Marine Pollution Bulletin xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

A comparative study of marine litter on the seafloor of coastal areas in the Eastern Mediterranean and Black Seas

C. Ioakeimidis [a,b,*], C. Zeri [a], H. Kaberi [a], M. Galatchi [c], K. Antoniadis [d], N. Streftaris [a], F. Galgani [e], E. Papathanassiou [a], G. Papatheodorou [b]

[a] Hellenic Centre for Marine Research, Institute of Oceanography, 19013 Anavyssos, Greece
[b] Laboratory of Marine Geology and Physical Oceanography, Department of Geology, University of Patras, 26500 Patras, Greece
[c] National Institute for Marine Research and Development "Grigore Antipa" Constanta Romania, Blvd Mamaia No. 300, Constanta 3, RO-900581, Romania
[d] Department of Fisheries and Marine Research, Marine Environmental Division, 1416 Nicosia, Cyprus
[e] Institut Français de Recherche pour l'Exploitation de la Mer, LER/PAC/Corse, Imm. Agostini, ZI Furiani, 20600 Bastia, France

ARTICLE INFO

Article history:
Available online xxxx

Keywords:
Litter
Benthic
Pollution
Eastern Mediterranean
Black Sea

ABSTRACT

In the present work, abundance, spatial distribution and qualitative composition, of benthic marine litter, were investigated in five study areas from the Eastern Mediterranean and Black Seas (Saronikos, Patras and Echinades Gulfs; Limassol Gulf; Constanta Bay). Surveys were performed using the monitoring protocol proposed by the Technical Group for Marine Litter. Densities ranged from 24 items/km^2 to 1211 items/km^2, with the Saronikos Gulf being the most affected area. *Plastics* were predominant in all study areas ranging from 45.2% to 95%. *Metals and Glass/Ceramics* reached maximum values of 21.9% and of 22.4%. The size distribution of litter items showed that $\geqslant$50% fall into medium size categories (10×10 cm, 20×20 cm) along with an elevated percentage of small-sized ($<5 \times 5$ cm) plastic litter items. The comparative analysis of the data highlighted the dependence of the marine litter problem on many local factors (human sources and oceanographic conditions) and the urgent need for specific actions.

1. Introduction

In 2012, global production of waste had reached 3.4 million tons and this figure is expected to double by 2025, while about half of this amount concerns non-biodegradable materials (i.e. plastics and metals) (World Bank, 2012). It is an evident fact that much of this waste escapes management schemes and ends up in the environment. More specifically, in the marine environment litter can be transported from land, via rivers, stromwater, wind and sewage, or can be disposed off directly at beaches and at sea (UNEP, 2011). The growing amounts of generated litter and the slow degradation rates result in the accumulation of litter in the oceans and pose a serious threat for healthy oceans and indeed, litter has been found widespread in the global marine environment (Barnes et al., 2009).

The impacts of marine litter on marine life and the environment include deviation in epi-benthic community structure and composition (Katsanevakis et al., 2007); entanglement of organisms especially in derelict fishing gear and 'ghost nets' (Waluda and Staniland, 2013; Adimey et al., 2014; Anderson and Alford, 2014) and ingestion (Goldstein and Goodwin, 2013; Lusher et al., 2013; Anastasopoulou et al., 2013; Bond et al., 2013; Madeira Di Beneditto and Arruda Ramos, 2014). In addition floating litter facilitates the migration of non-native species to other marine regimes. Also it has been demonstrated that microplastic fragments are sources of persistent organic pollutants (POPs) such as phthalates (Lopez-Carillo et al., 2010; Mathalon and Hill, 2014) and have the potential to concentrate POP's on their surface and consequently act as pollutant carriers (Karapanagioti and Klontza, 2007, 2008; Karapanagioti et al., 2011; Bakir et al., 2014; Mizukawa et al., 2013; Ivar do Sul and Costa, 2014) with secondary effects to organisms which eventually digest them.

