Development of EIA protocol for deep-sea ecosystems and seabed mining

Hiroyuki Yamamoto, Ryota Nakajima, Takehisa Yamakita, Dhugal Lindsay, Tomohiko Fukushima

Environmental Impact Assessment Research Group, R&D Center for Submarine Resources, Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

Deep-sea environments are faced with cumulative effects of many human activities, e.g. waste deposition, oil exploitation, fishing, maritime transport, and potential seabed mining. Recently, growing interest in deep-sea mining, within States Exclusive Economic Zones (EEZ) or in areas beyond the limits of national jurisdiction, has increased demand for exploration, engineering development and scientific research. From the mid 1990s, attention has been paid to potential environmental impacts caused by deep-sea mining, and many workshops, meetings, and conferences have been held. Survey methods for deep-sea environments, and protocols for Environmental Impact Assessments (EIA) have been developed using multidisciplinary approaches. In the Pacific region, the first site likely to be commercially exploited is located in Papua New Guinea, where seafloor massive sulphide (SMS) deposits at 1600 metres water depth have been discovered in the Bismarck Sea. The mining company, Nautilus Minerals Ltd., which has received permission for exploitation from the local government, is expected to begin production by 2018. In Japan, Japan Oil and Gas, Metals National Corporation (JOGMEC) has started a feasibility project for SMS mining from 2008 (Narita 2015). In 2015, the leaders' declaration from the G7 summit in Germany identified the conducting of EIA and scientific research as priority issues for sustainable deep-sea mining. EIA for deep-sea mining is recognized as an upcoming issue in our oceans and a key component for ensuring effective protection of ocean ecosystems.

Issues pertaining to EIAs in the deep ocean have been discussed at international workshops held over the past five years. The development of EIA protocols has begun in Japan as a National project. This paper describes key issues concerning deep-sea environmental assessment and monitoring.

Data availability and collection

Lack of easy accessibility to deep-sea environments causes difficulty in data collection. The number of biological specimens and amounts of observational data able to be collected from deep-sea habitats is limited, because of the water depth and operation costs of submersible tools. Several millions of yen per day is usual when budgeting for a cruise for deep-sea surveys. Deep-sea research activities over the past two decades have collected much data and this is now accumulated in several databases.

Several online, official database systems such as the Biological Information System for Marine Life (BISMaL) and the Ocean Biogeographic Information System (OBIS) already exist. These are supported by data submission from marine biologists and/or their institutions, and provide useful data and analytical tools to investigate biogeography and biodiversity. OBIS includes text-based data on a global scale concerning species occurrence in time and space, and has been increasingly recognized as a useful tool for elucidating marine biodiversity on a global or regional scale. BISMaL is a regional-scale database, concentrating mainly on data from marine areas around the Japanese archipelago and western Pacific Ocean (Yamamoto 2012). Video records from deep-sea surveys accessed via the BISMaL archives might provide useful information for EIAs. Although OBIS and BISMaL contain datasets allowing biodiversity assessment and also provide mapping tools, these do not always satisfy the requirements of fine-scale quantitative data at local scales or at specific points for EIAs and for planning of resource exploitation. To improve our ability to do EIA at proposed seabed mining sites, the International Seabed Authority (ISA) requests of the contractor countries, who occupy sites in the ISA mining area, to accumulate data for construction of a database for assessment of biodiversity and environmental conditions in such open-ocean seabed-mining areas. Several advanced technologies and techniques for data collection and analysis have been developed and applied in the deep-sea during the course of pure scientific research surveys. A pending issue is the modification of such scientific tools and techniques for commercial use.

Evaluation of deep-sea environments

Criteria to evaluate marine environments, including offshore and deep-sea areas, have been proposed by agencies of the United Nations, e.g. Ecologically and Biologically Significant

Areas (EBSAs) by the Convention for Biological Diversity, Vulnerable Marine Ecosystems (VMEs) by the Food and Agriculture Organization, and Particularly Sensitive Sea Areas (PSSAs) by the International Maritime Organization (Auster 2010, IMO 2006). While the purposes for which each of these criteria were made differ, each of the criteria employ very similar indices to assess the ecosystems, with the aim to ensure conservation of the quality of the environmental conditions (Table 1). The concepts and protocols for evaluation can be applied for screening and scoping processes related to deep-sea EIAs. Case studies to evaluate deep-sea communities using baseline data sets collected from databases have been carried out, and suggest the usefulness of the EBSA criteria (Nakajima 2014, Yamakita 2014). These criteria, shown in Table 1, can be applied to site screening and scoping for strategic environmental assessments, and provide knowledge to formulate conservation plans based on biological connectivity among remotely-isolated communities on a regional scale.

