule collection for terrestrial mining later in this report.

While WWF argues that extracting nodules will poison the human food web, imposing another indirect cost, this is not the case. In fact, to the extent that we replace terrestrial mining with nodule collection we will greatly reduce human food web poisoning. The only pathway from nodule collection that could have had an impact on the human food web was when certain operators were contemplating returning sediment from the bottom (brought up in riser pipes with nodules) to mid-water levels at approximately 1,200 meters depth, not too far from pelagic species which are found at depths up to 1,000 meters. In that case, there was a chance that the resulting midwater plume could have released sediment carrying metals at a level that could possibly impact fish and other animals that enter the human food chain. The human food web generally extends to around 1,000 meters in depth in the ocean, to include epipelagic and mesopelagic organisms (NOAA, 2024) (Wikipedia, n.d.).

Yet, based on our discussions with operators and presentations made at industry conferences, it is evident that operators no longer plan to return sediment to levels close to the pelagic layer. Most, important, the majority of technologies do not use risers at all, so their systems won't transport sediment, meaning there will be no midwater discharge plume (see skip system here and autonomous vehicle system here). Those operators who do use risers have committed to following the science and will return sediment to levels where there is little or no probability it could enter the food web (at least 2,000 meters depth per conversations). Thus, for operators who plan on using riser systems, the depth of discharge and the rapid dilution of sediment mean that the opportunity for impacts on the human food web are very small—much smaller than in terrestrial mining, or in bottom trawling (Wang, 2024). Trawling happens every day on a scale that is far larger than collecting would ever reach, in waters inhabited by pelagic species.

With little or no risk from a midwater plume, there is no mechanism by which nodule extraction would otherwise impact the human food web. Extraction activities on the sea floor create a plume, but that plume rapidly resettles, and it doesn't travel far vertically or horizontally (McLachlan, 2023). Nodule collection operations have demonstrated that plumes rise only a few meters off the ocean floor and don't travel more than 1,000 meters across the bottom of the plains (Munoz-Royo, 2022) (McLachlan, 2023). The density and temperature of bottom water means that this water remains at the very bottom of the ocean, and it does so for long periods of time—perhaps 1,000 years or more (Time Scavengers, n.d.). Pelagic species are unable to dive to the depths of the abyssal plains, and there is no mechanism by which they or their primary food sources would be exposed to the bottom-water plumes from nodule collecting operations.

While there is little to no pathway for nodule extraction to impact the human food web, the same is not true of terrestrial mining which generates toxic emissions that enter the human food web, putting indigenous and local populations particularly at risk (Blanco, 2022) (Landers, 2018) (Muimba-Kankolongo, 2022). Particles in the air from blasting, drilling, and excavating vast tonnages of overburden and ore can travel long distances and can contaminate agriculture and livestock (Entwistle, 2019) (Does, 2018). Acid mine drainage and mine operation run-off frequently contaminates fresh water supplies which can impact human drinking supplies as well as fish and other animals that consume that fresh water (Levings, 2004) (Pure Earth, 2008). To the extent we substitute nodule collection for terrestrial mine production, that pollution could be prevented from entering the food web.

While picking up nodules from the deep ocean floor rather than strip mining near human populations is certain to spare human lives and result in less disease and suffering for humanity, there is reason to believe that benefits extend beyond those solely related to extraction. For instance, we know that nodules are "friable," or easily crushed, so less energy is required to grind them for processing (reducing energy and emissions) than is required in hard rock deposits. Crushing rock is reported to represent 56% of the mining industry's energy usage, so this is not a small matter (Mining Technology, 2019). In addition, some nodules may be processed entirely in a hydrometallurgical flow which will further reduce energy requirements (vs. terrestrial energy minerals often processed in a pyrometallurgical fashion) as well as CO_2 and other potentially dangerous emissions.

Perhaps most importantly, there is little to no solid waste generated when processing nodules into mineral products, eliminating the need for tailings dams, ocean dumping, or dry stacking waste in large piles vulnerable to release during earthquakes or monsoons/typhoons (common in mining hotspots such as SE Asia). The lack of mine waste has significant implications for both humans and the environment and is covered in a later section (Aska, 2024) (Helser, 2022) (Silva-Rego, 2022).

If we examine other potential impacts to human health post-extraction, we find that any risks are not exclusive to nodule collection, and in any case, are less dangerous than those associated with terrestrial mining. Handling large quantities of nodules can expose workers to small amounts of radon or radiation, necessitating standard safety precautions. However, these exposures are no different to those encountered by workers handling various other ores. Moreover, the high-grade nature of nodules compared to terrestrial ores means that less ore needs to be handled to produce a given amount of end product.

More destruction of endangered tropical rainforests

The incremental supply of energy minerals often comes from tropical rainforests in SE Asia, Africa, and South America (Rainforest Rescue, n.d.). If we were collecting nodules today, we wouldn't need to open as many new strip mines in tropical rainforests. This is a simple and demonstrable fact. As stated earlier, if we are collecting nodules, it means the industry is able to do so with an attractive cost structure (money losing operations will not survive) and it is thus either displacing existing terrestrial production or it is supplanting the need to create new terrestrial mining operations.

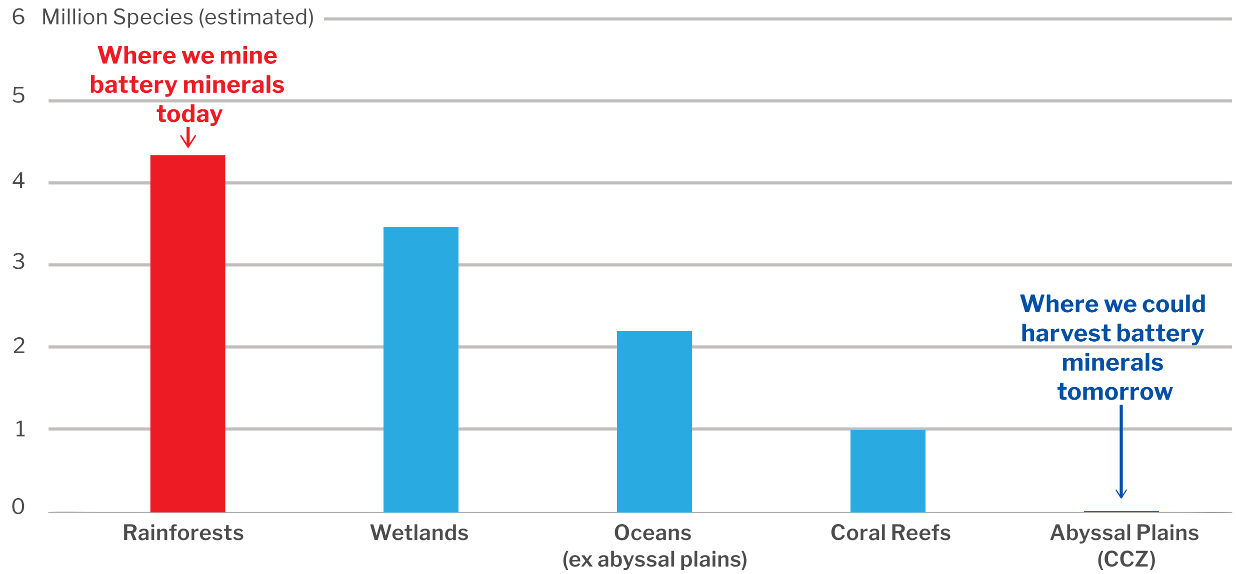
Laterite nickel ore mining in Weda Island, Halmahera, Indonesia; global nickel demand has caused terrestrial mine activity to skyrocket, with deep impacts on local rainforest habitats. (iStock/Nanang Sugianto)

