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Bridging the Gap Between Policy and Practice: A Multi-Stakeholder Assessment of Marine Litter Management in the Adriatic–Ionian Region

Abstract:

Objective: The Adriatic and Ionian Seas form a semi-enclosed and heavily used marine basin in which limited water exchange, dense coastal urbanisation, tourism, fisheries and maritime traffic favour the accumulation of marine litter, particularly plastic debris. Despite an advanced governance framework, anchored in the EU Marine Strategy Framework Directive (MSFD) and the Barcelona Convention system, a persistent gap remains between policy ambition and operational delivery. This paper examines these challenges based on findings from Activity 1.3 of the Interreg IPA ADRION PREVENT project.

Research Design & Methods: The study applies a concurrent mixed-methods design, combining a synthesis of more than 70 scientific and institutional sources with a targeted stakeholder consultation (N = 67) across six ADRION partner countries: Albania, Croatia, Greece, Italy, Montenegro and Slovenia.

Findings: Marine litter in the region is dominated by plastics, with coastlines and seabed habitats functioning as key accumulation zones. Stakeholders identify plastic waste (71.6%) and tourism-related pollution (67.2%) as the main perceived drivers, followed by shipping and maritime activities (52.2%). Although monitoring capacities have advanced, from beach surveys and trawl-based assessments to Sentinel-2-supported detection of floating debris, governance remains fragmented and enforcement uneven. Strong support for stricter penalties (85.1%) indicates that the main challenge lies not in regulatory acceptance but in translating legal obligations into effective, risk-based enforcement and season-adaptive waste-management capacity.

Implications/Recommendations: Progress towards Good Environmental Status requires stronger cross-sector coordination, clearer attribution of pollution sources, better-resourced frontline inspection and the integration of advanced monitoring into compliance workflows.

Contribution/Value Added: The study provides a regional overview of marine litter management challenges, highlighting the gap between existing governance frameworks and their operational implementation across the ADRION region.

Article classification: research article

Keywords: marine litter; implementation gap; Adriatic–Ionian region; MSFD; Barcelona Convention; stakeholder consultation; marine governance; enforcement

JEL classification: Q58, Q53, H83, K32

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1. Introduction

The introduction should briefly place the study in a broad context and highlight why it is important. It should define the purpose of the work and its significance. The current state of the research field should be reviewed carefully, and key publications cited. Finally, briefly mention the main aim of the work and highlight the principal conclusions. As far as possible, please keep the introduction comprehensible to scientists outside your particular field of research (Smith, 1976).

1.1 The Geo-Physical Context: A Basin Under Pressure

The Adriatic and Ionian Seas represent a unique and vulnerable sub-basin within the Mediterranean ecosystem. Characterized by a semi-enclosed geomorphology and specific hydrodynamic circulation patterns, the Adriatic Sea, in particular, functions as a "trap" for floating and benthic debris. The basin's shallow northern section, combined with significant riverine inputs from the Po, Adige, and Neretva rivers, creates a conveyor belt for land-based pollution, while the cyclonic surface circulation redistributes floating debris along the coastlines of Italy, Slovenia, Croatia, Montenegro, Albania, and Greece.

The scale of the contamination is severe. Recent harmonized assessments conducted across the Adriatic-Ionian macroregion have estimated average beach litter densities at 0.67 items per square meter, a figure that places the region among the most polluted in the Mediterranean. The composition of this litter is overwhelmingly anthropogenic; artificial polymers account for approximately 91.1% of all recorded items, with single-use plastics (SUPs) and packaging materials dominating the waste stream. Unlike floating debris, which may eventually be flushed into the wider Mediterranean or washed ashore, the seabed acts as a permanent sink. Trawl surveys covering the Northern and Central Adriatic have recorded benthic litter densities exceeding 900 items per square kilometer, posing long-term risks to demersal fisheries and benthic biodiversity.

1.2 The Socio-Economic Dimensions

This environmental degradation is inextricably linked to the region's socio-economic fabric. The ADRION area is heavily dependent on the "Blue Economy," particularly coastal tourism, fisheries, and maritime transport. However, these very sectors are both the primary victims and significant perpetrators of marine litter.

