Planet Tracker

How to Lose Half a Trillion

Deep sea mining to destroy at least half a trillion dollars in corporate value and natural capital

March 2024

CONTENTS

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EXECUTIVE SUMMARY

Should nature be protected from exploitation, or should it be valued on the basis of the benefits it provides to people? Financial markets have opted for the latter, with a narrow definition of 'benefits', focused on extraction.

This report found that financial market participants consistently **value economic sectors dependent on the exploitation of nature's products more than sectors dependent on nature remaining intact**. Yet investing in the latter over the last three decades would have yielded financial returns three times higher than investing in the former.

As corporate, financial and public attention increasingly turn to the Earth's last frontier, the deep sea, this could be the time for financial markets to learn from past mistakes. Instead, some argue that deep sea ecosystem services should start being monetised via deep sea mining.

From a natural capital perspective, this would be wrong: this report found that **preserving the planet's abyssal plains is worth at the very least ten times more than exploiting them.**

From a pure financial perspective, mining the deep sea would also be a mistake. If companies were to mine polymetallic nodules in international waters, it **would destroy USD 30-132 billion of corporate value**. That is three to 13 times the combined GDP of all Pacific island small states. Despite potential gains for providers of subsea mining equipment, much of that value destruction would occur in the mining sector itself. This is due to negative returns on invested capital for the mining of deep sea nodules (negative margins given high operational expenditures) and an increase in the cost of capital for large, high-cost terrestrial mines of nickel, cobalt and copper– the most at risk from disruption from deep sea miners.

The negative impact that the industry would have on the deep sea's ecosystem services would add at least another USD 465 billion of value destruction, mostly via habitat destruction. The good news is that financial market participants can prevent this potential loss of at least half a trillion dollars by **supporting a moratorium on deep sea mining**.

It is not often that financial markets can claim a major success in nature conservation while avoiding significant destruction in corporate value and natural capital. Preventing deep sea mining would be such an opportunity.

HIGHER VALUE, LOWER RETURNS: ARE FINANCIAL MARKETS MISPRICING PROVISIONING SERVICES?

Ecosystem services: an imperfect tool to guide resource allocation

The way nature conservation is framed has changed several times over the past six decades, leading for instance to a shift in emphasis from species to ecosystems. None of these different views disappeared as new ones have emerged, resulting in multiple framings in use today[1] - see Figure 1.

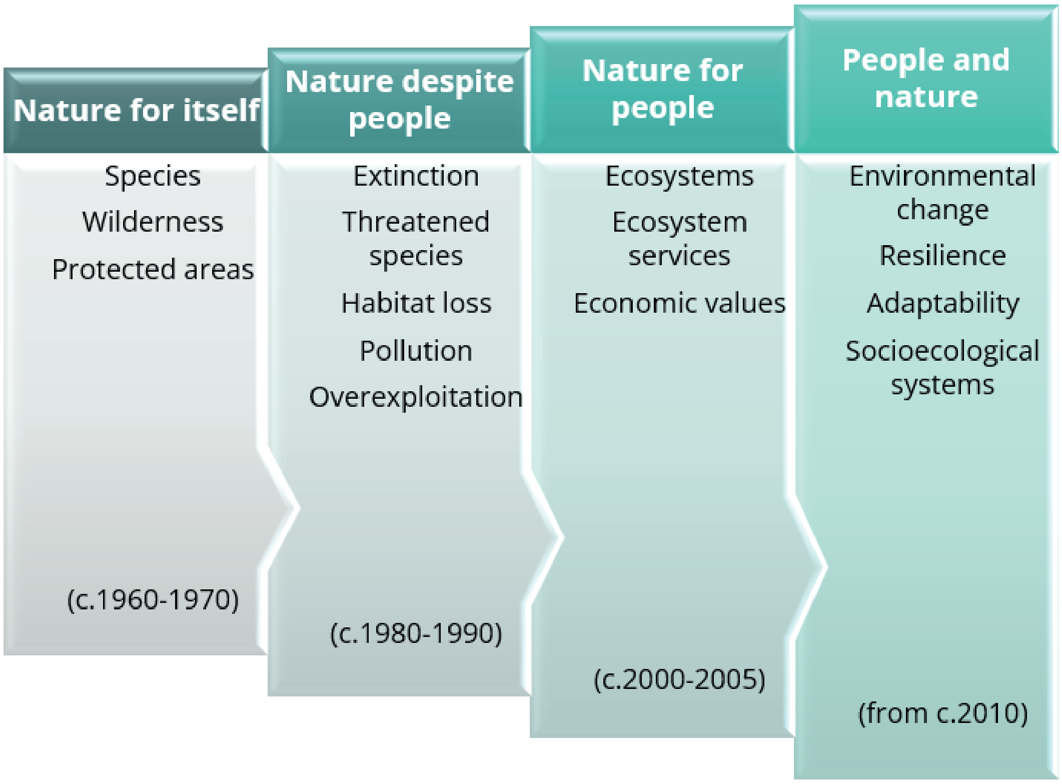

Figure 1: *Changing framings of nature conservation with key underpinning ideas. (Source: Mace, G., 2014).*[2]

Of key importance to the 'nature for people' approach is the concept of ecosystem services - the benefits people obtain from ecosystems.[3] **Characterising ecosystem services and the relevant state of knowledge for each of them is necessary to build decision-support tools like ecosystem accounts or Environmental Impact Assessments.** In terrestrial and shallow water marine environments, explaining how ecosystems support human wellbeing has been helpful in designing and to agreeing sustainability objectives.[4]

Ecosystem services include provisioning, regulating and cultural services, which directly affect people, and supporting services needed to maintain the other services – see Table 1.[5]

Table 1: *Types of Ecosystem Services (Source: Millenium Ecosystem Assessment).*[6]

Supporting services *Services necessary for the production of all other ecosystem services* (E.g., soil formation, nutrient cycling)		
↓ **Provisioning services** *Products obtained from ecosystems* (e.g., food, fresh water, fiber)	↓ **Regulating services** *Benefits obtained from the regulation of ecosystem processes* (e.g., climate regulation, disease regulation, water purification)	↓ **Cultural services** *Nonmaterial benefits obtained from ecosystems* (e.g., educational benefits, tourism, cultural heritage)

Provisioning services are the easiest to understand since they are tangible and are used as inputs in production processes – indeed, provisioning services are also called direct physical inputs in the British context. Throughout this report, provisioning services will be distinguished from others.

There are many challenges and limitations associated with the concept of ecosystem services:

- it was constructed to facilitate assessments and is anthropocentric in nature;
- there are disparities between expert and public conceptualisation of ecosystem services;[7]
- it is focused on economic valuation, thus contributing to a commodification of nature;[8]
- it promotes an exploitative human–nature relationship.

These limitations are acknowledged in this report: valuing nature's benefits by segmenting them in different categories (different 'ecosystem services') makes little sense since these services do not operate in silos and are interdependent.

Still, since financial markets have long operated without assigning any value to nature, **this report argues that an imperfect approach to estimating the value of nature's benefits is a lesser evil than ignoring its value altogether.** The concept of ecosystem services is a far from perfect tool that is however helpful in guiding resource allocation to prevent further degradation of ecosystems.

Ecosystem services dependency and financial markets

The linkage between ecosystem services and financial markets is made via a) the *dependency* of economic sectors on these ecosystem services, b) the *monetisation* of these services (e.g. via commodity or carbon markets), and c) the *impact* that economic activity funded by financial markets has on these services.

Dependency, monetisation and impact will be examined in turn in this report.

Using a methodology detailed in **Appendix 1** based on the ENCORE database,[9] Planet Tracker has quantified the dependency of each industry to ecosystem services. Distinction was made between dependency on provisioning ecosystem services (also called direct physical inputs, i.e. linked to nature's direct exploitation) and other ecosystem services.

The ten sub-industries with the highest dependency score on direct physical inputs include:

- Forest Products
- Agricultural Products
- Tobacco
- Textiles
- Paper Products
- Apparel, Accessories & Luxury Goods
- Leisure Products
- Personal Products
- Hotels, Resorts & Cruise Lines
- Renewable Electricity.

