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SHORT PAPER

Marine Litter Quantification in the Black Sea: A Pilot Assessment

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Abstract

Various programs and organizations (IMO, UNEP, IOC UNESCO, FAO) and recently the EU MSFD recognized marine litter (ML) as an issue of global threat from environmental, economic, human health and safety, and aesthetic aspect. Among the efforts to combat the problem adequate monitoring and application of harmonized methodological approaches for quantification are essential. This research presents the results of a pilot assessment of bottom ML in the Black Sea during the MISIS Project Joint Black Sea Cruise (22–31 August, 2013) along 3 transects in the NW Black Sea. The aim of the present study is a pilot quantitative assessment of bottom.

Keywords: Marine litter, NW Black Sea, coastal seafloor, shelf seafloor, ROV survey.

Introduction

According to "Marine Litter (ML) analytical overview (UNEP, 2005) about 6.4 million tons of debris are disposed in the ocean each year, weighing about the same as a million elephants, while over 13 000 pieces of plastic litter are floating on every km^2. Studies of ML in the Black Sea region are very scarce and fragmented. Single vessel-based transect surveys estimations range between 6.6 and 65.7 items/km^2 of floating plastics (UNEP 2009). According to some reports (BSC 2009, UNEP 2009, Topcu et al. 2012) municipal waste/sewage, landfills and marine transport were identified as the most important sources of ML, wheres ARCADIS Report (2013) top-ranked recreational and tourism activities contributing to 45%. Illegal, unreported and unregulated (IUU) fishing in the Black and Azov Seas has also been considered an important source of ML due to discarded and abandoned nets ("ghost" fishing), although comprehensive specific studies are very limited (Birkun, 2002, Radu et al., 2003).

The aim of the present study was to conduct a pilot quantitative assessment of bottom ML in selected North Western Black Sea coastal and shelf areas and test the applicability of Remote Operational Vehicle (ROV) applying the methodology reccomended by Marine Strategy Framework Directive (MSFD) Guidance (2013).

Material and Methods

Study Area

The pilot survey of bottom ML was conducted during the MISIS Project Joint Black Sea Cruise (22–31 August, 2013) along 3 transects in the North-Western Black Sea - in front of Romania, Bulgaria and Turkey, at 6 polygons (Figure 1, Table 1).

The surveyed sites were selected so as to ensure that they cover one coastal and one shelf area along the polygon of each country and have similar characteristics regarding generation/accumulation of ML as recommended by UNEP (Cheshire et al., 2009).

Methods

The methodology was in compliance to MSFD GES TSG-ML Monitoring Guidance (2013) for large scale evaluation and monitoring of sea-floor ML. ML was collected by towing a beam trawl (2.5 m width and mesh size aperture 5 cm) at a speed of 2.5 – 3 knots. The hauls were positioned following a depth stratified scheme in the coastal (23–35m) and shelf bottom (depths within 40–69m) (Table 1). All collected items were measured on board, sorted by type of the material and size. The integrated data from 3–4 tows per site were averaged per km^2, according

Table 1. Coordinates of sampling polygons and trawled area

Polygon	Depth [m]	Start		End		Dredged area [m^2]
		Latitude	Longitude	Latitude	Longitude	
P1-Ro	33.0	44°10.125'N	028°48.973'E	44°10.121'N	028°49.349'E	1250
P2-Ro	65.0	44°10.103'N	029°40.399'E	44°10.101'N	029°42.918'E	4600
P3-Bg	24.0	43°09.999'N	028°10.026'E	43°10.074'N	028°18.771'E	7925
P4-Bg	69.0	43°08.790'N	028°27.147'E	43°09.066'N	028°27.110'E	1280
P5-Tr	38.0	41°50.763'N	028°01.808'E	41°50.234'N	028°02.191'E	3550
P6-Tr	67.0	41°52.495'N	028°07.455'E	44°10.121'N	028°49.349'E	1250

