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Assessing Marine Litter on beaches and the seafloor in the Saronikos Gulf, Greece

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Abstract Marine litter is a pressing environmental issue that requires urgent attention from international and local authorities. The European Marine Strategy Framework Directive emphasizes the need to achieve Good Environmental Status (GES) in European marine waters by 2020, with a specific focus on marine litter. This study focuses on the Saronikos Gulf, a highly polluted area in the Mediterranean, to assess the abundance, composition, distribution, and possible sources of marine litter. Data were collected from various sources, including databases, published studies, and fieldwork. The study analyzed both stranded litter on beaches and litter on the seafloor to provide a comprehensive understanding of pollution in the area. Results revealed a high prevalence of plastic litter on beaches, particularly polystyrene pieces and cigarette butts. Litter density varied across locations, with higher concentrations in the western part of the gulf. The cleanliness index classified most beaches as having "very low cleanliness." On the seafloor, plastic and metal were the most common types of litter, with litter density decreasing with increasing depth. This study contributes valuable insights into the extent and characteristics of litter pollution in the Saronikos Gulf, aiding in the development of targeted solutions for its management and conservation.
Keywords: Saronikos gulf, litter, beach, seafloor, plastic

1. Introduction

Marine litter represents one of the most pervasive and persistent pollutants in marine ecosystems, transforming it into one of the most crucial environmental issues of our era. Several surveys have been conducted to assess the abundance, distribution, and sources of marine litter in Greece. Stefatos et al. (1999) examined marine litter retained in trawl nets during surveys in the Patras Gulf and Echinadhes Gulf. Katsanevakis and Katsarou (2004) studied the distribution of benthic litter in the Saronikos Gulf and other shallow coastal areas. Koutsodendris et al. (2008) studied benthic marine litter in four Greek gulfs, identifying land-based, vessel-based, and fishery-based sources. Kordella et al. (2013) focused on beach-stranded litter on 80 Greek beaches, collecting data through a volunteer network. Ioakeimidis et al. (2014, 2015) investigated benthic marine litter in the Saronikos, Patras, and Echinades Gulfs, using bottom trawlers and ROV. Politikos et al. (2017) developed a model to simulate the transport of floating litter particles in the Aegean Sea, revealing high concentrations in specific regions, including the Saronikos Gulf, and indicating that the Aegean Sea acts as a source of floating litter pollution in the Eastern Mediterranean. Also, in 2020, Politikos et al. used a particle tracking model to explore the transport and residence time of floating litter originating from the eastern Ionian Sea. Papachristopoulou et al. (2020) quantified the abundance of marine litter on inaccessible beaches in the western Saronikos Gulf, utilizing vessel-based photography and in-situ sampling surveys. They developed a regression model to accurately assess the abundance of marine litter on remote coastlines, serving as a cost-effective tool for monitoring inaccessible areas. Studies suggest that marine litter is abundant in the Mediterranean Sea (Cózar et al., 2015), and lately, the influx of marine litter to the Greek seas has been exacerbated by the COVID-19 pandemic due to improper disposal and management of personal protective equipment (PPE) (Kouvara et al., 2022).

A multi-perspective approach, where both beach-stranded and benthic litter are studied in a specific area is essential for more effective environmental conservation and management. It enables the researchers to grasp the extent of pollution, identify its sources, evaluate its impacts on ecosystems, and develop targeted solutions. To the best of our knowledge, this study is one of the few where both beaches and seafloor data are analyzed for a specific area. The aim of this work was to assess the abundance, composition, spatial distribution, and possible sources of marine litter in the Saronikos Gulf, which is one of the most polluted areas in the Mediterranean.

2. Materials and methods

2.1. Data collection

In the present study, all available data on marine litter in the Saronikos Gulf were collected through a variety of sources: a publicly accessible database (Marine LitterWatch), already published data (Ioakeimidis et al., 2015, 2014; Katsanevakis and Katsarou, 2004; Kouvara et al., 2022; Papachristopoulou et al., 2020), and new fieldwork consisting in collection and categorization of stranded material on beaches and visual census of macrolitter on the seafloor.