Opponents will counter that we are trading off the destruction of one sensitive environment for the destruction of another, and that there is no benefit in doing so, but data and studies demonstrate the fallacy associated with this narrative.

The reality is that the destructive nature of strip mining in tropical rainforests is vastly more impactful to that ecosystem than is picking up nodules from the floor of the deep abyssal plains (Paulikas, 2022) (Benchmark Min Int, 2023). This fact is patently obvious to anyone who has compared the damage from a strip mine to the videos showing the abyssal plains before and after nodule collection (The Metals Company, 2023). In addition, since tropical rainforests are orders of magnitude more biodiverse and endangered than the abyssal plains, the invasive nature of strip mining does much more harm than does nodule collecting.

Most readers will understand implicitly that blasting, drilling, and digging in a strip-mining operation will cause large scale irreversible damage to that environment, while picking up rocks from the seafloor surface is a less destructive alternative (Climate Rights International, 2024). The empirical data confirm this idea (Farjana, 2019) (Paulikas, 2020) (Benchmark Min Int, 2023). A strip mine will cause a near 100% decline in biodiversity and biomass within a mine's footprint because all the biomass is removed (some microbes may survive, but terrestrial biodiversity/biomass figures generally do not include these populations). On the other hand, data from a recent nodule collecting operation showed a 50% decline in biomass within the footprint and a 20% decline in biodiversity (using foraminifera as a bioindicator) (O'Malley, 2023). That data also revealed little or no impact to biomass or biodiversity within the plume zone of the nodule harvester.

Figure 4 Estimated Number of Species by Ecosystem



Source: Rainforests: https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/fee.2420
and https://iournals.plos.ora/plosbiology/article?id=10,1371/journal,pbio,1001127
Wetlands: https://unfecc.int/news/wetlands-disappearing-three-times-faster-than-forests
Ocean: https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1001127
Coral Reefs: https://www.epa.gov/coral-reefs/basic-information-about-coral-reefs
CCZ: https://www.cell.com/current-bioloay/pdf/S0960-9822/23\00534-1.udf

Opponents will correctly counter that a collecting operation covers approximately 3.25x more land than a terrestrial mining operation for a given unit of metal produced, making the area subject to impact from collecting larger than in a terrestrial mine (Paulikas, 2020). Yet, this fact is more than offset by two principal factors.

First, as just discussed, the damage done from a strip mine is far more severe than from picking up nodules. It is far better to "disturb" a larger portion of land than to destroy and disfigure a smaller piece of land. A farmer doesn't destroy his/her land when he/she runs a harvester over the ground, but when miners bulldoze the vegetation and organisms residing in the topsoil and then blast or drill deep into the rock underneath, the impacts are far more consequential and long-lasting.

Second, and perhaps more importantly, the indirect impacts from terrestrial mining operations are so large that the smaller mine footprint argument becomes irrelevant. Studies have demonstrated that deforestation associated with terrestrial mining extends the mine footprint to 12x its original size, more than offsetting the direct footprint differential vs. nodule collecting (Sonter L. J., 2017).[10] That large footprint is caused by the roads, the waste, the infrastructure, and all the associated population and services that are required to support mining projects. In addition, the pollution of air and water pathways in a terrestrial mine can increase the footprint of impacts to an even larger extent (Lakshman, 2024) (Airquoon, 2022). The indirect effects of nodule collecting are modest by comparison (see footnote) (Prizma LLC, 2022).

Finally, while opponents of collecting emphasize the unique nature of the abyssal plains and the fact that this ecosystem is untouched by human influence, the reality is that tropical rainforests are far more sensitive than the abyssal plains, far more threatened, and far more unique.

Tropical rainforests are believed to hold half of the world's species in an area that comprises only 1.8% of the world’s surface, or 9.18 million km^2 (6% of the world's land surface) an area that is highly threatened by mining, agriculture, and human encroachment (WWF, n.d.) (Pillay, 2021) (Mora, 2011). By contrast, the abyssal plains are the world’s largest ecosystem and hold comparatively little biodiversity and biomass. The Clarion Clipperton Zone, an area of the abyssal plains which is equal in size to half of the world’s rainforests, is estimated to hold approximately 8,000 metazoan species, while rainforests are thought to hold approximately 4.35 million species (Pillay, 2021) (Mora, 2011) (Rabone, 2023).

The abyssal plains are massive, encompassing as much as half of the earth’s surface (Smith C. , 2008). Nodule fields are expected to cover between 10% to 50%+ of the plains (Smith C. R., 2020). If we use a 25% figure, this implies nodule fields cover an area approximately 12.5% of the surface of the earth or 63.75 million km^2. Tropical rainforests encompass an area that is more than 25x smaller than the abyssal plains and approximately 7x smaller than the size of nodule rich abyssal plains.

Rainforests are highly threatened today. Already more than two-thirds of rainforests have been destroyed or significantly degraded by human intervention (Krogh, 2021). What remains of intact tropical rainforests is being deforested at an alarming rate. Estimates of annual rainforest destruction range widely with low-end figures hovering around 43,000 km^2 and high-end estimates at around 300,000 km^2 (Butler, 2020) (Taylor, n.d.). Mining is a large part of the threat to rainforests. A recent study estimates that around nine percent of tropical rainforest deforestation in

[10] Collecting disturbs approximately 3.25x the surface area vs. terrestrial mining (Paulikas, 2020), so terrestrial mining uses 31% of the land required to generate the same quantity of mineral. Yet the 31% needs to be increased by 12x to reflect the indirect deforestation impacts from terrestrial mining. When these indirect impacts are considered, terrestrial mining impacts 3.72x more surface area to generate a unit of mineral vs. nodule collecting. Indirect impacts from collecting include the bottom plume which results in a negligible increase in the collecting footprint per empirical data. A minority of lift systems may use risers, and create a midwater plume, but studies have demonstrated that impacts to surface area from that midwater plume are also negligible, resulting in increased sedimentation rates of approximately 1% vs. natural sedimentation (Munoz-Royo, 2021). If we calculated surface areas impacted by terrestrial mining to include plume impacts, the disparity between the two methodologies would only increase, as plumes from terrestrial mining are larger due to the larger amount of disturbed ground and the reduced friction in air vs. water.

the Amazon is due to mining (Sonter L. J., 2017). That figure, however, likely understates mining's impacts.

