Seasonal Dynamics of Solid Marine Debris Along the Batumi Coastline

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Abstract. The growing accumulation of marine litter has emerged as a serious global ecological challenge, exerting significant pressure on coastal and marine ecosystems. This study aimed to identify and evaluate the quantitative, morphological, and compositional characteristics of marine debris along a specific section of the Batumi coastline. The research further sought to classify the waste types and determine their primary sources. The study was conducted using the methodology developed by the Food and Agriculture Organization of the United Nations (FAO) for beach macro-litter monitoring (>5 cm) (Methodology, 2016). The surveyed area extended across coastal coordinates from 41°31'24.3"N – 41°32'47.8"E to 41°39'25.7"N – 41°38'33.8"E.

Findings revealed that the dominant categories of waste included plastic, wood, metal, textile, rubber, and organic matter, with plastic comprising the highest proportion—40.6% of the total waste collected. The distribution of other waste types varied significantly across seasons. The primary sources of pollution were identified as urban runoff, polluted rivers, tourism-related activities, and transit transportation.

This study underscores the substantial ecological and socio-economic impacts of marine debris, particularly its detrimental effects on tourism and fisheries. The findings highlight the urgent need for integrated coastal zone management strategies and transboundary environmental cooperation, offering an evidence-based foundation for sustainable marine and coastal ecosystem protection in the Black Sea region.

Keywords: Marine debris, plastic waste, Black Sea, seasonal variation, coastal pollution

Introduction

The Black Sea, situated between Eastern Europe and Western Asia, is a unique semi-enclosed marine ecosystem characterized by its limited water exchange with the global ocean, elevated biodiversity, and high socio-economic value for the surrounding nations (Stanev & Ricker, 2019). In recent decades, the influx of solid marine litter—predominantly plastics—has emerged as a global environmental crisis, significantly affecting both marine ecosystems and human livelihoods (Galgani, Hanke, & Maes, 2015; UNEP, 2016). Marine litter is not only persistent and slow to degrade but also fragments into microplastics, posing severe threats to aquatic biodiversity, food chains, and public health (Simeonova et al., 2017).

Despite various international initiatives and regional monitoring programs addressing marine litter in the Black Sea basin (e.g., EMBLAS-II, BBSEA), significant knowledge gaps remain—particularly regarding the Georgian coastline. The Batumi coast, a key recreational, ecological, and economic zone, is increasingly vulnerable to anthropogenic pollution from riverine discharge, tourism, and urban runoff. However, scientific data on the structural composition, quantity, and source identification of marine litter along this area remains scarce.

This study aims to perform a structural, compositional, and quantitative assessment of marine litter along the Batumi coastline, thereby contributing empirical data to an understudied region of the Black Sea and supporting future policy frameworks for marine environmental protection.

To achieve the stated aim, this study focused on the structured assessment of marine litter along the Batumi coastline through spatially representative data collection and seasonal evaluation. The key objectives were to identify and delineate coastal sampling zones based on environmental

criteria; to assess the volume and composition of stranded marine litter during multiple seasonal phases; to classify debris by material category, including plastics, metals, glass, wood, textiles, and rubber; and to determine the relative proportions and dominant types of litter present. A further objective was to evaluate the primary sources of pollution influencing the Batumi coastal zone, including land-based inputs such as river discharge and urban runoff, as well as maritime and recreational activities. This framework provided the analytical foundation necessary for understanding the spatial and temporal patterns of marine debris in a critical area of the Eastern Black Sea.4. Significance of the Study

This research addresses a critical environmental and data-driven gap by providing the first systematic, seasonally stratified investigation into the nature and origin of marine litter along the Batumi coastal zone. The outcomes are highly relevant to environmental governance, contributing to marine conservation strategies, integrated coastal zone management, and public awareness. The study directly supports global efforts to achieve key Sustainable Development Goals—specifically SDG 14 (Life Below Water), SDG 12 (Responsible Consumption and Production), and SDG 3 (Good Health and Well-being).

While selected sections of the Georgian Black Sea coastline, such as the Sarpi beach area, have been partially included in broader international assessments, no comprehensive studies have yet investigated the full Batumi coastline, particularly in a seasonal framework. This study is the first to systematically map marine debris along the entire coastal stretch from the Sarpi border crossing to the Alphabet Tower in Batumi. By identifying major litter categories and their likely sources, the research highlights the necessity of long-term monitoring systems and advances the understanding of marine litter dynamics in a strategically significant, yet previously under examined, region of the Black Sea.

