frontiers in Marine Science

ORIGINAL RESEARCH
published: 28 January 2022
doi: 10.3389/fmars.2021.784829

# Public Perceptions of Marine Plastic Litter: A Comparative Study Across European Countries and Seas

*Lotte van Oosterhout[1]*, Hanna Dijkstra[1], Pieter van Beukering[1], Katrin Rehdanz[2], Salma Khedr[2], Roy Brouwer[1,3] and Sem Duijndam[1]*

*[1] Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, Amsterdam, Netherlands, [2] Department of Economics, Kiel University, Kiel, Germany, [3] Department of Economics, Water Institute, University of Waterloo, Waterloo, ON, Canada*

Marine plastic litter (MPL) is a growing global problem and its prevention requires public engagement and behavioral change. Statistics of public perceptions of MPL are scarce and hardly comparable due to varying definitions and interpretations of the concept. This study identifies and classifies relevant components of public perceptions of MPL based on a large-scale survey across eight European countries sharing three European seas (North Sea, Baltic Sea, and the Mediterranean Sea). High levels of concern about MPL were observed throughout the EU and water pollution and plastics in oceans were consistently ranked in the top four most worrisome environmental challenges of our time. Most of the respondents (70%) reported noticing MPL, which influenced knowledge and feelings of responsibility with regards to MPL. The general public held companies and consumers most responsible for cleaning up MPL. Self-responsibility to reduce MPL varies considerably across and within countries, with the highest scores being reported in Greece and the lowest in Netherlands. Public knowledge on the recyclability of plastics was low in all countries. At the marine region level, the lowest scores for concern, perceived consequences and personal responsibility to reduce the use of plastics were reported in the North Sea region, followed by the Baltic Sea region and the highest scores were recorded in the Mediterranean Sea region. Using these results, policy implications and possible intervention strategies are discussed, to improve and increase public awareness, understanding, engagement, and sense of responsibility to change lifestyles and purchasing behavior to prevent and reduce MPL.

**Keywords: marine plastic litter, public perception, public engagement, European Seas, cross-country analysis, plastic policy**

OPEN ACCESS

***Edited by:***
*Khuong Van Dinh, Washington State University, United States*

***Reviewed by:***
*Thanh-Son Dao, Ho Chi Minh City University of Technology, Vietnam*
*Olgaç Güven, Akdeniz University, Turkey*

****Correspondence:***
*Lotte van Oosterhout*
*lotte.van.oosterhout@vu.nl*

***Specialty section:***
*This article was submitted to Marine Pollution, a section of the journal Frontiers in Marine Science*

***Received:*** *28 September 2021*
***Accepted:*** *20 December 2021*
***Published:*** *28 January 2022*

***Citation:***
*van Oosterhout L, Dijkstra H, van Beukering P, Rehdanz K, Khedr S, Brouwer R and Duijndam S (2022) Public Perceptions of Marine Plastic Litter: A Comparative Study Across European Countries and Seas. Front. Mar. Sci. 8:784829. doi: 10.3389/fmars.2021.784829*

## INTRODUCTION

Throughout the last decade, the problem of marine litter pollution has gained considerable worldwide attention while continuing to degrade marine and coastal ecosystems (Geyer et al., 2017). Marine litter has been defined by the United Nations Environment Programme (2009, p. 13) as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment." The most prevalent share of litter pollution in the marine environment is comprised of plastics, which is also considered the most harmful type due to its abundance, toxicity, persistency and its ability to disseminate

(Barnes et al., 2009). Marine plastic litter (MPL) constitutes up to 95% of the waste that accumulates on shorelines, the sea surface and the sea floor and is increasingly polluting European seas (Galgani et al., 2015). This results in growing threats to marine and coastal ecosystems and the services they provide, causing environmental, economic, health and esthetic harm. The economic costs associated with marine litter are estimated to be between €259 million and €695 million per year in Europe alone (European Parliament Research Service, 2018).

The complex and borderless nature of MPL requires problem solving and cooperation at local, regional, national and international level. In the EU, due to the magnitude and omnipresence of the marine litter problem, it has attracted significant attention from the European Commission and the European Union's Member States over recent years and is included as one of the key indicators of the Marine Strategy Framework Directive (MSFD–European Directive 2008/56/EC). Consequently, a variety of EU legislative instruments, policy initiatives and funding schemes are created to reach the EU's goal of "Good Environmental Status" (GES) by 2020, which is defined as "the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive" (Article 3 MSFD, European Commission, 2008, p. 25). Even though GES may not have been fully achieved in 2020, the EU has increased its efforts to monitor and collect marine litter, as well as to reduce the amount of litter entering the oceans (European Environment Agency, 2020; Frantzi et al., 2021).

The vast majority of MPL originates from land-based sources, and several stakeholders are involved in reducing, reusing and recycling plastics to prevent leakage into the environment. Among these stakeholders, the general public holds a special and influential position. Their way of living, waste management, purchasing behavior, and compliance with policies are essential in achieving EU goals for MPL reduction (Hartley et al., 2018). Therefore, influencing the general public's behavior is becoming a priority in European environmental policy (Niva and Timonen, 2001; Hartley et al., 2015), and has been emphasized in a number of studies (e.g., Steel et al., 2005; Hynes et al., 2014; Jefferson et al., 2014; Veiga et al., 2016; Hartley et al., 2018; Forleo and Romagnoli, 2021). Understanding public perceptions around plastic pollution in the European marine environment can support the desired behavioral change through more tailored communications, targeted information distribution and more effective policy and decision-making.

