State of the Science FACT SHEET:

Deep-Sea Mining

Deep-Sea Mining (DSM) refers to the extraction of critical mineral deposits on or below the seafloor. *Of the 50 critical minerals identified as essential to U.S. economic and national security, at least 37 are found in seafloor deposits. Critical minerals include manganese, nickel, cobalt, and zinc, which are essential elements for manufacturing high-technology devices and advanced batteries, and have national defense applications. To date, no commercial-scale DSM has occurred globally; however, the increasing demand for critical minerals and rising costs of terrestrial sources, improvements in deep-sea technology and capabilities, and the potential for supply chain disruptions have reinvigorated discussions of DSM potential.*

Critical mineral deposits are found in oceans around the world. The most common types of marine mineral resources are (1) polymetallic nodules on the abyssal seafloor that grow at a rate of 1 to 10 cm per million years, (2) slow-growing cobalt-rich ferromanganese crusts found on seamounts, and (3) seafloor massive sulfide deposits formed by faster hydrothermal processes at mid-ocean ridges and submarine volcanoes. Deep-sea exploration continues to reveal new locations of critical mineral deposits globally, including in high-latitude regions. Characterization and additional research of these sites will improve our understanding of their associated biodiversity, ecological functions, vulnerability to disturbance, mineral formation processes, and economic value.

What could be the impacts of DSM?

Detailed baseline data to understand the impacts of DSM to marine environments and ecosystems are limited. As of January 2024, only 52% of U.S. waters have been bathymetrically mapped to modern standards, with only 26% of the seafloor mapped globally; and very little of the deep sea has been characterized in detail. Deep-sea exploration routinely reveals new species whose biology and roles in the ecosystem are unknown. NOAA, in partnership with federal and international agencies, and academic, and commercial collaborators, continues to provide environmental baseline data about the deep sea through science-driven exploration and open data sharing. These efforts are a step toward identifying DSM's potential environmental impacts due to disturbance or loss of deep-sea habitat.