All mining sub-industries are also in the top quartile when it comes to dependency on direct physical inputs. For instance, Diversified Metals & Mining, the sub-industry to which deep-sea mining belongs, is ranked 22nd out of 138 for its dependency score – see Figure 2, where sectors with a zero score (e.g. Human Resource & Employment Services or Wireless Telecommunication Services) have been removed.[a]

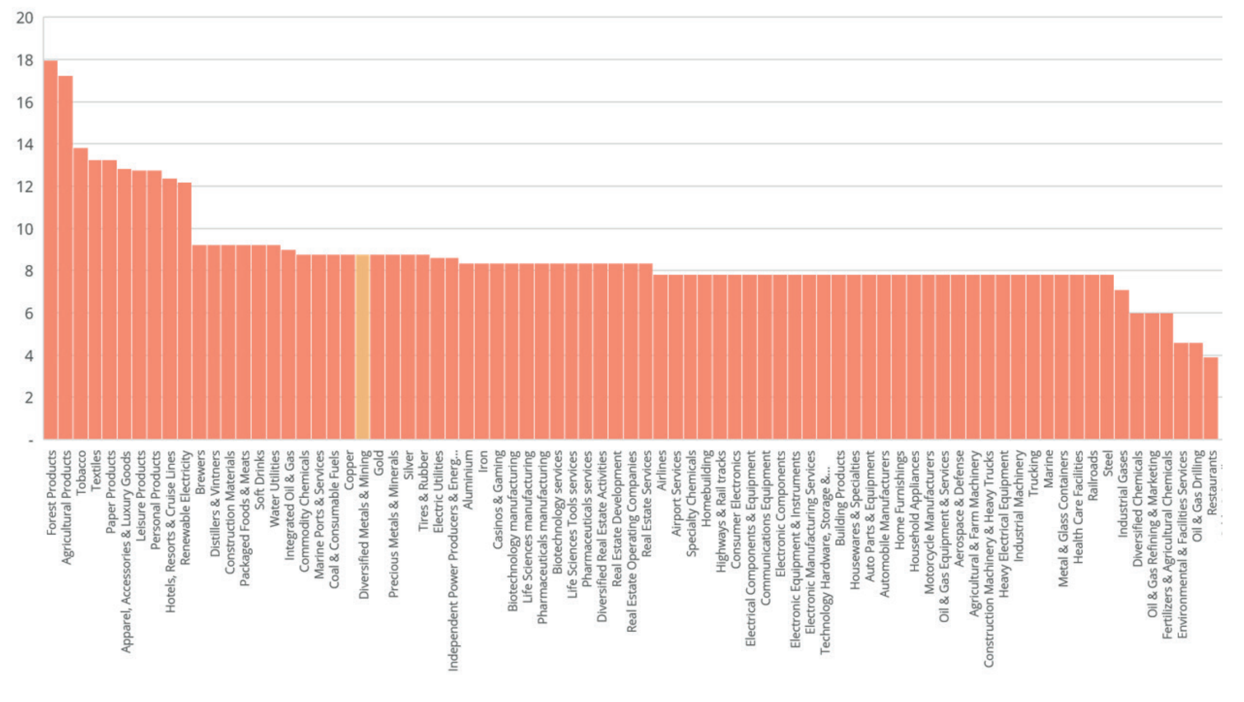

Figure 2: *Dependency score to provisioning services by sub-industry. (Source: Planet Tracker based on ENCORE data; the orange highlight indicates Diversified Metals & Mining; sectors with a zero score are not displayed).*[10]

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a As per the ENCORE methodology, some sectors have a zero dependency score because their dependency does not include that of the sectors they rely on (e.g. the dependencies for the production of paper products exclude those related to growing and harvesting wood products). Please see Appendix 1 for more details.

Financial markets value provisioning services more than other ecosystem services

Over the last thirty years, **financial markets have assigned a higher valuation multiple to those sectors whose dependency on ecosystem services is skewed to provisioning services compared to those skewed to other ecosystem services** – see Figure 3.

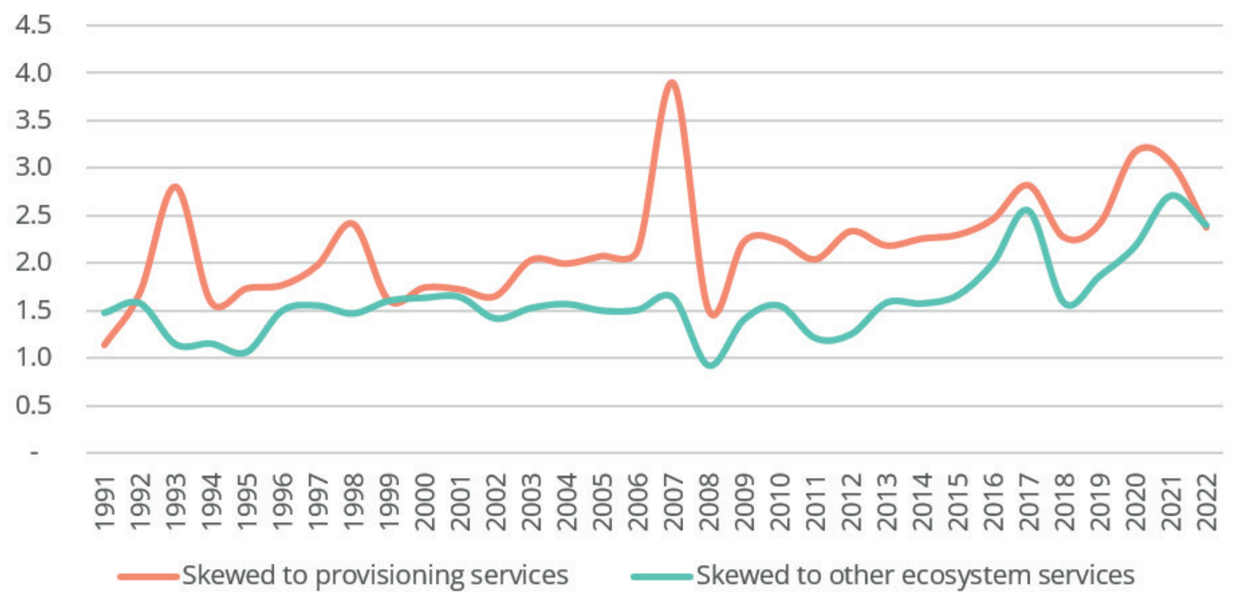

Figure 3: *Median EV/Sales ratio of sectors based on the type of ecosystem service they depend on. (Source: Planet Tracker based on ENCORE and Bloomberg data).*[11]

Sectors skewed to provisioning services underperform those skewed to other ecosystem services

Yet based **on total annual returns, sectors skewed to provisioning services are lagging behind sectors skewed to other ecosystem services.**

To illustrate this point, USD 100 invested in 1991 into sectors skewed to provisioning services would have reached USD 848 in 2022. The same USD 100 invested into sectors skewed to other ecosystem services would have been USD 2,479, a return three times higher - see Figure 4.

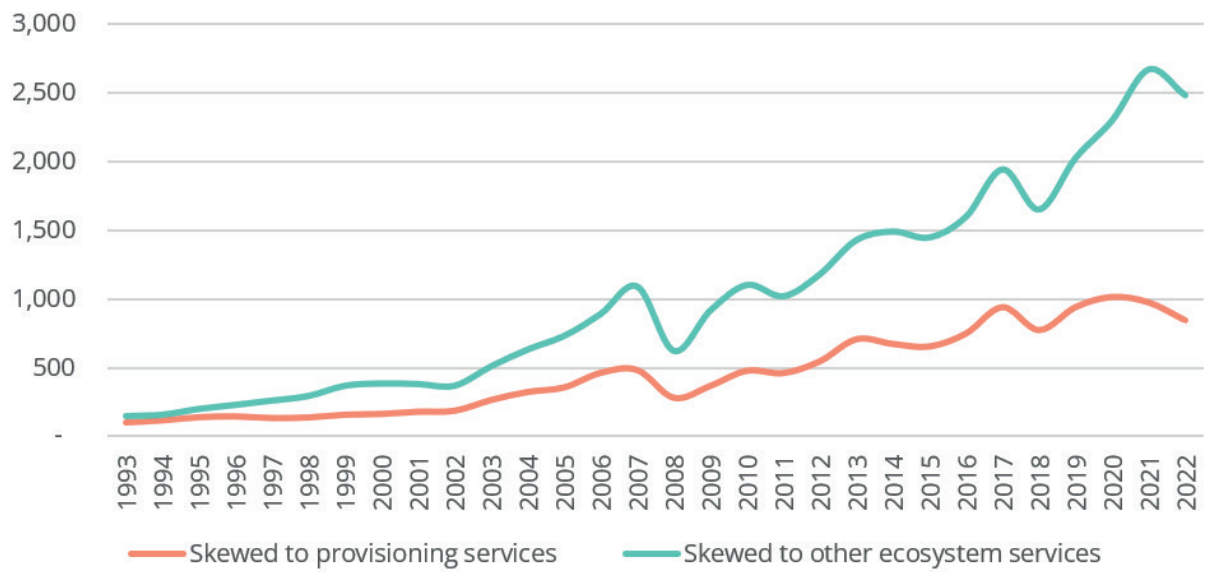

Figure 4: *Historical value (rebased to 100 in 1991) of sectors based on the type of ecosystem service they depend on. (Source: Planet Tracker based on ENCORE and Bloomberg data).*[12]

This means that **financial markets have consistently valued economic sectors that rely on exploiting nature's products rather than those that depend most on nature's ecosystems remaining intact**, even though the latter outperform the former. This is a mistake from which financial market participants should learn.

