

Article

Marine Litter in Croatian Adriatic: Sources, Quantities and Stakeholders' Perspectives

Marina Funduk ¹, Pero Tutman ² , Anamarija Farkaš ¹, Sanja Tišma ^{1,*}  and Ana-Maria Boromisa ¹

¹ Institute for Development and International Relations, Lj. F. Vukotinovića 2, 10 000 Zagreb, Croatia; marina@irmo.hr (M.F.); afarkas@irmo.hr (A.F.); anamaria@irmo.hr (A.-M.B.)

² Institute of Oceanography and Fisheries, Šetalište Ivana Meštrovića 63, 21000 Split, Croatia; tutman@izor.hr

* Correspondence: sanja.tisma@irmo.hr

Abstract: The problem of marine litter is becoming more visible in Croatia. The main goal of this paper is to investigate issues related to marine litter in the Croatian Adriatic, from the current state of sources and quantities of marine litter, through marine litter monitoring and legislation, to stakeholders' awareness about the marine litter issue in Croatia. The topic was designed as a case study and was covered by the method of document analysis and the survey method. Quantitative analysis was done for involved stakeholders and their level of interest. The mean value method and method for stakeholder mapping for marine areas was used. In addition, an exhaustive review of Croatian marine litter studies was done. The results of the research indicate that our knowledge about marine litter sources and quantities in the Croatian Adriatic is still quite scarce and that the stakeholders in Croatia have a moderate level of interest in the marine litter issue. Conclusions indicate that in Croatia particular attention is committed to strengthening both bilateral and multilateral relations with the neighboring countries given the transboundary nature that allows marine litter to spread over long distances.

Keywords: marine litter; Croatian Adriatic; sources; quantities; monitoring; legislation; stakeholders' interest



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1. Introduction

Regardless of the source or method of arrival, marine litter is a growing environmental problem in the Adriatic Sea and a permanent environmental and sociological problem for all surrounding countries [1]. The area along the Adriatic Sea is densely populated and highly developed. Thus, the litter from about four million people living along its shores ends up in the sea. The number of people using the area increases almost six times during the tourist season [2]. If we add to this the increase in already intensive economic activities beyond tourism, maritime transport, fisheries, and aquaculture, the result is increased litter input into the marine environment [3]. In addition to the environmental costs, marine litter also has an important socio-economic impact affecting coastal communities because of the importance tourists place on clean coast [4].

Through a range of circumstances, litter reaches the marine environment, and may be floating on the sea surface, in the water column below the sea surface, on the seabed, or stranded on the shore [5]. In this research, marine litter is defined as any persistent, manufactured, or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment [4,5]. Once in the sea, most litter soon sinks to the bottom, and therefore through wave and tidal action accumulates heavily in coastal areas [6,7]. The largest share of marine litter is plastic [4,6]; as such, a number of plastic objects remain floating on the surface even for a long period of time, enabling movement of debris away from the source [8,9]. Over time, these objects may be gradually overgrown with numerous marine organisms, become specifically heavier than seawater, and slowly sink to the seabed, where they accumulate in certain areas [6,7]. The spatial distribution and accumulation

of litter on the seabed shows great variability and is the result of a number of influences, such as sea hydrodynamics, seabed geomorphology, local human activities, and input via rivers [5–7]. Usually, higher concentrations of litter at the bottom are found on frequent sea routes, fishing areas, and in the zones of convergence of sea currents [10,11]. According to the *United Nations Environment Programme* (UNEP) [4] almost 70% of litter that reaches the sea from land ends up on the seabed and accumulates there for years out of human reach.

The Adriatic is a small (138,600 km²) and shallow semi-enclosed sea connected to the rest of the Mediterranean Sea by the 70 km-wide Otranto Gate. It stretches from the Gulf of Venice in the northwest to the Otranto Strait in the southwest for about 800 km, separating the Apennines from the Balkan Peninsula [12]. The level of socio-economic development in surrounding countries, Italy, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, and Albania, differs. Due to the length and complexity of the Adriatic coast, the area exhibits a great diversity of hydrodynamic environments. For a better understanding of transport and points of accumulation of litter in the sea, it is necessary to know the prevailing current regimes and winds, which impact distribution once litter reaches the sea. The general Adriatic surface circulation is characterized by cyclonic circulation, with northern inflow along the eastern coast and southern outflow along the western coast with the appearance of several cyclonic vortices, the most prominent of which are those in the southern and central Adriatic. In winter, the broad eastern current is more pronounced, whereas in summer the western current prevails. The circulation of Adriatic surface water is stimulated by the inflow of fresh water from the River Po, as well as the inflow of Mediterranean water through the Otranto Strait and secondary rivers [13,14]. Rivers are also key input vectors, allowing litter to travel from a variety of terrestrial sources to marine and coastal environments. In the northwestern part of the Adriatic, the rivers Po, Adige, and Isonzo, and in its southeastern part the river Neretva and the Buna-Bojana basin, play an important role in the delivery of transboundary litter [1]. The Po River is the largest river in the western part of the Adriatic basin, and since its valley is the main industrial zone in Italy, it is under great pressure from various types of pollution, including plastic materials from different uses and origins. Furthermore, the winds have an important influence, namely the Bora blowing from the northeast and the Scirocco blowing from the southeast [14], which causes the distribution of floating litter and in combination with local geomorphology and hydrographic conditions affects the way it can be accumulated on coastline or further transported on the sea surface. The Italian coast, having very little indentation and no major islands, allows the smooth flow of the western Adriatic current. In contrast, the Croatian side, with about 6000 km of karst coastline and 1246 islands, islets and reefs, as well as its position on the upwelling sea current, acts like a floating sieve that accumulates marine litter [1]. Such litter poses an environmental threat, whether by endangering the aesthetics of the coastal environment [3], absorbing ecotoxins on its surface [15], undergoing fouling by foreign organisms, fragmenting into microplastic, or degrading chemically [16].

Compounding the Croatian problem is litter brought by sea currents and wind from the neighboring Adriatic countries, especially during extremely unfavorable meteorological and hydrological conditions during autumn and early winter storms [1,3]. In the last decade, Croatia has experienced several extreme environmental disasters related to floating litter that travelled to the coast in huge quantities [3]. The problem of plastic litter pollution particularly affects the Southern Dalmatian islands. Due to the current circulation regime and due to the long period of strong southerly winds, there is a markedly increased accumulation potential of transboundary litter on the southern shores of the exposed islands, especially Mljet, Vis, Korčula, and Lastovo, as well as the Pelješac peninsula, [1,3,7]. The accumulation of such litter is particularly favored by the coastal geomorphology, which is rocky and steep with occasional narrow bays that act like funnels, so the beaches at the bottom of such bays are flooded with a significant amount of litter. The bays facing southeast, south, and southwest are especially endangered, but those in the north are also under pressure. This indicates that accumulation is driven both by sea currents and

southerly winds. A significant part of the litter is not dumped on the shore but rather floats along with currents until it sinks and accumulates on the seabed in areas of low sea flow energy [6,7]. Plastic is a major component of such litter and often makes up over 90% of the litter that accumulates on the coast, surface, and seabed [4]. Plastic bags, food containers, and beverage bottles are the most common items that sometimes make up over 80% of the litter recorded on beaches [1]. The results of modeling [17] the amount of plastic litter in a narrow coastal area over a period of six years show that the islands of Vis and Mljet are characterized by high plastic intakes of 4 kg/(per km per day) and 18.8 kg/(per km per day). Litter accumulation rates vary widely and are influenced by many factors, such as the proximity of larger cities and settlements, the geomorphological features of the coast, the hydrodynamics of the sea, and maritime activities. Therefore, it is clear that the numbers obtained for the islands of Vis and Mljet are not the result of local litter input, but rather a consequence of winds and sea currents. There is a major gap in our knowledge about the actual quantities of plastic marine litter and microplastic and the proportion coming from different sources [3].

