22 Years Later: Evaluating Glover & Smith's 2003 Predictions of the 2025 Deep-Sea Ecosystem

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Abstract

Earth's deep-sea ecosystem remains one of the least explored and understood ecosystems on the planet. Human interest in the resources available in the deep-sea must be balanced with potential harm to the deep-sea ecosystem. Accurately predicting the effects of human activites on the deep-sea floor can help guide policies and actions today. This research evaluates prior predictions of human impact on the deep-sea floor ecosystem to aid in more accurate predictions in the future. In 2003, Glover & Smith published the frequently cited "The deep-sea floor ecosystem: current status and prospects of anthropogenic change by the year 2025" that made 15 predictions about the state of the deep-sea in 2025. In this paper we now examine their predictions for 2025 and assess the accuracy of each prediction. We classify each of the predictions as either accurate, partially accurate, or inaccurate. Using current studies and evaluations of the deep-sea, alongside news sources detailing deep-sea progress, we compare the state of the ocean today with Glover & Smith's predictions to test their accuracy. 7 of their predictions proved to be accurate, 4 were partially accurate, and 4 more were inaccurate. We identified common themes of both accurate and inaccurate predictions to guide future predictions. Predictions regarding technological development were largely inaccurate while predictions concerning sources of damage to ecosystems were largely accurate.

1 Introduction

The ability to forecast future ecological and industrial developments in the deep-sea is critical for shaping policy decisions and conservation processes. As deep-sea data is comparatively sparse, and there are limited points of comparison, making such predictions can be challenging. It is important to critically assess previous predictions so that future predictions do not contain similar errors when prior predictions proved inaccurate. Glover & Smith's influential 2003 article made 15 predictions about the state of human impacts in the deep-sea by 2025. Glover and Smith categorized their predictions into 5 broader categories: 1) deep-sea waste disposal, 2) deep-sea fisheries, 3) deep-sea oil and gas drilling, 4) deep-sea mineral and methane fuel extraction, and 5) climate change impacts on the deep sea. Now in 2025, it is possible to review and reflect on their predictions. Understanding which predictions were accurate, and which ones were not, yields valuable information about the drivers of change in deep-sea ecosystems and the limitations of long range forecasting in a data-poor environment. Here we assessed the accuracy of Glover & Smith's predictions by comparing them to peer-reviewed literature, policy documents, industry reports, and news reports that reveal the current state of the deep-sea.

2 Evaluation

Glover & Smith's article contains information and predictions regarding the deep-sea in 2025, and they then summarize their predictions with 15 succinct bullet points. We use these 15 points to evaluate their predictions. To find current references on the deep-sea to compare to Glover &

Smith's article we conducted a literature search dated subsequent to 2003. Our literature search was conducted using Web of Science, and Google Scholar. We used search terms that included *deep-sea mining*, *ultra-deep drilling*, *deep-sea fisheries 2025*, *AMOC slowdown*, *methane hydrate extraction*, and *CO2 sequestration deep ocean*. Policy and industry reports were primarily sourced from IMO, ISA, FAO, OSPAR, BOEM, and national energy agencies. As the deep-sea is an environment with the majority of human innovation relevant to the predictions coming in the 2020's, peer reviewed literature was not sufficient to get up to date information on new developments. We also included industry reports and policy documents that revealed new progress to broaden our assessment and understanding of the current state of the deep sea. To reduce subjectivity, explicit inclusion and exclusion criteria were defined. Peer-reviewed articles, policy documents, and industry reports published between 2003 and 2025 were included if they provided quantitative or regulatory updates directly relevant to a prediction. News articles were included only when reporting first-hand information about technological milestones that was not yet published in academic literature. Approximately 60% of our data was derived from peer-reviewed scientific literature. 30% came from policy and industry reports. 10% of the citations are from news sources that detailed developments that occurred within the past few years. To determine the accuracy of each prediction, we evaluated if it was fully recognized in the current state of the deep-sea. If a component of each prediction came true then it factually occurred with consistency either regionally or globally. If each component of a prediction matched the current state of the deep-sea, it was deemed accurate. A prediction was evaluated as partially accurate if only some of its facets were accurate. We also evaluated predictions as partially accurate if it is only applicable to a few areas of the deep sea. A prediction that hadn't proved true in any facet was designated as inaccurate. All evaluations were performed by a single assessor (the author). As such, inter-rater reliability could not be calculated. To mitigate bias, all classifications were checked against multiple independent sources wherever possible.

