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Scale, origin and spatial distribution of marine litter pollution in the Lithuanian coastal zone of the Baltic Sea

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Abstract The first attempt to investigate the marine litter pollution level of the Lithuanian coastal zone was carried out based on different marine litter monitoring methods and according to the lists of identifiable items. The results have proven that plastic is the dominant type of marine litter. It seems that tourism and fishery related marine litter occurrence do not significantly depend on seasonal variations. The outcome of the study will serve as basic information for future inventory of the character of marine pollution, provide the scientifically grounded limit value for Good Environmental Status (GES) assessment in the Lithuanian coastal zone, and will contribute for the enhancement of the ecological status of the south–eastern coasts of the Baltic Sea.

Keywords *• marine litter • plastics in marine environment • good environmental status*

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INTRODUCTION

The understanding of growing pressure on natural marine resources has resulted in the first legislative instrument developed by the European Union - Marine Strategy Framework Directive (MSFD) aiming to achieve Good Environmental Status (GES) of the EU's marine waters by 2020. The key objective is protection of marine resources ensuring the effective growth of marine related economy and social welfare. Marine pollution (litter and chemical compounds) is one of the main target areas covered by the Directive.

This study focuses on variety and abundance of litter in the marine environment. Both due to the intensity of littering (gaps in litter management policy) and caused by persistency of the materials that has the potential to stay none disintegrated for centuries. The potential negative impact became even more significant since Eduard Simon's discovered the polystyrene in 1839 along with extensive development of modern plastics in the first half of 20 century. This has determined that majority of the solid waste contain synthetic elements and plastics. According to Plastics Europe Report (2013) a continuous growth for more than 50 years resulted in annual production of plastics of 288 million tons worldwide and 57 million tons in Europe (for year 2012).

Little quantitative information is available on amounts of plastics getting into the marine environment. However, it is suggested that as much as 10 % of all plastic litter end up in the sea (Thompson 2006). This would mean that presently 5.7 million tons of plastics produced in Europe per year would eventually find their way to the seas or oceans.

Beached marine litter (BML) is one of the most obvious signs of marine litter pollution. The sources of litter found on the coastline can be land- or sea-based. Major land based sources include tourism, recreation, illegal dumping, waste disposal sites, input from rivers, sewage and storm water outflows. Survey of litter stranded on the coastline is a primary tool for monitoring the load of litter in the marine environment and have been used worldwide (Walker *et al.* 1997; Kusui, Nora 2003; Ryan *et al.* 2009; Ribic *et al.* 2012) to quantify and describe marine litter pollution. It can also be used

to measure the effectiveness of management or mitigation measures and activities leading to litter pollution and threats to marine biota and ecosystems (Cheshire *et al.* 2009). An evaluation of the sources and scale of the littering in marine environment allows assessing the possible impacts and/or take measures for some scenarios to manage the consequences.

MATERIAL AND METHODS

The Lithuanian coastal zone accommodates Kuršių Nerija National and Pajūris Regional parks, Klaipėda Port and city, Palanga city and Šventoji settlement. Several recreational areas are located along the Lithuanian coastal zone, of which the most important is the Palanga resort. Four different beaches (Fig. 1) were selected for survey of beached marine litter following these criteria:

- composed of sand or gravel;
- exposed to open sea;
- free of permanent and temporal buildings all year round;
- having different functional use;
- maintained using different litter cleaning techniques/strategy;
- a minimum length of 100 m and, if possible, over 1 km in length.

All beaches used in this research are subnatural recreational areas, however often visited. Palanga (B1) and Melnragė (B4) beaches are zones of intensive recreational activities. In contrast, Nemirseta (B2) and Karklė (B3) locations face more scattered tourism attention. The study sites are located in different dynamic zones of the coastline. As is described (Bagdanavičiūtė *et al.* 2012; Žilinskas 2008), B1 and B3 beaches belong to the accumulative, B2 and B4 – to erosional type of the coast. Apart of Karklė beach, which is part of protected area, all beaches are subjects of beach cleaning during the summer season.

Beached marine litter in the selected sites was investigated during eight surveys (four for each season in 2012 and 2013). Four 100 m long beach transects were surveyed according to the Guidelines for Monitoring Marine litter on the Beaches in OSPAR Maritime area (OSPAR, 2010). All locations were investigated on the same day and usually several days after a stormy weather. The selected transects were georeferenced using a GPS device. Survey was not carried out if the conditions were unfavorable or beach sand was covered by ice/snow.