The seasonality of pollution is a critical factor. Research on Mediterranean islands has demonstrated that marine litter generation can increase by a factor of 4.7 during the high tourist season compared to winter months. This "tourist load" overwhelms local waste management infrastructures, which are often dimensioned for the resident population rather than

the seasonal peak. The economic implications are profound; visible marine litter acts as a deterrent to tourism, necessitating costly daily cleaning operations by municipalities to maintain the "clean coast" image required for economic viability. Furthermore, the ingestion of microplastics by commercial fish species and bivalves - documented in 53.3% of mussels sampled in Boka Kotorska Bay introduces potential risks to food safety and the reputation of the regional seafood industry.

1.3 The Governance Paradox

The persistence of high litter densities in the ADRION region presents a governance paradox. The area is not unregulated; on the contrary, it is covered by some of the most advanced marine environmental legislation in the world.

EU Member States (Italy, Slovenia, Croatia and Greece) operate under the Marine Strategy Framework Directive (MSFD) (2008/56/EC), which mandates the achievement of Good Environmental Status (GES) by 2020, a target that has largely been missed regarding Descriptor 10 (Marine Litter). Non-EU ADRION partner states, including Albania and Montenegro, are covered through the Barcelona Convention system, which provides a binding regional framework for Mediterranean Contracting Parties, articulated through the Regional Plan on Marine Litter Management and the Integrated Monitoring and Assessment Programme (IMAP).

Despite this dense regulatory landscape, operational results remain insufficient. Reports from the PREVENT project and broader literature suggest that while *monitoring* has improved significantly allowing for precise quantification of the problem, the prevention and *remediation* have lagged. This disconnect is often termed the "implementation gap," a phenomenon where policy objectives fail to translate into behavioral changes due to barriers at the enforcement level.

1.4 Research Objectives and Project Context

This paper derives from the activities of the "PREVENT" project (Pollution Reduction and Early-warning for Vulnerable Ecosystems in Adriatic-Ionian Territories), funded by the Interreg IPA ADRION Programme. Specifically, it addresses the objectives of Activity 1.3, which sought to establish a comprehensive baseline of marine litter status and stakeholder readiness in the region.

The primary objectives of this study are threefold:

1. To synthesize the scientific state of the art: We aim to consolidate fragmented data on pollution sources, distribution pathways, and emerging monitoring technologies (such

as remote sensing and machine learning) to provide a unified scientific basis for decision-making.

2. To assess the "implementation gap" through stakeholder consultation: Utilizing a dataset of 67 respondents from across the governance spectrum (NGOs, Government, Academia, Private Sector), we aim to diagnose the specific structural and operational barriers that prevent effective policy execution.
3. To propose an evidence-based pathway to GES: By triangulating scientific data with stakeholder feedback, we seek to identify actionable strategies that move beyond "soft" awareness-raising toward "hard" enforcement and infrastructure development.

Through this multi-stakeholder assessment, we argue that the ADRION region has reached a saturation point regarding *diagnostic* knowledge. The scientific community knows *what* pollution is (plastics), *where* it is (coastal hotspots and seabed sinks), and *who* generates it (tourism and maritime activities). The urgent task remains the reconfiguration of governance structures to act upon this knowledge effectively.

2. Governance Architecture And Theoretical Framework

2.1 The Legislative Backbone: MSFD and Barcelona Convention

The governance of marine litter in the Adriatic-Ionian region is characterized by a complex interplay of international, regional, and national legal instruments. At the European Union level, the Marine Strategy Framework Directive (MSFD) (2008/56/EC) serves as the overarching environmental pillar of the EU's Integrated Maritime Policy. The MSFD establishes a framework for community action in the field of marine environmental policy, requiring Member States to develop marine strategies that apply an ecosystem-based approach to the management of human activities. Its primary objective is to achieve or maintain Good Environmental Status (GES) of the EU's marine waters by 2020. Marine litter is explicitly addressed under Descriptor 10, which mandates that "properties and quantities of marine litter do not cause harm to the coastal and marine environment".

Complementing the EU framework is the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, which provides the principal legally binding regional framework for both EU and non-EU riparian states. Under this convention, the Regional Plan on Marine Litter Management in the Mediterranean was adopted, setting out specific measures and operational targets for litter reduction. This plan is notable for establishing legally binding timetables and requiring Contracting Parties to implement National Action Plans (NAPs).

A critical component of this regional governance is the Integrated Monitoring and Assessment Programme (IMAP), adopted to harmonize monitoring efforts across the Mediterranean. IMAP defines common indicators to ensure data comparability, including:

- Common Indicator 22 (CI22): Trends in the amount of litter washed ashore and/or deposited on coastlines.
- Common Indicator 23 (CI23): Trends in the amount of litter in the water column including microplastics and on the seafloor.
- Ecological Objective 10 (EO10): Marine and coastal litter.

