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Ingestion of microplastics by natural zooplankton groups in the northern South China Sea

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ABSTRACT

The ingestion of microplastics by five natural zooplankton groups in the northern South China Sea was studied for the first time and two types of sampling nets (505 μm and 160 μm in mesh size) were compared. The microplastics were detected in zooplankton sampled from 16 stations, with the fibrous microplastics accounting for the largest proportion (70%). The main component of the found microplastics was polyester. The average length of the microplastics was 125 μm and 167 μm for Nets I and II, respectively. The encounter rates of microplastics/zooplankton increased with trophic levels. The average encounter rate of microplastics/zooplankton was 5%, 15%, 34%, 49%, and 120% for Net I, and 8%, 21%, 47%, 60%, and 143% for Net II for copepods, chaetognaths, jellyfish, shrimp, and fish larvae, respectively. The average abundance of microplastics that were ingested by zooplankton was 4.1 pieces/m^3 for Net I and 131.5 pieces/m^3 for Net II.

1. Introduction

The widespread occurrence and accumulation of plastic waste in the environment has become a growing global concern over the last decade (Lonnstedt and Eklov, 2016). Microplastics, the small-sized plastic fragments of <5 mm in size (Moore, 2008), have recently drawn increasing attention due to its high abundance in sea water (Ng and Obbard, 2006) and bioavailability to organisms throughout the food-web (Cole et al., 2011). The sources of these microplastics are extensive, mainly including raw materials used in the plastic industry, plastic particles, plastic debris from the large plastics degraded by various physical processes, additives from common daily items, and polishing material used in the industrial production (Fendall and Sewell, 2009; Thompson et al., 2009). In the past years, most studies have focused on quantifying microplastics abundance in the marine environment (Hidalgo-Ruz et al., 2012). The studies mentioned above covered the coastal area of different countries, the open ocean, and the deep sea (Barnes et al., 2009; Van Cauwenberghe et al., 2013; Law and Thompson, 2014), providing useful information on the background concentrations of microplastics in various environments.

Microplastics can affect marine organisms physically by blocking the alimentary tract upon ingestion (Cole et al., 2013), and chemically by toxic pollutants contained in or absorbed by the plastics (Rochman et al., 2013). Laboratory experiments have indicated that a variety of invertebrates ingest microplastics, including planktonic organisms such as copepods, cladocerans, salps and larval fish (Brown and Heseltine, 1968; Wilson, 1973; Frost, 1977; Kremer and Madin, 1992; Cole et al., 2013; Lonnstedt and Eklov, 2016), and benthos such as lugworms, amphipods, barnacles, holothurians, and blue mussels (Thompson et al., 2004; Browne et al., 2008; Graham and Thompson, 2009; von Moos et al., 2012; Wegner et al., 2012). The majority of the laboratory experiments have revealed the impact of microplastics on the feeding, growth, physiological function, immune system, and the development of the relevant marine biota. In natural ecosystems, microplastic fibers have been reported in Norway lobster (Murray and Cowie, 2011) and Chinese mitten crab (Wójcik-Fudalewska et al., 2016), pelagic and demersal fish (Lusher et al., 2013), mesopelagic fish (Boerger et al., 2010), gooseneck barnacles (Goldstein and Goodwin, 2013), bivalves (Van Cauwenberghe and Janssen, 2014), and zooplankton (Frias et al., 2014; Desforges et al., 2015). The ingestion and accumulation of microplastics in a wide range of marine species ranging from zooplankton to bivalves, crustaceans, and fish indicate the potential for microplastics to accumulate in the marine food chain (Vandermeersch et al., 2015). However, information on the ingestion of microplastics by natural populations and their possible accumulation is scanty (Lusher et al., 2013).

In pelagic ecosystems, zooplankton links the primary producers and the higher trophic levels, thus playing an important role in the marine food web. The ingestion of microplastics by zooplankton serves as an important link to the marine food web, transferring these materials to higher trophic levels along the food chain. It is thus essential to

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understand the ingestion and transfer of microplastics by different groups of zooplankton in natural sea water in order to lay a foundation for the ecological risk assessment of microplastics in natural ecosystems.

The coastal area of China is a hotspot for microplastic pollution (Zhao et al., 2014). Both the diluted water from the Pearl River Estuary and the waters of the South China coast have affected the northern part of the South China Sea. China's annual fishing output in the South China Sea is about 3×10^6 t, and the northern South China Sea is an important fishery ground (Wang et al., 2015). The impact of microplastics on the fishery resources through the transfer of zooplankton is thus of prime concern. To study the ingestion and transfer of microplastics in marine zooplankton in the natural ecosystem, the present study, for the first time, investigated the ingestion of microplastics by five groups of zooplankton in the coastal area of China, which include copepods, chaetognaths, jellyfish, shrimps, and fish larvae. The purpose of this research was to: 1) identify the characteristics of microplastics that are ingested by different groups of zooplankton, 2) determine the encounter rates between microplastics and zooplankton, 3) estimate the abundance of microplastics ingested by zooplankton, 4) discuss the transfer of microplastics between trophic levels in the northern South China Sea.