2.1 Deep-Sea Waste in 2025

1. Ships will continue to sink, but will not pose any greater environmental hazard than today.

Assessment: Accurate

Ships have continued to sink from 2003 to 2025. Over 340 ships have sunk in the past decade alone, and there has been a downward trend in the number of ships sinking yearly (Allianz, 2025). Bulk carriers, ships that frequently cross the deep-sea and have the potential to greatly affect the deep-sea due to their contents, sank 71 times between 2005 and 2014 but only sank 20 times between 2015 and 2024 (Intercargo, 2016, 2025). Additionally, sunken ships do not pose any greater environmental hazard than in 2003. The introduction of doubled hulls to oil tankers, which are mandated in US waters, reduced oil spills by 20-62% on average (Yip et al., 2011). Sinking ships do continue to sink and pose less environmental hazard than in 2003.

2. Sewage sludge and dredge spoil disposal will have begun in the deep sea, with significant localized impacts.

Assessment: Partially Accurate

Sewage sludge disposal does not occur at the deep sea, but dredge spoils are disposed of at deep sea. At the 2022 London Convention, the International Maritime Organization (IMO) removed sewage sludge from the list of permitted waste for dumping. The IMO cited that sewage dumping had been declining for the past decades and that many regional and domestic policies banned sewage sludge dumping. Additionally, there exist many safer alternatives to removing sewage waste than dumping it at sea (IMO, 2022). While sewage sludge dumping was in practice before its ban, it did have significant localized impacts, causing measurable changes to benthic ecology near the dumpsite (US Department of Commerce, 2014). Dredge spoil dumping does occur at sea, but it is often focused around established sites (OSPAR, 2017). Deep-sea disposal of dredge spoils is preferred to other methods of disposal since it has the least environmental impact (Svensson et al., 2022). The sites of dredge spoil dumping do often see some localized significant environmental impacts including metal pollution, faunal smothering, and fluxes in turbidity (Stronkhorst et al., 2003; Chen et al., 2018; Palanques et al., 2022). The effects are mostly localized and don't affect areas beyond the dump site (Blake et al., 2009).

3. Large quantities of CO_2 (up to 1 Gt C yr1) will be sequestered in the deep ocean; major environmental effects will initially be localized to within 10–100 km of injection points, but traceable far-field effects will begin to be observed.

Assessment: Inaccurate

We could find no data to suggest that large quantities of CO_2 are being sequestered in 2025. The technology remains experimental and simulation heavy (Aman et al., 2025). CO_2 Sequestration mainly does not occur because of the dangers it poses to deep-sea ecosystems. Sequestered CO_2 increases the pH of surrounding waters, harming organisms, especially those with calcium carbonate skeletons. Many deepwater species cannot adapt to instant drastic changes in pH so are extremely sensitive. Ocean acidification leads to a high mortality rate of meiofauna and can jeopardize entire food webs (Barry et al., 2004).

2.2 Deep-Sea Fisheries in 2025

4. All existing (2003) deep-sea fisheries will be commercially extinct.

Assessment: Inaccurate

Not all 2003 deep-sea fisheries are commercially extinct. While many are commercially extinct, some fisheries from 2003 still exist today such as New Zealand's Orange Roughy fishery which is still active today (Moor et al., 2025). The fishery is still alive due to auditing and regulation that prevent overfishing. The species saw a rapid decline towards the end of the 20th century but has since then seen a recovery in population (MSC, 2016). This regulation of fisheries extends internationally through Regional Fisheries Management Organizations (RMFOs) which partially successfully have helped their survival. The persistence of several deep-sea fisheries can be attributed to strengthened governance frameworks introduced by FAO guidelines (e.g., the International Guidelines for the Management of Deep-Sea Fisheries in the High Seas) and by RMFOs, which implemented catch limits, observer programs, and spatial closures. (Tuohy et al., n.d.). More local economic factors have also played a role with declining market demand and the increased access to aquaculture alternatives reducing the pressures on some fisheries. These interacting policy and economic forces reveal how a subset of deep-sea fisheries remained viable, enduring through widespread collapses.

5. New fisheries will have been discovered and 'mined', but each fishery will have 20–30 year lifespans or less.

Assessment: Accurate

Most deep-sea fisheries often see a boom-bust cycle in which they are rapidly farmed over a short period of time until the area is commercially depleted. Due to this fact, it is difficult for deep-sea fisheries to be commercially active for more than 20-30 years. Deep-sea fisheries suffer from the reproductive habits of many deep-sea fish which often produce a small number of offspring. Additionally, their mating can be erratic and episodic, leading to slow recovery (Maribus gGmbH, 2013).

6. Significant environmental impacts will have occurred on seamounts and deep-water coral beds; extinctions may have been prevented through the setting up of marine protected areas.