The study was conducted along the urban beaches of Batumi, Georgia, within the geographical boundaries defined by GPS coordinates 41°31'24.3"N to 41°39'25.7"N and 41°32'47.8"E to 41°38'33.8"E. Field surveys were performed during four distinct seasons—spring, summer, autumn, and winter—between 2024 and 2025, covering different sections of the coastline. The collected material consisted of marine debris deposited onshore by wave action.
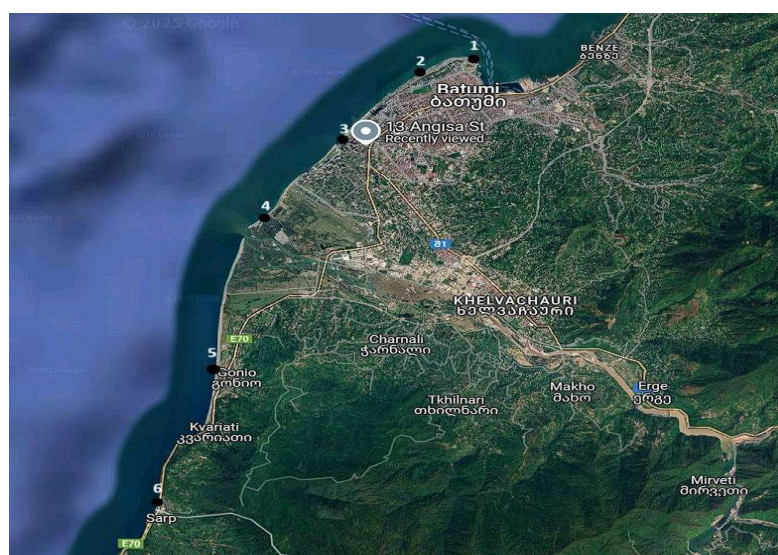

Figure 1. Study Area

The collection, morphological categorization, and quantitative assessment of marine litter were carried out in accordance with the FAO-recommended methodology for beach macro-litter monitoring (>2.5 cm) (FAO Methodology, 2016). This standardized protocol was developed within the DeFishGear project, funded by IPA-Adriatic, with the primary objective of supporting integrated regional efforts to reduce marine litter and promote sustainable coastal and marine

environmental management in the Adriatic–Ionian macro-region.

The methodology is grounded in international frameworks, including the EU Marine Strategy Framework Directive Technical Group on Marine Litter (MSFD TG10) "Guidance on Monitoring of Marine Litter in European Seas" (2013), the OSPAR "Guidelines for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area" (2010), NOAA's "Monitoring Marine Debris: Guidance and Protocols" (2013), and the UNEP/MAP MEDPOL monitoring document for Ecological Objective 10: Marine Litter (2014). These documents collectively informed the design of the survey protocol, ensuring consistency, comparability, and scientific rigor in the assessment of macro-debris on Batumi's beaches.

Results and Discussion

Marine Litter Composition and Seasonal Variability on the Batumi Coastline

Marine litter surveys conducted across four coastal sectors of Batumi in 2023–2024 revealed significant seasonal fluctuations in debris composition, reflecting both anthropogenic pressures and hydrometeorological events. The study areas included the Sarpi border beach, the mouth of the Mejinistskali River, the section near Batumi State University (BSU), and the Alphabet Tower beach.

Quantitative and morphological analyses were performed using the FAO methodology for macro-litter monitoring (>5 cm). The total weight of debris collected (excluding wood) on the Alphabet Tower beach over a 3200 m² area reached 56 kg. When including storm-transported wood fragments, the total weight increased to 2 575 kg, highlighting the disproportionate influence of extreme weather on natural debris inflow.

Across all seasons, plastic emerged as the most dominant litter category, with an average share of 40.6%. Its highest prevalence was observed in autumn (51.05%) and the lowest in winter (36.08%), indicating relatively consistent year-round pollution from plastic packaging, bottles, caps, and fragments. These findings are consistent with global assessments showing that plastic constitutes the bulk of marine litter due to its durability and ubiquitous usage (Galgani et al., 2015; UNEP, 2016).

Wooden debris exhibited a dramatic seasonal spike, reaching 97.87% of total litter in summer, likely due to intense rainfall and riverine floods transporting logs and branches into the sea. By contrast, its presence was significantly lower in spring and autumn, averaging 34.45% annually. This variability underscores the role of inland hydrological processes and forestry activities in natural debris generation.

Rubber waste, primarily from footwear and vehicle parts, peaked in summer (26.61%) and averaged 15.74%, suggesting intensified tourism and transport-related inputs. Organic matter, including food residues and agricultural byproducts, was highest in summer (26.61%)—likely associated with peak tourist activity—and declined to 4.54% in winter. Textile waste was most frequent in spring (20.2%), possibly from spring cleaning and urban runoff.