Despite the relevance of the role of the general public in solving the MPL problem, there is limited literature on factors affecting public perceptions of marine litter, and even less on perceptions of MPL specifically. Perceptions can be explained as an umbrella term that encompasses a range of psychological components, such as concern, knowledge, interest, social values, attitudes, or behaviors (Jefferson et al., 2014; Ankamah-Yeboah et al., 2020). In the context of marine litter, scientific literature defines perception in different ways. Brouwer et al. (2017), for example, define perception as the act of seeing marine litter, adopting a more tangible definition that includes personal experience. Others define perception in terms of knowledge (e.g., Henderson and Green, 2020), responsibility (Hartley et al., 2018), perceived consequences (e.g., Forleo and Romagnoli, 2021), or concern (e.g., Pereira, 2019). A number of these papers consider more than one component in their operationalization of the concept of perception, but none seem to cover all relevant aspects. It is therefore unclear which component(s) best address the issue and on which aspects decision makers should focus for effective policy making.

To address this multitude of definitions and approaches and lack of coherent interpretation, the aim of this paper is three-fold. First, this study aims to better conceptualize public perception in the context of MPL. Based on the existing literature, we define public perception of MPL as a composite of concern, perceived consequences, responsibility, knowledge and personal experience and observations. We test this new conceptualization of perception through a factor analysis. Second, we examine if these components differ geographically, at national and regional sea scale. Comparison across spatial scales provides useful information on variance in MPL perceptions, which in turn could improve the relevance and effectiveness of public engagement and policy strategies. So far, studies on public perceptions of marine litter focus either on one European country only (e.g., Henderson and Green, 2020; Forleo and Romagnoli, 2021), or generalize perceptions of citizens from different European countries for Europe as a whole (e.g., Hartley et al., 2018). Our study is the first to compare public perceptions in Europe based on a standardized collection and processing procedure of data which allows for country and regional (shared) sea comparisons.

To this end, we conducted a large-scale public survey among a random selection of citizens residing in eight European countries who had visited a beach or coastal area in the previous year. The eight countries cover three major regional seas in Europe: (1) Estonia, Denmark, Germany, and Sweden bordering the Baltic Sea; (2) Germany and Netherlands situated along the North Sea; and (3) Greece, France, and Italy bordering the Mediterranean Sea. Third, we examine the salience of MPL by comparing public concern about MPL with concerns about other environmental challenges and investigate who the general public holds responsible for managing MPL. In doing so, the findings of this study provide useful insights for national, regional and EU policymakers in developing effective and appropriate targeted strategies and interventions, accounting for public perceptions of MPL, ultimately with the aim to reduce plastics entering our seas and oceans.

## BACKGROUND

There is no single definition of perception. Efron (1969, p.137) describes perception as "[. . .] a man's primary form of cognitive contact with the world around him." This conceptualization of perception focuses on the fact that our sensory systems provide an observer with knowledge about what is present in his or her immediate environment (Boothe, 2002). However, perceptions entail more than (past) experiences, and the inputs provided by the sensory system are organized, transformed and elaborated leading to interpretation and understanding. As

Pomerantz (2006) pointed out, the complicating factor is that perceptions are private, subjective experiences, which are locked up inside our individual minds. Nevertheless, various research efforts have been made to explore and operationalize public perceptions and understanding of the marine environment. This background section provides an overview of the existing body of literature focusing on public perceptions of marine pollution, the components covered to examine perceptions, and the existing lack of balance in coverage.

Several studies measure perception as a combination of awareness, knowledge and concern. A recent study by Forleo and Romagnoli (2021) explored public perceptions of MPL sources and impacts in Italy. Pereira (2019) studied Rhode Island residents' perceptions of marine plastic debris and their support for plastic and paper bag legislation. Levels of concern, awareness and knowledge were generally high. Henderson and Green (2020) conducted qualitative research in the United Kingdom to explore the relationship between knowledge and understanding of microplastics and the role of the media in influencing these perceptions. Most participants were unaware of microplastics and its associated problems; only few made connections between their personal use of plastics and ocean pollution (Henderson and Green, 2020).

The majority of the literature studies perceptions for a selected country or area. An exception is the study by Brouwer et al. (2017), who assessed the social costs of marine litter along European coasts by asking beachgoers in Bulgaria, Greece, and Netherlands for their experiences with beach litter, their willingness to volunteer and pay for cleaning practices. The cross-country comparison revealed that significant differences exist in perception and valuation across these three European countries. In addition, a multi-country survey conducted by the European MARLISCO project (MARine Litter in European Seas–Social Awareness and Co-responsibility) examined the perceptions toward marine litter of 3,748 respondents from 16 European countries (Hartley et al., 2018). Results are, however, aggregated at EU level as the number of respondents in each country was very different. This study found that the quantity of perceived marine litter positively influences visitors' level of concern and their subsequent willingness to act, but no information was given on where these visits took place. In all these studies, personal experience and observation of marine litter is included as a driver behind perception.

Beyond marine litter and MPL, other literature addresses a variety of hazards to marine and coastal ecosystems and discusses to a varying degree the role of marine litter as a threat to ecosystem health. A nation-wide survey in Ireland asked the public about their values, concerns and preferences toward the Irish marine environment (Hynes et al., 2014). In this study, perceived consequences and knowledge were found to shape individuals' opinions regarding the marine environment. Jefferson et al. (2014) found that in the United Kingdom, citizens' personal experiences and knowledge were important factors for individuals' relationship with the sea. Dilkes-Hoffman et al. (2019) found that the Australian public perceived ocean plastics as the most worrisome environmental issue from a list of nine. Additionally, a large-scale public perception study based on just over 10 thousand respondents in 10 European countries confirms that citizens perceive pollution as one of the most important marine environmental problems (Gelcich et al., 2014).