REPEATING THE MISTAKE IN THE DEEP SEA

Deep sea ecosystem services are not well known

At the time of writing, using an ecosystem service-based approach to support decision-making in the deep sea is not possible, since too little is known about this ecosystem. For instance, when examining existing environmental baselines on eleven topics[b] about seven areas globally that could be exploited for mining, scientists found that knowledge was strong enough to enable evidence-based management in only one[c] of these 77 (7x11) combinations. In contrast there is no, or next to no, scientific knowledge to enable evidence-based management in the majority (39 out of 77) combinations of topics and areas.[13]

Still, our understanding of which ecosystem services the deep sea provides us has increased enough to allow for a classification of these services (that could be modified as scientific knowledge progresses) – see Table 2.

Table 2: *Ecosystem Services in the Deep Sea (Source: La Bianca et al, 2023).[14]*

Ecosystem service category	Ecosystem service
Supporting	Nutrient cycling
	Chemosynthetic primary production
	Secondary production[d]
	Biologically mediated habitat[e]
Provisioning	Medicinal, biochemical and genetic resources
	Wild animals used for nutritional purposes
	Minerals substances used for material purposes
	Minerals substances used as an energy source
Regulating	Mediation of wastes or toxic substances of anthropogenic origin by living process
	Pest and disease control
	Regulation of chemical composition of atmosphere and oceans; Atmospheric composition and conditions
Cultural	Intellectual and representative interactions with natural environment
	Spiritual, symbolic and other interactions with natural environment
	Other biotic characteristics with a non-use value

This report focuses on abyssal plains and therefore the ecosystem services represented in Figure 5.

b e.g. species taxonomy, trophic relationships, seabed properties, etc.

c high-resolution bathymetry in active sulfides in the Mid-Atlantic ridge

d the production of new organisms that eat other plants and animals for energy and nutrients

e habitat which is provided by living marine organisms through their normal growth, (for instance, reef forming invertebrates).

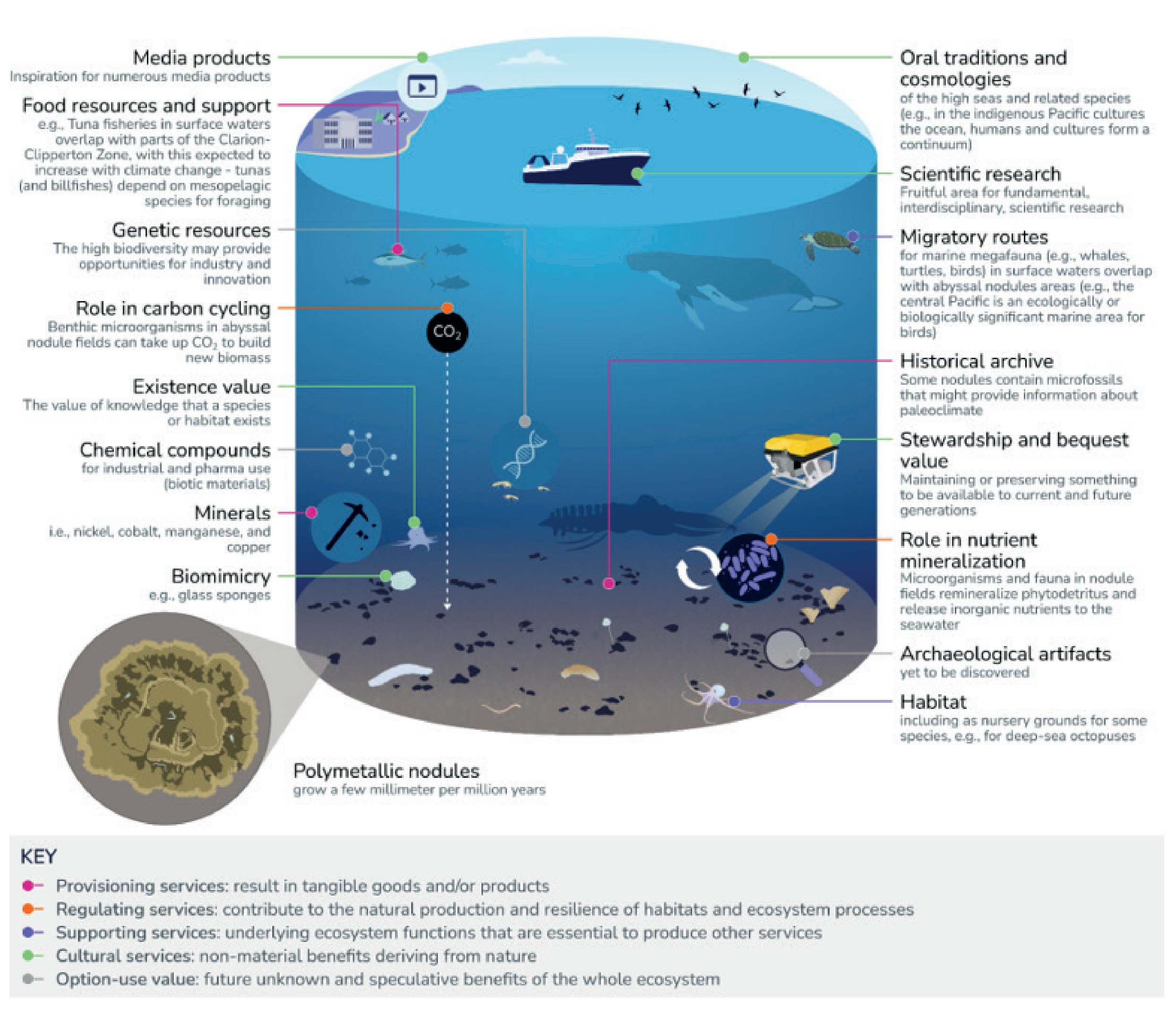

Figure 5: *Ecosystem Services in Polymetallic Nodules Fields on Abyssal Plains. (Source: DOSI).*

For instance, deep sea mining relies on a provisioning service provided by the deep sea (minerals substances used for material purposes, see above in Table 2).[15]

The monetisation of deep sea ecosystem services is extremely low

Globally, the monetisation of ecosystem services is relatively low. In general, monetisation is easier to achieve for provisioning services than for other ecosystem services since the former serve as inputs in production processes and are therefore tangible. For instance, **commodity markets are the result of the monetisation of provisioning services.** These services are now highly monetised globally. In the deep sea they are the only services for which a significant level of monetisation exists – see Table 3.

Monetising intangible services is harder. Willingness-to-pay becomes a key factor. Still, through the development of multiple forms of payments for ecosystem services (including carbon markets or nature-based tourism (see Table 3), many services across terrestrial and marine biomes have been monetised, at least to some extent. This is barely the case for the deep sea though – see Table 3.

***Table 3:** Estimated Current Status of the Monetisation of Ecosystem Services in the Deep Sea Compared to Other Biomes (Source: Planet Tracker, based on classification by La Bianca et al (2023)).*[16]

Ecosystem service category	Ecosystem service	Monetisation level in the deep sea	Monetisation level in other biomes
Supporting	Nutrient cycling	Nonexistent	Limited (e.g. waste biomass)[17]
	Chemosynthetic primary production	Nonexistent	Nonexistent
	Secondary production[f]	Nonexistent	Nonexistent
	Biologically mediated habitat[g]	Nonexistent	Limited
Provisioning	Medicinal, biochemical and genetic resources	Limited	High (e.g. traditional medicine)
	Wild animals used for nutritional purposes	Significant (deep sea fisheries)	High (e.g. fisheries)
	Minerals substances used for material purposes	Nonexistent for now (deep sea mining)	High (e.g. mining, construction)
	Minerals substances used as an energy source	Significant (deepwater oil drilling)	High (e.g. oil and gas)
Regulating	Mediation of wastes or toxic substances of anthropogenic origin by living process	Nonexistent	Limited (e.g. wetland, bivalve aquaculture)[18]
	Pest and disease control	Nonexistent	Significant (e.g. agroecology)[19]
	Regulation of chemical composition of atmosphere and oceans	Limited (deep blue carbon markets)[20]	Significant (e.g. carbon markets)
Cultural	Intellectual and representative interactions with natural environment	Limited[21]	Significant (e.g. movies)
	Spiritual, symbolic and other interactions with natural environment	Limited	High (e.g. nature-based tourism)[22]
	Other biotic characteristics with a non-use value	Limited	Limited

Deep sea ecosystem services are thus barely monetised, and significantly less than in other biomes.