Benthic litter tend to become trapped in areas of low circulation and high sediment accumulation in contrast to floating litter, which accumulates in frontal areas. Litter that reaches the seabed may already have been transported considerable distance, only sinking when weighed down by entanglement and fouling. The consequence is an accumulation of litter on specific seabed locations in response to local sources and oceanographic conditions

* Corresponding author at: Hellenic Centre for Marine Research, Institute of Oceanography, 46.7km Athens-Souniou Ave., 19013 Anavyssos, Greece. Tel.: +30 22910 76370.
E-mail address: cioakeim@hcmr.gr (C. Ioakeimidis).

http://dx.doi.org/10.1016/j.marpolbul.2014.09.044
0025-326X/

(Galgani et al., 2000; Keller et al., 2010; Watters et al., 2010; Ramirez-Lolodra et al., 2013; Pham et al., 2013).

Marine litter has been an issue of concern by the United Nations Environment Programme since the early 1970s (UNEP, 2011). In Europe, Marine Strategy Framework Directive (MSFD) (2008/56/EC) has been developed in order to protect the marine environment as well as to ensure its sustainable use. The ultimate goal of MSFD is the achievement of Good Environmental Status (GES) for the marine environment and the *Clean Seas by 2020*, by the Member States. MSFD is based on eleven Descriptors and sets targets for each Descriptor that should be met in order to achieve the GES. Marine litter is addressed as Descriptor 10: "*Properties and quantities of marine litter do not cause harm to the coastal and marine environment*".

A first step to understanding and alleviating the problem of marine litter is to quantify the existing amounts. Especially for the implementation of the MSFD, this information is urgently needed for setting the targets of Descriptor 10 – Marine Litter. Information on marine litter quantities and distribution in the Mediterranean Sea is still fragmented and its impacts on the marine ecosystem have not been properly addressed. To date, systematic studies dealing with benthic litter have focused on the western Mediterranean Sea (Galgani et al., 1995, 1996, 2000; Ramirez-Llodra et al., 2013; Pham et al., 2013) while for the Eastern Mediterranean Sea relevant information covers only few geographical areas (Galil et al., 1995; Koutsodendritis et al., 2008; Stefatos et al., 1999; Katsanevakis and Katsarou, 2004; Sanchez et al., 2013). In the Black Sea, only one reported work deals with the occurrence and distribution of benthic litter on the western continental shelf in the vicinity of Bosphorus Straits (Topçu and Oztürk, 2010). Therefore, more efforts are needed in order to resolve many scientific questions and to provide the stakeholders on the regional and national levels, with the appropriate information and knowledge.

The objective of this study is to determine the abundance, spatial distribution and qualitative composition of benthic marine litter as well as to investigate the factors affecting benthic litter accumulation and distribution (external sources *vs* internal transport mechanisms) in five selected study areas in the Eastern Mediterranean (Saronikos, Echinades, Patras Gulfs in Greece, Limassol Gulf in Cyprus) and Black Seas (Constanta Bay in Romania). The monitoring protocol proposed by the Technical Group on Marine Litter was applied throughout our surveys (Galgani et al., 2013b). Up to our knowledge, this is the first comparative study on benthic marine litter including several coastal areas in the interconnected Eastern Mediterranean and Black Seas. In particular for three of our study areas (Saronikos Gulf, Limassol Gulf, Constanta Bay), the present work provides the first recorded data on benthic marine litter.

2. Study areas

Benthic marine litter was investigated in the Saronikos Gulf (SR), the Gulf of Patras (PT), the Echinades Gulf (EC) in Greece; the Limassol Gulf (LM) in Cyprus and in the Constanta Bay (CN) in Romania (Fig. 1).

Saronikos Gulf is located in the South Aegean Sea. It is a semi-enclosed gulf (2600 km^2) which practically constitutes the sea border of the metropolitan city of Athens and the alongshore outskirts (Attica region; approx. 4 million inhabitants). The Piraeus city-port (~17,525 arrivals in 2013; www.olp.gr) is located at its northeastern edge. Saronikos Gulf is characterized by extreme marine navigation, tourism and well-developed fisheries (professional and recreational). Our samplings covered the western basin of the gulf, which is basically an elongated north–south trough with maximum depths of ~220 m in the north and ~450 m in the south consisting the deepest part of the gulf.