# MATERIALS AND METHODS

A large online public survey was conducted as part of the Horizon 2020 funded CLAIM project (Cleaning Litter by Developing and Applying Innovative Methods in European Seas). The main focus of the survey was on European citizens' perceptions of marine plastics and their behavioral intent to reduce MPL. The survey was translated into the official languages of the eight countries surveyed (Denmark, Sweden, Estonia, Germany, Netherlands, France, Italy, and Greece), thoroughly pre-tested in focus groups and an online pre-test sample, and then launched online by the survey company Norstat in July and August 2020 with a sample goal of 1,000 representative participants per country.

## Structure of the Survey

After asking questions about their socio-demographic background for quota sampling purposes to ensure representativeness, including age, gender, education and region of residence, respondents were asked in the second part of the survey about their beach and coast visitation behavior, the leisure activities they undertake and their experience with marine litter, the first component of perception that we cover. This was followed in the third part by a section eliciting respondents' willingness to pay for marine litter clean up measures. The fourth part of the survey contained questions on the other three components of perception: knowledge, concern, and responsibility.

The analysis considers only respondents that had visited a beach or coastal area in 2019. Visual perception is one of the key components of our definition of public perceptions in the marine litter context. We were unable to examine the visual perceptions of respondents who had not visited a coastal area in 2019 for leisure, hence they were excluded from the dataset. 15 Questions were employed to examine the components of public perceptions of MPL identified in the literature review. The 15 survey questions are presented in **Appendix Table 1** in the **Supplementary Material**.

Respondents' perception related to experience and observation was examined through four statements. Participants were first asked about the water clarity of the visited coastal area and whether they had noticed the presence of MPL. Those indicating that they saw litter were asked to indicate the amount and size of the litter. Concern was operationalized through two questions. The first question asked for the respondent's level of concern for marine plastics specifically. The second question asked the respondent to rank environmental issues of concern, including water pollution and marine plastic, allowing us to identify the relative importance of MPL in relation to other environmental issues. Similarly, two statements measured the level of responsibility. Respondents were first asked to indicate how responsible they felt personally to reduce plastic pollution, and next to rank listed parties (including plastic consumers) who

they felt are responsible for cleaning up MPL. Three statements were included to inquire about respondents' perceptions of consequences of MPL. Knowledge was measured both subjectively and objectively. Respondents first indicated their self-perceived or subjective knowledge, and this was followed by three right or wrong statements about marine plastic. Their responses to the statements were coded into a single variable for objective knowledge. Including both subjective and objective knowledge allows us to investigate the potential "illusion of knowing"; the result of an overestimation of self-perceived knowledge in relation to actual knowledge (Park et al., 1988).

## Analysis

The software program SPSS (version 26) was employed to quantitatively analyze the survey results and identify salient findings regarding public perceptions of marine litter. An exploratory factor analysis with varimax rotation was performed to examine variable relevance and relationships.

General patterns across respondents' responses are explored by reporting and comparing mean scores and distributions of responses. Statistical differences between various subsets are examined by means of the non-parametric Mann-Whitney *U*-test for comparisons of the central tendency of distributions across two subgroups and the Kolmogorov-Smirnov *Z*-test to test for differences in response distributions (e.g., respondents who noticed the presence of marine litter during their visit versus those who did not) and the Kruskal-Wallis *H*-test and multiple pairwise comparisons for testing more than two independent samples (e.g., across three marine regions: the Baltic Sea, the North Sea, and the Mediterranean Sea), using a critical *p*-value to identify statistical significance of 5%.

The analysis applies two geographic scopes. First, comparisons of relevant perception variables are made across the eight surveyed countries. Second, survey outcomes are compared at regional sea level by examining responses from households residing in a specific marine region (Baltic Sea, North Sea, and Mediterranean Sea). Since some surveyed countries border multiple seas (Germany, France), respondents residing in the same country may be allocated to different marine regions based on their region of residence and distance to the marine region. Although France is located along the Atlantic Ocean and Mediterranean Sea, respondents are clustered into the Mediterranean and North Sea region to maintain acceptable sample sizes per marine region. To be more specific, the Baltic Sea region consists of residents from Sweden, Estonia and the eastern part of Germany; the North Sea region of respondents living in Denmark, Netherlands, the western part of Germany, and northern part of France; and the Mediterranean by Italy, Greece and the southern part of France and Germany.

# RESULTS

## Socio-Demographic Profiles

In each of the eight sampled countries we gathered data for approximately 1,000 individuals aged 18 or above. Since the study is focused on those who have had personal experience with marine litter, a subset is used in our study of 4,664 individuals who visited a sea or coastal area in Europe in 2019. The remaining sample of respondents excluded from further analysis here had not visited the beach or coastal zone in their country in the previous year. Socio-demographic characteristics of the survey participants are summarized in **Appendix Table 2** in the **Supplementary Material**. Examination of the data reveals variability in the demographic and socio–economic characteristics across the eight samples. Although respondent numbers vary per country, the variation was limited, ranging from 497 useable respondents in Italy to 657 respondents in Denmark. Germany had almost the same number of respondents as Italy, and Estonia a similar number of respondents as Denmark. With just over 600 respondents, Greece, Sweden, and Netherlands were found somewhere in between these minimum and maximum numbers of respondents.

The overall gender ratio (female = 49.5%; male = 50.4%; other = 0.1%) is considered representative for the whole population of the participating countries, although in some countries female respondents were slightly overrepresented (e.g., Estonia) and in other countries male respondents (e.g., Greece and Netherlands). All adult age groups were represented; the respondents' age ranged between 18 and 92 years, with an average age of 46 years. Greek respondents are on average significantly younger (40.59 years) than the sample mean, while the Swedish respondents are significantly older (48.41).