The data from the DeFishGear project [1] indicate that most of the marine litter found on the Croatian coast is made up of anthropogenic polymeric materials, i.e., 92% plastic, which is not surprising given the large quantities of plastic entering the Adriatic-Ionian area annually [18]. Potential litter sources in the Adriatic Sea are coastal activities and transboundary litter, and to a lesser extent urban and industrial areas, maritime transport, fisheries, and aquaculture [1,19,20]. The results of research on litter deposited on beaches [1] show that in Croatia the largest percentage (57.7%) comes from sources that cannot be precisely determined since the largest share is represented by pieces of plastic 2.5–50 cm, the source of which is very difficult to determine. The size and degraded nature of this debris indicates that the plastic had been in the sea for a period of time, experiencing wear due to hydrodynamic effects and UV radiation. Furthermore, 28% comes from coastal activities, including poor waste management practices, as well as tourism and recreational activities [1]. Finally, 12.33% originates from sanitary (personal hygiene, i.e., ear sticks, tampons) and medical activities (i.e., medical waste, etc.), a significant part of which is of cross-border origin [1]. A smaller proportion stems from illegal waste disposal (1.23%), maritime transport (0.6%), fishing and aquaculture (0.10%), and agriculture (0.04%) [1]. Nevertheless, scientific research data on the amount, distribution, composition, and especially origin and sources of marine litter in Croatia remain relatively limited.

Currently, there is also a lack of an effective legal framework for marine litter at the global level. The processes of globalization and the rise of the personal responsibility and associated social influences, the role of non-governmental organizations (NGOs), and the citizen science approach have changed and gained greater importance. By addressing the problem of marine litter these actors can play an important role, trying to influence the wider society to change its course of dealing with waste on land. The influence of NGOs differs from lobbying in exerting big influences in environmental governance [21,22]. Likewise, the citizen science approach has proven to be an efficient way to deal with scientific investigations [23], and can be used as a tool to bridge gaps between wider communities and scientists. Citizen scientists can help to determine local litter sources, thereby contributing to keeping coastal regions clean. There are several serious NGOs in Croatia dealing with the problem of marine litter [24], but operating at the local level. They implement their goals through various activities such as awareness raising, capacity building, implementation of clean-up actions, assessment and monitoring, and participation in proposing recommendations for marine litter management. Beach cleanup actions have proven to be suitable citizen science activities engaging volunteers from the general public [23]. However, due to the lack of systematic organized support and coordinated guidance, the effectiveness of this method lacks the systematic collection and recording of data related to marine litter that would be a future benefit for scientists [3].

The main goal of this paper is to investigate the issue of marine litter in Croatia, including the current state of sources and quantities of marine litter in the Croatian Adriatic,

the state of monitoring and legislation, and an assessment of the stakeholders' interest in the issue of marine litter in Croatia.

The specific objectives are to maximize the involvement of stakeholders with a high level of interest and to influence those with medium and low levels of interest, to identify efforts to remove marine litter deposited on the coast and on the seabed, and to identify systematic coordination of such marine litter collection activities in order to improve the monitoring and reporting system for marine litter in the Croatian part of the Adriatic.

The hypotheses of this research are as follows:

Hypothesis 1 (H1). *Stakeholders in Croatia have a moderate level of interest in the marine litter issue.*

Hypothesis 2 (H2). *Data from scientific research on marine litter quantity, distribution, and composition in Croatia are rare and limited.*

The paper starts with an explanation of the methodology, which includes a description of the surveys carried out and their results, whereas the main part of the paper is dedicated to the in-depth analysis of the achievements in the field, and their causes and consequences, with guidelines for further actions.

2. Materials and Methods

The topic was designed as a case study by R.K. Yin [25], using the method of document analysis and the survey method. The survey was carried out on the level of stakeholders' interest in the issue of marine litter. We wanted to understand the perception of this problem by stakeholders in the Croatian part of the Adriatic, so we focused on organizations, groups, and individuals affected by, interested in, and involved in dealing with marine litter. Stakeholders estimated the degree of their own interest about marine litter according to the given criteria, which were expressed in questionnaires. Quantitative analysis of the questionnaires was done according to types of criteria from Vierros et al. [26]. Then an exhaustive review of Croatian marine litter studies was conducted to help explain the quantitative findings and to provide an overview of the current state of the field for marine litter in Croatia.

The mean value method and the stakeholder management method according to the Guide to the "Project Management Body of Knowledge," 6th ed. (PMBOK) [27] were used, as well as the method for stakeholder mapping for marine areas according to Vierros et al. [26]. Stakeholders were structured hierarchically so we could differentiate their role in marine litter management. Then we used the breakdown structure to divide them into smaller parts to point out dependencies, responsibilities, and roles that influence their level of interest in marine litter. We followed the 100% rule as we incorporated representatives from all stakeholders. Stakeholders were then divided into groups according to Vierros et al. [26]. Mutual exclusivity was respected since all groups were mentioned just once in the structure, which comprised three levels. The results and findings of the survey are presented further in the text. They are expressed through the analysis of the level of stakeholders' interest in each identified group.

Stakeholder Analysis

The data collection process was launched in February 2020 and was completed by March 2020. Survey target groups included stakeholders from sectors such as fisheries (fishermen's associations, individual fishermen, skippers of vessels, sailors), harbors and marinas (staff members from harbors and marinas of various sizes and types), the tourism sector (hotel associations and chains, owners of hotels of various sizes, beach bars, entertainment parks, restaurants, travel agency associations), municipalities (competent environmental or waste management staff within each coastal municipality), and NGOs (environmental organizations, small volunteer groups such as local environmental initiatives, scuba diving associations).

The targeted number of respondents per target group was decided to be as follows: around 80–90 respondents from the fisheries and the tourism sectors and around 15–20 from the rest of the sectors.

The questionnaire was built around stakeholders' level of interest in marine litter. Out of 329 targeted respondents, a total of 273 filled in the questionnaire, mostly via online questionnaire, e-mail communication, or over the phone. A total of 273 responses represented a response rate of 83% on average at the national level.