Mining in tropical rainforests is accelerating markedly due to the increasing demand for battery minerals. Studies indicate that the demand for many battery minerals could increase fivefold or more over the next twenty years, suggesting we could easily lose over half of our world's rainforests over that period if we continue to deforest for non-mining purposes as well (IEA, 2021). A recent study indicated that between 10-33% of the world's forests are threatened by the indirect impacts of mining (Radwin, 2023). Indonesian nickel production is expected to replace palm-oil plantations as the primary cause of deforestation in that country (The Economist, 2023). And with ore grades for a number of energy minerals in secular decline, this means that we will do even more damage to the environment and to human health for each unit of metal we extract in the future (Calvo, 2016).

> *Mining activities have seen an alarming acceleration—more than 1/3 of the mining-related deforestation seen in the last 20 years occurred in just the last five years—and are tipped to increase in coming years. (Kind-Rieper, 2023)*

Since tropical rainforests are by far the most sensitive and biodiverse environments in the world, terrestrial mining and other tropical rainforest land use could result in the loss of countless species and astounding quantities of biomass. A recent study notes that threats to biodiversity are so great from energy transition mineral mining that we could lose more biodiversity to mining than we would if climate change threats were not addressed.

> *Mining threats to biodiversity will increase as more mines target materials for renewable energy production and, without strategic planning, these new threats to biodiversity may surpass those averted by climate change mitigation.*
> *(Sonter L. , 2020)*

We wouldn't necessarily lose a single species if we harvested nodules from the abyssal plains given what the data says about the modest impacts to biodiversity from collecting (O'Malley, 2023). Not only will operators set aside large, contiguous areas to encourage recolonization, but they are also likely to leave a percentage of nodules in place within a collecting footprint by selecting only nodules that meet certain size parameters, so the 20% loss in biodiversity cited in the O'Malley study may turn out to be too high.

This point is made all the more clear when we put the scale of proposed extraction activities in context. If nodules supplied all of the NCM cathode minerals (nickel, cobalt, and manganese) needed to electrify the world's auto fleet under the maximum annual quantities required per the IEA's Stated Policies Scenario, we would need approximately 75 collecting vessels operating annually over the next twenty years (assumes 950 ktons nickel, 127 ktons cobalt, and 120 ktons manganese as maximum volume annually per IEA estimates) (IEA, 2021).[11]

Those 75 vessels would harvest an area equivalent to approximately 175,000 km^2 over 20 years. This figure assumes 120 km^2 per year per harvester, to collect approximately 1.5 million dry tons per year based on nodule abundance statistics.[12] The 175,000 km^2 of disturbed abyssal plain would impact less than one tenth of one percent (a total of 0.06%) of the 300 million km^2 abyssal plains and approximately 0.2% of the estimated worldwide nodule fields (nodule fields are expected to cover between 10% to 50%+ of the plains so we use an estimate of 25% (Science Struck, n.d.) (Smith C. R., 2020).

Displacement of humans and loss of human land rights

> *There is an uneasy paradox here. The mining industry can be devastating to the natural environment, and individuals trying to defend their land are being attacked by national security forces as well as private corporations. At the same time, the minerals that mining produces are vital for the clean energy transition, and that energy transition is in turn vital if we are to protect the climate and environment humans depend on to survive. (Ferris, 2023)*
>
> *According to UN Environment, more than 40 per cent of internal conflicts from 1950 to 2009 were connected to the exploitation of natural resources, and those conflicts linked to natural resources are twice as likely to relapse during peacetime (United Nations Environment Programme, 2009). Further studies on civil conflicts have found that natural-resource-dependent countries tend to have higher rates of poverty, ethnic fractionalization and weak institutions for conflict resolution. (Church, 2018)*

At the risk of stating the obvious, collecting nodules will not displace any humans from their land, nor will it result in the loss of human land rights, nor will it cause humans to lose lands used for hunting, or cultivating plants for medicinal and agricultural purposes. Mining causes all of these consequences for humans and more (WRI, n.d.). Thus, to the extent that we extract minerals from nodules, this will decrease the need for terrestrial minerals, thereby reducing the displacement of people and the loss of land rights.

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[11] Assumes 5,000 tpy cobalt and 13,000 tpy nickel per vessel per operator volume plans at 1.5 mtpy dry tons. This assumes that production is coming from both CCZ and Cook Islands and is based on combined mineralogy from those locations.

[12] Nodule abundance assumed at 15kg/m^2 per (Geomar). Operators generally target single vessel production of 1.5 million tons of nodules per year, so if they were to clear all nodules in the harvester path, they would cover 100 million $meters^2$ to gather that many nodules (100 million meters * 0.015 tons/meter = 1.5 million tons). When we convert 100 million m^2 into square kilometers we get 100 km^2 for one year of collecting. We boost the number to 120 km^2 to account for the leave behind of 15% of nodules.

Because energy transition mineral extraction activities largely take place in areas of the Global South that are not developed, they tend to overlap with indigenous people and pristine forest environments.


Terrestrial mining operations often rely on laborers with poor pay and working conditions. (iStock/joakimbkk)

> *Our analysis reveals that more than half of the ETM resource base is located on or near the lands of Indigenous and peasant peoples, two groups whose rights to consultation and free prior informed consent are embedded in United Nations declarations. (Owen, 2022)*

As previously mentioned, the seizure and degradation of land and other resources from indigenous communities pose significant risks, as these populations often rely directly on their surrounding environment for sustenance. The contamination or loss of land and water can lead to severe consequences, including economic hardship, displacement, disease, and even death for these vulnerable people (Climate Rights International, 2024) (Yeung, 2023). By replacing the need to open destructive terrestrial mining operations, nodule collection can spare lands that are used and claimed by indigenous people.

Many areas which are exploited for energy minerals are remote. Even when the federal government, which has jurisdiction over these regions, establishes robust regulations to protect indigenous populations, local governments often lack the necessary resources to enforce rules effectively.

