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Human footprint in the abyss: 30 year records of deep-sea plastic debris

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ABSTRACT

This study reports plastic debris pollution in the deep-sea based on the information from a recently developed database. The Global Oceanographic Data Center (GODAC) of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) launched the Deep-sea Debris Database for public use in March 2017. The database archives photographs and videos of debris that have been collected since 1983 by deep-sea submersibles and remotely operated vehicles. From the 5010 dives in the database, 3425 man-made debris items were counted. More than 33% of the debris was macro-plastic, of which 89% was single-use products, and these ratios increased to 52% and 92%, respectively, in areas deeper than 6000 m. The deepest record was a plastic bag at 10898 m in the Mariana Trench. Deep-sea organisms were observed in the 17% of plastic debris images, which include entanglement of plastic bags on chemosynthetic cold seep communities. Quantitative density analysis for the subset data in the western North Pacific showed plastic density ranging from 17 to 335 items km^{-2} at depths of 1092–5977 m. The data show that, in addition to resource exploitation and industrial development, the influence of land-based human activities has reached the deepest parts of the ocean in areas more than 1000 km from the mainland. Establishment of international frameworks on monitoring of deep-sea plastic pollution as an Essential Ocean Variable and a data sharing protocol are the keys to delivering scientific outcomes that are useful for the effective management of plastic pollution and the conservation of deep-sea ecosystems.

1. Introduction

Plastic pollution is emerging as one of the most serious threats to ocean ecosystems [1], and world leaders, scientists, and communities recognize the need for urgent management measures for the sustainability of marine ecosystem services in the future [2]. Previous studies have reported the accumulation of plastic debris on the coasts [3–5], and ship-based observations have revealed plastic debris accumulation in offshore surface waters [6]. The damage caused by plastic debris in large animals through accidental ingestion and entanglement in floating plastic [7] and the hazards posed by toxic chemicals released from fragmented plastic on the biological function of marine organisms have been well studied [8]. Micro-plastic ingested by zooplankton can be transferred to higher trophic level animals, including commercially important fish species, through the food web [9,10], with potential effects on human health. The United Nations Sustainable Development Goal 14.1 urges the world community to take action to reduce marine pollution by 2025, and one of the indicators to track its progress is the density of floating plastic debris (http://www.un.org/sustainabledevelopment/oceans/).

An increasing number of studies have been conducted on plastic pollution in coastal and surface waters, limited information is available for mesopelagic and deeper layers that occupy a vast area of the global ocean. In those studies, deep-sea debris distribution using bottom sampling [11–15], and video observation *via* remotely operated vehicles (ROVs) and submersibles [12,13,16–21], in regional oceans were revealed. Although pollution in the deep sea was often perceived as being less dependent on land-based human activities, those studies reported that plastic debris were frequently observed in the deep sea, particularly in areas close to highly populated regions, *e.g.* the Mediterranean Sea [12,22,23]. Potential threats of plastic pollution to the biodiversity of deep-sea ecosystems, which are highly endemic and have a very slow growth rate [24], are concerning. However, a majority of the previous studies are based on one-off projects over several years,

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Table 1
Summary of the total and plastic debris occurrences during deep-sea surveys by remotely operated vehicles and submersibles of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) in the six oceanic regions for 1982–2015. The information is based on the Deep-sea Debris Database of Global Oceanographic Data Center (GODAC) of JAMSTEC (updated on July 3rd, 2017) (http://www.godac.jamstec.go.jp/dsdebris/e/). Single use plastics are plastic bags, bottles and packages.

Oceanic Region	Year of observation	Geographical range (Latitude - Longitude)	Dive depth range (m)	Debris depth range (m)	Max. depth (m) of plastics	Total dive number	Total debris number	Plastic debris number	% Single use plastic
Western North Pacific	1982–2015	1°15' - 45°34'N 122°42' - 163°15'E	100– 10,899	100–10898	10,898	4552	3370	1108	89
Eastern North Pacific	1998–2002	17°12' - 24°24'N 154°14' - 159°13'W	1714–5569	3879–4684	4684	85	8	2	100
South Pacific	1990–2013	3°10' - 34°53'S 149°52'E - 112112°29'W	499–6498	1846–4460	1986	168	12	1	100
North Atlantic	1994–2013	14°44' - 36°14'N 33°54' - 81°48'W	2265–6024	2300 − 4935	–	68	17	0	N.A.
South Atlantic	2013	20°38' - 31°06'S 34°03' - 41°39'W	921–4219	2493–2721	–	16	5	0	N.A.
Indian Ocean	1998–2013	4°02'N - 32°57'S 57°04' - 105°53'E	1276–5290	1923–3264	2573	121	13	4	100
Total						**5010**	**3425**	**1115**	**89**