Stakeholders were divided into 5 groups: (1) groups of fisheries and transport, (2) groups concerned about management decisions, (3) groups with interest in the area or resources, (4) groups dependent upon resources to be managed, and (5) groups with special seasonal or geographic interest (Figure 1).



Figure 1. Stakeholder breakdown structure.

Groups of fisheries and transport included the fishing industry and marine transportation companies and covered 94 respondents (34%). Groups concerned about management decisions covered non-governmental organizations (NGOs), business interest organizations, and national and international development agencies and provided 16 answers (6%). Groups with interest in the area or resources included national governments and international organizations, e.g., fisheries management, and covered 23 respondents (8%). Groups dependent upon resources to be managed comprised research and educational organizations and provided 17 answers (6%). Groups with special seasonal or geographic interests included tourist operators and tourist offices and comprised 123 respondents (45%).

Stakeholders estimated the degree of their own interest in marine litter according to 10 criteria: (1) existing rights to high seas resources, (2) continuity of relationship with resources, (3) unique knowledge or skills for the management of the resources at stake, (4) losses and damages incurred in the management process, (5) historical and cultural relations to the resources, (6) degree of economic and social reliance on the resources, (7) degree of effort and interest in management, (8) equity in access to the resources and distribution of benefits from their use, (9) compatibility in interests and activities of stakeholders, and (10) present or potential impact of activities of stakeholders on the resource base [26]. The degree of interest was marked as H/high, M/medium or L/low.

In the context of this analysis, criterion (1), existing rights to high seas resources, means that if we take as an example the port authority, it would score H (high) in this criterion. The rationale is the fact that its jurisdiction over the marine/coastal area provides the possibility for quite a large scope of activities they can undertake in relation to marine and coastal resources.

Criterion (2), continuity of relationship to resources, in this context means that if we take into consideration a resident fisher versus a migratory fisher, then the resident fisher would score H (high) and the migratory fisher L (low) in this criterion. In this case, the port is considered a resource (marine and coastal resources). The rationale for a score of H (high)

is the fact that a resident fisher usually, at least in case of Croatian ports, is a member of a fishing association that usually has concession over a particular port. Concession over the port ensures a strong legal relationship with the resource by definition. A resident fisher in that case pays a membership fee and is actively involved in the activities of the fishing association. The rationale for the migratory fisher to score L (low) is the fact that a migratory fisher is not a member of the resident fishing association, and probably does not pay any membership fees to the fishing association that has concession over the port. Therefore, he is considered to have a poor relationship with the resources and usually just an occasional relationship with the resource (i.e., the port as a shelter in case of bad weather).

Criterion (3), unique knowledge or skills for the management of the resources at stake, in this analysis means that if we take into consideration that the stakeholder is a port authority and it is being evaluated by this criterion, it would score H (high). The rationale would be that they (stakeholders) usually have legal jurisdiction over the resources, they represent larger systems (in organizational terms), and have (or are assumed to have) technical and human capacities for the management of the resource.

Criterion (4), losses and damages incurred in the management process, means that if we take as an example the port authority, it would probably score H (high) in this criterion. Of course, this depends on which port authority we are talking about. In case of the port authority of Split-Dalmatia County and the port of Vira/Hvar, these losses and damages in the management process occurred, resulting in a score of H (high).

Criterion (5), historical and cultural relations to the resources, in this analysis means that the stakeholders who could have high scores here are fishermen, tourist boards, and local communities. A good example is the town of Hvar, with 3700 inhabitants, where small hotels and apartment operators depend, socially and economically, on sustainable marine and coastal resources.

Criterion (6), degree of economic and social reliance on the resources, in this context means that a local community, as a stakeholder in this criterion, would probably score H (high). The rationale is that the majority of the economic activities are oriented towards marine resources (tourism, yachting, and aquaculture).

Criterion (7), degree of effort and interest in management, in this analysis means that if we take as an example the town of Hvar as a representative of a regional/local community, it would probably score M (medium). The rationale is the fact that, despite the general possibility of dealing with the issue of port management, the town of Hvar assigned this obligation to another entity (i.e., transferred the concession over the port for trawlers to the local public entity). If we take an example of an NGO as a stakeholder, it would probably score L (low). The rationale is that the NGO rarely has claims for management over the resources. It usually represents the corrective and public voice for what has been done in a wrong manner at the level of the local/regional/national government or by a business organization.

Criterion (8), equity in access to the resources and distribution of benefits from their use, means that if we take as an example a local community (town, municipality) that has concession or ownership over a particular port, such as the town of Hvar, the score for this particular case would be M (medium). The rationale in this case is the fact that the town of Hvar has all the tools at its disposal but does not get any earnings from the port.

Criterion (9), compatibility in interests and activities of stakeholders, in this context means that if we take an example of an NGO active on either the local or national level its score would probably be H (high). The rationale is the fact that its mission is completely compatible with its activities: An NGO represents a corrective to the society and its activities are oriented towards the improvement of the resource, in this case improvement of the situation of protection of marine and coastal resources.

Criterion (10), present or potential impact of activities of stakeholders on the resource base, in this context means that if we take as an example a large marine transportation company, the score would be H (high). The rationale for the score is the fact that they, at the present moment, are a producer of marine litter but have the possibility to change the

situation and to act towards the decrease in the marine litter quantity. Another example could be a fishermen community. Its score would be M (medium). The rationale is the fact that they perhaps do not produce as much marine litter (in terms of plastic bags, cans, etc.) but their potential impact could be enormous if they were actively involved in marine litter collection.

Regardless the type of criteria, in our analysis 36% stakeholders were identified as those with (H) high interest, 47.6% of them as those with (M) medium interest, and 16.4% as those with (L) low interest. Given the type of criteria, the highest interest of 73.08% was shown in category (10), present or potential impact of activities of stakeholders on the resource base, whereas the lowest among these high interest scores was present in category (3), unique knowledge or skills for the management of the resources at stake. If we look at the medium level of interest, most stakeholders (69.32%) were in categories (4), losses and damages incurred in the management process, and (7), degree of effort and interest in management. The leading criteria in the low interest level of 34.62% was (8), equity in access to the resources and distribution of benefits from their use. The lowest sub-percentage of low-level interests of 0% were in categories (9), compatibility in interests and activities of stakeholders, and (10), present or potential impact of activities of stakeholders on the resource base (Figure 2).