## Factor Analysis of Perception Variables

First, we calculated the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and conducted Bartlett's sphericity test to determine whether the data is suitable for a factor analysis. We excluded the two ranking questions and recoded the three questions to examine one's objective knowledge into a single variable, leaving 11 perception components. The KMO measure has a value of 0.809, which is considered "meritorious" according to Kaiser (1974). Bartlett's test of sphericity indicated a significant correlation between the variables ($p < 0.001$).

Second, we conducted Spearman's multivariate factor analysis to define the underlying structure in the data and to model interrelationships among the perception variables. Analysis of the communalities of the perception variables indicated that one variable of the component group "experience and observation," namely responses to the question about perceptions of water clarity, did not contribute as much as the other components and was therefore eliminated. The scree plot test identified three eigenvalues greater than one, suggesting that the remaining 10 components could be organized into three component groups: experiences and observation, concern and consequences, and knowledge and responsibility (see **Table 1**). Experience and observation are related to one's visual perceptions and can be explained as the process of absorbing what one sees, including memories and experiences, and organizing it in the brain. Respondents' observations of the frequency, amount and size of marine litter are part of this first factor component group. The second component group encompasses psychological factors that influence one's level of concern and perceived consequences associated with MPL. The third component group consists of

**TABLE 1 |** Rotated component matrix suggesting three factor groups.

| Component groups | Variable | Component group | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Experience and observation | MPL Frequency | 0.834 | | |
| | MPL Amount | 0.800 | | |
| | MPL Size | 0.780 | | |
| Concern and consequences | Consequences Marine Organisms | | 0.871 | |
| | Consequences Human Health | | 0.829 | |
| | Consequences Coastal Appearance | | 0.839 | |
| | Concern | | 0.780 | |
| Knowledge and responsibility | Responsibility | | 0.333 | 0.645 |
| | Objective knowledge | | | 0.781 |
| | Subjective knowledge | | | 0.605 |

subjective and objective knowledge, as well as perceived personal responsibility. Responsibility was spread across two component groups, which was not unexpected since the mean score analysis showed high deviations across responses for self-responsibility (**Appendix Table 3** in the **Supplementary Material**). The 10 perception variables in the three component groups explain 63.6% of the variation within the data. The participants' responses per component group will be discussed next.

## Visual Perception

### Magnitude and Location of Observed Marine Plastic Litter

The first cluster of variables relates to the observed marine litter, as well as the amount, size and frequency of the litter. Considering all respondents who visited a beach or coast in the previous year, **Figure 1** shows that 70% of the respondents confirmed having noticed marine litter during their visit to the coast, whereas 23% reported not seeing any marine litter and 7% did not remember whether they saw marine litter or not. Furthermore, when asked how many pieces of MPL the respondents had seen on the beach or in the water, the vast majority of the respondents stated that they saw "some pieces" (72%) and most of the observed pieces of MPL were considered "small" (52.8%), like cigarette butts or bottle caps. The share of respondents reporting that they did not remember the amount (7.4%) or size (9.9%) of litter is limited and could also be indicative of a lack of interest or attention paid to MPL.

When analyzing more specifically where MPL was observed, we identified the top 15 most-frequently visited European countries, which represent 90% of the total sample. The remaining visited countries are not considered due to low visitation numbers, resulting in sensitive scores. **Figure 2** presents the relative frequency of seeing MPL in the 15 most-frequently visited countries with beaches and coastlines. Note that the choropleth map presents proportionated visual perception scores of MPL, ranging from least often to most often, which are based on relative differences of perceived MPL between the visited countries. These visual perceptions do not necessarily correspond to actual levels of MPL in a country or sea.

Marine plastic litter was most often observed in Netherlands (*Mean score* = 2.13), Sweden (*Mean score* = 2.10), and United Kingdom (*Mean score* = 2.04) and least often in Finland (*Mean score* = 1.58) and Croatia (*Mean score* = 1.61). Fewer pieces of plastic were observed in the Nordic countries, such as Finland (*Mean score* = 2.00), Denmark, and Sweden (both have a *Mean score* of 2.07), and larger quantities in France (*Mean score* = 2.25) and Italy (*Mean score* = 2.19). Larger pieces of MPL were reported in the North Sea region, in Netherlands (*Mean score* = 2.32), Denmark (*Mean score* = 2.30), United Kingdom (*Mean score* = 2.29), and Germany, whilst somewhat smaller pieces were noticed in countries located around the Mediterranean Sea, such as Croatia (*Mean score* = 2.07), Spain (*Mean score* = 2.09), Greece (*Mean score* = 2.14), and France (*Mean score* = 2.14).

