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Estimation of the annual flow and stock of marine debris in South Korea for management purposes

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ABSTRACT

The annual flow and stock of marine debris in the Sea of Korea was estimated by summarizing previous survey results and integrating them with other relevant information to underpin the national marine debris management plan. The annual inflow of marine debris was estimated to be 91,195 tons [32,825 tons (36% of the total) from sources on land and 58,370 tons (64%) from ocean sources]. As of the end of 2012, the total stock of marine debris on all South Korean coasts (12,029 tons), the seabed (137,761 tons), and in the water column (2451 tons) was estimated to be 152,241 tons. In 2012, 42,595 tons of marine debris was collected from coasts, seabeds, and the water column. This is a very rare case study that estimated the amount of marine debris at a national level, the results of which provide essential information for the development of efficient marine debris management policies.

1. Introduction

The importance of determining the amount of marine debris has been emphasized. The United Nations has encouraged relevant national and international organizations to undertake further studies on the extent and nature of the marine debris problem, noting the lack of information and data available (UNGA, 2005). However, a lack of information regarding the amount of marine debris still persists. UNEP (2009), after reviewing the available data from 12 regional seas, concluded that no systematic measurements of the amount of marine debris have been conducted in the 12 participating regions.

Very few studies have examined the total amount of marine debris anywhere in the world. NAS (1975) estimated the annual flow of marine debris into global oceans to be 6,360,000 tons. Cantin et al. (1990) estimated the annual marine debris inflow for seas belonging to the United States to be 565,791 tons and 337,306 tons before and after MARPOL Annex V, respectively. Fujieda et al. (2010) estimated the marine debris standing stock in Seto Inland Sea to be 3400 tons and the annual inflow and outflow to both be 4500 ton/year under steady-state conditions. AMRF (2008) suggested that the stock of marine debris worldwide is more than 100 million tons. Previous studies have limitations as they are outdated (NAS, 1975), limited to sea-based sources in the United States (Cantin et al., 1990) and to a narrow semi-enclosed area (Fujieda et al., 2010), or lack a scientific basis (AMRF, 2008). Therefore, Cheshire et al. (2009), by referring to Derraik (2002), indicated that reliably estimating the amount of debris entering the marine environment is difficult due to the various sources of marine debris. NRC (2008) also noted that the task of estimating the stock is challenging.

This lack of reliable information regarding the amount of debris in the marine environment has also been problematic in South Korea. The First Basic Plan to Manage Marine Debris, which applied to the period from 2009 to 2013 (MLTM et al., 2008), estimated the annual flow to be 159,800 tons (109,400 tons from land-based sources and 50,400 tons from sea-based sources). Land-based sources included 34,644 tons of debris from rivers, 64,394 tons from floods, and 10,362 tons from coastal activities. The sea-based sources included 45,360 tons of derelict fishing gear and 5040 tons from other activities. However, the authors of the plan admitted that these figures were not based on scientific information. Due to lack of information regarding the amount of marine debris, policy outcomes could not be scientifically assessed, resulting in an inefficient budget allocation (Jang and Song, 2013).

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This study aimed to estimate the amount of marine debris in South Korea. Annual inputs, annual outputs, and stock were calculated from available debris survey data and other oceanographic information sources. This information was included in the Second Basic Plan to Manage Marine Debris (MOF and MOE, 2013) for the purposes of future management (the 5-year period of 2014–2018). This report presents basic information regarding the methods used and the results of the estimation process.

2. Methods

2.1. Definition of marine debris

In this study, marine debris was defined as "any manufactured or processed solid waste material (typically inert) that enters the marine environment from any source," following Coe and Rogers (1997). The definition does not include either trees or bushes (Cheshire et al., 2009), which are known to comprise the greatest portion of debris washed ashore by flooding. As marine debris contains materials that decay very little or not at all in the marine environment (Andrady, 2011), decomposition was assumed to be zero.

2.2. Model of marine debris flow and stock

The marine debris flow and stock was estimated according to a system dynamic model, which has an inflow and an outflow affecting the stock (Eq. (1)). In this model, the standing stock at the end of a period is calculated by adding the inflow minus the outflow during the period to the standing stock at the beginning of the period (Eq. (1)),

$$\text{Stock}\ (t) = \text{Stock}\ (t-1) + \text{Inflow}\ (t) - \text{Outflow}\ (t) \quad (1)$$

where Stock (t) is the amount of marine debris at the end of the period (t), and flow (t) is the amount of marine debris within the in/outflows to/from the sea for the period t.