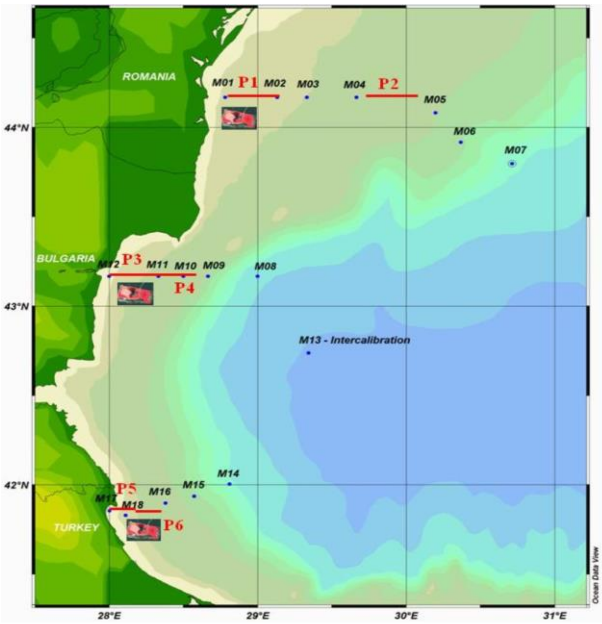

Figure 1. Map of sampling polygons.

to the classification system in the Monitoring Guidance (2013). The trawled area at each polygon is presented in Table 1.

In addition to trawling, in the coastal bed (depth of ~ 40 m), the ROV (Remote Operating Vehicle) “Diablo” (Mariscope) was deployed in order to test its applicability to detect and quantify ML (full details of the vehicle are provided bellow).

ROV Specification:

Model: Mariscope FO 200
Length: 1300 mm
Weight: 65 kg
Highest horizontal velocity: 4 kn
Operating horizontal velocity: 2 kn
Maximal depth: 300 m
Maximal operating depth: 150 m
Image resolution: 500 × 582 px
Camera resolution: 330 lines
Camera focus: 3.5 mm
Camera horizontal viewing angle: 52° (in water)
Navigation: sonar, compass

Results

Trawl survey

The polygons surveyed area ranged from 1250 to 7925 m^2, covering a total of 19 855 m^2 (~ 0.02 km^{-2}). The abundance and distribution of ML showed considerable spatial variability. Marine debris densities ranged from 304 to 20 000 items/km^2 in average - 6359 items/km^2 (SE = 2015). The number of items decreased from north to south with maximum in front of Romanian coast (Figure 2). The densities were approximately 3 times less in front of Bulgaria (9598 items/km^2) and Turkey (7956 items/km^2). In coastal areas (< 40 m depth), the abundance of ML was generally much higher than on the continental shelf. In the three coastal polygons, fishing and tourism related activities obviously contributed significantly to littering of the seafloor. The marine debris at the coastal sites (9234 items/km^2) exceeded about two times shelf density (5603 items/km^2), the only exception was the observed area in front of Bulgaria (Figure 2).

By material the most frequent and abundant debris were plastics, constituting ~ 68 % (Figure 3). A high variety of marine litter was accumulated in polygon P2 (natural products – 50 %, metals – 9 %, miscellaneous – 16 %), while metal dominated in polyon P1, accounting for more than 90 % (Figure 3). The nature of the ML suggested mainly shipping/fishing origin (Figure 4).

By size categories "B" size (100 cm^2) fragments of marine debris were the most common fraction found in the study area, contributing to 67 %. Plastics dominated in all size categories between A-D, while the large (E) size class was represented by metal (Figure 5).

Remote Operating Vehicle (ROV) Test

As one of the critical elements in application of ROV is the adequacy of observation regarding the size of the object the following equation was theoretically derived:

$$l = k_h \times l_h \times h \times tg\left(\frac{\pi}{2} - \alpha + k_v \times l_v\right) \quad (1)$$

where:

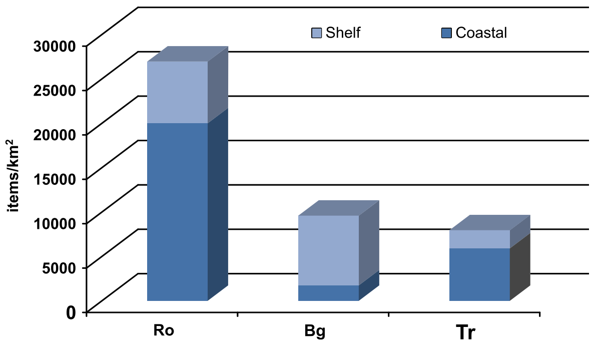

Figure 2. Coastal –shelf distribution of marine litter integrated by transects in the NW Black Sea.