> *Climate Rights International interviewed 45 people living near nickel mining and smelting operations who described serious threats to their land rights, rights to practice their traditional ways of life, right to access clean water, and right to health due to the mining and smelting activities at IWIP and nearby nickel mining areas. Some companies, in coordination with Indonesian police and military personnel, have engaged in land grabbing, coercion, and intimidation of Indigenous Peoples and other communities, who are experiencing serious and potentially existential threats to their traditional ways of life.*
>
> *The Indonesian government is actively promoting the nickel industry over the wellbeing of its citizens. Over the past decade, the Indonesian government has enacted policies and laws to prioritize the growth of the nickel industry and weaken environmental protection and the rights of Indigenous communities. In doing so, it has failed to fulfill its obligation to protect and respect the rights of those affected by mining and smelting operations. The Indonesian government is*

also failing to protect the climate and mitigate climate change. (Climate Rights International, 2024)

The introduction of terrestrial mining can lead to increased social friction and violent conflict as well as the abuse of human rights.

"Extractive and industrial development projects often create landscapes of violence in which Indigenous communities are the first casualties and the last line of defense. With this study, we wanted to contribute to bring global visibility to these issues,"...The Business & Human Rights Resource Centre has documented 510 allegations of abuses associated with the mining transition minerals between 2010 and 2022, including 65 new allegations in 2022 alone, according to the 'Transition Mineral Tracker: 2022 Analysis' report published in June 2023. "The scale of social-environmental burdens faced by Indigenous communities shows that these are not singular cases of bad practice and project implementation, but rather systemic features of how the world economy operates," (Cuffe, 2023)

The human and environmental destruction caused by mining in the DRC is staggering. Entire communities have been forced to leave their homes to make way for a new mining concession. Toxic waste has contaminated critical water sources and arable land. Millions of trees have been razed. The air, hazy with dust and particulates from open-pit mines, is dangerous to breathe.

These inhumane working conditions, environmental harms, and the exploitative companies that underpin the deadly global cobalt trade aren't a recent phenomenon in the DRC. From the rubber farms of King Leopold's brutal Congo Free State in the 1890s to the palm oil plantations and uranium mines of the twentieth century, cobalt mining is just the latest chapter in a centuries-long story of exploitation in the DRC. (Global Human Rights, 2023)

Some terrestrial mining, particularly that which is conducted by Western enterprises in well-regulated jurisdictions, prioritizes human rights. In these cases, the most severe impacts from land right losses and conflicts can be mitigated, though some level of impact is inevitable. Nevertheless, a significant portion of the world's accessible energy mineral resources are located in regions with inadequate mining regulations or enforcement to protect indigenous populations. Moreover, the majority of mining activities in these areas are undertaken by companies based in countries which are not aligned with the US and Europe.

To this point, the US and Europe have been forced to compromise our ideals and purchase energy minerals from places where massive deforestation and pollution results, where free and prior informed consent is not the standard, from places where child labor is the norm, and even from people who we have sanctioned under the Magnitsky Act (Africa Confidential, 2024). **Compromising our ideals undermines the legitimacy of the "Green Transition" and risks consumer revolt.** Tapping seabed nodule resources can relieve some of the pressure to compromise our ideals as we attempt to decarbonize. Nodules afford the Western world the ability to steer our demand away from mining companies who abuse human rights. **A moratorium locks us into the most damaging and dangerous mining the world has to offer—it is an irresponsible position to take.** By spreading misinformation about nodule collecting, WWF and its partners are harming the world.

Dramatically greater toxic waste streams & pollution of freshwater resources

It's often overlooked, but much of the damage from mining originates with mine waste. Terrestrial mine waste takes a number of forms, there is a lot of it, and it is almost always a source of danger to people and the environment. Substituting nodule collecting for terrestrial mining dramatically cuts mine waste and thus has the potential to materially reduce the serious negative impacts from waste to people and the environment.

Open pit mine in Mindanao, Philippines with clearly visible tailings. (iStock/Mary Grace Varela)

> *It's not a matter of if a mine will pollute, but when, and for how long. Earthworks' research of operating U.S. copper mines (accounting for 89% of U.S. copper production) found that 100% had pipeline spills, 92% failed to control mine wastewater and 28% had tailings impoundment failures—polluting drinking water, destroying fish and wildlife habitat, harming agricultural land and threatening public health.*
>
> *According to the U.S. Environmental Protection Agency's Toxics Release Inventory, metal mining is the nation's #1 toxic polluter. Mine waste contains toxic substances like arsenic, mercury, and cadmium that are harmful to public health and fish and wildlife when released into the environment. (Earthworks, 2024)*

The removal of overburden generates massive quantities of waste rock, often stored in large piles near the mine site. These piles not only release sequestered CO_2 into the atmosphere, but also contribute to acid mine drainage. Rainwater interacting with sulfides in the waste rock can produce sulfuric acid which subsequently dissolves heavy metals like lead and mercury and carries them into nearby streams (USGS, n.d.). That acid mine drainage poisons drinking water and kills wildlife that people depend on to survive. It can harm people too. A study completed in 2023 estimated that over 23 million people live on flood plains containing toxic levels of mining waste (Macklin, 2023).

The toxic remains from waste may continue to impact the environment and human health long after a mine has closed—even if steps were taken to protect the environment at closing (AP, 2019).

> *Mining exposes sulfides in rock which react with water and air to form sulfuric acid. Once the process starts it's impossible to stop until the acid generating material is depleted, which can take thousands of years. Some Roman mines in Spain still drain acid. The acid drainage can only be treated. The EPA estimates 40% of the headwaters of western watersheds have been polluted by mining, and acid mine drainage is a main reason why. Globally, mining also dumps mining waste directly into lakes, rivers and oceans: over 220 million tonnes each year. (Earthworks, 2024)*

Because nodules are found on the surface of the earth, there is no overburden to remove when we extract them. Consequently, there is no waste rock or acid mine runoff from waste rock (a plume does result and we have cited its impacts). Taking nodules thus avoids entirely a major source of long-term contamination of fresh water supplies that results from waste rock. That waste stream is difficult for terrestrial mines to avoid, which is why it is present even in well-regulated jurisdictions.

A different terrestrial mining waste stream results from the processing of a mine's ore. A typical ore body grades at 1% to 2% of "pay" metal, meaning that the remaining 98-99% of material being processed is waste. The waste material that comes out the backend of the processing line is called tailings. A mine will generate large volumes of tailings waste, which can carry contaminants from the processing operation (Cacciuttolo, 2023). Tailings can produce acid mine drainage, similar to waste rock, but because they contain chemical reagents, they can produce other dangerous contaminants as well.

A single nickel processing plant in Indonesia produces approximately four million tons of toxic tailings per year (enough to fill 1,667 olympic-sized swimming pools) (Tan, 2023). Tailings disposal is difficult, especially in the wet, warm climates where many energy mineral mines are found. Indonesia had been treating tailings to neutralize their acidity and then piping them into the ocean but backed away from that practice due to obvious environmental concerns. Currently the tailings are being dried and stacked behind dams for storage, but this may be an even more dangerous proposition. Frequent landslides, monsoons, and earthquakes mean that these tailings dams are likely to be ineffective at containing these tailings for the long-term.