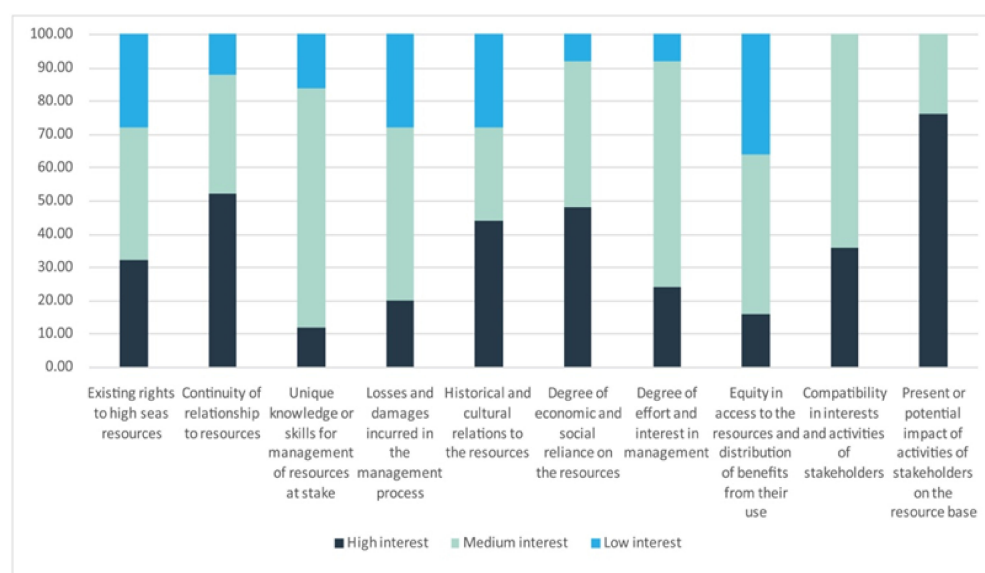


Figure 2. Percentage of level of interest, according to types of criteria, in all groups of stakeholders.

A group of participants from fishing industry and marine transport showed a balanced distribution of the level of interest in all 10 types of criteria (Figure 3). Blue Line ferries (Blue Line International, international shipping company specializing in passenger and vehicle transport on the Croatia-Italy line) had high interest in (4) losses and damages incurred in the management process, (6) degree of economic and social reliance on the resources, and (10) present or potential impact of activities of stakeholders on the resource base. However, their interest in the following categories: (1) existing rights to high seas resources, (2) continuity of relationship to resources, (3) unique knowledge or skills for the management of the resources at stake, (7) degree of effort and interest in management, and (9) compatibility in interests and activities of stakeholders, scored medium. All stakeholders in this group showed the highest interest in category (6), degree of economic and social reliance on the resources, whereas they showed the lowest interest in category (8), equity in access to the resources and distribution of benefits from their use.

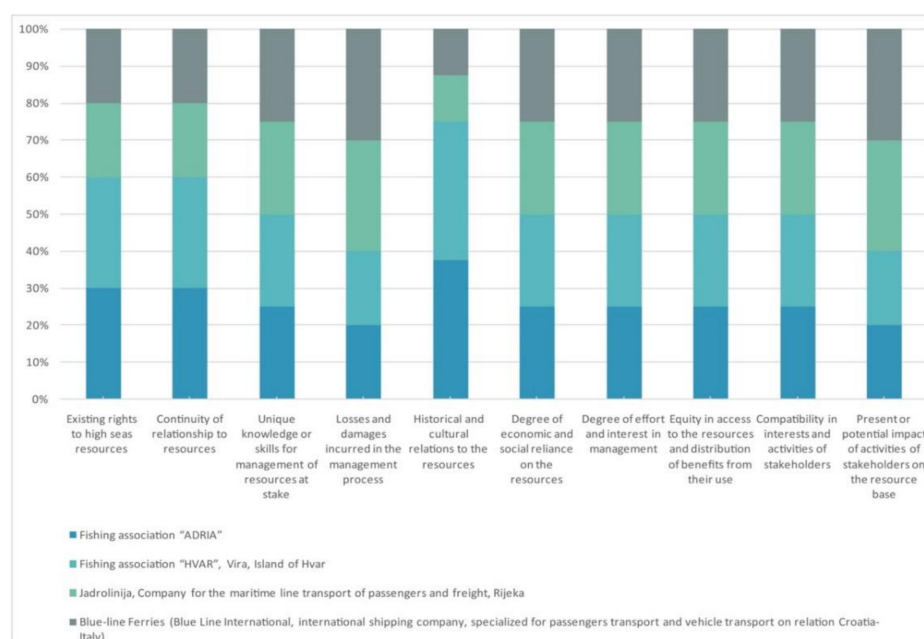


Figure 3. Level of interest in the fishing industry and marine transport.

Stakeholders concerned about management decisions showed little difference in the distribution of the level of interest in categories (1)–(10). The smallest difference was between categories (5) and (8). The levels of interest varied between high and medium for (1), (2), and (9), whereas categories (3), (4), (5), (6), (7), and (8) received all three levels of interest and (10) had the highest level of interest. The highlights were the NGO “Sunce” from Split, with high interest in nine categories. The NGO “Sunce” only showed a medium level of interest in (8), equity in access to the resources and distribution of benefits from their use. Development agencies on the regional, national, and international level (Nautical Center, Croatian Environment Agency and the UNEP: Priority Actions Programme/Regional Activity Centre (PAP/RAC) Split office) showed significant differences in level of interest throughout all 10 categories (Figure 4).

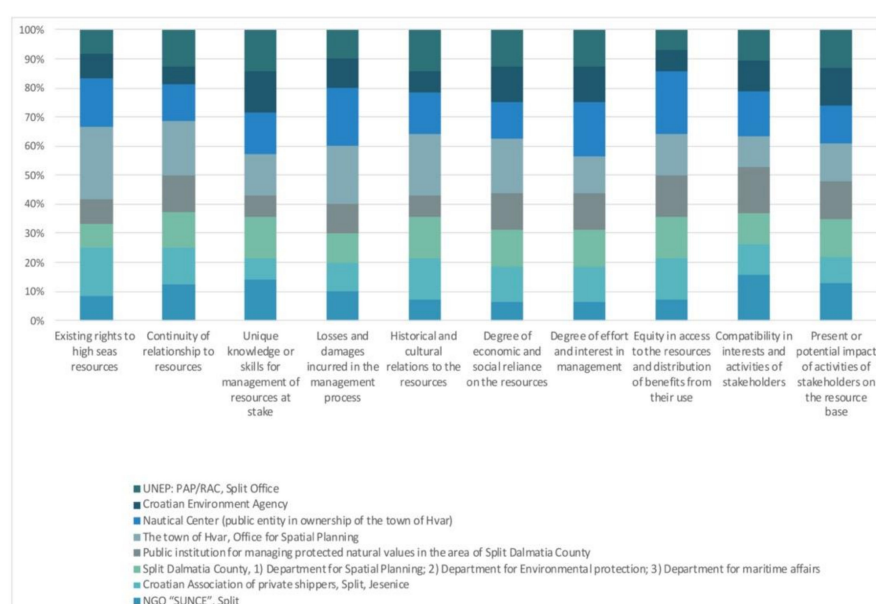


Figure 4. Level of interest in groups concerned about management decisions.

Stakeholders from the groups with interest in the area or resources (national government, international organizations) showed highest interest in categories (1), (2), (6), (7), (9), and (10). They indicated no low interest. Ministries showed a trend of medium interest in almost all categories, except for category (8), equity in access to the resources and distribution of benefits from their use (Figure 5).