Financial markets bet on provisioning services in the deep sea

At the time of writing, markets have supported the monetisation of the deep sea's ecosystem services by focusing on provisioning services only (e.g. via deep sea fisheries). Exploitation, rather than conservation, has been the focus. The possible exploitation of polymetallic nodules in abyssal plains by a few aspiring deep sea mining companies is another example of that bet.

It has been proven many times that this is the wrong bet from an environmental and societal perspective.[23] But is it the right bet from a pure financial perspective? It turns out the answer is no.

f The production of new organisms that eat other plants and animals for energy and nutrients.

g Habitat which is provided by living marine organisms through their normal growth, (for instance, reef forming invertebrates).

PRESERVING THE DEEP SEA WORTH AT LEAST TEN TIMESMORE THAN EXPLOITING IT

Less than 10% of the value of the deep sea comes from provisioning services

Mindful of the many challenges linked to the valuation of ecosystem services in general, and those of the deep sea in particular, Planet Tracker has estimated the *minimum* value of the *supporting, regulating and cultural services* provided by the deep sea area where deep-sea mining could be authorised and compared that to the *maximum* value provided by *provisioning services* – see Figure 6.

Planet Tracker adopted this approach to demonstrate that even when using very conservative (low) values for supporting, regulating and cultural services, and generous (high) values for provisioning services, the latter are worth only a fraction of the former.

We found that **provisioning services** (mining, oil & gas, bioprospecting and fishing) **account for a maximum of 10% of the total valuation.** Please see details in **Appendix 2** - Valuing abyssal plains.

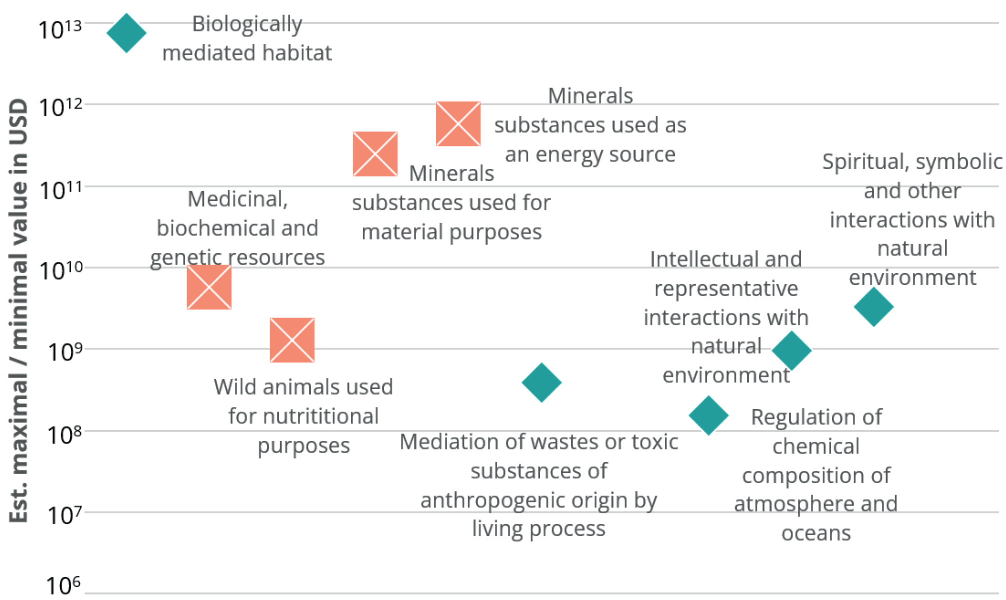

Figure 6: *Estimated maximum/minimum valuation of the ecosystem services provided by the abyssal plains where deep sea mining could occur in international waters. (Source: Planet Tracker; red squares indicate maximum values for provisioning services and green diamonds indicate minimum values for other ecosystem services; values in USD, logarithmic scale).*

Major limitations about this finding include:

- The estimated values are not comparable to one another since the underlying assumptions for provisioning services were chosen on purpose to be as high as possible, whilst those driving the valuations for other ecosystem services were chosen to be a floor valuation
- Valuing ecosystem services separately goes against the interconnectedness of the deep sea, and that of the deep sea to the wider biosphere and geosphere.

For these reasons, attributing a total financial value for the deep sea would make little sense. This is even more the case since many of the non-provisioning services the deep sea provides us with (e.g. spiritual value) arguably have an infinite value.

Still, since economic decisions that can lead to important consequences for the natural environment can be formed on the back of such valuations, it is important to distinguish this finding from existing valuations.

For instance, our results differ widely from the often-mentioned Ottaviani paper that valued ecosystem services in the whole of the high seas,[24] since that paper only used market-based valuations, thereby excluding all ecosystem services that were not provisioning services with the exception of carbon sequestration and cultural services. Using Ottaviani's valuation, provisioning services seemingly account for 97% of the total valuation – see Figure 7.

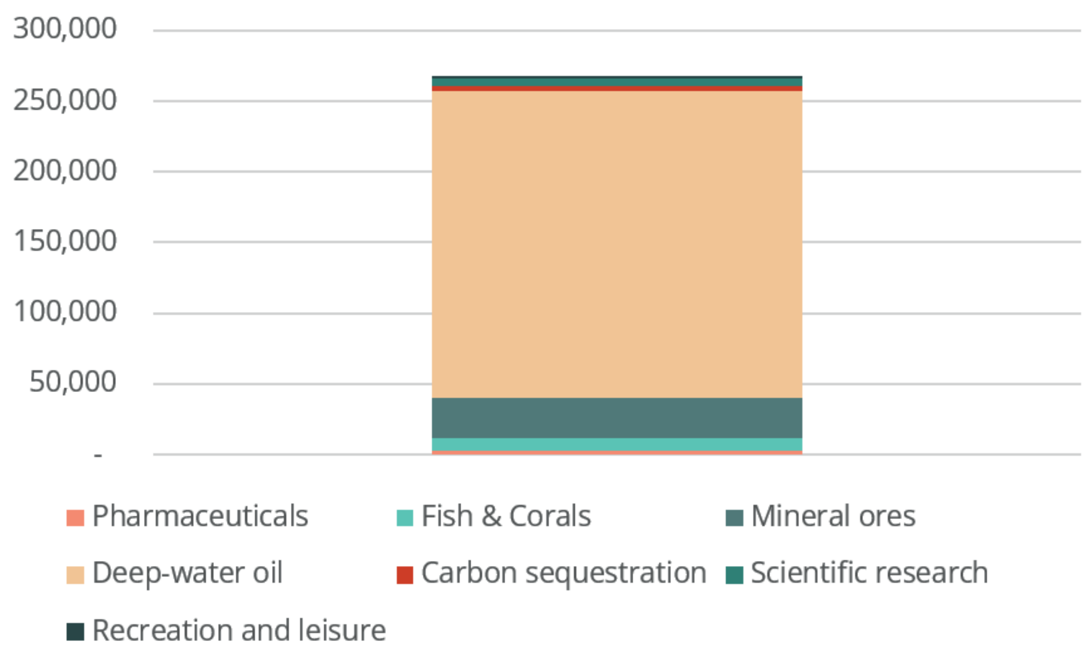

Figure 7: *Annual value of ecosystem services provided by the high seas using a market-based approach. (Source: Ottaviani (2020), in 2014 USD millions).*[25]

In addition to the many limitations of the concept of ecosystem services (e.g. is nature's value limited to what it offers humanity?), focusing only on market-based valuations perpetuates the key pitfall of the 'take-make-waste' economy.

Focusing on the above figure without knowledge of the deep sea could lead someone to (wrongly) think that mining and oil and gas extraction is the key way to realise value from this ecosystem.

Instead, as demonstrated in Figure 6, at least 90% of the value of the abyssal plains in international waters comes from ecosystem services other than provisioning services.

Put differently, **the value of the natural capital of the deep sea overwhelmingly lies in the absence of exploitation.** Mining the deep sea would damage this value.

DEEP SEA MINING WOULD DESTROY AT LEAST HALF A TRILLION DOLLARS IN VALUE

Deep sea mining refers to the extraction of metals and minerals from the seafloor of the deep ocean, which covers around 50% of the earth's surface (360 million km^2) and represents 95% of the global biosphere.[26] There has been a surge of interest in deep sea mining in recent years, driven by the forecast rise in demand for metals for technology and the low-carbon transition.[27]

There is a temptation to monetise some of the deep sea's ecosystem services by extracting minerals from the deep sea. But from a pure financial perspective, this would be a mistake.