Assessment: Accurate

There have been significant and irreversible impacts on seamounts and deep-water coral beds. Approximately 70% of fishing ships deploy demersal trawling nets that can reach depths up to 2000m (Maribus gGmbH, 2013). Trawling causes major irreversible damage to deep-sea ecosystems, and there are no legally binding regulations on them currently (Maribus gGmbH, 2013; Goode et al., 2020). In reef habitats, heavy fishing results in 90% of the reef becoming bare rock, and heavy fishing on seamounts can lead to 97% of coral being destroyed (Koslow and Glowlett-Holmes, 1998; Clark and O'Driscoll, 2003). Marine protected areas (MPAs) have been established to protect species in pristine areas from being destroyed (Goode et al., 2020). Converting previously fished areas into MPAs does not greatly affect the ecosystem. There is little regrowth or recolonization of corals, demonstrating the low-resilience and slow recovery time of deep-sea communities (Huvenne et al., 2016).

2.3 Deep-Sea Oil and Gas Drilling in 2025

7. Deep (500 m) drilling will be commonplace, and may dominate the offshore market by 2025. Ultra-deep (1000 m) drilling rigs will be coming on line at depths up to 4000 m.

Assessment: Accurate

To evaluate Glover & Smith's prediction, we must quantify the term "commonplace". The authors decide that a greater 10% market share in offshore drilling is commonplace. Deep drilling is now commonplace, and ultra-deep drilling rigs have come on line at depths up to 4000m. There is limited information on the exact number of oil rigs globally; the majority of reports are regional (e.g. Gulf of Mexico or Brazil). Data differs between regions because of differences in size of the continental shelf. Additionally, the definition of "deep" differs between studies. To assess the prevalence of deep-drilling within the market we only considered reports that consider "deep" between 400-600m of water depth. While it is difficult to exactly judge how much deep-water drilling comprises the market, most sources place the figure between 20% and 55%, establishing deep drilling as commonplace (Rystad, 2024; Precedence, 2025; Research Nester, 2025). Ultra-deep drilling rigs are now implemented. By 2006 there were already more than 500 ultra-deep drilling rigs globally, and in the United States alone there are 38 active platforms at least 1000 meters deep (Shaughnessy et al., 2007; BOEM, 2025). Glover & Smith were very accurate when predicting that ultra-deep water drilling will not pass 4000m. The deepest drill currently being constructed is the Komodo-1 drill in the Colombia basin which will reach a depth of 3950m (Carvajal-Arenas et al., 2024).

8. Significant, but localized, impacts will be occurring at the deep-sea floor surrounding deep oil drilling structures, but oil companies will be mandated to minimize the impacts and acquire baseline survey data before commencing drilling operations.

Assessment: Partially accurate

The effects of deepwater drilling are localized, rarely spreading further than 2 km from the rigs. Within 100 m of the drilling sees the greatest impacts. This damage can come from anchors which rip up biogenic habitats on the ocean floor causing scars as they are dragged along the seabed (Hall–Spencer et al., 2002; Watling, 2014). Direct impacts of infrastructure installation such as sediment resuspension and burial also occur within a 100 m radius. Within 200-300 m sees the most common ecological impacts on the population and community levels (Cordes et al., 2016). Organisms from a few 100 m to 1km from the drilling are susceptible to sound induced behavior disruption (Southall et al., 2008). Discharges of water-based and low-toxicity oil-based drilling muds and produced water can extend over 2 km from the source, and evidence suggests that benthic organisms within 2 km of the source will be affected by produced water (Bakke et al., 2013; Cordes et al., 2016). There are mandates around the world for oil companies to minimize impacts, but varied regulations exist in different maritime jurisdictions and for areas beyond national jurisdiction (Mazor et al., 2014; Katsanevakis et al., 2015). Some mandates do not require acquisition of survey data (Cordes et al., 2016). The United Nations Convention on the Law of the Sea allows for individual countries to decide the regulations within their exclusive economic zone (EEZ), and there has been no significant effort to standardize EEZ regulations across countries (Cordes et al., 2016). Many of the world's leading nations in offshore drilling, including the United States, the UK, and Norway, all require risk assessments from organizations prior to starting drilling (Larsson and Purser, 2011). Not every oil company is required to acquire survey baseline data, though many of them do (Cordes et al., 2016).

9. Large-scale accidents will be an occasional hazard to marine life, but are unlikely to cause more than temporary ecological incidents.