In comparing mean scores for the public's experiences and observations of MPL across countries, which are presented in

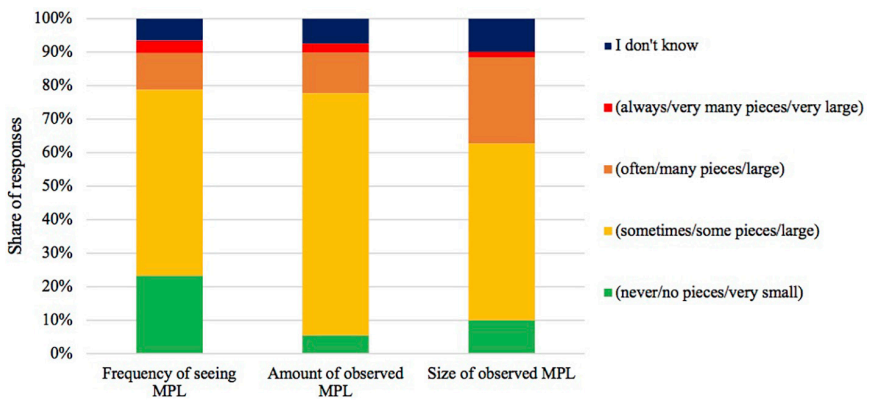


**FIGURE 1 |** Distribution of beach or coastal visitors' experiences with MPL. Explanatory note: the shares refer to the replies to the following three questions: Frequency: "*How often did you see plastic litter on the beach or in the water?*" Amount: "*How would you describe the amount of plastic litter on the beach or in the water?*" Size: "*How would you describe the size of the most noticeable plastics on the beach or in the water?*"

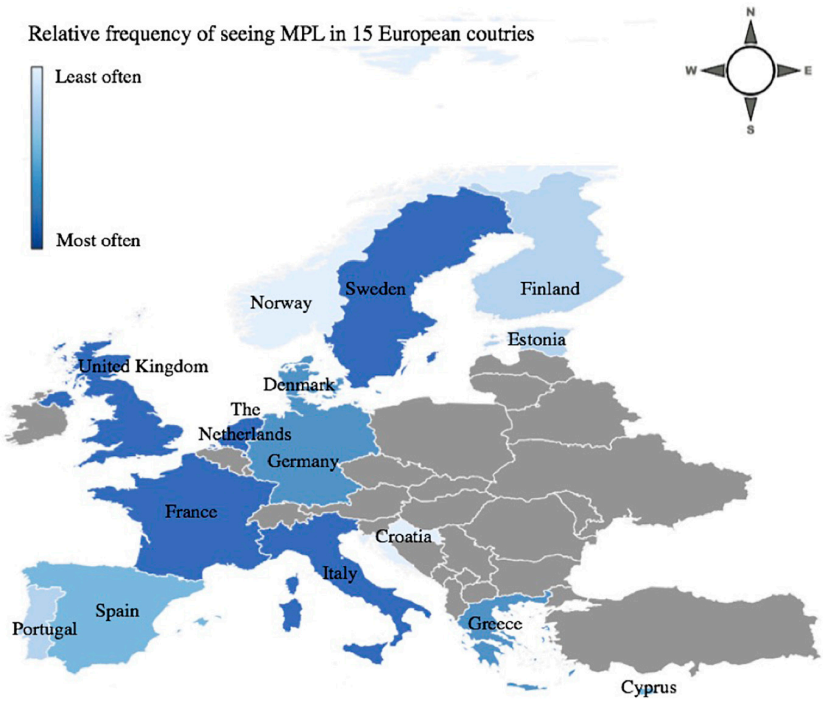


**FIGURE 2 |** Geographical distribution of mean scores of seeing marine plastic litter across visited European countries. The mean scores refer to the question "*How often did you see plastic litter on the beach or in the water?*", where the answers are 1 = never; 2 = sometimes; 3 = often; 4 = always).

**Appendix Table 3** in the **Supplementary Material**, it is notable that relative to the other participants, the Danish observed litter less often and in smaller amounts. The Dutch noticed the presence of litter most often and, along with the Italians, in relatively high amounts. Generally, larger pieces were seen by respondents in the North Sea region (Netherlands, Germany, and Denmark), whilst smaller pieces were observed and reported by respondents from France, Estonia, and Greece.

### Influence of Marine Plastic Litter Observation on Other Public Perception Components

**Figure 3** shows two subgroups: respondents who noticed MPL ($N$ = 3,274) and those who reported that they did not see MPL ($N$ = 1,086) when visiting beaches or coastlines. To explore whether visual perception of MPL influences other variables, we compared these two sub-groups revealing that respondents who witnessed marine litter ranked higher mean scores for all variables, except for the perceived impacts of MPL on marine organisms, scenery and human health.

Running the non-parametric Mann-Whitney $U$-test to test for statistical differences in perceptions across the two groups, statistically significant differences are detected for objective ($U$ = 1639647, $p < 0.001$) and subjective ($U$ = 1685706, $p < 0.01$) knowledge between the two subgroups, namely significantly higher mean scores were recorded for respondents who witnessed marine litter. Additionally, significant differences also exist when it comes to feeling personally responsible: respondents who noticed the presence of MPL felt significantly more responsible to reduce the problem ($U$ = 1675563, $p < 0.01$). Similar findings emerged from the non-parametric Kolmogorov-Smirnov test, which indicated a statistically significant deviation in the distribution of data related to sense of responsibility ($Z$ = 1.728, $p < 0.01$) and objective knowledge ($Z$ = 1.863, $p < 0.01$) across the two subgroups.

## Concern and Consequences of Marine Plastic Litter

Considering public concerns across the eight countries, the results in **Figure 4** show that the vast majority of respondents selected "totally agree" and "somewhat agree" to the statement "I am very worried about plastic pollution in seas and oceans." In total, 83% of the respondents confirmed being concerned about MPL, whilst only 4% expressed not to feel concerned. It was noted that the Greek sample was most concerned about the negative impacts of MPL with 92% confirming concern and only 1% disagreeing, whereas the Scandinavian countries were least concerned. Nevertheless, still 77% of the respondents in Sweden and 80% of the respondents in Denmark confirmed being concerned about MPL. These results are confirmed when comparing the mean scores across the five-point scale statements (1 = strongly disagree, 5 = strongly agree). These reveal that the respondents are generally highly concerned about marine litter (*Mean score across all respondents* = 4.26) and are aware of the associated negative impacts of MPL on marine organisms (*Mean score* = 4.58), followed by coastal appearance (*Mean score* = 4.53), and human health (*Mean score* = 4.39).