Hazardous waste, such as pesticide containers, chemical bottles, and batteries, was detected in all seasons, averaging 3.63%, and found particularly after storms near the Alphabet Tower. Paper and cardboard appeared only in autumn (8.39%), representing a small but notable fraction of overall litter (2.1%).

Spatial Trends and Pollution Sources

Spatial analysis showed higher plastic concentrations near the Alphabet Tower and the Mejinistskali estuary—areas exposed to wave accumulation and river discharge. In contrast, Sarpi beach revealed a higher presence of organic and wooden debris, potentially originating from upstream agriculture and waste mismanagement. The BSU coastal sector demonstrated a more balanced distribution, with plastic and textile waste predominating.

The Mejinistskali River, classified as heavily polluted, contributes substantially to coastal debris inflow. Additionally, the coastal current from Turkey to Georgia further complicates source identification, as marine litter may drift across national borders. Seasonal hydrodynamics, storm events, and land-based activities collectively shape the litter distribution across Batumi's beaches.

Environmental and Socioeconomic Impacts

The study confirms that Batumi's coastline faces significant environmental challenges due to

persistent marine litter, primarily plastics. These materials threaten marine biodiversity, impact recreational beach quality, and impose escalating cleanup costs on municipal authorities. Moreover, the presence of hazardous and medical waste introduces potential public health risks, particularly during peak tourist seasons.

Despite daily municipal cleaning, litter accumulation remains a persistent issue, often due to upstream inputs and storm-driven deposition. Comparisons with studies conducted along Turkey's Black Sea coast (Terzi & Seyhan, 2017) reveal similar patterns, emphasizing the transboundary nature of the problem.

Illegal landfills near river sources (e.g., Mejinistskali and Barkhana) and poor waste management infrastructure further exacerbate pollution. Strengthening legislative frameworks—such as Georgia's Waste Management Code—and implementing targeted interventions (e.g., public education, monitoring systems, enforcement of river protection laws) are critical to addressing this multifaceted issue (Shainidze, Dumbadze, 2023).

Table 1. : Seasonal Distribution of Marine Litter Types (%)

| Category	Spring	Summer	Autumn	Winter	Average
Plastic	43,13±14,73	40,17±10,45	51,05±1,85	36,08±11.47	40,60
Wood	9,5±3,86	97,87±0,27	7,15±3,64	23,29±12,56	34,45
Rubber	14,5±5,63	26,61±11,44	3,5±2,58	18,35±3,29	15,74
Organic	3,82±1,16	26,61±11,44	16,08±3,64	54±1,37	12,76
Textile	20,2±9,32	9,11± 1,47	—	±2,35	10,06
Metal	—	12,67±1,11	—	4,1±1,33	4,19
Glass	5,72±2,34	—	4,89±2,37	—	2,65
Hazardous	3.05±1.09	3,91±2,09	4,89±2,37	2,68±1,13	3,63
Paper/Cardboard	—	—	8,39±2,64	—	2,1
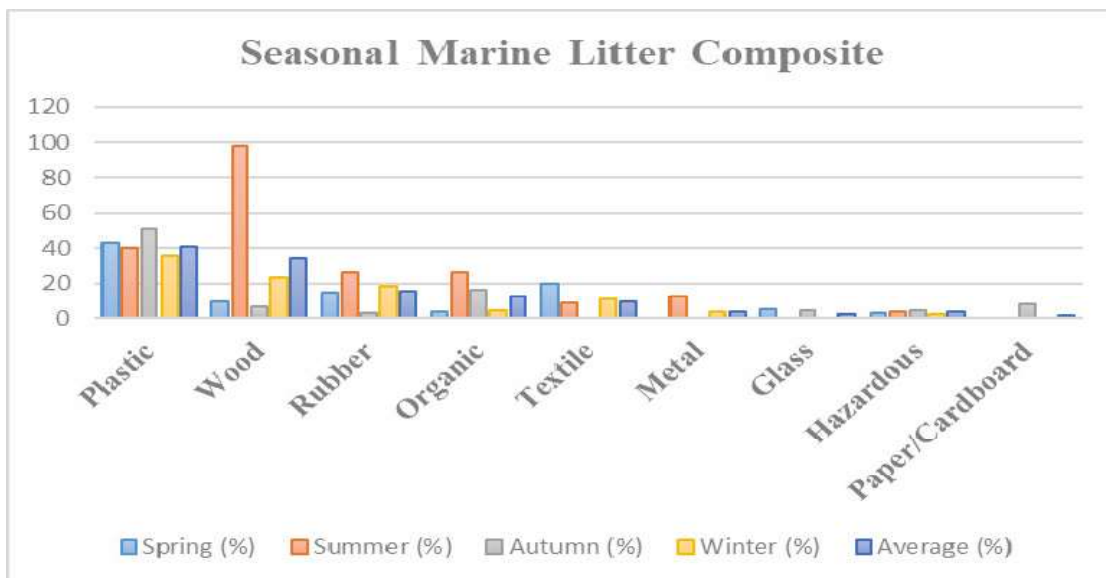
Figure 2: Marine debris composition in the research area