Assessment: Partially Accurate

Large scale accidents do occasionally happen, but the effects are much longer than temporary incidents, especially for larger accidents such as the Deepwater Horizon oil spill. While small oil spills are unlikely to have persistent effects, large scale accidents can have long-term ecosystem perturbations. The oil affects all ranges of organisms including benthic fauna, deep-water corals, coastal wetlands, marine mammals, and seabirds. It is virtually impossible to clean up all of the oil lost from drilling accidents, and it can last for decades once spilled (Barron et al., 2020). Additionally, the rig accidents expel tons of harmful gases that can never be recaptured (Hu, 2025). In oil spread to saltmarshes, contaminated sediments lead to extreme death, and it can take up to decades for meiofauna to recover. In heavily oiled-areas, oil-induced erosion can cause permanent regional declines in abundance and diversity of meiofauna (Pant et al., 2025). Deep-water oil spills lead to immediate death of many deep-sea species that are less resilient and take longer to reproduce, often taking years to come close to pre-accident abundance and diversity. Most corals take multiple decades to recover after an oil spill, and some sites that are heavily affected show little evidence of possible recovery (Schwing et al., 2020). In benthic species, polycyclic aromatic hydrocarbon levels can remain elevated for up to 6+ years (Gohlke et al., 2011). Many fish exposed to oils during drilling accidents have cardiotoxic effects that restrict fitness (Pasparakis et al., 2019). Oil spills also impact the maternal health of dolphins which has effects on their reproductive success, affecting the population in the long-term

(Murawski et al., 2021). Large-scale accidents are an occasional hazard to marine life, but the effects are not temporary and can harm ecosystems for generations.

2.4 Deep-Sea Mineral and Methane Fuel Extraction in 2025

10. The first deep-sea marine mineral extraction of gold-rich hydrothermal sulphide deposits will have proved commercially successful.

Assessment: Inaccurate

The first deep-sea mineral extractions have not proved commercially successful. Japan conducted the only large-scale extraction of hydrothermal sulfide deposits in 2017 in the Okinawa Trench. The project wasn't commercial, instead run by Japan Organization for Metals and Energy Security, a government organization. They successfully excavated around 650 kilograms of cobalt, nickel, and gold (Giseburt, 2024). The project was overall a success, but was unable to prove commercial viability. The only other project to mine deep-sea hydrothermal deposits was the Solwara 1 project. Working with the Papua New Guinea (PNG) government, the Canadian based company, Nautilus Mineral Corporation, attempted to excavate the Manus Basin. In 2011, PNG granted a 20 year mining license in the Bismarck Sea. Over the next few years, the project received criticism from many climate activists and many financial setbacks (Hutt, 2018). In 2019, due to major pushback against the project and other environmental concerns, PNG and other Melanesian countries banned deep-sea mining for 10 years in the Udaune Declaration on Climate Change (Cannon, 2023).

11. Developing countries will begin to encourage high-risk mining ventures on offshore deposits.

Assessment: Accurate

Many island nations in Oceania view deep-sea mining as a potential catalyst for development. The Cook Islands, Nauru, Tonga and Kiribati are among the region's most active proponents (Abe et al., 2025). The Clarion-Clipperton Zone in the Eastern Pacific Ocean is the region with the most activity in deep-sea mining with many nations aiming to claim parts of it. The International Seabed Authority (ISA) has granted exploration licenses to explore mining in the Clarion-Clipperton zone to 31 nations including developing countries such as Cook Islands, Nauru, Tonga, and Kiribati (Keating-Bitonti, 2025). While many developing countries support deep-sea mining, other developing nations such as Palau and Costa Rica oppose deep-sea mining ventures. Nauru is one of the main proponents, sponsoring The Metals Company. In 2021 Nauru gave a two year notice to the ISA to draft their regulations on deep-sea mining, but they failed to develop a mining code by the 2023 deadline because an agreement couldn't be reached (Alberts, 2023). Instead, the ISA promised to have rules set in place during 2025 which have not been released yet, but are currently being developed in the July 2025 ISA conference (Letra, 2025).

12. Developed countries will continue to rely on land-based mineral extraction, but will maintain strategic interests in offshore deposits.

Assessment: Accurate

Many developed nations are in the process of exploring offshore deposits in addition to relying on land-based mining. Of the 31 countries who were granted exploration licenses in the Clarion-Clipperton zone, many are developed and already have land-based mines such as France, China, Germany, and Russia (Keating-Bitonti, 2025).

13. Offshore oil industries, faced with declining oil and gas reserves, will start to extract methane hydrate at commercially viable quantities.

Assessment: Inaccurate

There have been successful methane hydrate extractions and tests done by governments, but it has not been commercially realized (Yin and Linga, 2019). In 2013 Japan became the first country to excavate methane hydrate from deep-waters, but the project was temporary and didn't extend into the commercial market (Yiallourides, 2019). The methane hydrate deposit in the South China Sea was first discovered in 2007, and recently China announced that they have successfully extracted it with 16 thousand cubic meters of gas being extracted daily (Zhengzheng, 2017; Akhmetkaliyeva, 2020). Due to its high cost, methane hydrate extraction commercialization has yet to have been achieved and is only done by larger governments (Akhmetkaliyeva, 2020).