HPAL (High Pressure Acid Leaching) processing in Indonesia and elsewhere produces an enormous amount of corrosive chemical tailings — often in the millions of tons for each mine per year — that are extremely challenging to neutralize, store and contain. Even after the slurry is treated, studies show, this waste can contain harmful heavy metals, such as certain types of chromium, linked to respiratory illnesses and an increased risk of cancer.

In 2021, Brazilian mining conglomerate Vale exited a multibillion-dollar HPAL nickel-mining project in the Pacific archipelago of New Caledonia after having five chemical spills in 10 years. Studies by scientists in New Caledonia had by that time found "high levels" of toxic hexavalent chromium in water samples collected in and around the HPAL refining facility. The facility, now owned by a consortium of New Caledonia companies, had yet another leak in November at its tailings dam, prompting local authorities to impose new regulations that could limit production (Tan, 2023).

In fact, in Indonesia a study was published which concluded that it was more dangerous to store tailings in dams on land than to dump them in the ocean due to the seismicity in the region and the high amounts of rainfall received (Gultom, 2020). Waste systems frequently fail, and spill large amounts of toxic tailings into rivers and oceans. These failures can kill people (Silva, 2023) (Bilgic, 2019) (Sullivan, 2017). Mine waste poses an existential danger to many Indonesian communities, yet the process continues to this day as there are few other options.

> *Liyus, who goes by one name, said he used to drink from the rivers that run past his village, but since the nickel mine added its acid-leaching refinery two years ago, the waterways have turned dark red, so thick with pollution at some points that rows of coconut trees have been killed off. He doesn't know what's in the water, only that it bleeds into the sea and that his nephews have had to go farther and farther out to find fish. He pointed to a fishing net drying on a nearby tree. It was stained a reddish brown. (Tan, 2023)*

Further, the toxic impacts from mine waste are not limited to local communities. They can be spread in the air and in the water over wide areas. Multiple studies have shown elevated levels of various chemicals and heavy metals in the blood of people living downstream from mine sites (Rzymski, 2017) (Moore, 2011) (Macklin, 2023).

Because nodule ores contain 100% commercial material, they will create little or no solid tailings. This explains why some life cycle analyses indicate a 100% reduction in solid waste when processing nodules rather than terrestrial ores. The large decrease in solid waste translates to a great reduction in risk to human death and disease, and a reduction in risk of damage to the environment.

While nodule extraction and processing will generate some waste, the volume is significantly less than that produced by terrestrial mines. Systems employing risers may transport sediment and bottom water to the surface before returning it to the deep ocean in a separate pipe, and this creates a waste stream. However, not all operators will use risers, and those that will have committed to returning sediment to depths that ensure that the release will not impact pelagic species and enter the human food web. The contrast is stark - that midwater waste stream created by some systems shouldn't threaten humans or human communities, nor would it be remotely close to the scale of terrestrial waste streams for a given quantity of metal produced.

Nodule processing operations can create liquid waste streams from reagents and process water, and any pyrometallurgical processing will produce airborne emissions. But these waste streams are created in terrestrial ore processing operations—meaning that we are not creating new or greater waste streams by shifting production to nodules (some nodules will be processed in a purely hydrometallurgical processing flow, reducing airborne emissions significantly).

An additional benefit from extracting nodules results from the fact that due to their jurisdiction, they can be transported to the US, Europe, Australia, or other well-regulated economies for processing. That processing will take place under strict waste controls which would help protect people and the environment. Today these minerals are extracted and/or processed in countries that often lack strict controls, and we are forced to buy them due to a lack of good alternatives (due to the moratorium).

The US, and the western world more generally, have outsourced mineral production to faraway places in the Global South because they don't want exposure to the toxic waste streams, and because they can afford to do so. This protects us from witnessing and experiencing first-hand much of the extreme environmental and human damage from these mines. This protection also affords some eNGOs the opportunity to fundraise to stop the collection of deep-sea nodules as it means that their wealthy donors in the US and Europe are largely unaware of the damage their support fosters by encouraging further reliance on the most destructive mining processes known in the most sensitive ecosystems.

> *But while the transition to EVs is widely considered essential in addressing climate change, there has often been little recognition of the toll that extraction and processing of these raw materials — including technologies now urgently needed to produce the quantity and quality of minerals required — will take on the lives and livelihoods of local communities and the surrounding environment.*
> *(Tan, 2023)*

Nodules create minimal waste streams. Terrestrial mines create massive waste streams, and these streams can be very dangerous to humans and the natural environment. WWF is gambling with human lives in pushing for a moratorium on nodule collecting. The payoff for the gamble is a fundraising campaign that helps WWF compensate its executives exceptionally well—even by for-profit standards (Paddock, 2022).

A slowdown of efforts to decarbonize

Efforts to decarbonize the world's economies require an increase in the production of energy minerals.[13] The simple geologic fact is that we have far more energy minerals like nickel, cobalt, rare earths, and manganese on the bottom of the ocean than we do in terrestrial formations (Hein, 2022) (The Metals Company, 2021) (Hein, 2013). This is partly a function of the fact that the abyssal plains are so large relative to terrestrial mine targets, partly a function of the fact that we have

13 Opponents of deep-sea mining argue that we can decarbonize without any mining. They say that if we change consumer behavior, advance new technologies, and recycle, we don't need to mine. If they are correct, then the mining industry will naturally cease operations. If there is no demand for these minerals the market will not pay for them, and miners will go out of business. But an overwhelming number of energy analysts believe that not only are opponents wrong about demand, but due to underinvestment in new mines there are looming shortfalls in key minerals ahead. Regardless of who is correct, our view is that we owe it to the world to produce minerals that have the lowest impact on humanity and the environment, thus the focus on seabed nodules.

already exploited the easiest to access and highest-grade resources on land, and partly a function of the unique geology that creates seabed accretions in high grades on the earth's surface. If we impose a moratorium on the largest source of key energy minerals, limiting supply during a period of high demand growth, we face the risk that we will slow decarbonization due to the relative scarcity of energy minerals that results.

Scarcity and slowing decarbonization is not an academic argument. We are witnessing it today, in the form of highly volatile mineral prices—a hallmark of scarcity (Moerenhout, 2023). Even at the early stages of the advance toward decarbonizing we saw how a supply constrained minerals market could slow down our efforts (Simon, 2024). Energy mineral prices skyrocketed in 2021 and part of 2022. Prices of lithium, cobalt, and nickel were up over 100% during the period (Kim, 2022). Market participants saw rapid increases in demand for energy minerals and realized that there was little hope that supply would keep pace moving forward, so they bid up these commodities.