Conclusions

This study provides compelling evidence that the Batumi coastline is under persistent pressure

from both land-based and marine-derived litter sources. Plastic debris was found to be the most consistent and dominant component across all seasons, indicating chronic pollution linked to widespread consumer use and insufficient waste management infrastructure. The episodic influx of wooden material, particularly during summer storm events, highlights the ecological consequences of extreme weather and riverine flooding. Furthermore, the spatial distribution of debris near hydrodynamic accumulation zones and river mouths suggests that both natural processes and anthropogenic activities jointly shape coastal litter dynamics. These findings underscore the urgent need for integrated, multi-scale approaches to address the ecological, public health, and socio-economic dimensions of marine litter pollution in the eastern Black Sea.

Recommendations
To effectively respond to the identified challenges, we recommend the institutionalization of long-term, seasonally stratified litter monitoring programs; the implementation of upstream pollution control measures targeting river discharges and urban runoff; and the reinforcement of cross-border cooperation within the Black Sea region. Strengthening public environmental awareness and ensuring the enforcement of national waste management legislation are critical steps toward behavioral change and systemic reform. Additionally, given the observed plastic fragmentation, the inclusion of microplastic monitoring should be integrated into future coastal assessment protocols.

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მყარი საზღვაო ნარჩენების სეზონური დინამიკა ბათუმის სანაპირო ზოლში
დუმბაძე გუგული
შაინიძე მარინა
მაჭუტაძე იზოლდა
შოთა რუსთაველის სახელმწიფო უნივერსიტეტი, ბათუმი

საზღვაო ნარჩენების რაოდენობის ზრდა დღეს წარმოადგენს სერიოზულ გლობალურ ეკოლოგიურ გამოწვევას, რომელიც მნიშვნელოვან გავლენას ახდენს სანაპირო და საზღვაო ეკოსისტემებზე. ამ კვლევის მიზანი იყო ბათუმის სანაპირო ზოლის მონაკვეთში საზღვაო ნარჩენების რაოდენობრივი და მორფოლოგიური შედგენილობის განსაზღვრა, მათი კლასიფიკაცია და წარმოშობის წყაროების იდენტიფიცირება. კვლევა განხორციელდა გაეროს სურსათისა და სოფლის მეურნეობის ორგანიზაციის (FAO) მიერ შემუშავებული

მეთოდოლოგიის საფუძველზე, რომელიც ეძღვნება პლაჟებზე მაკრონარჩენების (>5 სმ) მონიტორინგს (Methodology, 2016). კვლევის არეალი მოიცავდა კოორდინატების 41°31'24.3"N – 41°32'47.8"E-დან 41°39'25.7"N – 41°38'33.8"E-მდე ფარგლებში მდებარე ბათუმის პლაჟს.

შედეგებმა აჩვენა, რომ ნარჩენების ძირითადი ტიპებია: პლასტმასი, მერქანი, მეტალი, ტექსტილი, რეზინი და ორგანული მასალა, სადაც პლასტმასა დომინანტური იყო და შეადგენდა ნარჩენების საერთო რაოდენობის 40.6%-ს. დანარჩენი ტიპების წილი მნიშვნელოვნად იცვლება სეზონურად. ძირითადი დაბინძურების წყაროებად გამოვლინდა ურბანული ჩამონადენი, მდინარეების დაბინძურება, ტურისტული აქტივობები და სატრანზიტო მოძრაობა.

კვლევა ხაზს უსვამს საზღვაო ნარჩენების მნიშვნელოვან ზემოქმედებას როგორც ეკოლოგიურ, ისე სოციალურ-ეკონომიკურ ასპექტებზე, განსაკუთრებით ტურიზმისა და თევზჭერის სფეროში.

საკვანძო სიტყვები: საზღვაო ნარჩენები, პლასტმასა, შავი ზღვა, სეზონური დინამიკა, სანაპირო დაბინძურება