14. The vast bulk of the bathyal and abyssal deep sea will remain untouched by mineral and methane extraction and there will be no convincing evidence of species extinctions.

Assessment: Accurate

The vast majority of the bathyal and abyssal deep sea has been untouched by mineral and methane extraction. Outside of Exclusive Economic Zones, the ISA has granted a few exploration licenses, leaving the majority of the deep-sea untouched. Over 80% of the ocean still remains unobserved (McVeigh, 2021). There is no convincing evidence of species extinctions in the deep sea. There are very few studies that investigate the impacts of mining activities in the deep-sea, so there is little evidence of extinctions or how large the other environmental impacts are (Cuvelier et al., 2018). Even in the Clarion-Clipperton Zone, the most studied region of mining activity, around 90% of species are estimated to be undescribed, with thousands undiscovered (Jackson, 2023). We lack the technology to accurately monitor the species of the deep-sea, and the new technology isn't being created fast enough (Thomas et al., 2022). If there were species extinctions, there would not be convincing evidence since the majority of species are not tracked. Around seamounts there has been a little tracking of species, but there have not been any known extinctions yet, though some species have become endangered (McVeigh, 2021).

2.5 Climate Change Impacts on the Deep-Sea in 2025

> 15. Generally speaking, it will be too early for major effects of climate change (such as changes in thermohaline circulation) to be felt in the deep ocean, although subtle shifts in benthic standing crop and biogeochemical recycling in sea floor sediments may be detectable

Assessment: Partially Accurate

Data show that it is not too early to notice major effects due to climate change. Major changes have been felt in the deep-ocean, many of them due to global warming. The abyssal ocean has warmed up significantly and contributes a large amount to global heat content increases (Johnson and Purkey, 2024). Thermohaline circulation has been affected by climate change too. The Atlantic Meridional Ocean Circulation (AMOC) has slowed down recently. Anthropogenic warming is the most likely cause of the slowdown, and climate change models that simulate a weakened AMOC match real world data (Baker et al., 2025; Li and Liu, 2025). High resolution models reveal that the effects of the AMOC slowdown matches surface level observational data, including reductions in ice coverage and changes to precipitation patterns around the Atlantic. The AMOC slowdown reduces northward heat transport by more than half and suppresses deep-water formation in areas like the Labrador and Irminger basins, which has resulted in widespread declines in ocean ventilation (Ma et al., 2024). Several other model studies demonstrate that the weakened AMOC leads to basin-scale deoxygenation, deep-ocean warming, and altered nutrient and carbon transport pathways (Gérard and Crucifix, 2024). The decline in overturning reduces the renewal of deep waters, lowering oxygen supply to abyssal ecosystems, causing widespread deoxygenation. The ventilation slowdown traps heat in the deep-sea, producing long-term warming anomalies. The weakened AMOC disrupts nutrient transport, altering particulate organic carbon remineralization patterns, which in turn alters general carbon flux and reduces large-scale carbon export to the deep seafloor (Jackson et al., 2015). In effect, shifts in benthic standing crop and biogeochemical recycling have been detectable. There has been a decrease in meiofaunal biomass which indicates long-term shifts in benthic ecosystems. This change in carbon flux alters the carbon cycle, spreading the AMOC's effects across the ocean through food webs. Declines in carbon flux export reduce food availability to benthic consumers, triggering shifts in biomass structure, trophic composition, and nutrient regeneration rates. (Zhou et al., 2023). There have been observable significant changes to benthic populations which are correlated with changes to particulate organic carbon flux (Ruhl and Smith, 2004; Ruhl, 2007). There has also been a northward shift of species linked to rising temperatures and retreating ice cover (Goethel et al., 2019). Recent high-resolution climate simulations reproduced observed variability in the AMOC, including early-2000s fluctuations and sea-ice loss signals, giving credence to other models' projections (Karami et al., 2025). A 2024 inter-comparison study found that several climate models have replicated observed AMOC components (overturning strength, deep-water formation, and heat transport) over the past few decades (Bryden et al., 2024). However, substantial uncertainties remain. Some observational analyses found no clear downward trend, and recent direct measurements suggest a stabilization of AMOC strength since the early 2010s (Parker and Ollier, 2016). This ambiguity underscores the caution needed to link AMOC weakening to deep-sea ecological change. Ultimately, there have been noticeable major effects due to climate change in the deep ocean and shifts in benthic standing crop and biogeochemical recycling have been detected, demonstrating that major climate-driven changes in the deep-sea are already underway.