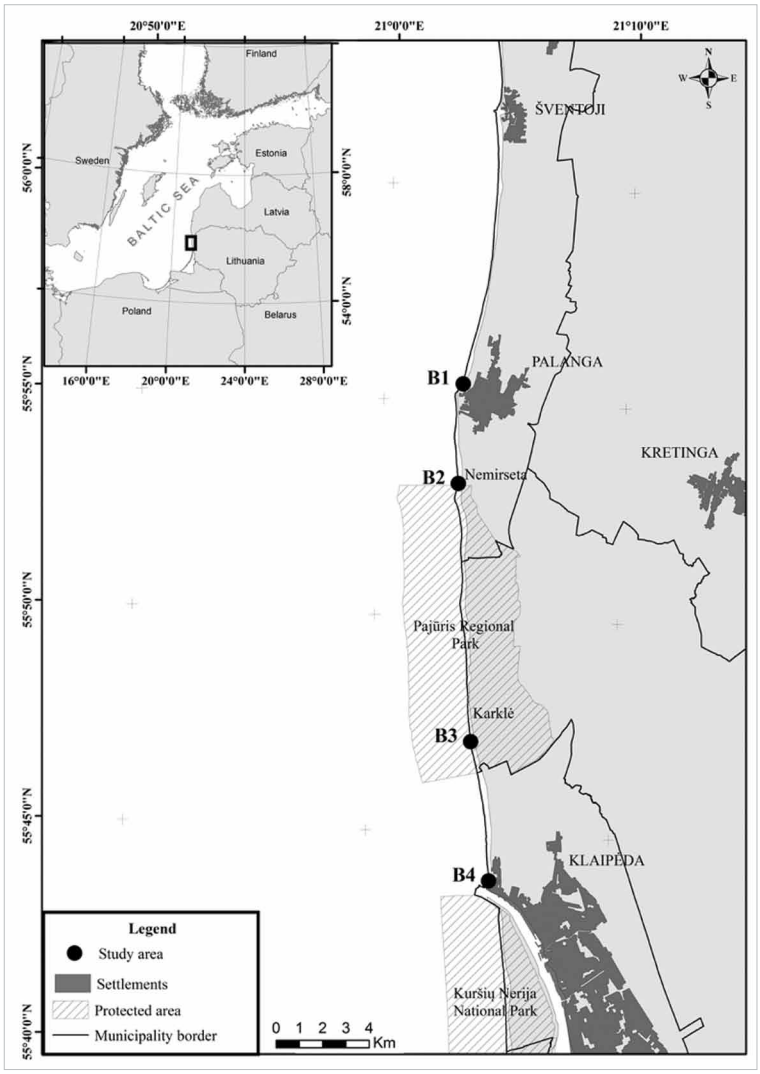

Fig. 1 The study sites. Compiled by A. Balčiūnas, 2014.

The classification of the BML was done according to the list provided in OSPAR guidelines (OSPAR, 2010) and expert judgement based on the UNEP guidelines (Cheshire *et al.* 2009) and Eda *et al*. (2012) research. This was done in order to associate the litter to the different possible functional use and/or source. Total of 67 different object types were collected but only 14 types were regularly found during each survey, therefore selected for comparative analysis (Table 1). Items of litter that were not regularly found (i.e. toys, shoes, wooden pallets, etc.) and those which functional use was hard to determine were attributed to 'other objects' category.

Data was analyzed statistically using SPSS software. Rank correlation coefficient *Spearman-rho* was used in order to determine whether amounts of BML items found differ significantly in different locations and across the seasons.

Even though, Lithuania is HELCOM country with established recommendation for identification of marine litter (Recommendation 29/2), our results show, that list of different identifiable litter items in OSPAR Guidelines is more suitable for BML survey. The main difference is number of identifiable litter items which is more extensive in OSPAR Guidelines if compared with the one presented in HELCOM recommendations (113 and 67 types respectively). Broader list allows identification of litter source being

Table 1 Types of collected BML. Compiled by A. Balčiūnas, 2014.