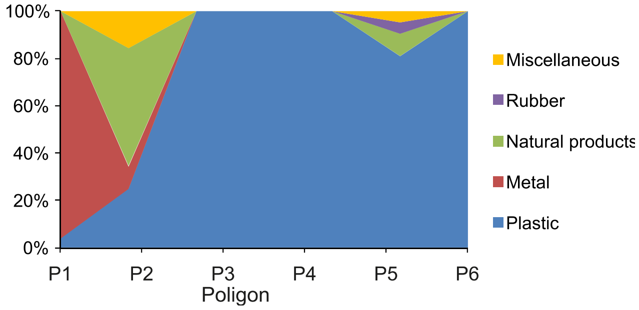

Figure 3. Composition of marine debris found on sea-floor (24 – 69 m) surveys off Romania-Bulgaria and Turkey by polygons (P).

Figure 4. Litter sorting.

l –dimensions of an object on a horizontal surface detected on a ROV camera image [units of h];

k_h –image horizontal angular coefficient (0.0091rad/%);

l_h–horizontal object partition in the image [% of image width];

h –vertical elevation of the camera from the horizontal surface;

α – angle of camera tilt [rad];

k_v–image vertical angular coefficient (0.0067 rad/%);

l_v – object vertical distance from the image centre [% of image height].

The equation was calibrated over standard objects and tested in working conditions during the Cruise: depth 23 m, at horizontal visibility 4 m and underwater current – 0.5– 1kn (S).

The bottom area surveyed was estimated to be 280sq.m per minute.

Five test objects were selected (Figure 6): a grab trace with known size – width 36 cm (used for formula calibration), a pile of sea grass with calculated length of 23 cm, a goby fish with calculated length of 17 cm, a Rapana snail with calculated length of 12 cm and a metal frame with calculated width of 8 cm. Vertical proportions marked on Figure 5 were used as l_v and horizontal ones – as l_h in equation (1). The angle of the camera tilt – α, and the vertical elevation – h were controlled by the operator. The other two parameters – k_h and v_h, were derived by the camera specifications and tested practically.

The test results suggest that image resolution was sufficient to eliminate the interference on the measurement error, but the accuracy would be high enough at object size over 5 cm, water current less than 1 kn, depth less than 100 m at optimal carrying vessel tonnage 10BRT.

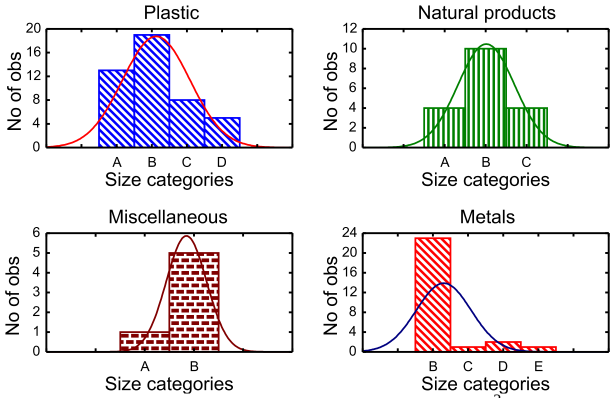

Figure 5. Histograms of ML size distribution by material A: < 5 * 5 cm = 25 cm^2, B: < 10 * 10 cm = 100 cm^2, C: < 20 * 20 cm = 400 cm^2, D: < 50 * 50 cm = 2500 cm^2, E: < 100 * 100 cm = 10 000 cm^2 = 1 m^2, F: > 100 * 100 cm = 10 000 cm^2= 1 m^2.