Framing value creation and destruction in financial terms

Prior to estimating the value generated or destroyed by the existence of the deep sea mining industry, the concept of value creation needs to be defined. This can be either financial value, or perceived value. This report chooses financial value since it is less subjective.

According to established but challenged financial theories, for a company to create financial value, it needs to grow and beat its cost of capital.[h] To create long-term value, it needs to consistently beat the cost of capital.[28]

The assumption that growth is a necessary condition for value creation is one of the main reasons why six of the nine planetary boundaries have been crossed,[29] and why the world's ecological footprint stands at 1.7 times what the Earth can regenerate.[30] However, and despite ever more successful attempts to challenge this status quo (see e.g. Triodos Bank's view on growth),[31] this is still the prevailing view among financial markets, and will therefore be used below.

Using the value driver formula[32] and based on calculations detailed in **Appendix 3**, Planet Tracker found that deep sea mining would create financial value if the change in the invested capital, returns and cost of capital of the different companies the industry would affect positively exceeds the change in the invested capital, returns and cost of capital of companies negatively affected.

For instance, if mining the deep sea resulted in increased returns for some companies that would see an increase in their invested capital and a decrease in the cost of their capital, this would clearly create value for these companies. If it also resulted in lower returns, lower invested capital and higher cost of capital for other companies, this would certainly lead to value destruction at this second group of companies. The sum of these two changes in value (one positive, one negative) would determine whether the industry created overall value or not.

The rest of this section demonstrates that the deep sea mining industry would destroy value.

h The cost of a company's capital is the combination of the pre-tax interest rate a company pays on its debts (cost of debt) and the compensation that the market demands in exchange for owning an asset and bearing the risk associated with owning it (cost of equity)

Mining the deep sea would destroy USD 30-132 billion in corporate value

Estimating the value generated or destroyed by the existence of the deep sea mining industry involves calculating the financial value of mining nodules in abyssal plains (in international waters) – see below.

***Table 4:** Key assumptions and calculations to estimate the value created/destroyed by deep sea mining (Source: Planet Tracker).*

	Item	Value	Source/ Comment
Revenue & Royalties	Period of exploitation	2028-2043	This does not mean that exploitation would stop in 2043, but is used as the end date for discounted cash-flow computations
	Average size of one mining operation (mn dry tonnes)	3	This is the standard used in the literature, e.g. Lèbre et al (2023),[33] or Van Nijen et al (2018).[34]
	Number of different mining operations (of 3mn tonnes)	31	Assuming growth in the number of nodule contractors (currently: 19)[35]
	Nodules mined per year (mn dry tonnes)	94	
	Revenue per tonne of nodule harvested (USD)	461	Using NORI-D grades and recovery ratios, and spot metal prices (as of Jan 2024).
	Annual sales (USDmn)	43,509	
	Royalties (USD per dry tonne)	33	In line with assumptions made by The Metals Company but royalty rates under discussion vary wildly
	Annual royalties (USDmn)	3,112	
Capex	Capex for mining and processing for one operation (USDmn)	5,272	Based on Van Nijen et al (2018),[36] adjusted by global 2018-2023 inflation. The cost of building a processing plant is c.60% of the total.
	Annual maintenance capex (USDmn)	870	Assuming an average of 2% of sales
	Implied capex per nodules extracted (USD per dry tonne)	83	This is significantly lower than what Abramowski et al (2021) found (USD 213 per wet tonne)
Assets	Annual depreciation (USDmn)	4,144	Assuming straight-lined depreciation over 40 years
	Book value of Property, Plant & Equipment - 2043 (USDmn)	112,290	
	Intangible assets (2043, USDmn)	2,518	Assuming a ratio of intangibles to PP&E similar to BHP
	Invested capital (2043, USDmn)	**114,808**	Assuming that net working capital is zero.
Opex	Annual opex per mining operation (mining only)	423	Based on Van Nijen et al (2018),[37] adjusted by global 2018-2023 inflation
	Annual opex per mining operation (processing only)	896	Based on Van Nijen et al (2018),[38] adjusted by global 2018-2023 inflation. Note that energy includes for c.60% of that total (see The Climate Myth of Deep Sea Mining for more details).
	Annual opex (USDmn)	41,474	Note: this excludes any restoration costs, which are expected to be colossal (see 'The Sky High Cost of Deep Sea Mining')
Returns	Annual EBITDA (USDmn)	2,035	Amortisation of intangibles is assumed to be neglectable
	Annual net operating profit after tax (USDmn)	(2,457)	
	Return on Invested Capital (%)	**(2%)**	

With an expected average return on invested capital of -2%, the deep sea mining industry would not beat the cost of the capital it requires to exist (estimated at 20%).

USD 35-49 billion of corporate value destroyed in the deep sea mining industry

If it were to reach c. USD 115 billion in invested capital by 2043 as per above, the deep sea **mining industry would destroy USD 35-49 billion in corporate value** (only in the deep sea mining and processing industry).

This depends on the change in expected cost of capital (from 20%, it could decrease if the industry becomes seen as less risky) and assumes no change in long-term growth (3%). This value destruction is calculated using the formula detailed in **Appendix 3** and based on operations in the abyssal plains of international waters only.

Importantly, this assumes no liabilities for the damage created by these companies to the seabed and the wider environment. Since the cost of attempting to restore the seabed would be higher than the revenue generated from mining it,[39] the estimated value destruction would be significantly higher if restoration costs were even partially included (the way they are on land)[40] since returns would be even lower. Liabilities for the destruction of ocean biodiversity, including important fisheries and marine genetic resources, or causing negative effects to earth's ability to regulate its climate – all of which are ill-defined and potentially significant, have also not been factored in.

USD 16 billion of corporate value created in the subsea mining equipment sector

As a client of subsea equipment providers, the industry would however create financial value for the capital goods sector. Estimating the combined revenue of a selection of companies that could possibly count deep sea mining companies among their clients in the future (such as SMD, Saab, Robert Bosch, Aker Solutions, or Kongsberg), Planet Tracker calculates that the deep sea mining industry could add 3% to the long term growth of this sub-industry (based on the capital expenditures detailed above). This would result in **USD 16 billion in value created in the capital goods sector.**

USD 11-98 billion of corporate value destroyed in the terrestrial mining sector

In addition, the deep sea mining company could impact terrestrial mining companies if it delivers on its promise to extract a significant amount of cobalt, copper, nickel and manganese from the deep sea. In fact, there is no evidence that minerals from the abyssal plains would even partially substitute land-based minerals. But the fear that this could be the case (within financial markets) could be enough to potentially impact the cost of capital of some terrestrial mining companies. The companies most at risk would be the owners of large, high-cost mining operations focused on these minerals. These include the following mines at the following companies - see Table 5.[41]

Table 5: *List of large and high-cost terrestrial mines focused on cobalt, copper and nickel (Source: Lebre et al (2023)[42]).*

Main owner	Mine name (Country)
Anglo American Platinum Limited	Mogalakwena (South Africa)
BHP Group Ltd.	Olympic Dam (Australia); Spence (Chile); Leinster (Australia)
Capstone Copper Corp.	Pinto Valley (USA)
China Daye Non-Ferrous Metals Ltd.	Dahongshan (China); Anqing (China); Fengshan (China); Tongshankou (China)
Eramet SA	SLN (New Caledonia)
EMR Capital Pty. Ltd.	Lubambe (Zambia)
First Quantum Minerals Ltd.	Ravensthorpe (Australia)
Glencore PLC	Kamoto (DRC); Mutanda (DRC); Murrin Murrin (Australia); Raglan (Canada)
Huili County Mineral Products Co. Ltd.	Lvshui (China)
Industrias Peñoles SAB de CV	Capela (Mexico)
Jervois Global Ltd.	Idaho Cobalt (USA)
Jinchuan Group Co. Ltd.	Jinchuan (China)
Jiangxi Copper Co. Ltd.	Yongping (China)
Metallurgical Corp. of China Ltd.	Ramu (PNG)
Navarre Minerals Ltd.	Mount Carlton (Australia)
Nexa Resources Perú SAA	Cerro Lindo (Peru)
Nickel Asia Corporation	Taganito (Philippines); Rio Tuba (Philippines)
Pacific Metals Co. Ltd.	Hachinohe (Japan)
Prony Resources NC consortium	Goro (New Caledonia)
Rambler Metals and Mining PLC	Ming (Canada)
Sherritt International Corp.	Moa Bay (Cuba)
Societe Miniere du Sud Pacifique SA	Koniambo (New Caledonia)
Terrafame Oy	Terrafame (Finland)
Tongdu Copper Works	Anqing (China)
Tongling Non-ferrous Metals Co. Ltd.	Shaxi (China)
Tongling Nonferrous Metals Group Co.	Tongshan (China)
Vale SA	Ontario Division (Canada)
Yunnan Copper Co. Ltd.	Dahongshan (China)

Quantifying the impact of deep sea mining on these companies is challenging. Assuming that the risk of deep sea mining disturbing the terrestrial mining industry results in a 0.1%pt to 1%pt increase in the cost of capital of the above companies and that between 1% and 10% of the investment in deep sea mining companies comes at the expense of investment in terrestrial companies, Planet Tracker calculates that **USD 11 to 98 billion of corporate value could be destroyed in the terrestrial mining sector** due to deep sea mining. This is assuming no change in the sector's returns and growth (i.e. it could be worse).