OSPAR ID	Object type
46	Expanded polystyrene (EPS)
46	Plastic/polystyrene pieces 2,5 cm > < 50 cm
3	Small plastic bags, e.g., freezer bags
4	Drinks (bottles, containers and drums)
6	Food containers incl. fast food containers
15	Caps/lids
21	Cups
32	String and cord (diameter less than 1 cm)
33	Tangled nets/cord/rope and string
64	Cigarette butts
78	Drink cans
--	Other objects
--	Sum of all objects originating from tourism (Sum tourism)
--	Sum of all objects originating from fishing (Sum fishing)

more precise. Nine litter items, such as crab/lobster pots, oyster nets or mussel bags including plastic stoppers, octopus pots, etc., which are associated with specific marine species and not associated with Lithuanian coastal zone were dismissed as not relevant for this particular research area (Table 2).

Table 2 Comparison of different marine litter monitoring methods. Compiled by A. Balčiūnas, 2014.

Marine litter category	Number of identifiable items		Not relevant
	OSPAR guidelines	HELCOM recommendation	
Plastic/ Polystyrene	54	22	6
Rubber	4	6	--
Cloth	5	5	--
Paper/ Cardboard	9	8	--
Wood (machined)	9	4	1
Metal	15	10	1
Glass	3	3	--
Pottery/ Ceramics	3	2	1
Sanitary waste	6	6	--
Medical waste	3		--
Bagged dog faeces	1	--	--
Other pollutants	1	1	--
Total	**113**	**67**	**9**

RESULTS

Composition of BML

The analysis of all collected items on the selected beaches revealed that the dominant litter is plastic and

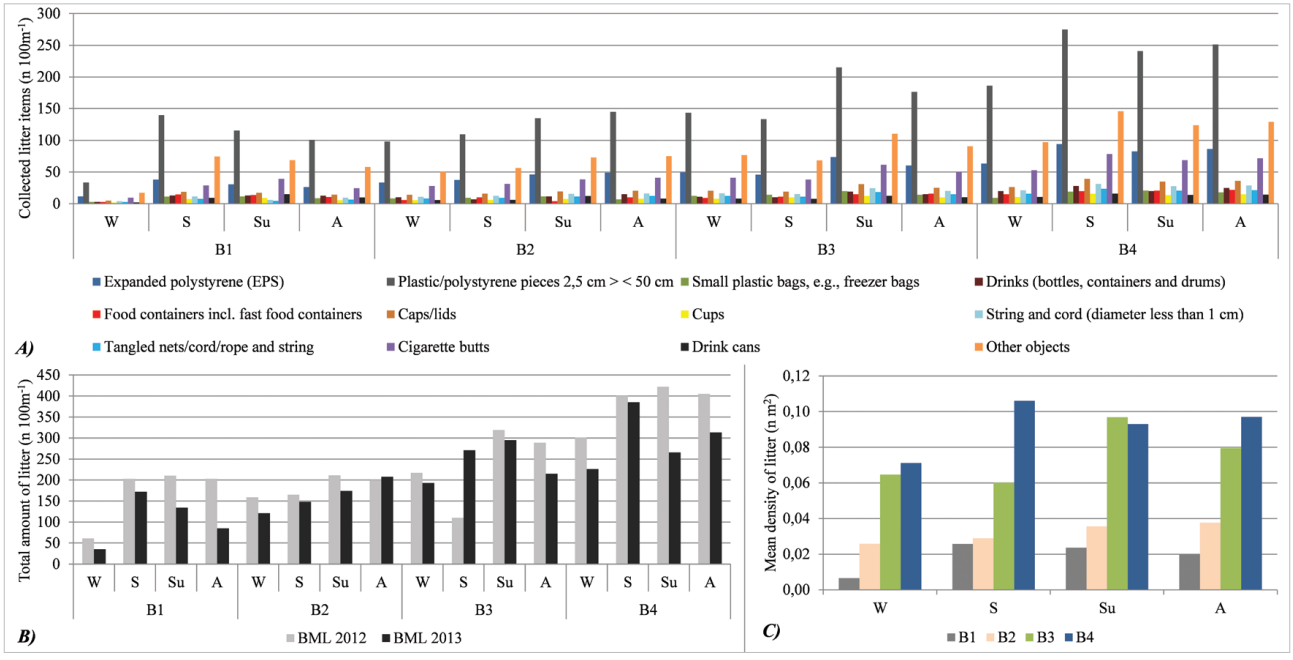

Fig. 2 Seasonal variation of BML (W – winter, S – spring, Su – summer, A – autumn): A – types of collected litter; B – total amounts of BML; C – mean densities of BML. Compiled by A. Balčiūnas, 2014.