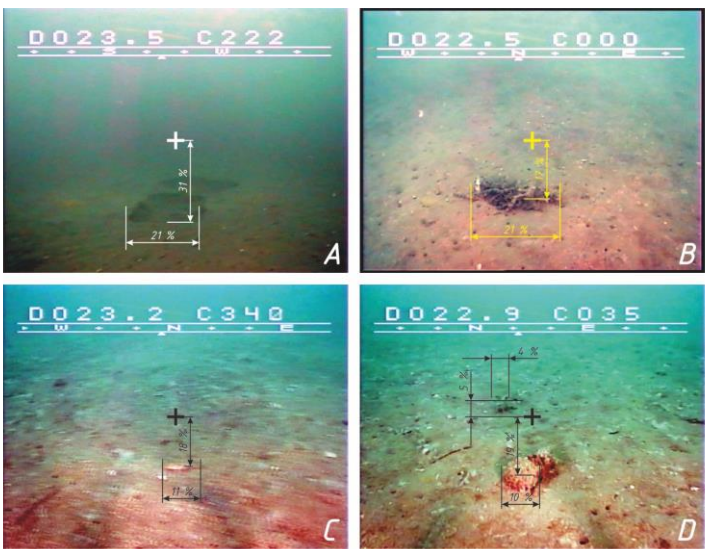

Figure 6. A. Grab trace (lights are off in order to eliminate turbidity); B. Pile of sea grass; C. Goby; D. *Rapana venosa* (in front) and a metal frame.

Discussion

Escalating concern about marine debris has been driven by the rapid and widespread accumulation of persistent plastics, representing between 75 % – 83 % of all items found globally and in Europe (Barnes et al., 2009; Gregory, 2009; Moore, 2008, UNEP/MAP, 2009). Plastic was the most common debris material found in our study (68 %) which was quite in line with the global findings. The average quantity of ML found in the NW Black Sea during this survey (6359 ± 2015 items/km^2) was an order of magnitude higher than the amount (126 ± 82 items/km^2) reported for example for the western Baltic Sea (Galgani et al. 2000), although significant ambiguity could be associated to differences in methods used for sampling and analysis.

The marine debris at the coastal area were found to exceed about two times shelf density related most likely to the proximity to land-based sources, intensive human activities in the coastal marine domain and accumulation on the bottom due to weaker currents (Barnes et al. 2009, Katsanevakis, 2009, Katsanevakis & Katsarou, 2004). The high ML density observed in the Bulgarian shelf polygon could be associated to the intensive fishing and shipping in this particular area (Initial Assessment report, 2013). In addition Barnes et al. (2009) discussed existing accumulation zones offshore with very high debris densities despite being far from coasts, related to a number of factors such as prevailing wind, currents, eddy circulation patterns and convergence zone of seabed sediment movements. Thus natural dispersal of floating and suspended ML by wind and sea currents represents a transboundary problem that needs basin scale concerted management strategies of different sectoral activities.

Solid waste management is one of the major environmental problems in the Black Sea region and is a likely source of marine litter especially in the shallow areas (Celik, 2002). Berkun et al. (2005) reported municipal and industrial solid wastes were dumped on nearby lowlands or directly to the sea on the southern coast of the Black Sea. The ML management is further complicated by the lack of consistent monitoring programs and data at regional and global scale.

Conclusions

Even if limited in time and spatial coverage the results represent a pilot effort for quantitative estimates of ML in the Black Sea bottom. The test of ROV offer useful practical information which altogether can be used to refine the design of monitoring programmes and suggest options for “statistical power introducing criteria”. The study implies the TSG-ML Guidelines methodology for collection, classification and quantification of litter, data integration, analysis and reporting as a tool for ML assessment in a harmonised way. However an accurate and meaningful estimation of ML distribution and density could be achieved only in the context of a broader regional management framework ensuring a large-scale integrated monitoring across countries and environments (beaches, water column and sea floor) complemented by adequate understanding of the hydrodynamic features and bottomscape of the marine environment. To this end monitoring programmes for demersal fish stock assessment combined with on-going monitoring of benthic communities using an harmonized protocol may provide consistent support for monitoring litter at Black Sea basin-wide scale on a regular basis at relatively low cost. The value of ML quantification can be empowered only by the identification of the main sources of pollution and further research on the potential harm on biota and the marine environment to enable a more target-orientated implementation of measures.

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