Value destruction in fisheries

The high-seas tuna industry and associated supply chain could also be affected by deep sea mining.[43] The financial value of that negative impact is likely to be expressed in millions rather than billions: catches of tuna average 35,000 to 78,000 tonnes in the CCZ and surrounding waters, with dock prices ranging from USD 1,000 to 5,000 based on the species.[44] A 5%pt decrease in the estimated ROIC of the tuna industry in the CCZ (from 7%[45] to 2%) would be equivalent to the destruction of USD 92 million in value. Whilst this is indicative only, Planet Tracker's research on the tuna industry has showed that its financial health is severely dependent on the environmental conditions of the ecosystem (see 'In Hot Water') which the deep sea mining would negatively affect.

In addition, mining the seabed would likely prevent any exploitation of deep sea fisheries in or near the areas mined. This would result in a loss of financial value of USD 252 million (simply assuming that the de facto no-take area would be twice the size of the area mined and based on profit calculations shown in **Appendix 2**).

Overall, while it is very difficult to model the likely **effect of deep sea mining on fisheries, a negative impact of USD 344 million** is likely to be an acceptable estimate.

Combined financial value destruction of USD 30 to 132 billion

Overall, Planet Tracker calculates that if it were to operate, mining polymetallic nodules in international waters would destroy **USD 30 to 132** billion of corporate value, about three to 13 times the combined GDP of all Pacific Island Small States.[46]

Financial value destruction of ecological damage

In addition to this major destruction of financial value, the deep sea mining industry would damage ecosystems. This has been extensively analysed (see a summary of this impact for instance in 'The Sky High Cost of Deep Sea Mining', or 'The Perils of Deep Sea Mining').[48]

Quantifying that loss in ecological value is challenging, not least because it is very difficult to estimate the baseline value in the first place. However, based on the estimated valuation of the ecosystem services provided by abyssal plains in international waters, Planet Tracker calculates that **the value of the loss in ecosystem services associated to the deep sea mining of 10,000 km^2 every year from 2028-2043 would be at least USD 465 billion.** This is a simple minimum estimate since it was assumed that:

- The valuation of each ecosystem service would be reduced proportionally to the area mined (in reality, the damage is unlikely to follow a linear function).

- The valuation of the ecological damage is limited to the area mined only (even though ecological habitats in the surrounding areas and different layers of the water column would also be damaged)[49]
- The valuation of the 'Biologically mediated habitat' ecosystem service would be reduced proportionally to the loss in carbon stock and fauna, using the simple average of:
    - The 46% difference in the carbon stock inside the plough tracks 26 years after the DISCOL experiment[i] compared to outside the plough tracks;[50]
    - The difference in epifaunal[j] densities in the CCZ based on nodule coverage (densities are more than two times higher at dense nodule coverage).[51]

In reality, it is quasi-impossible to estimate this loss accurately given the existence of a multitude of knowledge gaps[52] and the difficulty in valuing supporting ecosystem services.

- The social cost of the carbon emissions resulting from deep sea mining was calculated including mining and processing, but excluding the negative impact that deep sea mining would have on carbon sequestration (since the latter would not immediately lead to additional carbon in the atmosphere), assuming 2.03 kg of CO_2e per kg of dry nodule and using a USD 190 price for the social cost of CO_2.

Overall, deep sea mining would reduce the total (financial and ecological) value of different industries and ecosystem services by **at least half a trillion dollars** (at least USD 491- 593 billion) – see Figure 8.

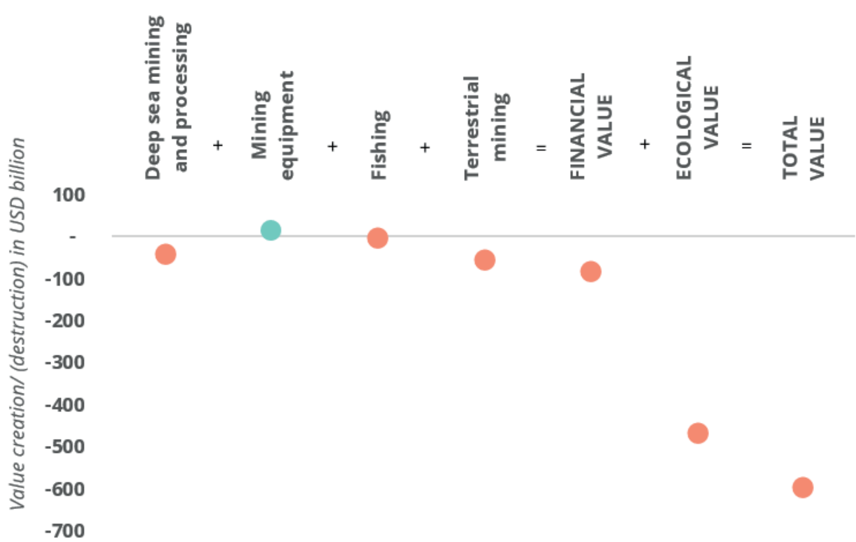

***Figure 8:** Total value destruction (orange dots) and creation (green dot) associated with the deep sea mining of 10,000 km² of abyssal plains in international waters every year over 2028-2043. (Source: Planet Tracker, mid-point estimates, in USD billion).*

i During the "DISturbance and reCOLonization" (DISCOL) experiment, 22 % of the seafloor within a 10.8 km2 circular area of the nodule-rich seafloor in the Peru Basin was ploughed in 1989 to bury nodules and mix the surface sediment. This area was revisited 0.1, 0.5, 3, 7, and 26 years after the disturbance to assess macrofauna, invertebrate megafauna and fish density and diversity.

j benthic fauna living on the substrate (such as a hard sea floor) or on other organisms.

CALL TO ACTION:

AVOIDING EXPECTED LOSSES BY SUPPORTING A MORATORIUM

This report demonstrates that deep sea mining could destroy USD 30 -132 billion in corporate value if it were to go ahead in international waters, and at least half a trillion dollars when including lost environmental value.

In risk management terms, it is commonly accepted that: Expected Loss = Loss Given Default (LGD) x Probability of Default (PD) x Exposure at Default (EAD). Borrowing this vocabulary and replacing the event 'default' by the event 'deep sea mining happens', this report's key finding can be rephrased as:

Loss Given Deep sea mining x Exposure to Deep sea mining > USD 500 bn.

At the time of writing, it is not possible to quantify the probability that deep sea mining will happen in international waters, and therefore not possible to quantify the expected loss associated with deep sea mining. However, financial institutions can reduce that probability, by showing their **support for a** **moratorium on deep sea mining.**

By opposing deep sea mining, financial institutions will reduce the expected losses they will incur should this industry be authorised to exploit abyssal plains. It is therefore in their interest to act.

APPENDIX 1:

QUANTIFYING ECOSYSTEM SERVICE DEPENDENCY

This report quantifies the dependency of each sub-industry to ecosystem services using the following approach.

The ENCORE database lists the direct dependencies and impacts of production processes on ecosystem services and natural capital assets.[53] For each sub-industry and based on the GICS classification, a list of production processes is provided. For each of these production processes, dependency on ecosystem services is assessed, using a scale ranging from Very Low to Very High – see example below in Table 6.

Table 6: *Dependency of one production process ('Mining') to ecosystem services (Source: ENCORE, where 'Mining' refers to terrestrial mining).*

Production Process	Ecosystem Service	Rating
Mining	Mass stabilisation and erosion control	Medium
	Surface water	High
	Water flow maintenance	High
	Ground water	High
	Climate regulation	High

Using this dataset, Planet Tracker calculated the dependency of each sub-industry to each ecosystem service by aggregating the dependency score of the relevant production processes (converted into numerical values, using a 0-100 scale, where Very High becomes 100, and Very Low becomes 10 – see Table 7).