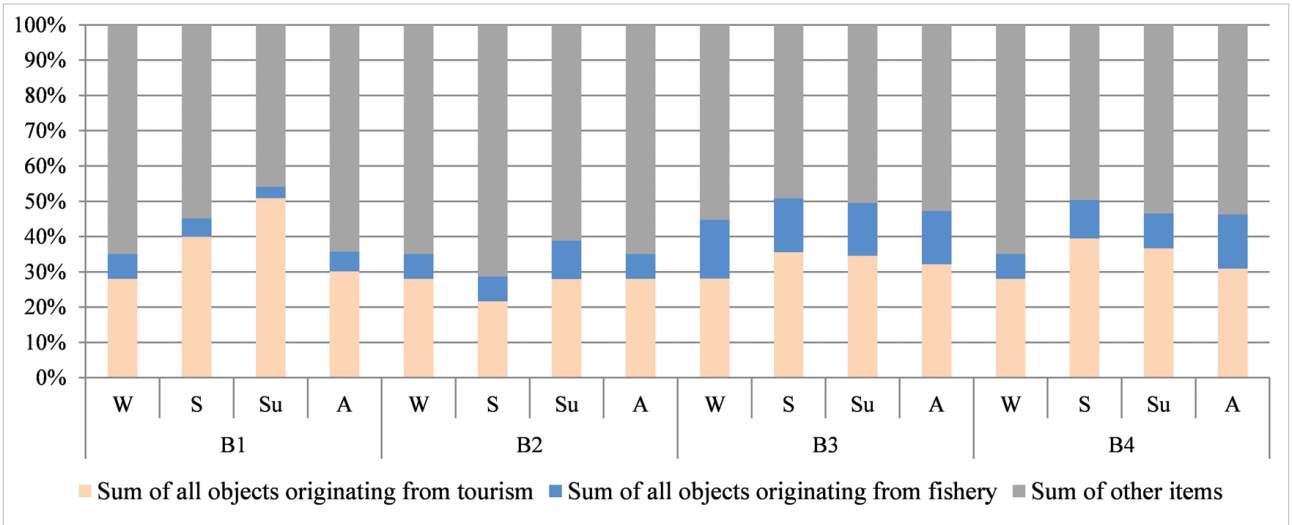

Fig. 3 Distribution of the BML according the source of pollution (W – winter, S – spring, Su – summer, A – autumn). Compiled by A. Balčiūnas, 2014.

Table 3 BML composition. Compiled by A. Balčiūnas, 2014.

Categories	B1		B2		B3		B4	
	amount	%	amount	%	amount	%	amount	%
Plastic / Polystyrene	803	72.7	1041	75.1	1352	70.8	1990	73.2
Paper / Cardboard	118	10.7	150	10.9	191	10.0	334	12.3
Glass	36	3.3	49	3.5	60	3.2	85	3.1
Wood (machined)	11	1.0	20	1.4	120	6.3	23	0.8
Rubber	18	1.7	20	1.4	52	2.6	51	1.9
Textile	32	2.9	40	2.9	68	3.6	76	2.8
Metal	83	7.5	65	4.7	66	3.5	156	5.8
Other	3	0.2	1	0.1	--	--	3	0.1
Total	1104		1386		1909		2718	

polystyrene (Fig. 2A). The amount of plastic ranges from 70.8 % (calculated for B3) to 75.1 % (found at B2 location; for locations see Fig. 1) of 7117 items collected. Paper and cardboard type marine litter, which mainly consisted of cigarette butts, were most abundant at B4 location (334 items or 12.3 %). Largest proportion of wooden (6.3 %), rubber (2.6 %) and textile (3.6 %) items were identified at B3 location. Metallic particles were most common (7.5 %) for B1 location (Table 3).

Data does not show significant difference in the proportions of different BML if comparing the sites of concentrated and scattered touristic activities. The same is true for erosional and accumulative type of beaches – i.e. no significant difference as well. The most abundant material of BML identified in all studied sites was the plastic of high and low density, with particle diameter between 2.5 and 50 cm (35 % in average of total identified items). Expanded polystyrene is also worth mentioning, as the most common object (28.5 %) of plastic/polystyrene category.

