Deep-Sea Litter Study Using Deep-Sea Observation Tools

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Abstract—Marine litter is a big social problem that crosses national boundaries. Little is known about how deep-sea litter is distributed and how it accumulates, and moreover how it affects the deep-sea floor and deep-sea animals.

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) operates many deep-sea observation tools, e.g., manned submersibles, ROVs, AUVs and deep-sea observatory systems. Over 4860 deep-sea dives of these research submersibles have been conducted. All dives have been recorded on videotape and stored as a film library. Some of them have been listed in a database and opened to the public via the WEB. Deep-sea litter can be found on that video footage and in the database. We can observe changes of deep-sea litter accumulation across the years using the film library and can collect deep-sea litter in situ with environmental data and samples using research submersibles. It is essential for deep-sea litter studies to use such deep-sea observation systems and the data collected in past times from deep-sea observation systems.

Keywords: deep-sea litter, ROV, submersible, AUV, Video analysis

INTRODUCTION

Marine litter, in particular floating and beach litter are recognized as big social problems that cross national boundaries (Criddele et al., 2009; Galgani et al., 2010). This litter is visible, therefore anyone who sees litter at sea or on the beach can easily realize the seriousness of the matter. Therefore, many studies and activities have been conducted concerning such maritime litter. However, floating litter can sink to the bottom, because of degradation or attachment of biofilms of bacteria, algae and large sessile organisms, predation by animals or for other unknown reasons (Moore et al., 2001; Graham and Thompson, 2009; Gregory, 2009; Ryan et al., 2009; Webb et al., 2009; Jacobsen et al., 2010; Law et al., 2010). Marine litter on the sea floor is not visible to the public, and this invisible character has kept our focus away from litter on the sea floor. Seabed litter has been studied from shallow waters to the deep-sea floor. Studies of litter of the sea floor have been conducted by snorkeling, SCUBA, trawl surveys, sonar, and submersibles and ROVs (Galgani et al., 1996, 2000; Spengler and Costa, 2008;
Keller et al., 2010; Watters et al., 2010). Surveys using snorkeling and SCUBA are limited to shallow waters and small areas. Surveys using sonar are good for searching over large areas but are not high in resolution (Stevens et al., 2000; Spengler and Costa, 2008). Using ROVs or submersibles entails high costs and it is therefore difficult to use these submersibles or ROVs multiple times. Studies on the sea floor typically focus on continental shelves. The best way is a trawl survey, because it covers a large area and can collect a large amount of litter for analysis (Spengler and Costa, 2008). However, research into the deeper sea floor is restricted and information about in situ deep-sea benthic litter comes only from the visual data using deep-sea observation tools like submersibles. Since 1996, submersibles or ROVs have been used to investigate benthic litter on the continental slope and at abyssal depths (Galgani et al., 1996, 2000; Watters et al., 2010). Watters et al. (2010) showed quantitative data for benthic litter (20–365 m depth) off California using the submersible Delta by analyzing the archived video for the dives. The study demonstrated that submersibles and the video archive of their dives were effective tools for deep-sea litter research. However that study did not cover deeper sea floor areas, though most of the ocean sea floor is over 3000 m depths. Even now, little is known about how deep-sea litter is distributed and how it accumulates, and moreover how it affects the deep-sea floor and deep-sea animals.

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has operated and still operates many deep-sea observation tools, e.g., the manned submersibles Shinkai 2000 and Shinkai 6500, the ROVs Dolphin-3K, Hyper-Dolphin, Kaiko, Kaiko-7000II and ABISMO, the AUV URASHIMA and the UROV PICASSO and three deep-sea observatory system off Tokachi, Hokkaido, Off Hatsushima, Sagami Bay, and off Muroto, Kochi. These research submersibles can dive up to 11000 m. Much litter on the deep-sea floor has been observed and some has been collected in situ. 4861 deep-sea dives of these research submersibles have been conducted in Japanese waters mainly since 1982 until the end of August 2010 (Table 1). All dives have been recorded on videotape and stored as a film library. Some of them have been recorded in a database and opened to the public via the WEB. Deep-sea litter can be found on that video footage and in the database. Given the expense and logistical difficulties associated with submersible research, effort should be made to extract the most information possible from all deep-sea dives (Hunt and Lindsay, 1999).