A comprehensive analysis was conducted on data from a total of 105 beaches, covering a time span from 2013 to 2023. The survey encompassed a 15-km coastline and a total area of 0.24 km^2. The studied beaches were classified into diverse categories, including urban, rural, touristic, and remote. Urban beaches are located in the city, rural are located far from urban areas and typically lack in infrastructure and amenities for visitors, and not actively promoted or sought after by tourists, touristic are popular and well-known among tourists, typically offering a range of amenities, infrastructure, and services to cater to visitors' needs and desires, such as accommodations, restaurants, water sports activities, and entertainment options and finally remote beaches are located far away from urban centers and tourist hubs, and are inaccessible or challenging to reach. In certain cases, beaches were subject to multiple samplings through the years. Sampling surveys were carried out following the "*Guidance on Monitoring of Marine Litter in European Seas*", developed by the Technical Subgroup on Marine Litter (TSG-ML) in collaboration with the JRC of the European Commission.

Information from 108 underwater samplings conducted in the gulf was accessible, dating back from 2003 to 2020. The data were collected using various methodologies and encompassed different depths, ranging from 0 to 350 m. Overall, the study covered an area of 5.98 km^2, providing a comprehensive overview of the extent of litter pollution in the seafloor of the Saronikos Gulf.

Fieldwork consisted of ROV transects performed at the center and west of the gulf, between the islands of Aegina and Agistri, and the passage of Methana-Poros, spanning a depth range of 20-54 m. A Blue Robotics ROV2 was used for one transect and a SubSea Tech Guardian Mini-ROV was used for the rest four transects. The ROV was armed with a high definition (4k) underwater camera facing down to acquire high definition planimetric seafloor images, protected via a 150 m depth rated casing, a manipulator, to be able to collect any interesting litter items and a Blueprint Seatrac USBL underwater positioning system with external battery pack and a navigation software installed on a laptop (Hypach 2013). Equipped with a Dynamic Positioning system, M.V. TYPHOON of "A.C. Laskaridis Charitable Foundation" has efficiently served as the surface support vessel for the study.

2.2 Data treatment

Litter density per area (items/ m^2) and per length (items/ 100 m) on each sample location were calculated to enable a comparison with already published results. Results were eventually expressed using the average density. In addition, the General Index (Marin et al., 2019) and Clean-Coast Index (Alkalay et al., 2007) were calculated for each studied beach. The ROV videos were accurately (<1 m precision) georeferenced using the USBL. Analysis of the video files included detection and classification of any visible benthic litter item on the video footage. The covered area was calculated by multiplying the linear distance of the ROV transects on the seafloor by the average field of view of the ROV's camera. Recordings of marine litter from beaches, dives, ROV, and bottom trawl have been used for mapping in the ArcMap 10.8 GIS application.

3. Results

Overall, 127,000 total items were counted from the 105 beaches around the gulf. Litter was found at 99.05% of the surveyed locations. Plastic was by far the most recurrent macro-litter category, with a frequency of occurrence of around 91.94%, followed by paper (2.43%). Polystyrene pieces between 2.5 cm and 50 cm (G82) were the most abundant litter category (29.94%) within plastics, followed by cigarette butts and filters (G27) (18.13%) and fragments of non-foamed plastic between 2.5 cm and 50 cm (10.03%). Litter density ranged from 0 to 23.57 items m^{-2} with a mean of 2.59 items m^{-2} and from 0 to 13,643 items/ 100 m with a mean of 1,458 items/ 100 m. The mean density (items m^{-2}) of beach samplings per 2.5 km grid is presented in Figure 1, showing areas with higher litter density in the western part of the gulf (Epidaurus Municipality). Higher accumulation of litter is observed on remote shores (Fig. 2).

According to the General Index and the Clean-Coast Index, most of the beaches (44.76% and 39.62% respectively) were classified as of "very low cleanliness".