Table 7: *Conversion of materiality ratings as assigned by ENCORE into numerical values (Source: Planet Tracker, ENCORE).*

Materiality	Value	ENCORE Definition
Absent	0	Empty value / Not mentioned
Very Low	10	Most of the time the production process can take place even with full disruption of the ecosystem service
Low	20	Most of the time the production process can take place even with full disruption of the ecosystem service due to the resilience of the production process to disruption
Medium	50	Although less practical, production process can take place without the ecosystem service due to availability of protection substitutes
High	80	The production process is extremely vulnerable to disruption. The degree of protection offered by the ecosystem service is critical and irreplaceable for the production process
Very High	100	Ecosystem service is critical and irreplaceable in production process

Note that this excludes dependencies and impacts that occur through the supply chain to avoid double-counting. For instance, the dependencies for the production of paper products exclude those related to growing and harvesting wood products.

For each sub-industry, the dependency to direct physical inputs (i.e., provisioning services) like groundwater, fish, timber, or fibre was separated from other ecosystem services. Planet Tracker calculated the number of unique ecosystem services each sub-industry depends on, and the average materiality value these dependency, both for direct physical inputs and other ecosystem services. Finally, a dependency score that factors in the number of unique ecosystem services and the average materiality value of these dependencies, was constructed. The higher the number of ecosystem services and the materiality, the higher the dependency score. The following formula was used:

$$D_i = \ln\left({M_i}^{p_i}\right)$$

where for each sub-industry i, D_i is the dependency score, M_i is the average materiality value of the dependency to ecosystem services, pi is the number of unique ecosystem services the sub-industry depends on, and $\ln$ is the natural logarithm. That formula was chosen to ensure that both the materiality value and the number of ecosystem services a sub-industry depends on are assigned importance in the dependency score.

The average materiality value of the dependency to ecosystem services M_i was calculated as the simple average of the materiality value (m) of the dependency of each combination of ecosystem service and production process, where n_i is the number of such combinations:

$$M_i = \sum_{k=1}^{n_i} \frac{m_k}{n_i}$$

Rather than calculating a dependency score (D_i) for all ecosystem services, a score was calculated for direct physical inputs only (provisioning services), and another one for other ecosystem services.

APPENDIX 2:

VALUING ECOSYSTEM SERVICES IN ABYSSAL PLAINS

This report establishes an estimated value of the ecosystem services provided by the abyssal plains in which polymetallic nodules could be mined in order to argue that the value of provisioning services is low compared to that of all other services. This was despite calculating high estimates for provisioning services (most likely overestimating them), and low estimates for other services (most likely underestimating them).

This approach was chosen to try to mitigate the many challenges and flaws there are in trying to quantify the dollar value of ecosystem services for which numerous knowledge gaps exist: while assigning an exact value is near impossible for the time being, determining a likely minimal or maximal value is more achievable.

Estimating a maximal value for provisioning services

Rather than estimating a fair value for the deep sea's provisioning services, generous assumptions have been used in order to obtain estimates of *maximum* values.

To value '**Mineral substances used as an energy source**', the estimated reserves of economically recoverable ultra deep-water oil and gas reserves were used, assuming that their geographical distribution in the area was similar to the global average – see Table 8. The resulting estimated value was USD 11 billion. This is (on purpose) likely to be a major overestimation since any oil and gas found in the area is unlikely to be 'economically recoverable'.

Table 8: *Key assumptions made to value the provisioning service 'Mineral substances used as an energy source' in the deep sea (Source: Planet Tracker).*

Key indicator	Value and unit	Source / Comment
Global reserves of ultra-deep water oil	35,182 million barrels	Offshore Technology[54]
Global reserves of ultra-deep water gas	207 trillion cubic feet	Offshore Technology[55]
Geographical distribution of oil and gas reserves in the Area	Same as global average	Likely to be a significant overestimation
Average free cash flow margin in the oil and gas value chain	4%	Fitch Ratings[56]
Average royalty rate	15%	To capture value for governments (excludes negative impact of fossil fuel burning)

To value '**Minerals substances used for material purposes'**, the estimated free cash flow associated to nodule mining in the Clarion Clipperton Zone and the related royalties were calculated assuming that all of the nodules in ISA concessions are mined – see Table 9. The resulting estimated value was USD 244 billion. This estimate does not include any negative impact of the ecological value, or the financial value destroyed by the industry, but rather is a 'pie in the sky' estimate of its maximal valuation under the most generous assumptions. Please see Table 4 above for more details.

Table 9: *Key assumptions made to value the provisioning service 'Mineral substances used for material purposes' in the deep sea (Source: Planet Tracker).*

Key indicator	Value and unit	Source / Comment
Nodule revenue	USD 461 per dry tonne	Estimate based on The Metals Company's NORI-D data and spot metal prices
Total area mined	1,425,000 km^2	Assumes all ISA concessions are mined
Royalties to government	USD 33 per dry tonne	Assumption used by The Metals Company
Free cash-flow as a % of revenue	2.7%	Based on calculations shown in Table 4

To value '**Wild animals used for nutritional purposes**', the value of the total catch of seafood species that are not large pelagic fish like tunas, sharks and marlins in the Pacific Eastern Central was used – see Table 10. This significantly overestimates the reality since not all species are deep-water species, and since the Pacific Eastern Central is about thirty times larger than the area potentially mined.[57] An estimated free cash flow margin was then used to compute a DCF-based valuation. The resulting estimated value was USD 1.3 billion.

Table 10: *Key assumptions made to value the provisioning service 'Wild animals used for nutritional purposes' in the deep sea (Source: Planet Tracker).*

Key indicator	Value and unit	Source / Comment
Annual value of seafood catch (excl. tuna, sharks, mackerels, sailfish and marlin) in the high seas of the Pacific Eastern Central	USD 12 million	Source: SeaAroundUs[58] This includes many other species that are not deep sea species and is therefore an overestimate both in terms of geographical area and in terms of species
Fishing revenue as a % of total wild catch value chain revenue	20%	This is to capture the value of fishing these species for the processing, wholesale, retail and food service industries
Long-term growth in catches	0%	Planet Tracker, based on FAO
Free cash flow to revenue	10%	Chosen high to maximise estimated value
Discount rate	5%	Chosen low to maximise estimated value

To value '**Medicinal, biochemical and genetic resources**', the annual value of the marine bioprospecting market was used to calculate an estimated free cash flow per km^2 in abyssal plains, assumed to grow by 3% a year and discounted at 5%. The resulting estimated value was USD 5.6 billion – see Table 11.

***Table 11:** Key assumptions made to value the provisioning service 'Medicinal, biochemical and genetic resources' in the deep sea (Source: Planet Tracker).*

Key indicator	Value and unit	Source / Comment
Annual value of the marine bioprospecting market...	USD 6.4 billion	Source: Coherent Market Insights[59]
...of which in abyssal plains	USD 750/km^2	Assuming that the potential per km^2 in abyssal plains is ten times higher than the current overall marine bioprospecting market
Free cash flow margin	10%	Chosen high to maximise estimated value
Long-term growth in free cash flow	3%	Source: Planet Tracker
Discount rate	5%	Chosen low to maximise estimated value

Estimating a minimal value for other ecosystem services

To value '**Regulation of chemical composition of atmosphere and oceans; atmospheric composition and conditions**', the annual amount of carbon sequestered in the Clarion-Clipperton Zone was used – see Table 12. The resulting estimated value was USD 289 million. This is a low amount given that the rate of carbon sequestration in this region is low compared to the global average (see 'The Climate Myth of Deep Sea Mining').[60]

***Table 12:** Key assumptions made to value the provisioning service 'Regulation of chemical composition of atmosphere and oceans' (Source: Planet Tracker).*

Key indicator	Value and unit	Source / Comment
Carbon buried in the Clarion-Clipperton Zone	0.01387 tonnes per km^2 per year	Yu (2023)[61]
Social cost of CO_2	USD190 per tonne	Based on US EPA[62]
Discount rate	5%	In line with other discount rates used to value other ecosystem services in this report

To value '**Mediation of wastes or toxic substances of anthropogenic origin by living process**', we chose to value the filtering capacity provided by just one species of sponge (*Plenaster craigi*) which is commonly encrusting polymetallic nodules in the Clarion-Clipperton Zone,[63] by calculating the cost of a human-engineered alternative – see Table 13.

Once in the environment the ultimate fate of many non-buoyant wastes is deposition to the ocean sediments. The service provided by deep sea sponges to humans might not be obvious at first, but due to the dynamic nature of the deep sea it is inevitable that eventually many persistent wastes will be re-circulated back into the environment and become "new" sources of waste.[64]

Choosing only one species ensures that our calculated value provides a conservative estimate of this ecosystem service. The resulting estimated value was USD 396 million.