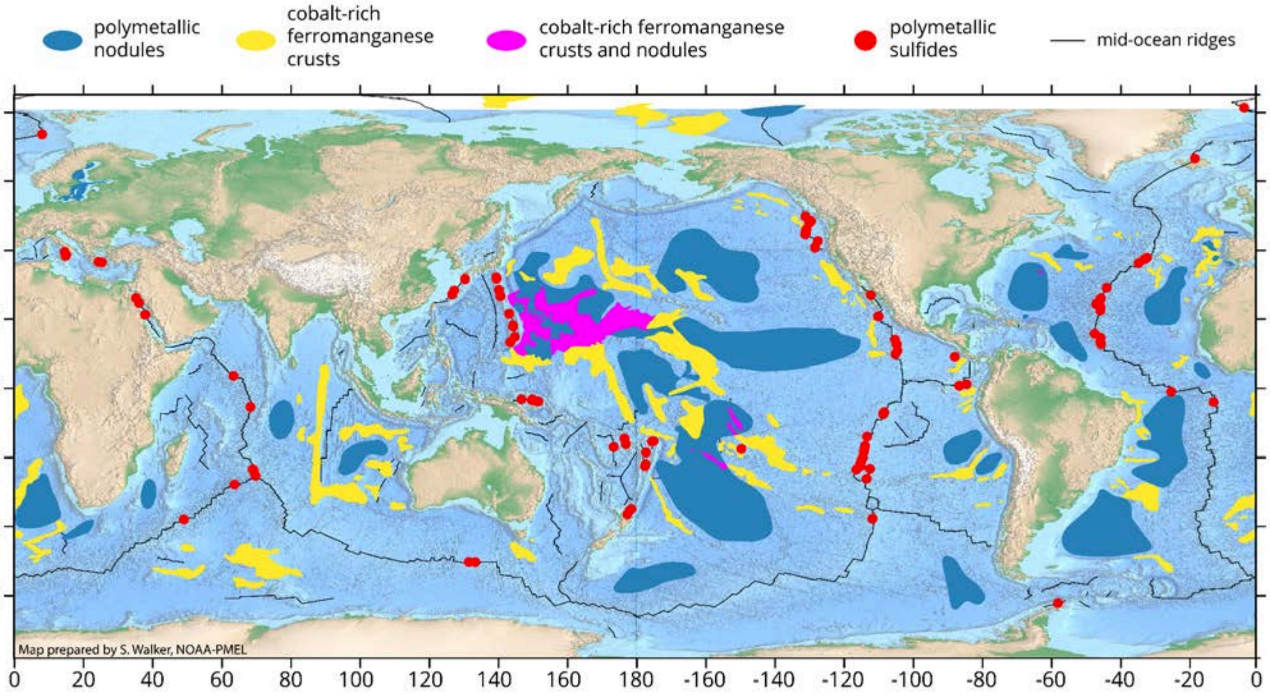

Figure 1. Map showing areas predicted to contain marine critical minerals based on geologic and oceanic criteria, including prospective regions of polymetallic nodules (blue), cobalt-rich ferromanganese crusts (yellow), and areas with both crusts and nodules (pink); these regions do not indicate the minerals are present or economically viable (Mizel et al., 2022; Fregoso et al., 2024). Polymetallic sulfides have been documented at hydrothermal vent fields (red; Beaulieu et al., 2020) and have potential to be found at hydrothermal vents associated with mid-ocean ridges (black lines; Müller et al., 2018) and submarine arc volcanoes.

DSM activities will potentially impact the ocean environment from the seafloor to the surface. Potential impacts include the disturbance of seafloor sediments by DSM machinery, destruction of benthic habitats, and generation of sediment plumes altering the composition of both benthic and deep midwater communities. Biological/ecological impacts may include smothering, bioaccumulation of toxic metals, food supply changes, and marine life damage. Connections among seafloor, midwater, and surface ecosystem functions (including for commercially important fisheries) need to be better understood before the significance of these impacts on marine ecosystems can be assessed. The potential impacts of DSM-introduced underwater noise and light have not yet been thoroughly studied. **The spatial and temporal scales of these impacts have yet to be determined, as well as what resulting impacts there may be to ecosystem-critical elements such as oxygen, carbon, iron and nutrients and their interconnected marine biogeochemical cycles.**

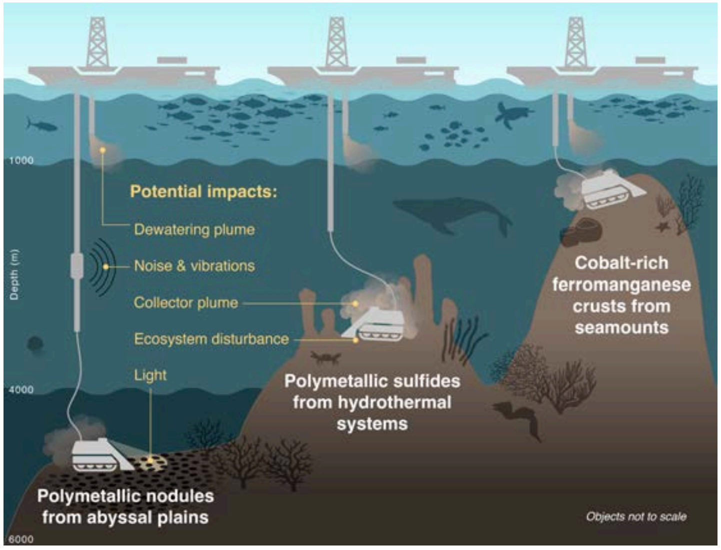

Figure 2. A generalized schematic showing some of the potential impacts on marine systems resulting from possible future DSM operations on abyssal plains, hydrothermal systems, or seamounts.

The significance of impacts from DSM has not been determined. Life in some energetically rich habitats, such as at hydrothermal vents, can begin to recolonize within years to decades after a disturbance. However, deep-sea corals and sponges often grow only a few millimeters per year, meaning they may not regenerate for many hundreds of years after being damaged, if they recover at all. Dredge marks in sediment created up to 50 years ago during mining equipment tests in a manganese nodule-rich area appear unchanged today. Taken together, these observations suggest that there is variability in the rate and ability of various deep-sea ecosystems to recover after disturbances. Additional scientific data are required to better understand this variability and to determine the metrics that should be used to assess DSM's impacts.

Additional natural and social science research is required to further understand how DSM's potential environmental and ecological impacts could potentially impose an uneven distribution of economic benefits, including whether such impacts may affect fisheries and cultural heritage. The disturbance of the seabed and the release of sediment plumes could impact marine ecosystems in ways we do not yet fully understand. Additional research is needed to quantify and characterize the uncertainty surrounding plume transport, the effects sea-surface processing may have on water quality, and associated implications for fisheries that depend on stable ocean habitats and clear water conditions.

How is DSM Governed and Regulated?

NOAA has long-standing licensing and permitting authority for deep-sea mineral exploration and commercial recovery by U.S. companies in international waters and in the development of science related to the potential impacts of deep seabed mining via the Deep Seabed Hard Mineral Resources Act (DSHMRA, 30 U.S.C. §§ 1401-1473 (1980))**.** From 1975-1980, NOAA conducted DSM tests in cooperation with sea mining development companies and studied the potential benthic impacts from deep seabed mining into the 1990s. Although these studies were not conclusive as to the significance of DSM impacts, their findings were used to develop the precautionary and adaptive management framework of NOAA's DSHMRA exploration and commercial recovery regulations (15 CFR parts 970 and 971).