The Mediterranean Quality Status Report (2023), a key output of this system, integrates national data to assess progress toward GES. It has established a threshold value for beach litter at 130 items/100m, a target that remains elusive for many Adriatic coastlines where averages can exceed 900 items/100m.

2.2 Theoretical Lens: The "Implementation Gap" and Street-Level Bureaucracy

Despite this robust legislative architecture, a significant disconnect persists between policy objectives and environmental reality, a phenomenon widely recognized in public policy scholarship as the "implementation gap". To understand why high-level directives, fail to translate into clean beaches, we employ two theoretical frameworks: Street-Level Bureaucracy and the Ambiguity-Conflict Model.

Street-Level Bureaucracy, a theory originally posited by Michael Lipsky, argues that policy is not ultimately made in legislative chambers but at the point of contact between citizens and the state. In the context of marine litter, the "street-level bureaucrats" are the port authority inspectors, municipal waste managers, and park rangers. These frontline actors exercise significant discretion under conditions of chronic resource scarcity and high workload. When faced with ambiguous mandates (e.g., "prevent litter") but insufficient tools (e.g., lack of boats, fuel, or personnel), they often develop coping mechanisms that dilute policy intent, such as prioritizing easily observable infractions over complex investigations.

The Ambiguity-Conflict Model (Matland, 1995) further elucidates the challenge in transboundary contexts like the Adriatic. Marine litter governance is characterized by:

- High Conflict: There is inherent tension between economic interests (e.g., maximizing tourism revenue, minimizing shipping costs) and environmental regulation.
- High Ambiguity: The source of litter is often diffuse and difficult to pinpoint (e.g., is it from a local tourist, a distant ship, or riverine input from a neighboring country?), complicating the assignment of responsibility.

Under these conditions, policy implementation becomes highly politicized and dependent on local coalition-building rather than top-down command. This theoretical perspective

helps explain the recurrent stakeholder complaints about "institutional silos" and "lack of communication" found in our consultation data. It suggests that without governance designs that explicitly reduce ambiguity (through clear attribution of sources) and manage conflict (through transparent enforcement), implementation will remain symbolic rather than substantive.

3. Methodology

3.1 Research Design

To address the complexity of marine litter governance—which spans ecological, technical, and socio-political domains—this study employs a concurrent mixed-methods research design. This approach allows for the triangulation of quantitative scientific data (e.g., litter densities, composition) with qualitative stakeholder perceptions (e.g., enforcement barriers, policy effectiveness). By integrating these distinct data streams, we aim to overcome the limitations of single-method studies, providing a holistic diagnosis of the "implementation gap" in the Adriatic-Ionian (ADRION) region.

3.2 Data Collection

3.2.1 The PREVENT Literature Corpus (N > 70)

A systematic review was conducted of over 70 bibliographic sources collected under Activity 1.3 of the PREVENT project. The corpus was stratified into three categories to ensure balanced coverage:

1. Academic Literature: Peer-reviewed studies on pollution sources, distribution models, and monitoring technologies (e.g., *Marine Pollution Bulletin*, *Remote Sensing*, *Journal of Marine Science and Engineering*).
2. Institutional Reports: Official assessments from the UNEP/MAP Barcelona Convention, the European Commission (MSFD implementation), and national monitoring bodies.
3. Project Deliverables: Technical outputs from key regional initiatives, specifically the IPA-Adriatic DeFishGear project, ACT4LITTER, and MEDITS surveys, which provide the primary baseline data for the region.

3.2.2 Stakeholder Consultation (N = 67)

Primary data were collected via a structured consultation survey distributed between February and September 2025 across the ADRION programme area. The instrument was designed to capture expert opinions on policy efficacy, enforcement challenges, pollution sources and collaboration barriers.

- Sampling Strategy: A purposive sampling approach was used to target key actors in the marine governance network.
- Sample Composition: After quality control and filtering for regional relevance, the final analytical sample comprised N = 67 respondents. The cohort is multi-sectoral, representing Governmental Bodies (local, regional, national), Research & Academic Institutions, Environmental NGOs, and the Private Sector (Maritime Transport, Tourism, Fisheries).
- Geographic Coverage: Responses were obtained from six ADRION partner countries: Albania, Croatia, Greece, Italy, Montenegro and Slovenia, ensuring representation of both EU and non-EU governance contexts. North Macedonia is represented through the authors' institutional affiliation in the PREVENT consortium, but it is not counted as a surveyed coastal ADRION country in the stakeholder sample.