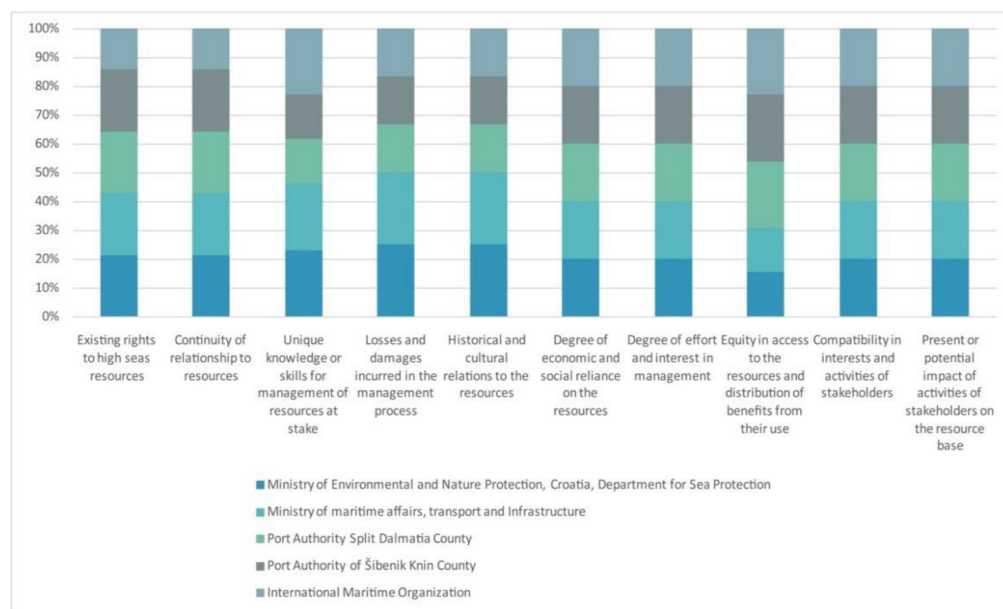


Figure 5. Level of interest in groups with interest in the area or resources.

Stakeholders from the groups dependent upon resources to be managed (research organizations) showed highest interest in category (10), present or potential impact of activities of stakeholders on the resource base, and their interest varied from medium to high in categories (2), (5), and (9). A medium level of interest was manifested in categories (1), (3), (4), (6), (7), (8), and (9) (Figure 6).

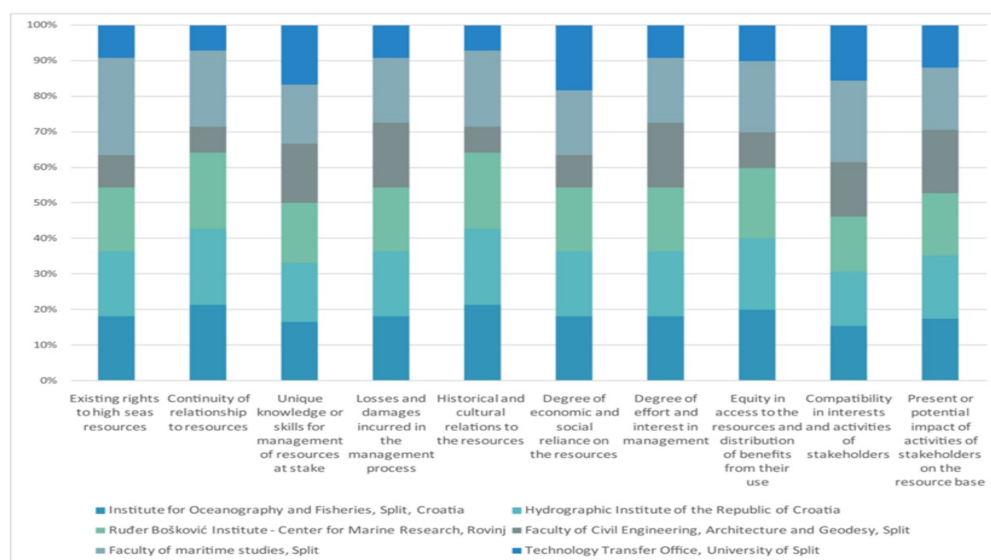


Figure 6. Level of interest in groups dependent upon resources to be managed.

Stakeholders from the groups with special seasonal or geographic interests, such as tourist operators and tourist offices, showed the highest level of interest for categories (2),

(5), and (6). They showed the lowest interest in category (3), and a medium level of interest in categories (1), (7), (8), and (9) (Figure 7).

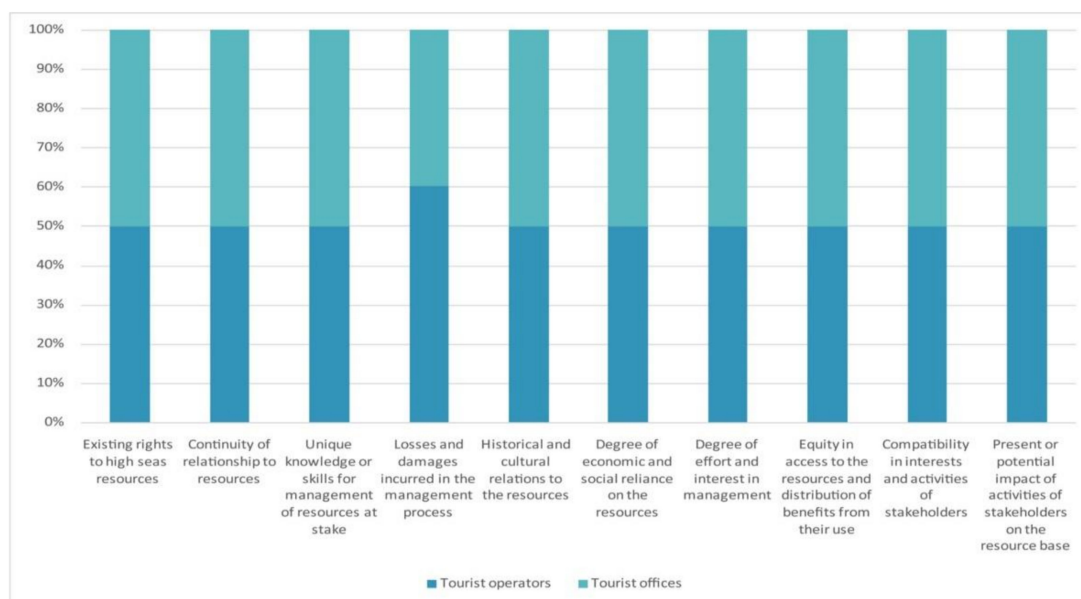


Figure 7. Level of interest in groups with special seasonal or geographic interests.