A total of 8,390 items were counted from the samplings on the seafloor of the gulf. Litter was found in all sampling efforts. Plastics were the most abundant litter type (82.74%), followed by metal (10.26%). The mean litter density was 0.01 items m^{-2} (range of 0.000117 – 0.25 items m^{-2}) and 31.58 items/100 m (range of 0.1 – 734 items/100 m). Scuba divers recorded the highest average litter density (0.0383 items m^{-2}) in shallow waters (0-25 m depth). Moving on to the next depth range (45-115 m), data from ROVs and trawlers revealed a significant decrease in average density, approximately 29 times lower. While progressing towards greater depths (200-250 m and 300-350 m), a small decrease in litter density was observed, as documented by trawlers (Fig. 3).

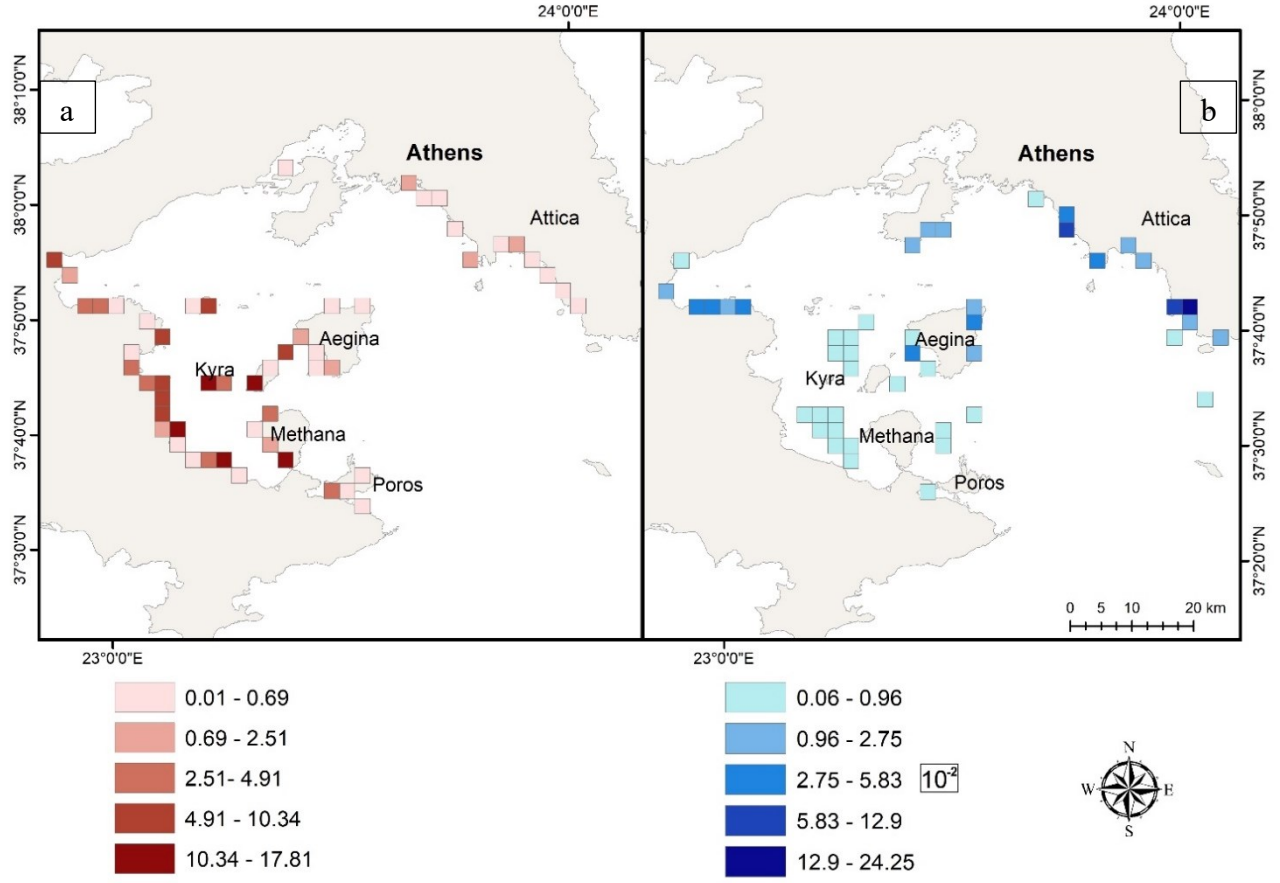

Figure 1 Mean litter densities (items m^{-2}) per 2.5 km grid (a) on beaches and (b) on the seafloor of Saronikos gulf