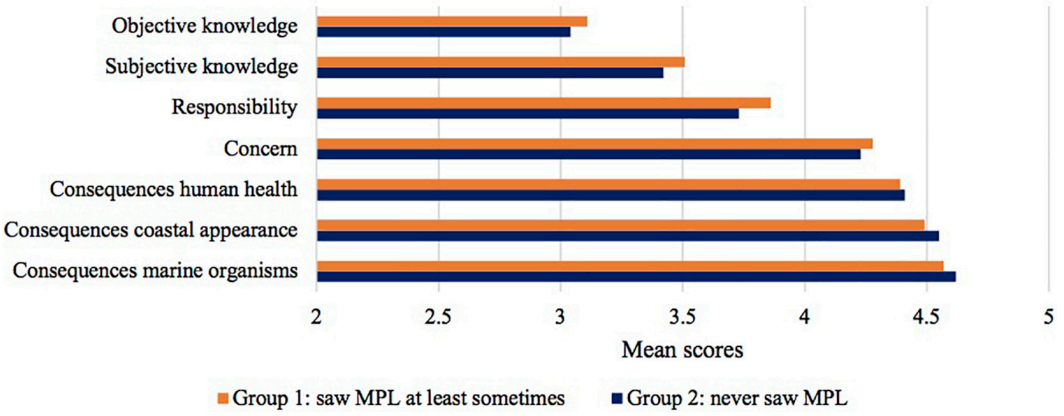


**FIGURE 3 |** Comparison of mean scores across respondents who saw MPL and who reported that they never saw MPL during their beach visit (response options range from 1 to 5: totally disagree–totally agree).

The study also sought to explore how concern about MPL relates to other environmental challenges. Survey respondents were asked to select the top three environmental issues that worry them most from a list of 14 (and an open-ended category where they could specify another environmental concern) and rank them in order of importance. **Figure 5** shows the weighted average of the highest ranked issues.[1] Respondents' concern about water pollution and plastics in oceans is high compared to other environmental issues. They are ranked as the second and fourth most worrisome issues, respectively, with about 10% of the total number of points being allocated to these issues. However, the ranking of the environmental issues differ across countries. For example, whilst a significant share (14%) of the points is allocated to plastics in oceans by the French, only 5% of the total points are assigned to this issue by respondents living in Estonia, who find air pollution more worrisome (17%) (a country by-country presentation of the distribution is presented in **Appendix Table 4** in the **Supplementary Material**).

**Figure 6** presents a comparison of mean scores associated with perceived consequences across countries and reveals a similar pattern per country: consequences of marine litter for marine organisms are considered most severe (except in France), followed by consequences for natural beauty and scenery and, to a lesser extent, consequences for human health. The highest mean scores for the three consequences are found in Greece, and the lowest mean scores are reported by Dutch respondents.

## Knowledge and Sense of Personal Responsibility to Reduce Marine Plastic Litter

The final cluster of variables addresses subjective and objective knowledge, as well as the sense of personal responsibility. Objective knowledge, also referred to as factual knowledge, is measured by means of three statements about the sources of plastic pollution and recycling practices, with a high average mean score indicating a high level of knowledge. **Figure 7** indicates that knowledge about the recyclability of plastics is low in all countries, whereas knowledge about the contribution of washing synthetic clothing and the role of consumers in the production of plastic pollution is considerably higher.

The scores of objective knowledge across the three themes presented in **Figure 7** are computed into one variable indicating the average level of objective knowledge per country. **Figure 8** presents the mean scores for objective and subjective knowledge across the eight European countries. On the one hand, the mean scores of objective knowledge do not differ much and vary from a high average score of 3.2 for the French and Greek samples as the most knowledgeable respondents to 2.9 for the German sample as the least knowledgeable respondents about MPL. On the other hand, the average scores for respondents' subjective self-reported knowledge show much more pronounced differences, with the Greek (*Mean score* = 4.0) and Italian (*Mean score* = 3.9) respondents considering themselves most knowledgeable, while the respondents from Denmark and Sweden ascribe significantly lower levels of knowledge about MPL to themselves with average scores of 2.96 and 3.12, respectively. Paired-samples *t*-tests indicated that scores of subjective and objective knowledge were statistically significantly different from each other at the 5% significance level in each surveyed country, except for Sweden; *t*-test statistic = −0.065 ($p$ = 0.948). **Appendix Table 6** in the **Supplementary Material** provides all test results of the paired-sample *t*-test to compare subjective and objective knowledge scores within countries and **Appendix Tables 7, 8** present the test statistics of the Kruskal-Wallis *H*-test and pairwise comparisons to test whether and how levels of objective or subjective knowledge significantly differ across countries.

Respondents were asked who they think should be made responsible for the clean-up of MPL. As shown in **Figure 5**, companies and consumers are considered most responsible, whilst the fishing and tourism industry are considered least responsible. A country-by-country comparison (**Appendix Table 5** in the **Supplementary Material**) reveals similar patterns

[1]Respondents were asked to assign three points to the most worrisome issue, two points to the second important concern and one point to the third environmental issue. No points were given to unselected options.