According to the Pareto principle (Figure 8), we saw that approximately 80% of low interest came from 20% of stakeholders, so efforts to increase the level of interest should be mostly concentrated on these stakeholders (NGO “Sunce,” Croatian Environment Agency, Faculty of Civil engineering, Architecture and Geodesy, Split, Public institution for managing protected natural values in the area of Split-Dalmatia County and UNEP: PAP/RAC, Split office).

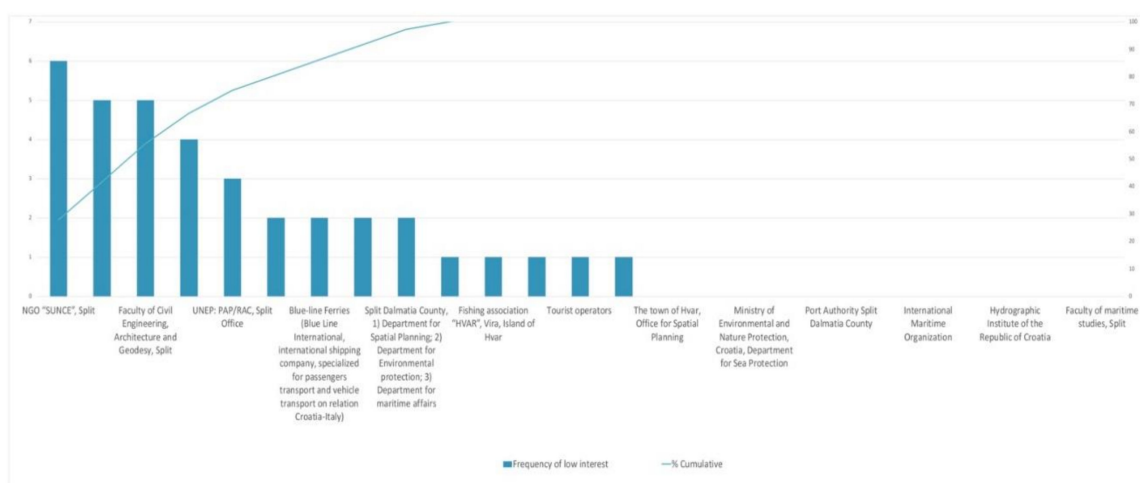


Figure 8. Pareto—low level of interest in groups of stakeholders.

3. Results and Discussion

3.1. Stakeholder Interest in Marine Litter Issues

The stakeholder breakdown structure (Figure 1) shows interest groups whose level of interest is more or less similar within each group. As previously mentioned, regardless of the type of criteria, 36% of stakeholders expressed high interest, 47.6% medium interest, and

only 16.4% low interest. If the interest of stakeholders increases, it will have an equivalent effect on their participation in solving the problem of marine litter.

Most stakeholders showed high interest in category (10), present or potential impact of activities of stakeholders on the resource base, mainly due to their own business interests. The strength of business benefits is reflected in the fact that no one expressed low interest in this category. The strength of motivation with regard to business interest can also be seen in both criteria (2), continuity of relationship to resources, and (6), degree of economic and social reliance on the resources.

Medium interest was evenly distributed across all categories, ranging from 24% to 72%. This shows that a large number of stakeholders would almost effortlessly jump from the medium interest to the high interest category, which should be the basis for further research. Otherwise, unless further efforts are made, some stakeholders might see their interest dropping to low.

The low interest (16.4%) points to Pareto's 80/20 rule. Resolving the problem of low interest in these roughly 20% of stakeholders would significantly influence the need for greater stakeholder involvement. The fact that low interest was shown by less than 35% for category (8), equity in access to the resources and distribution of benefits from their use, is rather encouraging because all other categories had significantly lower percentages. A low level of interest was completely absent for two categories, i.e., (9) compatibility in incentives and activities of stakeholders, and (10) present or potential impact activities of stakeholders on the resource base. Overall, the level of stakeholder interest can be used for better utilization of their impact on marine litter management in terms of maximizing the involvement of stakeholders with a high level of interest and influencing those who expressed medium and low levels of interest.

3.2. Contributions to Scientific Research

Marine litter-related information in the eastern part of the Adriatic Sea is still relatively scarce and spatially scattered. This does not apply to the information about the high seabed load of plastic litter in the Adriatic, which is the highest in Europe [6]. Although the scientific research data have been present for some time [28], more intensive consideration of its quantity and composition, distribution, and sources began after 2009 [19,29]. One of the first pieces of data in the scientific literature on marine litter was the analysis of floating litter and the litter deposited on the beaches on the island of Mljet [19]. The results of the research showed that over 80% of the found litter consisted of different types of synthetic polymers, whereas the rest consisted of glass, metal, rubber, and wood. Over 70% of the items collected came from neighboring countries. The loss of certain benthic habitats under the influence of litter on the seabed [30], and the death of whales and dolphins [28] as well as loggerhead turtles (*Caretta caretta*) [2] as a result of ingested marine litter, have also been reported. Valuable data on litter on the seabed were obtained from the MEDITS project—an international survey of demersal fish resources in the Mediterranean. Since 2014, as part of the project, litter was recorded and collected from the seabed at 60 different places in the territorial waters of Croatia [31]. With the beginning of the DeFishGear project the scientific community in Croatia has started to pay far more attention to marine litter at the institutional level [3,32]. Research efforts mainly focus on macrolitter [1,24,33,34], and fewer efforts have been invested in microlitter in other marine compartments [35–38]. Marine litter has been identified as a major growing environmental problem in the Adriatic-Ionian region, including both beach [1] and seabed litter [20]. Within litter collected, the most frequently found objects were 2.5 to 50 cm pieces of plastic and Styrofoam, ear sticks, and plastic bottle caps [1]. The project analyzed the occurrence of microplastic in the stomachs of red mullet (*Mullus surmuletus*), and on the sea surface and sandy sediment [18], which is a new topic in scientific research in the Croatian part of the Adriatic Sea. Ingested litter has been found in fish [39], and its effects are still largely unknown. Plastic was the most common category of marine litter (about 80%) collected from the seabed by trawlers during fishing [40,41]. Special danger comes from lost and/or discarded fishing

gear, especially nets and traps, which continue to be fished as such [42], whereas floating litter can serve as a potential vector in the transmission of pelagic crustaceans [43]. The distribution of floating marine litter in the Adriatic Sea is a consequence of surface currents, which later reach the bottom of certain areas [44]. In another study, it was established that with a relatively short particle half-life of 43.7 days, the Adriatic Sea is defined as a highly dissipative basin where the shoreline is, by construction, the main sink of floating debris with evident seasonality in the calculated plastic concentration fields and coastline fluxes [17]. Previous studies showed that marine litter and microplastic can be found in all segments of the Adriatic marine environment, such as biota vertebrates [2,37,39] and invertebrates [36], exposing them to threats related to marine litter such as ingestion and entanglement. Furthermore, marine litter and microplastic are present in the water column [3], sediments [35,37], sea bottom [20,38], and beaches [1,24,33,34], as well as in kitchen salt for human consumption [45]. Levels of heavy metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) [15] were found in the collected plastic pellets from two sandy beaches on the island of Vis, and microplastic was characterized from samples from the sandy sediment of Prapratna beach [46]. More intensive work on the issue of marine litter led to the first doctoral dissertation in the field [47]. An article providing a review of waste management policies adopted to date, current status, and country-specific features was presented by Runko Luttenberger [48]. This review in a comprehensive way described the current situation related to waste management challenges in the transition to a circular economy in Croatia, pointing to numerous problems and obstacles it faces. Nevertheless, scientific research data on the amount, distribution, and composition of marine litter remain relatively limited and scattered, and as such insufficient to draw systematic conclusions about its origin and trends.