Table 13: *Key assumptions made to value the provisioning service 'Mediation of wastes or toxic substances of anthropogenic origin by living process' (Source: Planet Tracker).*

Key indicator	Value and unit	Source / Comment
Estimated biomass of Plenaster craigi	3.8 kg/km^2	Assuming 15 individuals per m^2, an average diameter of 10mm and 2mm thickness[65]
Filtering capacity per sponge biomass	243 litres per kg per day	Assumed to be similar to deep-sea sponge grounds of the high seas in the North Atlantic[66]
Capital cost of human-engineered filtering capacity	USD 0.30 per litre per day	This includes only capex, not operating costs[67]

To value '**Intellectual and representative interactions with natural environment'**, the amount of research commissioned by just one organisation ("over USD 100 million" by The Metals Company)[68] was used to calculate a minimal estimate of the value of research per km^2 in abyssal plains with nodules. The estimated total for the abyssal plains in areas beyond national jurisdictions at risk of being mined is USD 953 million.

Valuing '**Spiritual, symbolic and other interactions with natural environment**' is probably the most challenging part. Using a monetary-based valuation for this 'service' is inappropriate, and one could argue that the spiritual value in particular could be deemed infinite. However, since the goal of this exercise is to assign a minimum valuation for each ecosystem service, the sum of three valuations was used:

i. The cumulative value of the *deep sea in movies*, based on the estimated total profit made on deep-sea representations in a series of seven movies (assuming a 20% EBITDA margin on average, and only accounting for the estimated proportion of the movie spent about the deep sea). The total was then divided to compute an estimated EBITDA of deep sea movies per km^2 and apportioned to abyssal plains where deep sea mining could occur only. The sub-total is USD 0.21 million, which provides a minimum valuation using a cultural angle (since it excludes e.g. books and music).

ii. The minimum value that the citizens of the 24 countries that oppose deep sea mining attribute to the deep sea (as of January 2024),[69] based on the (low) net present value of the deep-sea mining related *royalties that they are willing to forego* (USD 97,800).[70] The sub-total is USD 2.35 million and provides an estimated minimum valuation using a forgone earnings approach (since it was only based on a limited number of countries).

iii. The economic value of the estimated time spent by citizens of Pacific Islands on *deep-sea related spiritual activities* during their adult lifetime, where the value of time was converted in USD using GDP/capita and the estimated time per day spent on deep-sea related spiritual activities was estimated to average 14 min (where 'spiritual' refers to spiritual welfare as opposed to only including religion).

The sub-total is USD 3,315 million and provides an estimated minimum valuation since within Pacific Islands only Palau, Fiji, Solomon Islands, Tuvalu, Micronesia, Hawai'i, Vanuatu and Samoa were included, the countries/states that Planet Tracker considers to be against deep sea mining.

To value '**Biologically mediated habitat**', the cost of restoring abyssal plains post mining of polymetallic nodules using artificial clay-based nodules was used (USD 5.3 million per km^2).[71]

The resulting estimated value was USD 7.551 trillion, a very high amount given the very high cost of restoration and low probability of restoration success. However, this is still a minimum valuation for this service since restoration attempts would only drive a partial recovery in the ecosystem service; and are at a high risk of failure (see 'The Sky High Cost of Deep Sea Mining'), so the real value of this habitat is higher than its replacement cost.

'Biologically mediated habitat' is a supporting service, meaning that it contributes to the provision of other ecosystem services, such as for instance 'Medicinal, biochemical and genetic resources', 'Wild animals for nutritional purposes', or 'Pest and disease control'. To avoid double-counting, the estimated value of these services was removed from the USD 7.551 trillion estimate derived above; the final estimate is USD 7.544 trillion.

The ecosystem service '**Pest and disease control**' was not valued since:

- the potential for benthic trophic assemblages[k] to provide this service is not researched enough yet
- this service stems from the one called 'Biologically mediated habitat' (we therefore avoid double-counting).

For the same reason, and also given the low level of knowledge about many of the processes that support them, the supporting ecosystem services '**Nutrient cycling**', '**Chemosynthetic primary production**' and '**Secondary production**' were not valued. One thing that is clear is that microbial activity is key for the provision of these services, but the level of knowledge about such activity is low and it is at risk from different threats including deep sea mining.[73]

k A taxonomically related group of species populations that occur together in, on, or attached to the seafloor

APPENDIX 3:

QUANTIFYING VALUE CREATION AND DESTRUCTION

According to financial theories, for a company to create financial value, it needs to grow and beat its cost of capital. To create long-term value, it needs to consistently beat this cost of capital.[74]

One simple way to formalise this view mathematically is the value driver formula:[75]

$$V = \frac{(1-T)\ EBIT\ (1-\frac{g}{ROIC})}{WACC-g}$$

where V is the value of a company, T is the tax rate, g is the long-term growth rate, EBIT stands for Earnings Before Interest and Tax,[l] ROIC stands for Return On Invested Capital,[m] and WACC stands for Weighted Average Cost of Capital[n].[76]

Since:

$$ROIC = \frac{(1-T)\ EBIT}{IC}$$

(where IC stands for Invested Capital),[o] the value driver formula above becomes:

$$V = \frac{IC\ (ROIC-g)}{WACC-g}$$

Simplifying this further by calling R the long-term return on invested capital in excess of long-term growth rate ($R=ROIC-g$), and r the weighted average cost of capital in excess of long-term growth ($r=WACC-g$), the formula becomes:

$$V = IC\ \frac{R}{r}$$

For financial value to be created by the existence of the deep sea mining industry, the sum of the change in value in all companies involved in, dependent on or affected by the industry needs to be positive.

l A measure of a firm's profit that includes all incomes and expenses (operating and non-operating) except interest expenses and income tax expenses

m A metric to assess a company's efficiency in allocating capital to profitable investments

n A company's average after-tax cost of capital from all sources

o The combined value of equity and debt capital raised by a firm, inclusive of capital lease

Assuming that there are n companies involved in, dependent on or affected by deep sea mining, this condition can be formalised as:

$$\sum_{i=1}^{n} \Delta V_i > 0$$

where ΔV_i represents the change in value for each company i. This can be expressed as (Formula A):

$$\sum_{i=1}^{n} \Delta(IC_i)\, \Delta\left(\frac{R_i}{r_i}\right) > 0$$

Splitting the n companies between those involved in and dependent on deep sea mining (a total of m companies) and those negatively affected by it (a total of d companies), Formula A becomes:

$$\sum_{i=1}^{m} \Delta(IC_i)\, \Delta\left(\frac{R_i}{r_i}\right) + \sum_{k=1}^{d} \Delta(IC_k)\, \Delta\left(\frac{R_k}{r_k}\right) > 0$$

Essentially, deep sea mining would create value if the change in the invested capital, returns and cost of capital of the different companies it will affect positively exceeds that of the companies it will affect negatively.

This is what was calculated for the different industries affected by deep sea mining.

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ABOUT PLANET TRACKER

Planet Tracker is an award-winning non-profit financial think tank aligning capital markets with planetary boundaries. Created with the vision of a financial system that is fully aligned with a net-zero, resilient, nature positive and just economy well before 2050, Planet Tracker generates break-through analytics that reveal both the role of capital markets in the degradation of our ecosystem and show the opportunities of transitioning to a zero-carbon, nature positive economy.

ABOUT THE DEEP SIX PROJECT

This report is the third in a series of six (the ‘Deep Six Project’), focused on deep sea mining. The goals of the Deep Six project are to 1) assess the potential environmental impact of deep-sea mining, including in relation to equivalent land-based mining and 2) for investors to apply six different learnings from the risks and opportunities of deep sea mining to other industries that impact marine ecosystems, focusing on: climate change vs. nature considerations, resource-based valuations vs. natural capital value, restoration potential, circularity, sovereign risk and stranded assets risk.

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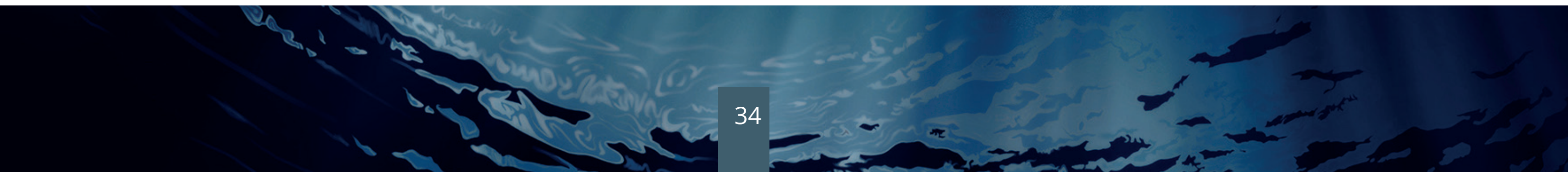

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