Season-wise, no dependencies were evident. During the survey of summer 2012, the highest amounts of BML items were found in all locations. However, following year highest amounts were recorded during spring (for B1 and B4), autumn (for B2) and summer (B3) (Fig. 2B). Mean density of BML was 0.05 objects per square meter and varied from 0.01 items/m^{-2} at Palanga beach to 0.11 items/m^{-2} at B4 location (Fig. 2C).

Origin of BML

Categorization of BML according to the possible sources showed that origin was not possible to determine for 56 % of collected BML (these items were classed as "others"), tourism related items share is 33 % (2349 items) and fishery related litter share is 11 % (783 items) of total identified objects. A total of 272 string/cord (diameter less than 1 cm) and 202

tangled nets/cord/rope and string items, respectively counts 35 % and 26 % of the fishery related category.

Cigarette butts are dominating litter of the tourism related category - 30 % (704) of the all items in this category. In addition, common items of this category were caps and lids (15 %), drinking bottles (9 %) and cans (6 %). Identified source of the litter varies depending on the season and location (Fig. 3). Tourism related marine litter items showed weak seasonal dependency, but were most abundant during spring and summer surveys.

Table 4 Results of non-parametric correlation analysis. *Spearman rho* correlation coefficients are given as measures of significant variable differences. Compiled by A. Balčiūnas, 2014.

Variable / Dependent variable	Sampling location	Year	Season
Total objects found	0.380	-0.097	0.161
Sum of all objects originating from tourism	0.730	-0.203	0.332
Sum of all objects originating from fishery	0.869	-0.142	0.243

Both tourism and fishery related BML strongly depend on the location indicating importance of functional use of the coast (Table 4). Even though B1 location was least littered it had the highest amount of tourism related BML items during the summer periods (>50 % of identified items), in comparison to other beaches. Fishery related items, such as tangled nets/cord/rope and string or fishing lines, etc., made 15.5 % (~37 items) of total identified objects in B3 and 11.2 % in B4 beach and were most abundant compared to other beaches.

Most of the identified litter had no evidence of marine organisms attached. This fact indicates, that period spent at sea floating/submerged was rather short and therefore allows interpreting that main sources of pollution are local.

DISCUSSION

If compared with results for the North Sea region, where amount of BML may vary from 236 items/100 m (MONAS, 2014) to 6429 items described by Cauwenberghe *et al.* (2013), amount of the litter on south-eastern Baltic coast is much lower, but relatively higher that observed in Central Baltics. Even though around 46 percent of marine litter is associated to land based activities (MONAS, 2014), not all of the items found on the beaches are possible to link to the source of pollution. Recent survey on beached marine litter carried out for the Central Baltic Sea area (MARLIN, 2013) has shown that the amount of litter might range from 75.5 items/100 m on rural beaches to 236.6 items/100 m on urban beaches.

High dominance of plastics in the marine environment is widely reported (Willoughby *et al.* 1997; Widmer, Hennemann 2010; Otley, Ingham 2003; Cauwenberghe *et al.* 2013) and is mainly due to their high persistence in the environment. Pollution by cigarette butts is easily attributed to tourism activities (smoking while visiting beach). This fact could serve in development of explanatory indicator of tourist environmental consciousness and of public regulation efficiency. As smoking at the beach is only allowed in specially prepared places in Lithuanian beaches this research clearly indicates that smoking related pollution at the beach is managed inefficiently. Ratio between tourism and fishing related items show that B1 beach pollution is more related to tourism; fishing activities have highest negative impact at B3 location.

Implementation of MSFD requires determining progress targets for achieving Good Environment Status of marine environment. Up to date, there was now knowledge on current state of marine litter pollution in the region. Therefore results of current investigation allows to define trend indicators for monitoring of level of marine littering as it was proposed by MSFD GES Technical Subgroup on Marine Litter (2011).

CONCLUSIONS

This study also showed that plastic was dominant marine litter material and made an average of 72.9 % of all items found on the beach. Cigarette butts were among the five most common beached litter types and most abundant non-plastic item. The accumulation and distribution of BML is variable within and between beaches, both in composition and across the seasons. Our study has shown that an average amount of marine litter on Lithuanian beaches is in the range of 138 to 340 items per 100 m long segment of the beach (222 items in average). From the methodology point of view, it is stated that Guidelines for Monitoring of Marine litter on the Beaches provided by OSPAR are suitable enough in order to identify and classify the litter as well as attribute to the potential source of pollution.

Acknowledgments

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