3.3. Marine Litter Issues in the Republic of Croatia

Croatia is a member and signatory of a number of global and regional conventions, from UNCLOS and MARPOL to the Barcelona Convention. On a European Union (EU) level, it has an obligation to implement EU directives on marine protection. Unfortunately, the existing international and national legislation regarding marine litter is not applied in practice at a satisfactory level. Activities related to the prevention of marine litter are carried out through the existing legal framework and strategic documents related to land-based waste management. The legal act incorporating issues of marine litter in Croatia is the Umbrella Act on Sustainable Waste Management [49], where marine litter is considered a special category of waste (Art. 53). The most important EU directive on these issues is the Marine Strategy Framework Directive (MSFD) [50], which establishes a framework for community action in the field of marine environmental policy. Member states were obligated to take measures to achieve or maintain good marine environmental status (GES) by 2020, including those related to marine litter, as one of the important pressures on the marine environment. Croatia transposed obligations from the Marine Strategy Framework Directive into national legislation. Furthermore, it adopted the program of measures for protection and management of the marine environment and coastal area [51], which determines the measures necessary to achieve and/or maintain good environmental status as well as measures to achieve the objectives of marine environment and coastal zone management. The program of measures includes key measures connected to the implementation of pilot actions for cleaning and disposing of marine litter, i.e., the collection of litter both from the coast and from the sea both through diving actions and trawling. The so-called “Fishing for Litter” initiative aimed at reducing the amount of marine litter on the seabed by including one of the key stakeholders—the fishery sector. Efforts to remove marine litter deposited on the coast and on the seabed were mainly focused on conducting local environmental actions with the participation of volunteers from NGOs and diving clubs. However, they were carried out without harmonized coordination, methodology, and analysis of the quantities collected. Therefore, the data collected are not comparable, and it is difficult to draw appropriate conclusions about the previous or current situation

and clearly follow the trends. Fisheries as a sector can make a significant contribution to the removal of marine litter accumulated on the seabed. “Fishing for Litter” practices refer to the collection of marine litter found as by-catches in nets during trawl fishing, and its disposal on shore in appropriate containers and subsequent disposal within existing waste management systems. It is estimated that significant amounts of litter ending up in the sea each year could be removed in this way. Since we do not have the data on the amount of marine litter accumulated on the seabed or the amount of its input, such efforts are certainly worthwhile. If such an initiative were implemented in the entire Croatian part of the Adriatic, it could act as a significant program and a measure to reduce the total amount of marine litter. However, undefined legislation and obscure bureaucracy, the lack of an organized management and accountability structure, and the lack of funding sources [31] are obstacles yet to be surmounted. This approach leaves the success of this initiative subordinated to personal initiative and different stakeholders’ willingness to collaborate, thus seriously affecting the potential for its long-term implementation [40,41]. Although since 2017 continuous monitoring has been conducted of marine litter from different compartments (beach, floating, deep seafloor litter and beach sediment, and microplastics ingested by fish), the data collected are still not sufficient for a broader assessment of the existing status and trends [52]. As previously stated, most of the existing published data come from scarce and spatially dispersed scientific research or cleaning actions carried out off-season mainly on beaches at the initiative of local governments, counties, or concessionaires, as well as individual actions of environmental NGOs (such as “Sunce,” “Green Action,” etc.). There are also activities of removing marine litter through certain actions of scuba diving clubs. Such scuba diving environmental actions are usually initiated for the removal of larger bulky waste along the shores and waterfronts of smaller settlements. Such voluntary initiatives of cleaning beaches and scuba diving environmental actions are part of the regular seasonal activities the NGOs conduct in cooperation with local governments. These activities are carried out to preserve habitats and increase the awareness of the local community about the problem of marine litter on the beaches and seabed, and to promote sustainable solutions for the preservation of the natural marine environment. Non-governmental organizations are better acquainted with the marine litter problems in the field because they have grown out of the needs of local communities. In addition, they are not dependent on inappropriate needs of state plans and are very resilient to changes in activity planning, unlike government ministries that implement changes very slowly. Despite many years of practice and acquired experience, unfortunately, no assessment of the potential and strengths of the NGOs and citizen science actions has been made in Croatia [2].

Although clean-up operations are carried out on a regular annual basis across the coast and islands, in almost every small town, there is still no organized collection and storage of data that could be used in the future. Systematic coordination of such marine litter collection activities has not been developed, nor have a recording and monitoring of the data on the composition, spatial distribution, and potential sources of the thus collected litter been developed. In most cases, the data collected were reported as the total amount of marine litter collected by type of material without further classification of the types of items. Certainly, with the application of appropriate protocols, methodology, and training, citizen scientist volunteers can make a significant contribution to marine litter data collection and such efforts can improve the national research program. Given the social benefits of community engagement, this could be a very valuable investment in environmental protection that can be agreed upon between the state administration and interested members of the public [53]. It is certainly advisable for Croatia to plan such an investment. In the current context of limited funding, unfortunately, limited guidelines of good practice have been established, and many activities are carried out without a structured and systematically organized plan. Therefore, many projects face challenges, usually due to the lack of funding, logistical constraints, lack of participant motivation, and/or lack of data. Regarding raising awareness of the role of NGOs in marine litter,

which is an important measure in the fight against marine litter in the EU, Croatia has not yet directed its policy to a more efficient cooperation with NGOs. The lack of strong and organized state support has led to the fact that citizen science is still at very low organizational levels. It has not taken strong enough root and has practically not gained due value.

Cross-border effects of marine litter are already a known issue of marine litter in Croatia [3], with floating marine litter traveling regardless of the state or administrative borders [1,19,29]. The DeFishGear project recognized the importance of a regional approach to addressing marine litter as a transboundary problem of multi-stakeholder engagement, coordination, and cooperation, and stressed the need to strengthen the science-policy interface, harmonize monitoring and methodologies, and prioritize a whole marine litter cycle approach [3]. However, despite the numerous international and regional initiatives providing a platform for cooperation and coordination of marine litter issues [3], and despite several bilateral state meetings at the highest political level, the continuous arrival of transboundary marine litter points to the lagging of cooperation and to the insufficiency of state efforts in these initiatives. Countries bordering the Adriatic Sea do not have adequate waste management schemes due to various economic constraints, although some of them have recently banned the use of plastic bags [1]. Poor cooperation and insufficient involvement of particular border states in international/regional initiatives are the main causes of this problem.