EV production factory; without abundant, low impact ETMs, our efforts to decarbonise our global transportation and energy sectors would fall even further behind. (iStock/SweetBunFactory)

As the saying goes, the cure for high prices is high prices—high prices destroy demand which leads to lower prices. Soaring mineral prices inevitably led to higher electric vehicle prices, precipitating a rapid deceleration in sales growth in a market that was supposed to be hitting a growth inflection. EV sales slowed from 113% in 2021 to a rate of 60% in 2022 and just 28% in 2023 (Korus, 2024). US sales in early 2024 have almost flatlined, registering a mere 2.6% year-over-year growth in the first quarter, and a 15% decline quarter-over-quarter (Cox Auto, 2024). While some deceleration in growth is normal during an inflection in market adoption, the absolute lack of growth, so early in adoption, is unhealthy and raises concerns about the long-term viability of widespread EV adoption without additional massive government intervention.

While lower commodity prices are currently helping to lower battery and electric vehicle prices, keeping EV sales from an even worse fate, volatile mineral prices are nonetheless hurting long-term efforts to decarbonize. Mines are long lead-time, risky investments. The average mine takes 17+ years to progress from idea to production and there isn't much capital in the world that is willing to take such risks (S&P, 2024). At a time when we need large increases in mine funding, low minerals prices are forcing many mines to close just as they cause large mining companies to cut back on investment to open future mines (S&P Global, 2024) (Kalinic, 2024). Reduced investment today will slow efforts to decarbonize in the future.

Falling mineral prices can create adverse selection. Only the lowest cost mines remain open, and because mines operating under strict environmental and labor regulations tend to be more costly, we are losing some of the lower impact terrestrial mines in favor of mines which are doing the most damage to the environment and taking the most risks with human lives (Biesheuvel, 2024). We are also losing mines that are owned by Western companies, concentrating power even further in the hands of the Chinese (Mills, 2024).

Volatile mineral prices spell bad news for decarbonization, but they are a function of a market that is supply constrained (Moerenhout, 2023). Bringing in a large and low-cost supply of polymetallic nodules can help ensure a dependable supply of critical minerals which will normalize markets and ease volatility over the long-term. Nodules can be produced inexpensively relative to terrestrial minerals (or they will not be produced), thus an unconstrained market may offer minerals at stabilized prices that are below historical norms. In addition, nodule resources may be scaled much faster than terrestrial mines because they sit on earth's surface.

Creating abundant, lower-cost minerals is key to realizing a smoother path to decarbonization. Ask any auto executive and they will tell you that having a dependable long-term supply of "clean" (no child labor, little environmental impact) energy minerals is a crucial factor in planning their electric vehicle growth strategy.

If the world is serious about decarbonizing, then it needs to get serious about nodule collecting. Constraining our mineral supply by imposing a moratorium on the practice, limiting energy mineral supply to an area that comprises 29% of the earth's surface, to only minerals whose extraction produces the greatest emissions, whose extraction releases the most sequestered CO_2, and whose extraction does the most damage to people and to the environment is not a recipe for success.

Increased CO_2 emissions and sequestered CO_2 release

Extracting minerals from nodules rather than strip mining in terrestrial locations for the same minerals results in a stunning 16x decline in CO_2 release from sequestered sources and up to 70% reduction in CO_2 emissions (see chart pg 24). These savings are meaningful as mining contributes 4-7% of worldwide greenhouse gas emissions (Global Data, 2022).

This information isn't apparent in WWF's literature. The group attempts to portray nodule collecting as a potential detractor to our efforts in combating climate change.

> *"We do know the seabed is an important carbon sink—making the idea of mining operations that would churn up sediment and release that carbon an unlikely "solution" to our climate crisis." (Lambertini, 2022)*

Because WWF hasn't considered both the costs **and** benefits of nodule collecting, they are unable to make an educated and critical assessment of the practice as compared with alternatives. As a result, they miss the fact that we cut the CO_2 put into the atmosphere by a wide margin when we substitute nodule collection for terrestrial mining. This wide differential is consequential in the context of fighting climate change (Cox, 2022).[14]

To delve a bit deeper, most of the CO_2 savings from nodule extraction are driven by a combination of the lack of overburden removal and the high grade of the ore body in nodules as compared to terrestrial mines.

A nickel refinery in South Sulawesi, Indonesia; nodules can be harvested at a fraction of the CO_2 emitted by terrestrial mining operations. (Getty/SOPA Images)

Nodules sit loose on the ocean floor, there is no digging required to access them, and they may be extracted in a non-invasive manner.[15] Terrestrial mining, on the other hand, is highly invasive and requires digging, blasting, drilling, and moving and storing large quantities of overburden to reach the relatively low-grade ore body.

Wide differences in overburden and ore grade mean that a terrestrial mine may have to excavate 500 tons of rock to produce one ton of mineral, whereas nodule collecting requires moving slightly more than one ton of rock to yield one ton of mineral.[16] Waste rock is a store of CO_2, so this massive differential helps to illustrate why the world benefits from so much less CO_2 release when we take nodules rather than extract low-grade terrestrial minerals from underneath tropical rainforests.

Ore grades are positively correlated with environmental and social impacts (Priester, 2019). Lower grades require moving more rock, creating more emissions, using more chemicals, unearthing more sequestered CO_2, and creating greater streams of (often toxic) waste, than higher grades. Because terrestrial ores usually grade at 0.5% to 2% and nodules contain ~100% commercial material, the resulting savings to the environment and to humanity resulting directly from grade differences are obviously quite significant(Singer, 2011) (Statista, 2010).

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[14] The global mining CO_2 footprint includes impacts from mining non-energy metals and it includes emissions from processing. Nodule collecting will not reduce the footprint from non-energy metals mining, and it would only partly mitigate emissions from processing (depending on processing flow).

[15] A jet of water is directed over the top of nodules which creates a pressure differential and lifts the nodules out of the sediment such that they are captured as the harvester passes (Coanda effect).

[16] The 500-ton figure assumes a strip ratio of 4:1 and an ore grade of 1%.

Carbon dioxide is sequestered in plants, soil, deep ocean water, and sediments. This stored CO_2 is released when vegetation dies and decomposes, when ground is unearthed, and when deep ocean water and sediment are brought to the surface.

When miners clear cut tropical rainforests, they convert a carbon sink to a carbon emitter. When they blast, drill, or dig into the ground to expose an ore body, they release CO_2 stored in the soil.