3.3 Data Analysis

Qualitative data from the consultation (open-ended responses regarding barriers to enforcement and collaboration) were subjected to thematic analysis. An initial coding frame was developed deductively from the theoretical framework—particularly Street-Level Bureaucracy and the Ambiguity-Conflict Model—and then refined inductively as recurrent motifs emerged from the responses, including institutional fragmentation, resource scarcity, conflict of interest, weak inspection capacity and limited inter-agency communication. Quantitative survey data (Likert-scale items and multiple-choice frequencies) were analyzed descriptively to identify patterns of consensus and divergence across the stakeholder cohort.

To enhance coding consistency, the coding frame was reviewed by the research team and a second coder checked the assignment of responses to the main thematic categories. Differences in interpretation were resolved through discussion and refinement of category definitions. As the purpose of the coding was exploratory and interpretive rather than hypothesis-testing, no formal inter-coder reliability coefficient is reported. Integration between the literature synthesis and stakeholder consultation was conducted through a structured cross-reference matrix that compared stakeholder perceptions with documented evidence on litter composition, sources, spatial distribution, monitoring technologies and governance barriers. This enabled the study to distinguish between areas of convergence (e.g., plastic dominance and tourism pressure) and divergence (e.g., the higher perceived importance of shipping relative to published source-attribution estimates).

4. State of The Art: A Synthesis of Scientific Evidence

4.1 The Plastic Fingerprint: Sources and Composition

The scientific consensus regarding the composition of marine litter in the Adriatic is unequivocal: it is a plastic-dominated crisis. Vlachogianni et al. (2018), in a landmark assessment of beaches across seven ADRION countries, classified 70,581 items and found that artificial polymer materials accounted for 91.1% of the total. This dominance of plastics is corroborated by Mokos et al. (2020) in the central Adriatic, where artificial polymers reached 94.88% of recorded items, with single-use plastics (SUPs) constituting nearly a third of the waste stream.

The sources of this pollution are mixed but distinct. While shoreline activities (tourism, recreation) are the primary driver—accounting for 33.4% of beach litter regionally—sea-based sources remain critically high in specific locales. Munari et al. (2016) and Vlachogianni et al. (2018**)** highlight that in proximity to shipping lanes and fishing grounds, sea-based litter can range from 1.54% to nearly 15% of the total, necessitating targeted interventions in the maritime transport and fisheries sectors.

4.2 The “Seafloor Trap”: Benthic Accumulation and Persistence

Perhaps the most alarming finding in the literature is the status of the Adriatic seabed as a permanent sink. Unlike the water column, where debris is mobile, the seabed traps high-density polymers and weighted gear. Strafella et al. (2019), analyzing six years of trawl survey data (2011–2016), estimated the average density of benthic litter at 913 ± 80 items/km², ranking the Adriatic as one of the most polluted basins worldwide.

This accumulation is not random. Spedicato et al. (2019), utilizing data from the MEDITS initiative, modeled spatial distributions and found distinct "hotspots" correlated with riverine inputs and heavy trawling intensity. Fortibuoni et al. (2019) further confirmed that widely distributed "generalist" litter coexists with sector-specific debris (e.g., mussel nets, fishing lines) in areas of intensive aquaculture and fishing, suggesting that "passive" accumulation from currents is compounded by "active" dumping at sea.

4.3 Technological Frontiers: From Trawls to Satellites

Monitoring methodologies are undergoing a paradigm shift. Traditional methods—beach transects and seabed trawling—are labor-intensive and spatially limited. The literature points to Remote Sensing as the new frontier for creating "early warning" systems.

Ciappa (2022) demonstrated the efficacy of the Sentinel-2 multi-spectral instrument (MSI) in detecting floating litter aggregates in the North Adriatic. By utilizing the "Red Edge"

spectral bands, the study successfully discriminated between vegetal debris (e.g., river reeds) and anthropogenic litter patches, identifying 16% of observed aggregates as mixed or plastic-dominated. Rußwurm et al. (2023) advanced this further by applying Deep Learning models to Sentinel-2 imagery, achieving high-accuracy segmentation of marine debris at a large scale. These technologies offer the potential to monitor vast areas of the open sea (the "Blue Desert") at a fraction of the cost of vessel surveys, provided they are integrated into operational workflows.