The total annual inflow consists of inflows from both the land and ocean (Fig. 1). The inflow from the land is affected by an inflow from the rivers during the non-flood season, an inflow from the rivers during the flood season, and an inflow from the coasts. The inflow from the ocean includes lost fishing gear, garbage from ships, styrofoam buoys lost from aquaculture facilities, and debris inflow to harbors.

The total outflow represents the sum of the debris collected from each sector of the sea. Collection from the coasts, the water column, and the seabed decreases the stock on the coasts, the stock in the water column, and the stock on the seabed, respectively. Note that the amount collected, which reduces the stock of debris, is also measured as a flow for a period of time and not as a stock, as collection projects operate for a certain period.

As the Sea of Korea is located close to the seas of neighboring countries, the flow to other seas might be substantial. Conversely, inflow from neighboring countries and other seas might also be significant. Although some studies on debris flow near the Sea of Korea have been undertaken (Seino et al., 2009; Yoon et al., 2010; Kako et al., 2011), reliably estimating the amount of debris flowing between the Sea of Korea and the surrounding seas is almost impossible. Therefore, flows to other seas were neglected in this study.

Marine debris might contain some materials that could be decomposed in the marine environment, which should ideally be considered (Cheshire et al., 2009). However, about 60–80% of marine debris is plastic (Derraik, 2002), which is essentially nondegradable in the marine environment (Andrady, 2011), along with other materials such as metal and glass, which also do not decompose. Some other materials such as paper and wood are degradable. Decomposable materials were overlooked in this study for the sake of simplification.

The total standing stock consists of the stocks on the coast, in the water column, and on the seabed. Although debris stocks in these three locations can be exchanged among each other, individual debris-collecting projects are typically conducted in only one of these locations. Though there might be debris stock inside the marine animals' body, as organisms at every level of the marine food web ingest microplastics (Ivar do Sul and Costa, 2014), we did not consider this as a component of debris stock, for simplification.

2.3. Boundary of the Sea of Korea

For the model of marine debris flow and stock (Fig. 1), the geographic boundary of the Sea of Korea was calculated using the ArcGIS tool. The result is shown in Fig. 2. The sea was divided into internal waters, territorial seas, and the Exclusive Economic Zone (EEZ). The EEZ in this study excludes territorial seas to avoid duplication when estimating the amount of marine debris. The sea was also divided into the West Sea (Yellow Sea), South Sea (East China Sea), and East Sea. In each area, the length of the coast, the

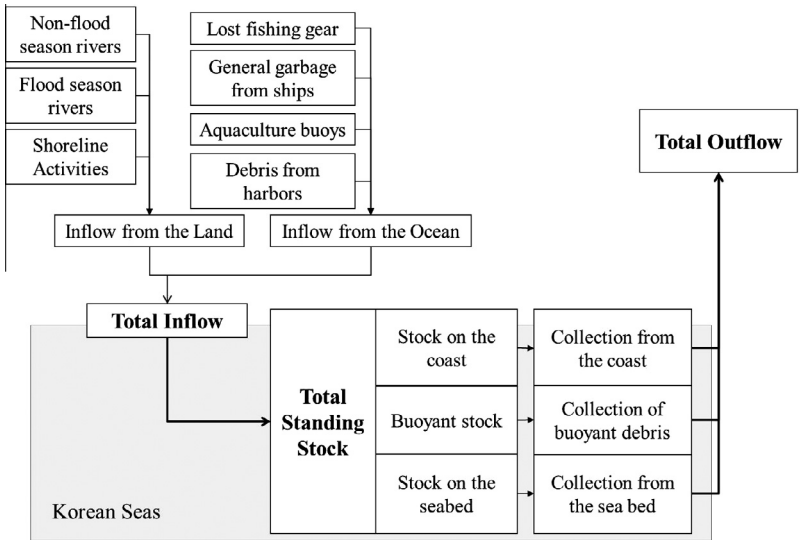

Fig. 1. Model of marine debris flow and stock.