When a harvester rolls over the abyssal plains it disturbs the top five centimeters of sediment, creating a plume (The Metals Company, 2024). That plume will contain CO_2 stores; however, empirical data show that the plume will only rise a few meters before resettling within a short distance over a short time, so there isn't a pathway for that carbon dioxide to be released into the atmosphere (McLachlan, 2023). CO_2 is soluble at abyssal plains depth, so it does not bubble to the surface but instead resettles with sediment or remains at the bottom if in a dissolved state (Teng, 1996). Some of the dissolved carbon could remain suspended for a time in the water at the bottom, but the vast majority of it would resettle through adsorption and hydrolysis (how the carbon came to locate in sediment in the first place). Bottom water takes thousands of years to circulate to the surface to release any CO_2 (Atwood, 2020).

Some operators will use riser systems to lift nodules. This technology brings bottom water and sediment to the surface, releasing some CO_2 to the atmosphere. The scale of this release is so small, however, that it pales in comparison to that which is associated with terrestrial mining. Non-riser lift systems will avoid that release entirely, meaning that the CO_2 savings will be even more profound than the 16x indicated in the life cycle analyses ("LCAs" anticipate riser system usage).

That analysis is confirmed by the Cook Islands Seabed Mineral Authority which writes, "The present scenarios for seabed mining in the Basin would not release significant amounts of deposited inorganic, deposited organic carbon or dissolved carbon, and would not have a significant effect on the climate crisis" (Seabed Minerals Authority, 2019). The same scientific underpinnings are evident in comments from Professor of Geoscience, Derrik Stow, Head of Institute at Heriot-Watt University in Scotland. According to Dr. Stow, "The sediment churned up and organic carbon released by seabed mining will have 'almost no effect' on climate. The amount of disturbance that could be caused to sequestered carbon dioxide in the sediment is almost terribly minimal in scale" (Gronewold, 2019).

Substantial threats to western national security and strategic industries

Nodule collection has the potential to create a giant reset in the market for nickel, cobalt, and rare earths, (it can help with copper too though copper is a much larger market), by opening up a major new supply of these minerals. That supply can feed a new, Western-oriented processing route. Today these markets are largely dominated by China, especially in processing (Emont, 2024)(WSJ, 2024) (Lavelle, 2022).

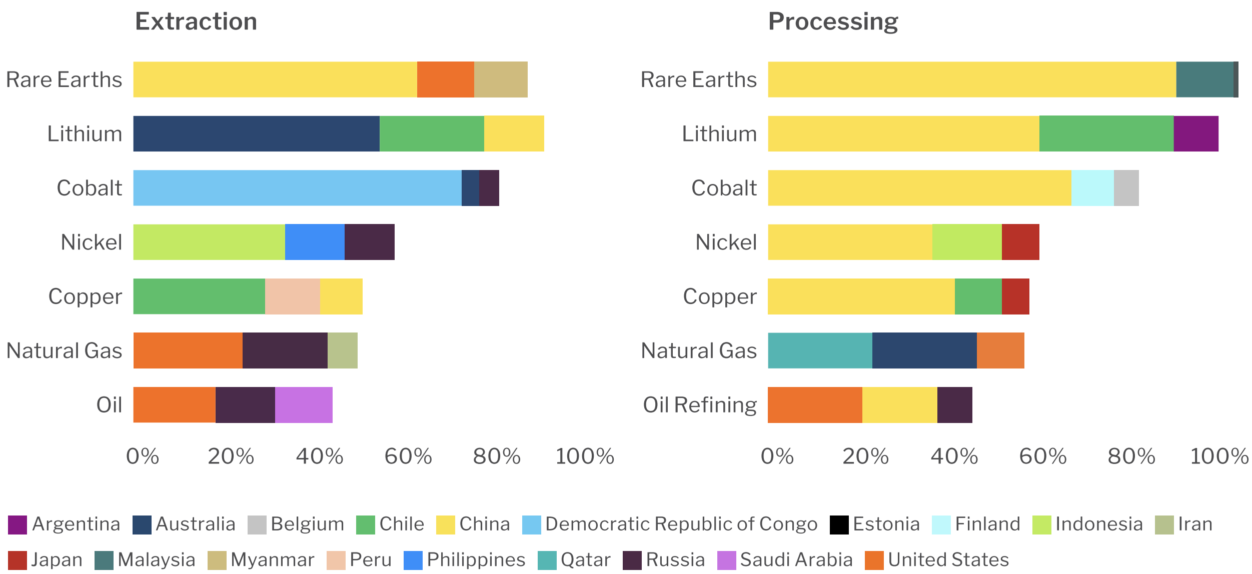
A moratorium on nodule collecting is helpful to China as it insulates Chinese companies from competition, and it protects the sovereign's political and commercial leverage. If energy mineral markets are disrupted, then it is the incumbents who lose. Though China will benefit from nodule collecting to a degree (as it owns licenses in the Clarion Clipperton Zone holding nodule resources), it will not control this new resource to the extent that it controls the terrestrial resources for many of these critical minerals. A large new source of energy minerals opens up the prospect of greater Western processing of these minerals and a more diverse, secure supply chain. The large investment required to construct processing will not materialize without a large and stable form of feedstock.

Victoria Harbour, Hong Kong - June 11, 2017 : Jinan (number 152) missile destroyer crossed Victoria harbour of Hong Kong. A moratorium would cement China's dominance over the ETM supply chain and threaten allied national, economic, and energy security. (iStock/ErnestTse)

China has repeatedly used its stranglehold over key minerals as a political weapon in the past and this impacts our national security interests in the West.

> *Beijing has already used its near-monopolistic global supply chain control of critical minerals to gain a strategic advantage over the United States and Japan. It has increased restrictions on its critical minerals exports nine times between 2009 and 2020, more than any other supplier. It has also threatened US defence contractors' supply chains. And in 2014, China lost a World Trade Organisation case after attempting to coerce Japan by cutting off its supply to critical minerals. (Coyne, 2024)*

Figure 5 China Leads World in Production of Minerals Needed for Clean Energy



Source: Canary Media and IEA

In 2020, the US declared a national emergency over its dependence on foreign adversaries for certain critical minerals. The US and EU depend on Chinese minerals for advanced electronics, almost all of our military weapons systems, automobile manufacturing, electric vehicle batteries, and renewable energy generation components.

The US has begun to take protectionist actions against China's mineral dominance. We see evidence of this in the Energy Act of 2020, the Inflation Reduction Act, the CHIPS and Science Act, and the Bipartisan Infrastructure and Jobs Act. Recently, President Biden announced 100%+ tariffs on Chinese-made electric vehicles.

While these measures will help protect the US from Chinese dominance in certain minerals, they are short-term solutions. Ultimately our system is weakened by protectionism and our economy suffers from the anti-competitive ramifications. Moreover, the Chinese will create workarounds to combat these measures (Liang, 2023). In addition, the measures will slow efforts to combat climate change as they hinder competition and prevent inexpensive Chinese electric vehicles and batteries from competing in the US. They are intended as short-term measures to help the US industry play catch up.