Prediction	**Assessment**
1. Ships will continue to sink with no greater environmental risk.	Accurate
2. Sewage sludge and dredge spoil disposal will occur in the deep sea with significant localized impacts.	Partially accurate
3. Large quantities of CO_2 will be sequestered and have localized major environmental effects.	Inaccurate
4. All existing (2003) deep-sea fisheries will be commercially extinct.	Inaccurate
5. New fisheries will have been discovered and 'mined', but each fishery will have 20–30 year lifespans or less.	Accurate
6. Significant environmental impacts will have occurred on seamounts and deep-water coral beds; extinctions may have been prevented through the setting up of marine protected areas.	Accurate
7. Deep drilling will be commonplace and ultra-deep drilling rigs will be coming on line.	Accurate
8. Significant localized impacts will be occurring at the deep-sea floor surrounding deep oil drilling structures, but oil companies will be mandated to minimize the impacts and acquire baseline data.	Partially accurate
9. Large-scale accidents will be an occasional hazard to marine life,	Partially accurate

but are unlikely to cause more than temporary ecological incidents.	
10. The first deep-sea marine mineral extraction will have proved commercially successful.	Inaccurate
11. Developing countries will encourage high-risk mining ventures.	Accurate
12. Developed countries will rely on land-based mineral extraction, but will maintain strategic interests in offshore deposits.	Accurate
13. Offshore oil industries will start to extract methane hydrate.	Inaccurate
14. The vast bulk of the bathyal and abyssal deep sea will remain untouched and there will be no convincing evidence of species extinctions.	Accurate
15. Generally speaking, it will be too early for major effects of climate change to be felt in the deep ocean, although subtle shifts in benthic standing crop and biogeochemical recycling in sea floor sediments may be detectable.	Partially accurate

3 Discussion and Conclusion

Glover & Smith accurately predicted 7 aspects of the deep-sea in 2025. 4 predictions were partially accurate, and 4 more predictions were inaccurate. Within the 5 broad categories described in Glover & Smith's paper (deep-sea waste disposal, deep-sea fisheries, deep-sea oil and gas drilling, deep-sea mineral and methane fuel extraction, and climate change impacts on the deep sea), there were similar levels of accuracy. Each one contained both accurate and inaccurate predictions. As assessment of past deep-sea predictions is an essential guide to improving future predictions, we should seek to unearth common themes linking either accurate and inaccurate predictions. To further assess the predictions, we created common themes in which to group predictions and analyze correlations between accuracy and types of predictions. We categorized the predictions into 4 themes: technological progress (predictions: 3, 7, 10, 13), sources of damage to ecosystems (1, 2, 8, 9, 14), effects of damage on ecosystems (4, 5, 6, 9, 15), and policy/regulatory (2, 8, 11, 12).

Prediction	Outcome	Primary Reason for Outcome	Evidence Type	Representative Sources

Ships will continue to sink with no greater environmental risk.	Accurate	Improved hull design reduced spill volumes; sinking frequency decreased.	Industry reports; accident databases	Allianz (2025); Yip et al. (2011)
Sewage sludge + dredge spoil dumping will occur at deep-sea sites with localized impacts.	Partially Accurate	Sewage dumping banned globally; dredge spoil disposal continues with localized disturbance.	Policy documents; ecological monitoring	IMO (2022); Stronkhorst et al. (2003); Chen et al. (2018)
Large quantities of CO_2 will be sequestered in the deep ocean.	Inaccurate	Technology remained experimental; high ecological risk; no commercial deployment.	Peer-reviewed experimental studies	Barry et al. (2004); Aman et al. (2025)
All (2003) deep-sea fisheries will be commercially extinct.	Inaccurate	Management interventions, rebuilding plans, reduced demand allowed some fisheries to recover.	Fisheries assessments; FAO/RFMO guidelines	MSC (2016); Moor et al. (2025)
New fisheries will be discovered and depleted within 20–30 years.	Accurate	Boom–bust exploitation cycles typical in deep-sea species with slow reproduction.	Ecological literature	Maribus (2013)
Major impacts will occur on seamounts/coral beds; MPAs may prevent extinctions.	Accurate	Extensive trawling damage; MPAs protect unfished areas but recovery is extremely slow.	Ecological surveys; conservation reports	Koslow & Gowlett-Holmes (1998); Huvenne et al. (2016)

Deep and ultra-deep drilling will be commonplace.	Accurate	Industry investment and drilling capability expanded; rigs >1000 m widespread.	Industry statistics	BOEM (2025); Rystad (2024)
Drilling impacts will be localized and baseline surveys required.	Partially Accurate	Impacts localized but mandates vary; baseline surveys not universally required.	Policy analyses; ecological studies	Cordes et al. (2016); Katsanevakis et al. (2015)
Large-scale accidents will occur but cause only temporary damage.	Partially Accurate	Accidents occur but ecological damage persists for decades, not months.	Post-spill ecological studies	Barron et al. (2020); Schwing et al. (2020)
Commercial extraction of hydrothermal mineral deposits will be successful.	Inaccurate	Pilot testing succeeded but economic + political barriers prevented commercialization.	Government reports; industry failures	Giseburt (2024); Hutt (2018)