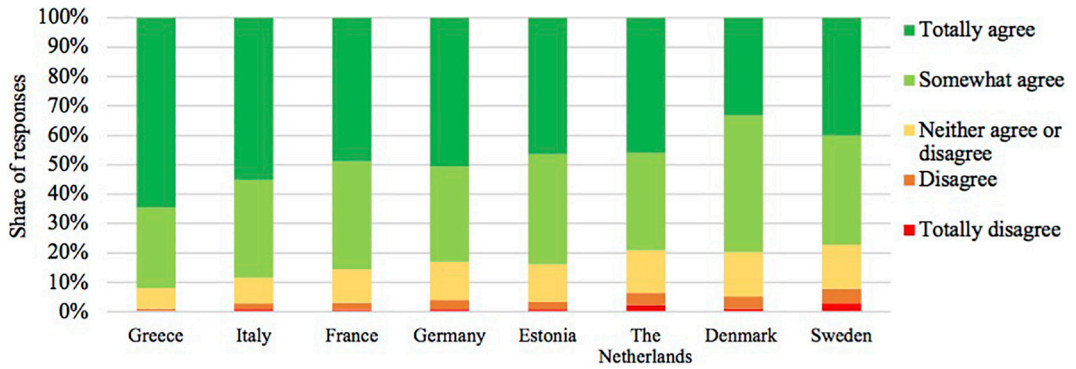


**FIGURE 4 |** Distribution of public concern about plastic pollution in seas and oceans. Responses to the statement "*I'm very worried about plastic pollution in seas and oceans*."

| Environmental issue | Percentage of respondents identifying this environmental issue as highest concern |
|---|---|
| *Extinction of plant and animal species* | 12% |
| *Water pollution* | 11% |
| *Air pollution* | 11% |
| *Plastics in oceans* | 10% |
| *Deforestation* | 10% |
| *Greenhouse gas emissions* | 8% |
| *Illegal waste disposal* | 6% |
| *Droughts* | 5% |
| *Overfishing of the oceans* | 5% |
| *Forest fires* | 5% |
| *Sea level rise* | 5% |
| *Disappearance of coral reefs* | 4% |
| *Heat waves* | 4% |
| *Flooding* | 3% |

| Held responsible | Percentage of respondents identifying who is main responsible for the clean-up of MPL |
|---|---|
| *Plastic-producing companies* | 20% |
| *Plastic consumers* | 17% |
| *Plastic-using companies* | 16% |
| *The European Union* | 16% |
| *My national government* | 12% |
| *Waste management companies* | 11% |
| *Nature organizations* | 5% |
| *The fishing industry* | 2% |
| *Hotels and the tourism sector* | 2% |

**FIGURE 5 |** Distribution of respondents' perception of the most worrisome environmental issues and who is responsible for cleaning up MPL. The percentages do not add up to 100% due to rounding errors.

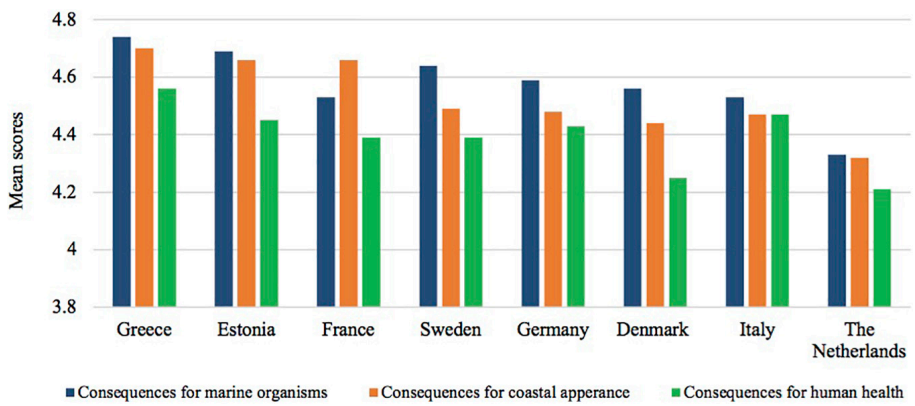


**FIGURE 6 |** Mean scores of perceived negative impacts of marine litter on biodiversity, human health and coastal appearance by country of residence. Response options range from 1 = totally disagree to 5 = totally agree to the following statements: "*Marine plastic severely harms marine organisms*"; "*Marine plastic reduces the beauty or coasts and seas*"; "*Microplastic is a potential health risk for humans*."

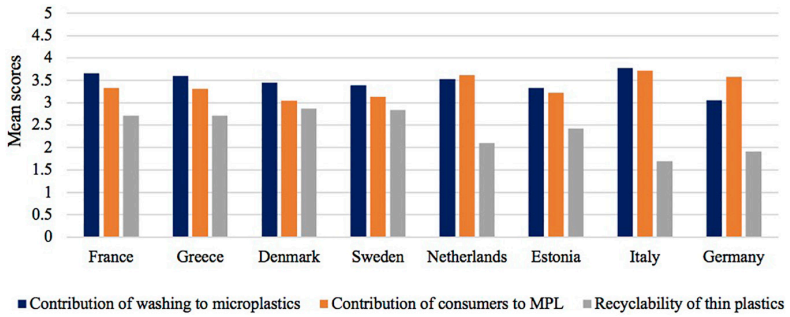


**FIGURE 7 |** Mean scores of respondents' level of knowledge and understanding across three plastic pollution themes. Scores range from 1 = low level of knowledge to 5 = high level of knowledge related to the following statements: "*Washing synthetic clothing is a significant contributor of microplastic litter*," overall *M* = 3.5 "*Consumers produce more plastic litter than industry and business*," overall *M* = 3.4 "*Thin plastic packaging is easily recycled*," overall *M* = 2.4.