Without nodules it will be very difficult for the US to make serious inroads in some of these critical minerals markets. Terrestrial mines take 17 years+ to reach initial production. China is so deeply entrenched in jurisdictions containing the largest resources that it will be virtually impossible for Western companies to make large progress in those markets—especially without compromising our ideals (as we have recently in the DRC (Lipton, 2024) and we are in Indonesia (Cramer, 2023).

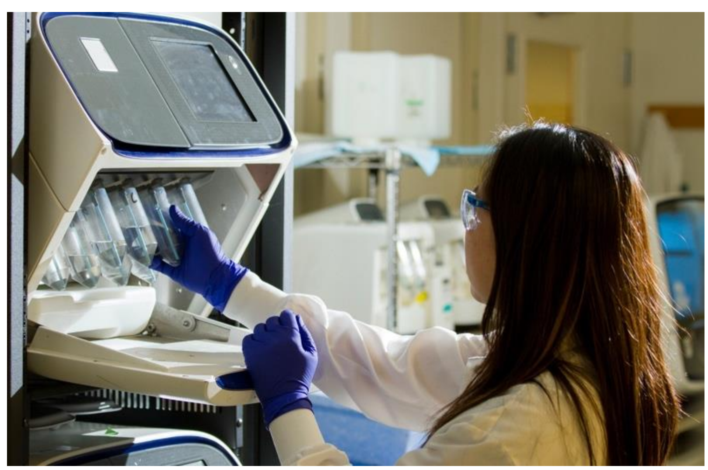
The correct response for America and the EU is to compete with China rather than retreat into protectionism. The drive to compete and to innovate is what made these regions global powerhouses in the first place. Politicians need to understand that nodules offer the opportunity to diversify mineral supply chains away from Chinese and Russian influence, build competitive mineral processing infrastructure and local technical talent, and build competitive industries that depend on a robust critical minerals supply chain. None of that can happen without access to abundant, cleanly-sourced, inexpensive, and reliable critical minerals. It is difficult to attract capital to invest in industries that depend on critical minerals when we don't have reliable, China-free upstream supplies of those critical minerals.

WWF's moratorium threatens to cement Western dependence on Chinese supply chains for a number of critical energy minerals. This dependence will ultimately choke our industries, compromise our global standing, and threaten our national security (Wischer, 2024).

Reduced opportunities to uncover breakthrough medical therapies

> *[Deep sea] mining will completely destroy the [biological] communities in the areas directly mined and over a substantially larger area… and there is no way to eliminate that. (Cambronero-Solano, 2020)*

Greenpeace and other eNGOs assert that nodule collection will impede our ability to create medical breakthroughs based on the idea that the activity will destroy key genomic material on the abyssal plains. The claim is based on the idea that 1) collecting completely destroys biological communities needed for study; and 2) collecting will impact large portions of the ocean. Empirical data demonstrates that each of these ideas is false. Ironically, it is the prospect of nodule collection that is driving increased access to biological data from the deep sea and the opportunity for medical breakthroughs based on that data. The threat of a moratorium has hindered prospects for further medical research.



Responsible deep sea nodule collecting could accelerate medical research and other scientific breakthroughs. (Unsplash/National Cancer Institute)

As we have noted previously, in the unlikely event that we begin large scale collecting operations tomorrow in a manner to meet all of the mineral requirements under the IEA's Stated Policy Scenario for key cathode materials over the next 20 years, we would harvest an area equal to 0.06% of the abyssal plains and 0.2% of the nodule covered plains over 20 years. We will not come close to nodule collecting this aggressively, but even in the event that we did it is still difficult to make the argument that either of these figures constitute a large part of the ocean. We know from plume data that the area isn't extended meaningfully by the collector plume, and the midwater plume (when present) is diluted so quickly that it would not enlarge the impact area either, nor would midwater sediment release have impact on our ability to create breakthrough medical therapies from abyssal dwelling creatures based on very low sedimentation rates (Munoz-Royo, 2021).

Likewise, it is very difficult to argue that in the small portion of abyssal plains which might be impacted (0.06%) by collecting, the biological community will be completely wiped out. Data from collecting operations has shown that the damage from this non-invasive extractive activity results in a 20% decline in biodiversity within the harvester footprint and a 50% decline in living biomass (O'Malley, 2023). This is far short of "complete destruction" claimed by Greenpeace (and well within the 100% destruction of biomass and biodiversity in terrestrial mining sites which host far greater and more complex biodiversity that has yet to be studied or characterized). The damage is quite likely to be less than implied in these figures as operators will leave behind a percentage of nodules that don't meet requirements (smaller than/larger than a set figure) and will leave large contiguous areas within their extraction areas untouched.

Studying the abyssal plains is expensive because it is difficult to access and recover material from water at the depth and pressure that exists on the plains. Because it is so expensive, most of the studies that are undertaken on the abyssal plains are funded by commercial interests. In the last several years, prospective operators have spent several hundred million dollars gathering data and preparing studies. Capital expenditures will expand in the future assuming approval (Sumaila, 2023). Removing commercial prospectivity from the abyssal plains would (and has already) dramatically reduce or eliminate much of the funding for the research required to generate breakthrough medical technologies.

While Greenpeace uses fundraising campaigns to create the perception that they want more research on the abyssal plains, their actions reveal an altogether different motivation. The truth is that activiststs are threatened by research, because the data generated from research has consistently dispelled the myths they've created about nodule collecting. Research works directly against eNGOs' ability to fundraise. In fact, Greenpeace was so threatened by research, that in 2023 the group illegally commandeered a vessel that was actively conducting research on the abyssal plains and demanded a halt to that research (Maritime Executive, 2023).

Greenpeace's actions only make sense when we understand that the group doesn't want research or progress. What they desire are camera-ready moments and wide coverage by media outlets, to help fundraising. If these made-for-media events sacrifice medical research (and possibly human lives) Greenpeace doesn't seem to mind. The group attracts more people and money to its cause with its showmanship.

A Call to WWF and Other eNGOs

It is our hope that this report will spark debate and discussion within organizations that have signed WWF's moratorium and across eNGOs such as WWF and others.

Several eNGOs have told us that they are in favor of careful nodule collection. While most of these groups are reluctant to publish anything that would undermine the fundraising campaigns of big, corporate NGOs such as WWF and Greenpeace, at least one, The Breakthrough Institute, has already broken ranks (Wang, 2024). We know that others have followed, and we are confident that more will come along as they critically analyze the scientific research and the data.

In the meantime, we think dialogue and debate can be helpful, and we encourage eNGOs to talk with us about the issues. Because nodule collecting can produce a win-win outcome for society and the environment, there is a lot of common ground to be found.

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