Table 1. Number of deep-sea dives from April, 1982 to August, 2010.

<table>
<thead>
<tr>
<th>Research submersibles</th>
<th>Number of dives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shinkai 2000 (retired)</td>
<td>1411</td>
</tr>
<tr>
<td>Dolphin-3K (retired)</td>
<td>576</td>
</tr>
<tr>
<td>Shinkai 6500</td>
<td>1216</td>
</tr>
<tr>
<td>Kaiko (retired) and Kaiko-7000II</td>
<td>481</td>
</tr>
<tr>
<td>Hyper-Dolphin</td>
<td>1177</td>
</tr>
</tbody>
</table>

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The aim of this study is to observe how much litter exists on the seafloor at abyssal depths, the effects of deep-sea litter on deep-sea organisms, and to show the potential possibility for deep-sea litter studies using deep-sea observation systems.

MATERIALS AND METHODS

To observe deep-sea litter, three dive videos recorded off Sanriku, Iwate, Japan, were used. These videos were ROV *Dolphin 3K* #294 Dive (299–400 m depth, observation time: 5:31:51), manned submersible *Shinkai 2000* #636 Dive (1086–1147 m depth, observation time: 4:44:04) and ROV *Kaiko* #242 Dive (1682–1753 m depth, observation time: 5:36:13) from the film library stored at JAMSTEC. Deep-sea litter was counted and the types of material identified along with the environmental data (occurrence time, depth, bottom material, bottom condition, animals on or around the litter). Observed litter was classified as plastic, metal, glass, sunken wood, fishing tackle or others.

The Deep-sea video database and Deep Sea Image Database on the home page of GODAC (Global Oceanographic Data Center) were used for searching for deep-sea litter. The URL of the GODAC database is http://www.godac.jp/portal/page/portal/GDC/GPSS216/. This database site has Japanese pages and English pages. We ran a search for deep-sea litter using the key words, litter or 塵 (gomi in Japanese) at the database site. There were useful data records in the search results. The data includes cruise number, dive point, latitude, longitude, depth, type of submersible, dive number, date of dive, type of camera, and serial number of dive video. We checked all the data and identified the types of material with the associated environmental data. All data were input into a Microsoft Excel worksheet, and converted from the Microsoft Excel file (xls) to a kml file which is able to be imported into Google Earth. The web site for conversion from an xls file to a kml file was located at http://www.earthpoint.us/ExcelToKml.aspx. Converted kml files were imported into Google Earth and the positions of deep-sea litter were plotted on the Google Earth map.

RESULTS AND DISCUSSION

Studies on deep sea litter at abyssal depths have been conducted using trawl nets and submersibles at depths of up to 4614 m (Galgani *et al*., 1995, 1996, 2000, 2010; Spengler and Costa, 2008; Keller *et al*., 2010; Watters *et al*., 2010). This study is the first report that shows evidence of much anthropogenic litter found in abyssal areas at more than 5000 m depth.

Much litter was observed in the video record of all three dives. There were 147, 24, and 48 litter records in *Dolphin 3K* #294 Dive, *Shinkai 2000* #636 Dive and *Kaiko* #242 Dive, respectively. The largest group of deep-sea litter was plastics, followed by sunken wood, metal and fishing tackle (Fig. 1). Much litter was also found on the GODAC database. 301 litter records were hit by the key word, 塵. Some of them were the same record with a different camera angle, so the actual number of litter records was 252. The distribution of litter is shown in...
Fig. 2. This observed distribution of deep-sea litter was affected by the type of deep-sea research being conducted, biology, chemistry, geology, fisheries, seismology, earth science, and so on. However, we were able to obtain much information on deep-sea litter at abyssal depths. The maximum depth record was for a waste can at a depth of 7216 m in the Ryukyu trench. Most of the deep-sea litter was plastic (Fig. 3). Accumulation of plastic bags was observed at a depth
Deep-sea litter study of 2176 m in a deep-sea valley in Suruga Bay and at a depth of 6272 m in the gap made by a big earthquake in the Japan Trench, off Sanriku (Fig. 4). These results demonstrate that it is an effective use of deep-sea submersibles for studying deep-sea litter to observe in places where fishing nets can not trawl, e.g., deep-sea valleys, outcrops of base rock, cliffs and gaps.