4.4 The Cost of Inaction: Biological and Socio-Economic Impacts

The impacts of this pollution are already manifesting in the region's biota and economy.

- Ingestion: Anastasopoulou et al. (2018) documented the ingestion of plastics by commercial fish species across the Adriatic-Ionian macroregion, establishing a direct pathway for pollutants to enter the food web.
- Microplastics: Bošković et al. (2023) found microplastics in 53.3% of mussels (*Mytilus galloprovincialis*) sampled in Boka Kotorska Bay, with fibers constituting the majority of particles.
- Socio-Economic: Grelaud and Ziveri (2020) quantified the link between tourism and pollution, showing that daily litter accumulation rates on Mediterranean island beaches can increase by 4.7 times during the high season. Tisma et al. (2019) argue that for tourism-dependent economies like Croatia and Greece, this degradation poses a direct threat to GDP, as "cleanliness" is a primary determinant of destination competitiveness.

5. Results

5.1 Sample Characteristics

The stakeholder consultation, conducted between February and September 2025, yielded a final analytical sample of N = 67 respondents after filtering for regional relevance and consent. The geographic distribution covered six ADRION partner countries and summed to 100% of the analytical sample: Montenegro (22.4%; n = 15), Slovenia (22.4%; n = 15), Greece (19.4%; n = 13), Italy (14.9%; n = 10), Croatia (10.4%; n = 7) and Albania (10.4%; n = 7). North Macedonia is not included in this distribution because it is represented through project authorship and institutional participation rather than as a surveyed coastal ADRION country.

Sectoral representation is well-balanced, ensuring a multi-perspective assessment of the governance landscape. Governmental bodies (national, regional, and local) constitute the larg-

est group (25.4%), followed by Research/Academic institutions (22.4%), Private Sector representatives (13.4%), and Environmental NGOs (13.4%). This diversity validates the findings as reflective of the broader governance network rather than a single interest group.

5.2 Perceived Pollution Drivers: The "Plastic-Tourism" Nexus

Respondents were asked to identify the most prevalent sources of marine pollution in their specific ADRION territories (multiple selections permitted). The results, illustrated in Figure 1, reveal a clear consensus on the dominant drivers.

- Plastic Waste: Identified by 71.6% (48/67) of stakeholders as a primary source, confirming the scientific data on polymer dominance.
- Tourism-Related Pollution: Cited by 67.2% (45/67), highlighting the strong seasonal pressure exerted by the visitor economy.
- Shipping and Maritime Activities: Selected by 52.2% (35/67). This is a critical finding; while scientific attribution often estimates sea-based sources at ~15% in the broader Mediterranean, stakeholders in the Adriatic perceive it as a much higher threat, likely due to the density of shipping traffic in this semi-enclosed corridor.
- Domestic/Sewage Wastewater: Identified by 43.3% (29/67), pointing to persistent infrastructure deficits in coastal municipalities.

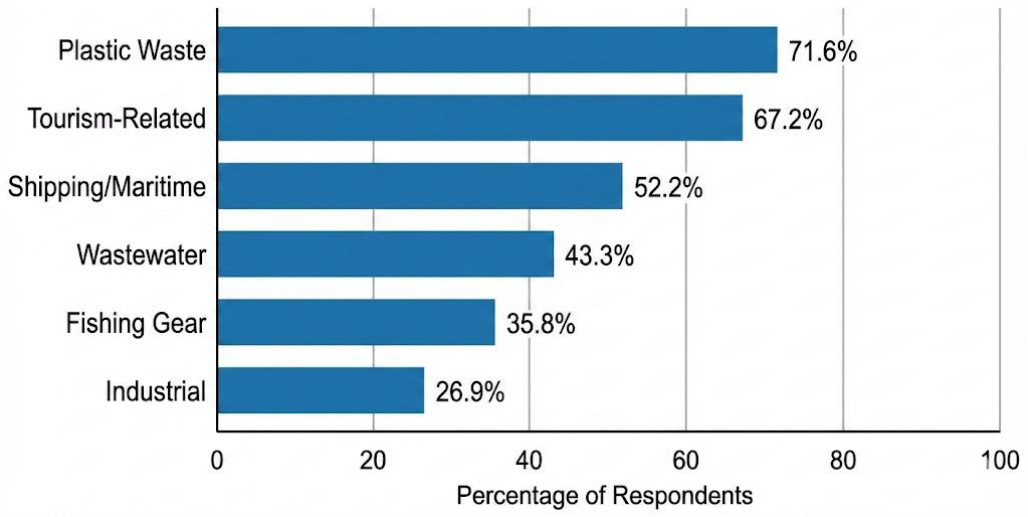


Figure 1. "Perceived Prevalent Sources of Marine Pollution (N=67)" showing the percentages for Plastic Waste, Tourism, Shipping, Wastewater, Fishing Gear, and Industrial Discharge.