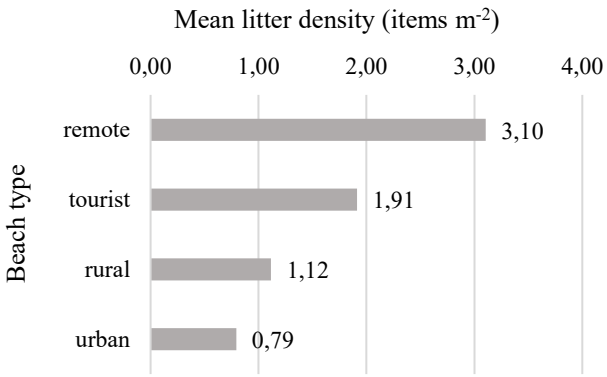

Figure 2 Mean litter density per beach type

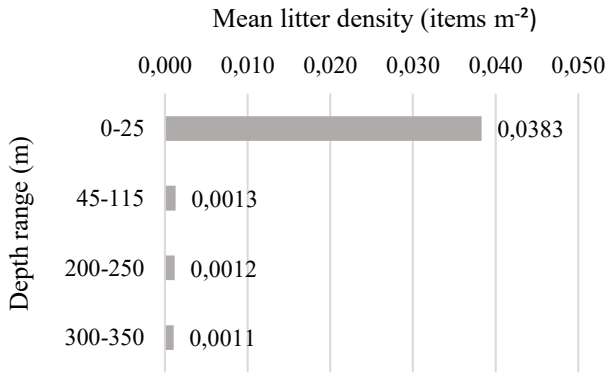

Figure 3 Mean litter density per depth range

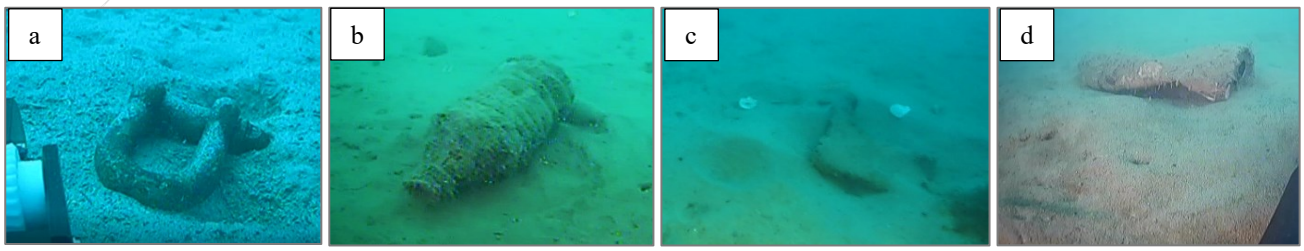

Figure 4 Some marine litter items detected in the ROV videos of Saronikos gulf: a) metal chain b) plastic bottle c) wellington boot d) beverage metal can

References

Alkalay, R., Pasternak, G., Zask, A., 2007. Clean-coast index-A new approach for beach cleanliness assessment. Ocean Coast. Manag. 50, 352–362. https://doi.org/10.1016/j.ocecoaman.2006.10.002

Cózar, A., Sanz-Martín, M., Martí, E., González-Gordillo, J.I., Ubeda, B., Á.gálvez, J., Irigoien, X., Duarte, C.M., 2015. Plastic accumulation in the mediterranean sea. PLoS One 10, 1–12. https://doi.org/10.1371/journal.pone.0121762