Table 1. Index items in criteria for ecosystem evaluation protocols

EBSA: Ecologically and Biologically Significant Area	**VME:** Vulnerable Marine Ecosystem	**PSSA:** Particularly Sensitive Sea Area
		Ecological criteria
● Uniqueness or rarity	● Uniqueness or rarity	● Uniqueness or rarity
● Special importance for life history stages of species	● Functional significance of the habitat	● Critical habitat
● Importance for threatened, endangered or declining species and/or habitats	● Fragility	● Dependency
● Vulnerability, fragility, sensitivity or slow recovery	● Life-history traits of component species that make recovery difficult	● Representativeness
● Biological productivity	● Structural complexity	● Diversity
● Biological diversity		● Productivity
● Naturalness		● Spawning or breeding grounds
		● Naturalness
		● Integrity
		● Fragility
		● Bio-geographic importance

The concept of Ecosystem Services, proposed in the Millennium Ecosystem Assessment, was adopted to help estimate socio-ecological relations and the economic value of various ecosystem functions. Although our understanding of ecosystem services provided by the deep-sea remains in its infancy, the functions/services of nutrient regeneration, carbon storage, heat circulation, and as a biological refuge zone are well-known. Seabed minerals and energy resources are thought to provide important ecosystem services in deep-sea ecosystems, though they are the products of primarily geological processes (Thurber 2014). The application of ecosystem service concepts for EIAs related to seabed mining is needed to assess economic impact to human communities in the context of fisheries, refineries, and social systems.

Assessment of impacts

Recoverability potential of communities and habitat conditions after disturbance due to human activities is essential information for EIAs and environmental management planning (EMP). Case studies including impact assessment and data on post-impact observations have been reported for seafloor volcanic eruptions, land slides due to tsunamis, ocean drilling, and test mining. The results provide useful information for evaluation of recoverability after disturbance and to estimate the capacity for resilience in deep-sea ecosystems.

Disturbance by scientific drilling operations (IODP Expedition 331) of the seabed landscape and on megafaunal habitat and occurrence patterns was surveyed for over 3 years using video camera observations around a deep-sea hydrothermal field in the Okinawa Trough (Nakajima 2014). Prior to drilling, the seafloor was entirely dominated by fine-grained silt sediments, and deep-sea clam colonies were the most prominent benthic communities. After the intensive drilling campaign, the clam colony was heavily impacted due to sedimentation of drilling deposits and the heightened seabed temperatures caused by flow-out of high temperature hydrothermal fluids from the adjacent borehole. This result was comparable with a long-term observation of post-volcanic activities in the literature (Qiu, J. 2010). Such studies, based on long-term surveys, have provided important scientific knowledge on community genesis and/or recovery after impacts, as well as suggesting practical methods for observation and assessment.

In the case of the huge disturbances in deep-sea environments caused by the recent M9.0 Tohoku Earthquake, the effect of land slides on deep-sea areas was shown to continue even after one month, before gradual recovery of the previous community (Kawagucci 2014, Kitahashi 2014). The results suggest robustness in the microbial and meiofaunal communities of sub-seafloor habitats in marginal seas, and illustrate their resilience.

However, a case study on experimental disturbance from test-mining in the Clarion-Clipperton Fracture Zone, Tropical Eastern Pacific Ocean, has shown that a deep-sea nematode assemblage has not recovered after 26 years since experimental mining occurred (Miljutin, 2011). The results from these case studies suggest that the recoverability of deep-sea communities is dependent on habitat conditions and is related to productivity and matter cycling.

Environmental management plan and monitoring:

Adaptive management is a useful tool for conservation of environments, and may be suitable for management related to deep-sea resource exploitation. A practical issue to address is the development of cost-effective observation and monitoring systems that can be used in deep-sea environments. Monitoring targets related to seabed mining operations occur both in the vicinity of the seafloor mining machines but also near the support vessel (Fig. 1). Undersea observatories that are cable-connected or incorporated into transposable platforms can be used, according to the monitoring needs.

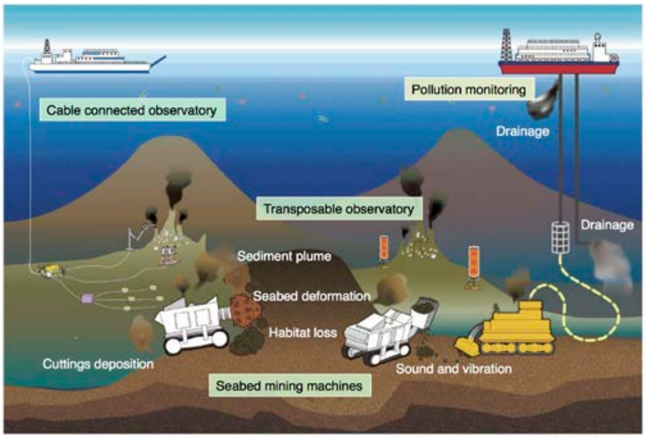

Fig 1. Monitoring targets and observation system

The development of an equitable management system based on scientific knowledge and advanced monitoring technology is underway as a national project.

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