Source: Authors' own elaboration based on the PREVENT D.1.3.2 Stakeholder Consultation Report (PREVENT Project, 2025).

5.3 Vulnerable Ecosystems

When mapping ecological vulnerability, stakeholders overwhelmingly prioritized the immediate shoreline. Coastal areas were identified as the most vulnerable ecosystem by 88.1% (59/67) of respondents.

Significantly, Marine Protected Areas (MPAs) were perceived as highly vulnerable by 55.2% (37/67). Qualitative responses elucidate this concern; stakeholders note that MPAs are often "protected on paper" but geographically exposed to litter transported by currents from unprotected areas. As one respondent from Montenegro noted, *"Pollution respects no boundaries; an MPA cannot fence out plastic floating from a neighboring port."*

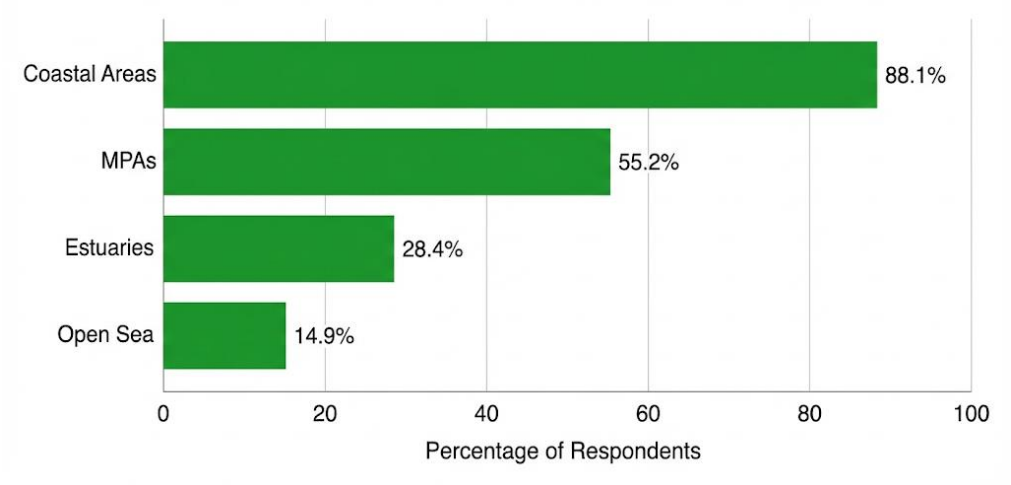


Figure 2 "Ecosystems Perceived as Most Vulnerable" contrasting Coastal Areas (88%) and MPAs (55%) with Open Sea (15%).

Source: Authors' own elaboration based on the PREVENT D.1.3.2 Stakeholder Consultation Report (PREVENT Project, 2025).

5.4 Policy Effectiveness and the "Enforcement Void"

A central objective of the consultation was to evaluate the perceived efficacy of the current governance architecture (MSFD, Barcelona Convention). On a Likert scale of 1 (Not Effective) to 5 (Very Effective), the results indicate a profound skepticism regarding implementation.

- The "Neutrality" Trap: The mode response was 3 (Neutral), selected by 58.2% (39/67) of respondents.
- Ineffectiveness: A substantial cohort (22.4%) rated policies as "Not Effective" or "Not Effective at All."
- Success Stories are Rare: Only 1 respondent (1.5%) rated current policies as "Very Effective."

This skepticism is not directed at the *rules* themselves, but at their *enforcement*. When asked, "Would you support stricter regulations and penalties for marine pollution violations?", an overwhelming 85.1% (57/67) responded "Yes." This finding challenges the assumption that stakeholders resist regulation; on the contrary, there is a strong demand for a transition from voluntary measures to credible deterrence.