Under U.S. law, the regulatory jurisdiction over DSM is shared by NOAA and the Bureau of Ocean Energy Management, which has authority under the Outer Continental Shelf Lands Act (OCSLA, 43 U.S.C. 1331-1356c) over all marine mineral extraction in U.S. waters. Neither agency has authorized DSM.

The International Seabed Authority (ISA) is the organization through which States Parties to the United Nations Convention on the Law of the Sea (UNCLOS) organize and control exploration and exploitation activities in the international seabed area, beyond national jurisdiction. Under UNCLOS, the ISA must ensure effective protection for the marine environment from harmful effects that may arise from deep-seabed-related activities within its jurisdiction. The U.S. has not yet joined UNCLOS, and therefore participates as an “observer” at ISA meetings. The ISA manages exploration contracts in the international seabed area and is currently developing regulations for mineral resource exploitation. Each nation has the ability to regulate seabed mining in areas within their national jurisdiction, and DSM licensing and permitting protocols are currently being developed in several countries.

Complementing NOAA’s DSHMRA responsibilities, NOAA’s mission and related responsibilities for conserving and managing marine ecosystems and resources (such as fisheries and aquaculture, protected and endangered species, and marine sanctuaries) are directly relevant to DSM. NOAA’s research and observational capabilities can advance efforts to better understand and evaluate DSM's environmental impacts. NOAA coordinates with other U.S. federal agencies on DSM-related science, including the U.S. Geological Survey, which leads on marine minerals science, and the Bureau of Ocean Energy Management Marine Minerals Program.

What are NOAA’s Deep-Sea Research Capabilities and Activities?

NOAA has extensive expertise in deep-sea science and is a leader in this field. Through public and private partnerships, NOAA develops innovative deep-ocean science technologies and undertakes comprehensive, interdisciplinary, and systematic studies to understand baseline environmental conditions, which can be applied to evaluating potential impacts related to DSM. NOAA collaborates on cross-cutting deep-sea research with other U.S. federal agencies, including the U.S. Geological Survey and the Bureau of Ocean Energy Management.

NOAA Ocean Exploration Program has supported numerous regional projects with relevance to DSM, including the mapping of unknown seafloor, and the collection and examination of unique biological and geologic samples, including in mineral-rich areas of the deep sea.

NOAA Pacific Marine Environmental Lab’s Earth-Ocean Interactions Program (formerly the NOAA Vents Program) has contributed significantly to global, interdisciplinary, and systematic exploration, discovery, and foundational research of hydrothermal vent processes and ecosystem studies along the mid-ocean ridges and submarine arc volcanoes, where polymetallic sulfides are formed.

NOAA Fisheries conducts controlled experimental studies of fishing gear impacts on benthic habitat, which could be adapted to inform the characterization of DSM impacts and recovery. NOAA Fisheries’ multidisciplinary ecosystem studies that are focused on the carbon cycle of water column communities, fishery movements, and protected species migrations can all contribute to baseline information needs.

NOAA Deep Sea Coral Research & Technology Program supports and coordinates exploration to locate deep-sea coral habitats and conducts research to characterize their associated communities. The program also monitors activities that could affect these sensitive areas and shares information with resource managers.

NOAA National Centers for Coastal Ocean Science (NCCOS) characterizes deep-sea environments by conducting benthic surveys and developing spatially explicit species distribution models of deep-sea coral communities throughout U.S. waters. NCCOS also contributes to seafloor mapping, particularly in coastal and nearshore environments. In addition, NCCOS is a leader in developing Marine Spatial Planning models for siting of ocean industries and conducting geospatial biogeographic assessments.

NOAA National Centers for Environmental Information manages and provides access to data gathered during research and exploration of the deep ocean and seafloor. Data are publicly available through interactive maps, data portals, and other products.

Other NOAA Research groups with deep-ocean science capabilities are also addressing potential impacts related to DSM activities, including; PMEL Acoustics, ‘Omics (eDNA), and deep and biogeochemical ARGO floats. Additionally, NOAA collaborates closely with its cooperative institutes, including the Ocean Exploration Cooperative Institute; Cooperative Institute for Climate, Ocean, and Ecosystem Studies; and Cooperative Institute for Marine Ecosystem Resources Studies to enable access to additional expertise and capabilities of the academic and commercial sectors.

Conducting research in the deep sea poses substantial practical and cost challenges and must be undertaken pursuant to a strategy that will yield results in which confidence can be placed and at the same time are cost effective. NOAA’s research must be responsive and adaptable as technology develops.