at maximum, and on surveys conducted in areas relatively close to the coast. There are only a few cases of long-term observation records on deep-sea plastic pollution [18,25,26] and of surveys conducted at depths greater than the abyssal zone (> 4000 m) [13–15] and in areas more than 1000 km off the coast of the mainland [13,19,27]. Information on deep-sea debris in the western North Pacific Ocean is also very limited [15,28]. Because high concentrations of plastic debris were reported in the shallow coastal waters in East Asia [29–32] and intensive research and management measures have been adopted on the beach and coastal areas of the highly populated East Asian countries [33], investigation regarding a possible link of the coastal plastic pollution to offshore and deep-sea ecosystems in the western North Pacific is urgently needed.

To assess the distribution of deep-sea plastic debris at the global scale, collating and sharing the best available data from past and present surveys will be essential. With such a background, the Global Oceanographic Data Center (GODAC) of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) launched the Deep-sea Debris Database for public use in March 2017 (http://www.godac.jamstec.go.jp/dsdebris/e/). Debris items identified in video footage taken during surveys *via* submersibles and remotely operated vehicles (ROVs) since 1983 were reviewed and recorded in the database, which includes a large amount of plastic debris observed in the abyssal and even the hadal zones (> 6000 m), for which hardly any information on artificial debris distribution is available. Although the data cover the global ocean, the majority of the records are from the western North Pacific and fill the regional knowledge gap on global deep-sea plastic debris pollution.

The aims of this study were to raise awareness about the ubiquitous distribution of macro-plastic debris, particularly of single-use plastic found in the deepest marine trenches and thousands of kilometres from the shore and to suggest effective strategies for scientific research on deep-sea plastic pollution. Using the 30 year worth of records of deep-sea debris available in the Deep-sea Debris Database, the objective of this study was to fill the current knowledge gap by depicting the occurrence of plastic debris in the abyssal and hadal zones of the world's oceans and the density distribution of plastic debris in the western North Pacific. Finally, we discuss how collaboration by the international deep-sea observation community could maximize the benefits of its scientific outcome to knowledge-based action for better conservation and management of the deep-sea environment and ecosystems.

2. Material and methods

2.1. Data

The data used in this study were from the Deep-sea Debris Database updated on July 3rd, 2017 (http://www.godac.jamstec.go.jp/dsdebris/e/). The debris data were obtained by visually analysing video footage taken from 1983 to 2014 by JAMSTEC's manned research submersibles *SHINKAI 2000* and *SHINKAI 6500* and the ROVs *DOLPHIN 3K*, *HYPER-DOLPHIN*, and *KAIKO*, with maximum survey depths of approximately 2000 m (1983–2002), 6500 m (1990–2014), 3000 m (1987–2002), 3000 m (2000–2014), and 11,000 m (1995–2014). For the specifications of these vehicles, refer to the following link to the JAMSTEC website: (http://www.jamstec.go.jp/e/about/equipment/ships/). The database is open to the public for academic use, and users can browse the list of debris photos and videos and other information, such as debris category; date, location, and depth of the observation; observation vehicle; substrate type of the sea floor; and taxonomic information of organisms observed with the debris (if present).

The records for dives conducted in areas deeper than 100 m were selected for analysis. The total number of dives examined was 5010. The diving points were mainly in the western North Pacific: around the Japanese archipelago, including the Japan Trench, and stretching south to the Mariana and Palau Trenches, but a number of dive records, shown in parentheses, were of other oceanic regions: the eastern North Pacific (85), South Pacific (171), Indian Ocean (121), North Atlantic (68), and South Atlantic (13) (Table 1, Fig. 1). In all regions, the maximum survey depth exceeded 4000 m. Many dives were conducted in the open ocean, more than 1000 km off the coast of the mainland, but only 3% of the dives were in the high seas, *i.e.* the areas beyond national jurisdiction.

Records of natural debris and unidentified debris in the database were excluded from the quantitative analysis of this study, and only anthropogenic debris was analysed, which was classified into seven categories: plastic, glass, metal, rubber, cloth/paper/lumber, fishing gear, and other. Plastic debris was sub-categorized into single-use products (bags, bottles, and packages) and other plastics.

2.2. Density analysis

The initial purpose of the dives in the database was to conduct biological and geological investigations, not debris monitoring. Thus, density estimation was possible only for the data subset from the *SHINKAI 6500* dives between 2004 and 2014. Those dives were selected