3.1 Technological Predictions

The most striking pattern in the accuracy of various themes was the failure of predictions about technology. Of the 4 technological predictions, only drilling depth proved to be accurate. This reflects an over-optimism in technological development. These predictions may have failed because they did not accurately consider technological, economic, and regulatory barriers. Predictions 3, 10, and 13 that environmental, economic, and scientific limitations explain why the technological predictions failed. CO_2 sequestration (prediction 3) does not exist because of environmental concerns that were not anticipated in 2003. While feasibility studies of impact modeling have proved that carbon sequestration can be done efficiently under perfect conditions, governments remain concerned about environmental impacts in practice. Concerns over accidents, such as CO_2 leakages, and ocean acidification prevent the technology from being fully developed. Additionally, there remains no international legal framework, adding to the hesitancy from governments. Future integration of CO_2 sequestration is still a possibility if the technology progresses to become more viable in non-ideal conditions. Its limits highlight the possibility for ethical and policy decisions to regulate deployment even when a technology exists. Commercial marine mineral mining (prediction 10) failed due to economic reasons. More than 20 countries have called for a ban on deep-sea mining because of the large plumes of sediments produced in the process. These concerns have kept marine mining in the experimental phase. Deep-sea mineral mining has progressed with prototype vehicles and some pilot excavations in Japan, but cost overruns, unreliable robotic systems, and unresolved sediment plume management issues in these proved that it is not economically feasible. The unanticipated gap between technological viability and economic feasibility was too large for the industry to become successful. Methane hydrate extraction (prediction 13) floundered and remains in the pilot-project phase. Only government-funded research has proven successful at extracting methane hydrate, and the technology has not reached the private sector. Methane Hydrate extraction has been limited scientifically and environmentally. Gas hydrate extraction is associated with a huge potential hazard because it bears a threat of an uncontrolled escape of methane. This has limited the technology to smaller implementations. The science has not progressed far enough to prove viability for commercial integration. Lastly, Glover & Smith's prediction on deep-sea drilling depths (prediction 7) was accurate because it extrapolated from 2003 data. Instead of predicting innovation and utilization of new technologies, it instead predicted continued progress in drilling technology which was already being commercially used in 2003. While many of these predictions proved to be overambitious, the future potential of the technologies remains relevant as they continue to be developed. Until engineering advances resolve these limitations, these technologies remain scientifically promising but operationally immature.

3.2 Sources of Damage Predictions

Predictions concerning the sources of damage to deep-sea ecosystems were all accurate except for the prediction that sewage sludge would be dumped at sea (prediction 2). All of the sources of damage that Glover & Smith predicted were already damaging ecosystems in 2003. These predictions succeeded by recognizing that humans would continue their activities that harmed the deep-sea. Unlike new technologies which may face sudden regulatory changes and economic barriers, current industrial activities may be more resistant to change. Instead of predicting change in the deep-sea environment, the predictions about sources of damage anticipated a lack of change and were accurate. However, our analysis does reveal important nuances. The prediction that sewage sludge would be disposed of at deep-sea, a seemingly predictable trend, was inaccurate due to policy making at the 2022 London Convention. This highlights how policy can alter otherwise predictable and stable trajectories.

3.3 Effects of Damage to Ecosystems Predictions

The accuracy of predictions about ecosystem responses to human activities were mixed. The predictions about the declines of fisheries (predictions 5 and 6) succeeded because they were based on decades of fishing records and the known vulnerability of deep-sea ecosystems. The fisheries extinction prediction (prediction 4) presents an interesting case where the prediction would have been accurate if not for human intervention. Glover & Smith specifically mentioned the Orange Roughy in their article as a species that was rapidly decreasing in catch size. They acknowledged that "current management practices" were leading to its extinction but didn't predict that the management process would change (Glover & Smith, 2003). Organizations such as the Food and Agriculture organization and RMFOs implemented quota systems, catch schemes, and closures to regulate the population levels. Local pressures like decreasing market demands and the rising prevalence of aquaculture has also contributed to the survival of some fisheries. This prediction would have been accurate if humans did not intervene and protect fisheries. The predictions about the effects of drilling accidents and climate change (predictions 9 and 15) on deep-sea ecosystems underestimated the magnitude of their damage. Prediction 15 most likely failed due to the unanticipated rapid acceleration of climate change in the past two decades.