The Gulf of Patras and the Echinades Gulf are interconnected and located in the Ionian Sea. The Echinades Gulf is formed by the Greek mainland and the islands of Kefalonia and Ithaki with maximum water depth of about 350 m. The Echinades Gulf connects the Gulf of Patras with the Ionian Sea. The coastal area of the gulf is used for agriculture without important population nuclei. Approximately 150 shipping routes are recorded weekly, connecting the city of Patras to the Ionian Islands and Italy. Moreover, the gulf is considered as one of the most important fishing grounds and aquaculture of the Ionian Sea. A major river, Acheloos River, flows to the Echinades Gulf with an average annual flow of about 7800×10^6 m^3 of water. The Gulf of Patras constitutes a relatively shallow (max 150 m depth), semi-enclosed gulf (400 km^2), to the east of the Echinades Gulf. The coasts around the Gulf of Patras are urbanized (the city of Patras hosts ~250,000 inhabitants); marine navigation (Patras port ~1923 arrivals in 2013; www.patrasport.gr), tourism and well-developed professional and recreational fisheries are the major anthropogenic activities in the gulf. River runoffs (Evinos River, Pyros and Glaucus torrents) have a small contribution in total water transfer into the Gulf of Patras, but may have an important contribution in solid waste transfer especially during heavy rain events.

Limassol Gulf in Cyprus is open to the Levantine Sea (Eastern Mediterranean Sea). The greater Limassol area counts approx. 192,000 inhabitants (2011, www.mof.gov.cy/cystat). Marine navigation is considered intense (Limassol port 3430 vessel arrivals in 2013; www.cpa.gov.cy) while professional fisheries are moderate. Limassol Gulf receives the effects of various kinds of pressures (urbanization, tourism, commercial, industry, crafts, warehouses and aquaculture).

Constanta Bay is located in the NW Black Sea. It receives the impact of Constanta city, the second biggest city in Romania (425,916 inhabitants – INSSE 2011) and also the most important urban center for the whole Romanian coastal zone. The large protected deltaic zone, including the Danube Delta is located in the northern Romanian coastal zone. Marine navigation is considered extreme due to the presence of the port of Constanta (14,066 arrivals in 2013; www.portofconstantza.com), the biggest port in the Black Sea. Professional and recreational fisheries are considered as intense.

In the following Table 1, are summarized the pressures related to marine litter generating activities for the different study areas.

3. Methodology

3.1. Survey design

Benthic marine litter items were collected in the selected areas (SR, PT, EC, LM, CN) during the period January to March 2013. In the Mediterranean Sea (SR, PT, EC, LM) marine litter items were collected by professional trawlers. For each study-area, marine litter was collected by the same trawler in order to ensure data homogeneity and quality control. In the Black Sea (CN) marine litter items were collected by the R/V "Sea Star". In Table 2, the characteristics of the vessels used in the surveys are summarized.

In total 94 trawlings were conducted in the studied areas (SR: 41; PT: 18; EC: 10; LM: 9; CN: 16) corresponding to a total of 713.6 km of surveyed area (SR: 207.1 km; PT: 192.6 km; EC 125.7 km; LM: 112.3 km; CN: 75.9 km). All five areas are commonly used fishing grounds. Bottom trawlers with otter operate in Saronikos, Echinades and Limassol Gulfs 8 months per year, and in the Gulf of Patras 3 months per year. It should be mentioned here that sampling with bottom trawlers can only be applied in sandy or muddy substrates and not in rocky substrates.

Please cite this article in press as: Ioakeimidis, C., et al. A comparative study of marine litter on the seafloor of coastal areas in the Eastern Mediterranean and Black Seas. Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.09.044