There are over 4861 deep-sea dive videos in the film library of JAMSTEC. Most of them were conducted in Sagami Bay (maximum depth is about 1500 m) which is one of the deepest bays in Japan and is next to Tokyo Bay, because there have been many studies on the cold seep ecosystem off Hatsushima Island at a depth of 1000 m. A total of 316 dives were conducted in Sagami Bay by the *Shinkai 2000* and *Dolphin 3K* from 1982 to 2002. Fig. 5 shows that much video footage of deep-sea dives in the same Bay in different years have been stocked. Other submersibles, such as the *Shinkai 6500* and *Hyper Dolphin* have also been

![Bar chart of the number of deep-sea litter observations in the GODAC deep-sea video database.](image)

Fig. 3. Bar chart of the number of deep-sea litter observations in the GODAC deep-sea video database.
adding deep-sea dives in Sagami Bay since 2002. We can analyze the chronological change of accumulation of deep-sea litter in this bay using the accumulated video library. A video library can play an important role in allowing us to observe the past like a time machine. Moreover, video analysis on deep-sea litter does not require high monetary outlay like using deep-sea submersibles for new studies. It is important to establish a useful database of submersible-collected observations (Hunt and Lindsay, 1999). The database of GODAC may be one of these useful databases, but this database must be used not only for deep-sea litter study but also for all science purposes more efficiently.

The places where deep-sea litter accumulated was almost always on a muddy sediment bottom where sea cucumbers such as Scotoplanes globosa, Enypniastes eximia, Peniagone sp. etc. were found frequently. This environment may only have small tidal currents and it is easy to accumulate nutrient-rich sediments and anthropogenic litter. The place where deep-sea litter accumulated was the same place where deep-sea benthic animals lived! Deep-sea litter was also utilized by sessile organisms. Sea anemones and feather stars were found attached to deep-sea litter. Interestingly, many predatory tunicates, Megalodicopia hians, were found attached to deep-sea litter in Toyama Bay (Fig. 6a). Predatory tunicates need a hard substrate upon which to attach for their existence. The habitat of predatory tunicates is usually outcrops of base rock (Fig. 6b). So they cannot live on soft bottoms. However, there is soft sediment where predatory tunicate can not inhabit visible in Fig. 6a. The tunicates in Fig. 6a are attached to a fishing net and on something else made by plastic. Hitch-hiking of animals on floating or suspended litter (Aliani and Molcard, 2003; Gregory, 2009) can also transport shallow water animals to deep-sea environments. This shows how deep-sea litter from our daily life can function as a substrate for sessile organisms in places they would otherwise be unable to inhabit.

Plastics are the major category of deep-sea litter but have the ability to adsorb chemicals and contain additives such as endocrine disturbing chemicals (Teuten et al., 2009). Marine litter can be ingested by many marine organisms,
Fig. 5. Bar chart of annual number of deep-sea dives using the manned-submersible *Shinkai 2000* and the ROV *Dolphin-3K* in Sagami Bay.

Fig. 6. Predatory tunicate, *Megalodicyopia hians*. a: Predatory tunicates attached to a fishing net lying on the soft sediment bottom. b: Natural habitat of predatory tunicates.
bacteria, zooplankton, fishes, sea turtles, birds, marine mammals, etc. (Moore et al., 2001; Thompson et al., 2004; Criddle et al., 2009; Graham and Thompson, 2009; Gregory, 2009; Oehlmann et al., 2009; Ryan et al., 2009; Webb et al., 2009; Galgani et al., 2010; Jacobsen et al., 2010; Sekiguchi et al., 2010a, b). There is a biological pump in marine ecosystems. The biological pump accelerates the transport of organic matter. Therefore, once any organisms intake any chemicals through ingesting floating or suspending anthropogenic litter, the chemicals may be transported from the surface to the deep-sea floor easily and quickly. Accumulation of those plastics on the deep-sea floor also transports these chemicals from surface waters to the deep-sea bottom and thence to deep-sea organisms that used to be remote from our daily life.

The study of deep-sea litter using submersibles has the difficulty of the expense and logistical problems. However, this study shows that in situ visual data collected from observations by manned submersibles, ROVs, AUVs, towed camera arrays, and deep-sea observatory systems is useful for the study of deep-sea litter at abyssal depths at low cost.

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