3.4 Policy/Regulatory Predictions

The accuracy of predictions about ecosystem responses to human activities were mixed. Glover & Smith's simpler predictions that countries will be interested in offshore mining ventures (predictions 11 and 12) were both accurate. They most likely were accurate because they merely predicted an expressed interest instead of systemic changes in the deep-sea. The prediction that oil companies would be mandated to acquire baseline survey data (prediction 8) was partially accurate since it does not apply to every company around the world. This reflects that policy decisions not made by an international organization will instead fall to regional managements that differ between locations. We cannot expect regulations to be the same around the world unless it is made by a global governing body. The prediction about dumping sewage sludge at deep-sea (prediction 2) proved to be inaccurate because of the IMO, a global governing body. Sewage dumping was banned to protect the deep-sea, reflecting that on top of leading innovation, policy making will also reverse old practices. Governance of the deep sea varies substantially across regions. For example, The EU employs precautionary strategies, mandating environmental impact assessments and adopting moratoria positions at the ISA. The United States, by contrast, regulates activities primarily within its EEZ under BOEM, while lacking a federal position on deep-sea mining due to non-ratification of UNCLOS. China holds an explorationist point of view, holding many contracts and permitting most experimentation. Lastly, many Pacific islands have the most pronounced gaps between nations as some favor expansion with the goal of economic growth while others favor more protectionist measures. These political divergences create regulatory gaps, especially in Areas Beyond National Jurisdiction where the ISA maintains limited jurisdiction. UNCLOS provides broad environmental roles, but it lacks the operational standards, leaving gaps in enforcement. While, The London Convention restricts several dumping practices, it does not directly regulate seabed mining, creating friction with ISA processes. In Areas Beyond National Jurisdiction, no binding mechanism currently exists to ensure cumulative impact assessments or protect vulnerable ecosystems, highlighting critical governance gaps. Conflicts between the London Convention, UNCLOS, and emerging biodiversity treaties highlight unresolved governance failures, revealing how policy practices can inhibit innovation just as easily as providing a framework for it.

3.5 Study Limitations

Our analysis faced several limitations. The sparse data environment of the deep-sea is an inherent challenge when determining accuracy. Some assumptions might be premature as more data is collected about the deep sea. We were forced to proxy indicators to evaluate some predictions because long-term monitoring datasets are scarce. The inclusion of non-academic sources, such as reports, introduces potential bias and variability in reliability, though they were necessary for tracking rapidly evolving technologies and policies. Specifically, topics regarding drilling and mining at deep-sea have limited data-availability because the sector is highly privatized and it is rapidly evolving. Critical gaps arose in finding exact data on the numbers of drilling rigs at certain depths proved difficult as many companies are hesitant to release their data. Similarly, finding context for the failure of technological advancements like mining were difficult for the same reason. In such cases, news sources and industry reports needed to be relied on instead of academic literature. Additionally, the ternary evaluation of predictions may oversimplify complex predictions and limit directionality of the interpretations. There was classification uncertainty where some predictions were more complex and difficult to fully evaluate. The lack of inter-rater reliability could have potentially caused subjective judgment to have influenced results when dealing evaluating complex predictions within the ternary framework Finally, the deep sea remains highly under-sampled; in many cases, absence of evidence (e.g., species extinctions) cannot be interpreted as evidence of absence. Several predictions, particularly those addressing species extinction and CO_2 sequestration, suffer from the uncertainty of not knowing whether empirical datasets are either absent or geographically sparse. Consequently, some “inaccurate” classifications may reflect insufficient evidence rather than true predictive failure. Future studies could enhance this analysis by developing more nuanced evaluatory metrics that account for partial success.

3.6 Conclusion

This current evaluation of Glover & Smith’s (2003) predictions about the 2025 deep-sea ecosystem reveals insights on the ability of long-term forecasting in a data-poor environment. Of the 15 predictions made, 7 were accurate, 4 were inaccurate, and 4 more were partially accurate. Overall, there was a mix of accurate, partially accurate, and inaccurate predictions with few correlations between result categories. Within the 5 broad categories of predictions that Glover and Smith used, there were a mix of accurate and inaccurate predictions. We created different categories of themes to find correlations between accuracy and type of prediction. Notably, predictions concerning technological innovation were largely inaccurate and current development lagged the predictions. Predictions on sources of damage to the deep-sea were mostly accurate. This analysis reveals the difficulty in making predictions about a region with sparse amounts of data. These findings underscore the need for enhanced data collection and improved methods for better forecasting the deep-sea ecosystem. This study also highlights the importance of integrating socioeconomic and regulatory factors in future predictions. By identifying the limitations and strengths of past predictions we can improve future predictions that will shape policy decisions and conservation processes.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

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All data discussed in this review are from published sources and properly cited within the manuscript.

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