5.5 Barriers to Implementation: A Qualitative Diagnosis

Thematic analysis of open-ended responses regarding "challenges in enforcing policies" (Q2.3) and "barriers to collaboration" (Q4.3) revealed three systemic bottlenecks:

1. Institutional Silos (The "Non-Communicating Ministries"): The most frequent complaint was the lack of coordination between key agencies. Respondents described a situation where Environment Ministries set targets, but Tourism and Transport Ministries pursue growth strategies that undermine those targets.
    - *Quote:* "Ministries within the same country do not communicate, hence hindering the possibility of improvement." (Recurring theme across multiple responses).
2. Resource Scarcity at the Frontline: While laws exist, the "street-level" capacity to enforce them is missing. Stakeholders cited a lack of fuel for inspection boats, insufficient staff during tourist peaks, and a lack of technical equipment for monitoring.
    - *Quote:* "Inspection is the weakest part of the chain because there are not enough human capacities." (Governmental Body, Montenegro).
3. Conflict of Interest: A pervasive tension was identified between short-term economic gain and long-term protection. This was particularly acute regarding the tourism sector, where strict enforcement is often feared to "scare away" visitors or investment.
    - *Quote:* "Profit-oriented relationship with the environment... instead of treating it as our home." (Governmental Body, Slovenia).

6. Conclusion

Marine litter in the Adriatic–Ionian region persists not because of an absence of regulation or scientific knowledge, but because of an implementation gap between policy ambition and operational delivery. The basin's semi-enclosed geomorphology, low exchange dynamics, dense coastal use and intensive maritime activity create conditions that favour the accumulation and redistribution of debris. The evidence synthesized in this paper confirms that marine pollution in the region is dominated by plastic litter, while coastal areas and seabed habitats function as key accumulation zones.

By combining a systematic synthesis of more than 70 scientific and institutional sources with a multi-sector stakeholder consultation (N = 67) across six ADRION partner countries, this study clarifies how the implementation gap operates in practice. Although the region is supported by a dense regulatory architecture—anchored in the EU Marine Strategy Framework Directive (MSFD) and the Barcelona Convention system, including the Regional Plan on Marine Litter Management and IMAP indicators—stakeholders remain unconvinced that

existing measures consistently deliver the intended environmental outcomes. The concentration of responses around a neutral assessment of policy effectiveness, together with strong support for stricter penalties (85.1%), suggests demand for more credible and predictable enforcement rather than resistance to regulation itself.

The findings show broad agreement across sectors and countries that plastic waste and tourism-related pressures are the dominant pollution drivers, with shipping and maritime activity also perceived as a significant contributor in this semi-enclosed basin. They also show that the weak point in the governance chain is not monitoring capacity or legislative design alone, but the translation of these tools into coordinated implementation. Although monitoring has advanced from manual beach transects and trawl surveys toward Sentinel-2-supported detection of floating debris, these capabilities are not yet consistently embedded in decision-making, inspection planning or compliance workflows.

The qualitative evidence explains why deterrence often remains symbolic. Key barriers include institutional silos between ministries and agencies, chronic resource scarcity among frontline inspectors, and conflicts of interest that prioritize short-term economic gains in tourism and maritime transport over long-term ecosystem protection. These patterns are consistent with implementation theory: discretion at the street level, combined with ambiguity over source attribution and conflict between economic and environmental priorities, produces fragmented and uneven delivery across jurisdictions.

In conclusion, the ADRION region has largely achieved diagnostic saturation: the dominant materials (plastics), priority ecosystems (coasts and seabed sinks) and key human drivers (tourism and maritime activities) are well established. The next phase of marine litter governance should therefore focus on reducing attribution ambiguity, managing cross-sector conflict and resourcing frontline implementation. Integrating advanced monitoring into risk-based inspection systems, strengthening inter-agency coordination and building season-adaptive waste-management capacity would help translate robust legal frameworks into measurable reductions in litter and progress toward Good Environmental Status.

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Conflicts of Interest
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The data presented in this study are available upon reasonable request from the corresponding author.
Author Contributions
A.I.: conceptualization, methodology, investigation, project administration, supervision, writing – original draft, writing – review & editing. K.B.: methodology, formal analysis, writing – original draft. H.P.: formal analysis, investigation, resources, writing – review & editing. G.B.: formal analysis, data curation, validation, writing – review & editing. U.N.: formal analysis, visualization, writing – review & editing. A.P.: investigation, data curation, validation, writing – review & editing. D.D.: investigation, data curation, resources, writing – review & editing.
AI Declaration Statement
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