Ioakeimidis, C., Papatheodorou, G., Fermeli, G., Streftaris, N., Papathanassiou, E., 2015. Use of ROV for assessing marine litter on the seafloor of Saronikos Gulf (Greece): a way to fill data gaps and deliver environmental education. Springerplus 4. https://doi.org/10.1186/s40064-015-1248-4

Ioakeimidis, C., Zeri, C., Kaberi, H., Galatchi, M., Antoniadis, K., Streftaris, N., Galgani, F., Papathanassiou, E., Papatheodorou, G., 2014. A comparative study of marine litter on the seafloor of coastal areas in the Eastern Mediterranean and Black Seas. Mar. Pollut. Bull. 89, 296–304. https://doi.org/10.1016/j.marpolbul.2014.09.044

Katsanevakis, S., Katsarou, A., 2004. Influences on the distribution of marine debris on the seafloor of shallow coastal areas in Greece (eastern Mediterranean). Water. Air. Soil Pollut. 159, 325–337. https://doi.org/10.1023/B:WATE.0000049183.17150.df

Kordella, S., Geraga, M., Papatheodorou, G., Fakiris, E., Mitropoulou, I.M., 2013. Litter composition and source contribution for 80 beaches in Greece, Eastern Mediterranean: A nationwide voluntary clean-up campaign. Aquat. Ecosyst. Heal. Manag. 16, 111–118. https://doi.org/10.1080/14634988.2012.759503

Koutsodendris, A., Papatheodorou, G., Kougiourouki, O., Georgiadis, M., 2008. Benthic marine litter in four Gulfs in Greece, Eastern Mediterranean; abundance, composition and source identification. Estuar. Coast. Shelf Sci. 77, 501–512. https://doi.org/10.1016/j.ecss.2007.10.011

Kouvara, K., Papatheodorou, G., Kosmopoulou, A., Giovos, I., Charitou, A., Filippides, A., Kaberi, H., Kalaitzi, L., Kyrkitsos, F., Koundouri, P., Triantafyllou, C., Gletsos, M., Fakiris, E., Geraga, M., 2022. COVID-19-related litter pollution on Greek beaches and nearshore shallow water environments. Mar. Pollut. Bull. 185, 114250. https://doi.org/10.1016/j.marpolbul.2022.114250

Marin, C.B., Niero, H., Zinnke, I., Pellizzetti, M.A., Santos, P.H., Rudolf, A.C., Beltrão, M., Waltrick, D. de S., Polette, M., 2019. Marine debris and pollution indexes on the beaches of Santa Catarina State, Brazil. Reg. Stud. Mar. Sci. 31, 100771. https://doi.org/10.1016/j.rsma.2019.100771

Papachristopoulou, I., Filippides, A., Fakiris, E., Papatheodorou, G., 2020. Vessel-based photographic assessment of beach litter in remote coasts. A wide scale application in Saronikos Gulf, Greece. Mar. Pollut. Bull. 150, 110684. https://doi.org/10.1016/j.marpolbul.2019.110684

Politikos, D. V., Ioakeimidis, C., Papatheodorou, G., Tsiaras, K., 2017. Modeling the fate and distribution of floating litter particles in the Aegean Sea (E. Mediterranean). Front. Mar. Sci. 4, 1–18. https://doi.org/10.3389/fmars.2017.00191

Politikos, D. V., Tsiaras, K., Papatheodorou, G., Anastasopoulou, A., 2020. Modeling of floating marine litter originated from the Eastern Ionian Sea: Transport, residence time and connectivity. Mar. Pollut. Bull. 150, 110727. https://doi.org/10.1016/j.marpolbul.2019.110727

Stefatos, A., Charalampakis, M., Papatheodorou, G., Ferentinos, G., 1999. Marine debris on the seafloor of the Mediterranean Sea: Examples from two enclosed gulfs in western Greece. Mar. Pollut. Bull. 38, 389–393. https://doi.org/10.1016/S0025-326X(98)00141-6