2. Materials and methods

2.1. Study area

The study area was the northern part of the continental slope of the South China Sea, which encompassed the continental shelf, slope, and deep water area. Samples were collected in June 2015 using the research vessel, Nan Feng. The sampling stations used in the present study are shown in Fig. 1.

2.2. Sampling

The zooplankton samples were collected by vertical tows using conical plankton nets from a depth of 200 m, or 10 m off the seabed when the depth was <200 m, to the surface. The nets were designed according to the Specifications for the Oceanographic Survey of China (2007). Two types of nets were used to compare the ingested microplastics collected by nets with different mesh sizes. Net I was 145 cm in length, 50 cm in the inner diameter of the net mouth, and 505 μm in mesh size. Net II was 140 cm in length, 31.6 cm in the inner diameter of the net mouth, and 160 μm in mesh size. The zooplankton samples were preserved immediately after collection in a formaldehyde solution (final concentration 5%). All samples were split into two equal parts. One part was used for zooplankton abundance analysis, and the other was utilized for microplastics analysis.

2.3. Zooplankton analysis

The zooplankton samples were analyzed with a ZooScan digital imaging system, which was developed in the Laboratory of Oceanography of Villefranche (LOV) (Gorsky et al., 2010). The zooplankton samples were split into suitable fractions with a Motoda Plankton Splitter (Motoda, 1959) until the subsample was dilute enough to allow separation of all organisms in the scanning tray. The samples that were collected using Nets I and II were digitized with the ZooScan at 2400 dpi and 4800 dpi resolution, respectively. Image standardization, separation, and data matrix acquisition were performed using the Zooprocess software. Automatic recognition by supervised-learning was performed with the Plankton Identifier software. The automatic classification of zooplankton was manually validated to ensure the correct classification of the zooplankton groups. The abundance of each group was determined based on the zooplankton abundance per net, which was divided

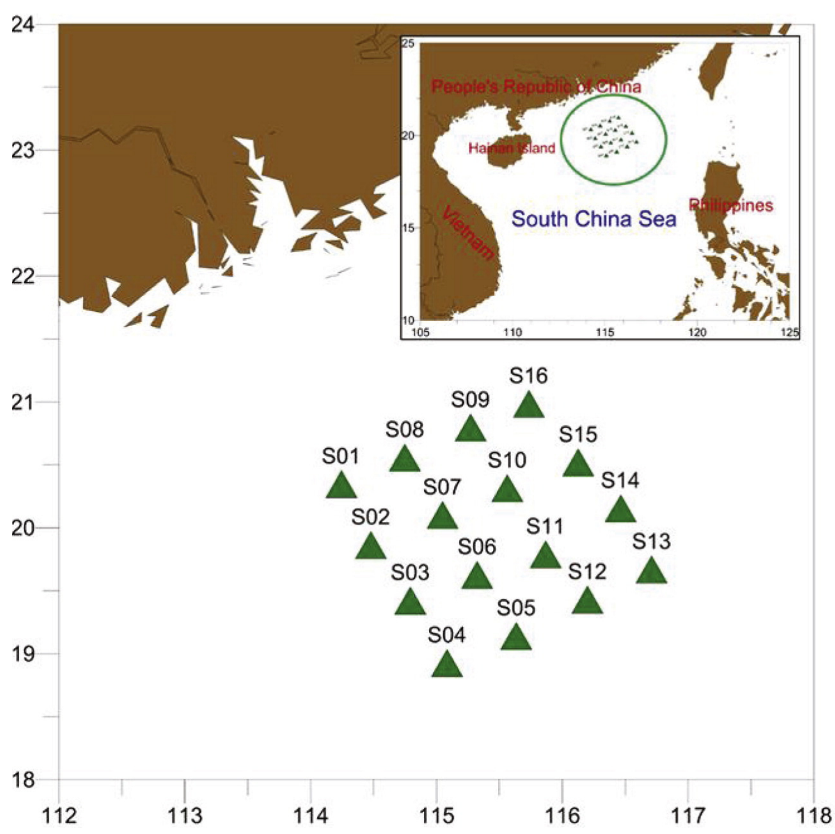

Fig. 1. Sampling stations in the northern part of the South China Sea.

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