3.4. Obligations to the EU

Based on the obligations from the Marine Strategy Framework Directive, which have been transposed into national legislation within the process of drafting and implementing the Marine Environment and Coastal Zone Management Strategy, Croatia had the obligation of conducting the following processes through adequate documentation: Determine the existing situation with marine litter (assessment of quantities, composition, distribution, and sources of marine litter in relation to sea sections, on beaches, on the sea surface, and on the seabed, as well as microplastic on the sea surface, in sand sediment, and in fish), determine the good state of the marine environment with marine litter as a pressure (GES), determine targets related to marine litter, develop and implement monitoring of marine litter, and define and implement measures related to marine litter. Considering the knowledge gained from the implementation of the first cycle of the strategy, it can be said that it was not possible to determine the existing status and trends for marine litter descriptors in the Croatian Adriatic since knowledge about the state, quantities, properties, and impacts of litter on the marine environment is currently insufficient. Therefore, in addition to the broader goal of the strategy related to the overall reduction of marine litter in the Croatian part of the Adriatic, it was concluded that it is necessary to further develop indicators and methodological approaches for monitoring the quantities and trends of litter and micro litter/micro plastic on the seabed, the stomach contents of marine organisms, and the levels of its impact on marine ecosystems and humans [52]. Two adopted action programs, the Monitoring and Observation System for Continuous Assessment of the State of the Adriatic Sea [54] and the Program of Measures for the Protection and Management of the Marine Environment and Coastal Zone [39], confirmed the lack of key information to assess the situation and pressures in terms of marine litter descriptors, and defined criteria and methodological starting points for monitoring marine litter. It should be noted that the legally binding UNEP MAP Regional Marine Litter Management Plan in the Mediterranean [55] was considered when defining measures related to marine litter. Unfortunately, Croatia currently does not have a systematic model for marine litter management, and neither it is able to determine the amount of litter that reaches it. A strategic document/a legal act exclusively relating to such litter has not yet been adopted. Activities related to the prevention of such litter are carried out through the application of the current legal framework and strategic documents dealing with waste management.

3.5. Marine Litter Monitoring in Croatia According to EU Obligations

Until 2017, Croatia did not systematically collect and record data from field research related to marine litter. However, since mid-2017, Croatia has been implementing a systematic model for monitoring all elements of marine litter. This includes the litter deposited on beaches, floating on the sea surface, and sunk on the seabed, as well as microplastic in sandy sediment on beaches, the sea surface, and in the digestive tract of fish, all as part of the Monitoring and Observation System for Continuous Assessment of the Adriatic Sea [54]. During this period, monitoring and observation activities of the parameters required for the assessment of the status of the descriptor D10—Marine Litter of the Marine Strategy Framework Directive [50] were carried out. These activities were successfully implemented on the Croatian side of the Adriatic for the first time according to the defined implementation methodology. The monitored parameters were as follows: (a) quantity and composition of bulky waste deposited on the shore; (b) quantity and composition of bulky waste on the surface and on the seabed; (c) quantity, distribution, and composition of microplastic on beaches and the sea surface; and (d) quantity and composition of ingested marine litter. All predicted parameters were monitored at designated locations by implementing a specific methodology that depended on the individual group of litter being observed/monitored, and included the determination and analysis of the status of the predicted indicators. However, due to insufficient financial resources during 2017 and 2018, sampling and subsequent analyses were performed on a smaller scale than the action program Monitoring and Observation System for Continuous Assessment of the Adriatic Sea envisaged [54].

Given the lack of a previous systematic database as well as the short period of the systematic monitoring program, the knowledge on marine litter in Croatia is still insufficient. One of the main shortcomings of the evaluation of the previously mentioned parameters in relation to the environmental impact is the undeveloped system of limit values, which is also expressed at the EU level. Therefore, at the moment, it is not yet possible to express reliable qualification of a possible degree of burden. However, comparing the results obtained by all monitored parameters with the existing preliminary data from the DeFishGear project, and those available for the Mediterranean area, it is possible to estimate that the monitored data are below the stated values for these areas. The data are insufficient for a broader expert assessment of the state of this parameter, given that, due to the lack of financial resources during 2017 and 2018, sampling and subsequent analyses were performed in a shorter period of time than expected.

The results of monitoring all parameters were entered into the structure of the existing indicators database (<http://baltazar.izor.hr/azopub/bindex>) (accessed on 22 April 2021), which will still need additional adjustment due to the specific structure and peculiarities of individual parameters. All results were recorded and prepared in the form and values recommended by the EC MSFD Technical Subgroup on Marine Litter (TG10) Guidance on Monitoring of Marine Litter in European Seas [56], according to the draft “UNEP/MAP MEDPOL Monitoring Guidance” document on Ecological Objective 10: Marine Litter (2014), whose applicability on the Croatian coast was tested in the field through the DeFishGear project.

4. Conclusions

Marine litter is a global environmental problem today. Although its issues have been present for a long time, when talking about the Croatian Adriatic, the knowledge about it is still quite scarce. The main shortcomings are insufficient databases on the quantities, composition, and trends of marine litter; poor understanding of oceanographic and climatic processes that affect its distribution and retention in the marine environment; and ignorance of its further fate upon reaching the sea (decomposition time, sinking, etc.).

Regarding Hypothesis 1 (H1), *Stakeholders in Croatia have a moderate level of interest in the marine litter issue*, the results show that stakeholders’ interest scores were medium for

ca. 50% of respondents. As such, the results provide support for Hypothesis 1 (H1) of our research.

In addition to non-governmental organizations playing an important role in developing awareness on marine litter and sensitizing the public, scientific institutions should also intensify basic research on this complex issue and participate in adopting strategies and legal frameworks in cooperation with the state administration. Results from our research provide support for Hypothesis 2 (H2), *Data from scientific research on marine litter quantity, distribution, and composition in Croatia are rare and limited*. Currently, Croatia does not have a systematic model for marine litter management, and neither is it possible to determine the amount of litter already in the sea or the amount of litter yet to arrive.

In Croatia, particular attention is paid to strengthening bilateral and multilateral relations with neighboring countries, with the aim of developing joint measures for better management of marine litter, given the transboundary nature and processes at sea that allow it to spread over long distances. Marine litter is not an environmental problem that can be solved only by law enforcement, beach cleaning, and technical solutions. It is also a cultural problem requiring great efforts, primarily through education, to change habits, approaches, behavior, level of awareness, and management as well as to achieve the active involvement of all sectors and stakeholders. Therefore, the issue of marine litter requires a joint approach of different countries with joint efforts in cross-border management to find the right and appropriate solution and approach that would reduce the amount of litter entering the Adriatic Sea. In this regard, national measures alone are insufficient to control marine litter, and more significant strengthening and coordination of NGOs and citizen science with more intensive and stronger regional cooperation is highly required.

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