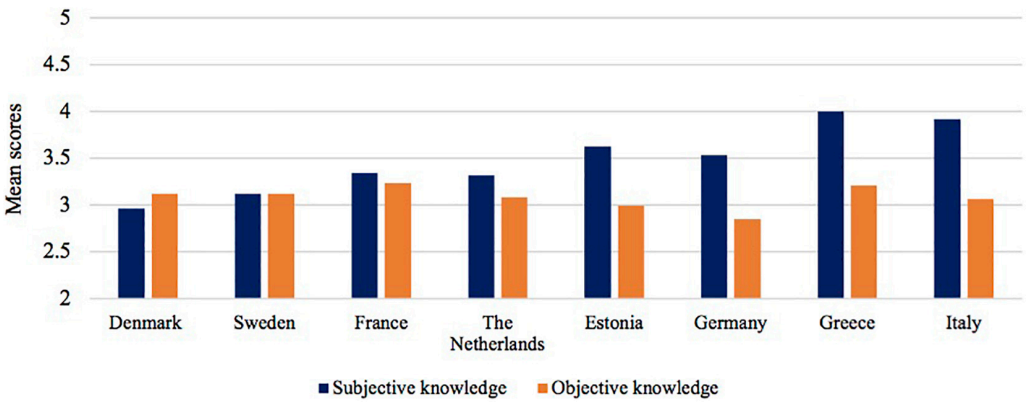


**FIGURE 8 |** Mean scores for respondents' subjective and objective knowledge of marine plastic litter across countries. Scores range from 1 = low (self-perceived) knowledge to 5 = high (self-perceived) knowledge.

within individual countries with two notable deviations. First, Estonians hold their national government mainly responsible for cleaning MPL (21% compared to the average of 12% for all eight samples together in **Figure 5**) and to a much lesser extent plastic-producing companies (12% compared to the average of 20% in **Figure 5**) or plastic-using companies (11% compared to the average of 16% in **Figure 5**). Second, German respondents do not ascribe much responsibility to consumers and companies, but instead defer mainly to the EU and their national government to manage MPL.

**Figure 9** shows the sense of responsibility that respondents feel regarding efforts to reduce MPL in their own country. Wide-ranging mean scores (3.17–4.43 on a five-point Likert-scale) and relatively high standard deviations indicate that personal responsibility to reduce MPL differs significantly across countries and within countries (see in the **Appendix Table 3** for detailed information on mean scores and standard deviations per country and **Appendix Table 9** for the outcome of the Kruskal-Wallis *H*-test and pairwise comparisons across countries). The share of respondents feeling personally responsible differ significantly across countries: 89% of the Greek respondents reported to feel personally responsible, whilst only 43% of the Dutch respondents agreed on being personally responsible. Greek, Swedish, and Danish survey participants barely reported disagreement to the statement of being personally responsible (respectively 1, 7, and 3% of all the Greek, Swedish, and Danish respondents). These percentages are significantly higher ($p < 0.001$ for all comparisons with Greece, Sweden, and Denmark) in Netherlands, Italy and Germany, where more than 20% reported not to feel personally responsible.

## Comparing Perceptions Across Marine Regions

The next series of analyses focus on public perceptions of marine litter at the level of the regional seas: the Baltic Sea ($N = 1{,}832$), the North Sea ($N = 1{,}534$), and the Mediterranean Sea ($N = 1{,}298$). The non-parametric Kruskal-Wallis *H*-test is applied to examine whether statistically significant differences can be detected among the three selected regions, accompanied by pairwise comparisons using the Mann-Whitney *U*-test.

The Kruskal-Wallis *H*-test results revealed that there are statistically significant differences (at least at the 5% significance level) for all selected perception variables across the three marine regions (see **Appendix Table 10** in the **Supplementary Material** for the test statistics). **Table 2** shows the results of

the pairwise comparisons across the three regional seas. First, testing for differences in respondents' perceptions of frequency and magnitude reveals that respondents from the Mediterranean indicated that they saw MPL more often ($U$ = 806316.000, $p < 0.001$) and observe larger quantities ($U$ = 449297.000, $p < 0.001$), significantly more so than respondents from the Baltic Sea region. The size of this observed litter, however, is significantly smaller than the size of litter observed by residents from the North Sea region ($U$ = 581673.000, $p < 0.05$). Second, comparisons indicate that the respondents from the Mediterranean Sea region are significantly more concerned than residents from the Baltic ($U$ = 840597.000, $p < 0.001$), and North Sea region ($U$ = 972319.000, $p < 0.001$), about MPL. Third, **Table 2** shows that perceived negative consequences of marine litter are rated significantly lower by respondents from the North Sea, whilst mean scores of participants from the Baltic and Mediterranean Sea regions are only significantly different for perceived consequences on human health ($U$ = 938988.500, $p < 0.05$). Fourth, the Kruskal-Wallis $H$-test showed statistically significant differences for the respondents' self-responsibility ($H(2)$ = 71.737, $p < 0.001$), self-perceived knowledge ($H(2)$ = 342.156, $p < 0.001$) and actual knowledge ($H(2)$ = 49.155, $p < 0.001$) across the three selected regional seas. **Table 2** presents that the highest mean scores were found in the Mediterranean Sea region, whilst significantly lower scores were found for the respondents residing in the North Sea and Baltic Sea region. In general, Mann-Whitney $U$-tests results presented in **Table 2** show that respondents from the North Sea region rated in general lower on the three perception component groups than respondents from the Baltic Sea region (with the exception of frequency of seeing MPL and subjective knowledge) and the Mediterranean Sea region. Respondents from the Mediterranean Sea, in turn, score comparably high to those from the Baltic Sea region.

# DISCUSSION

## Empirical Contributions

Positioning our results in the literature is hampered by the absence of comparative country studies and diverging research methods and approaches. Nevertheless, some interesting

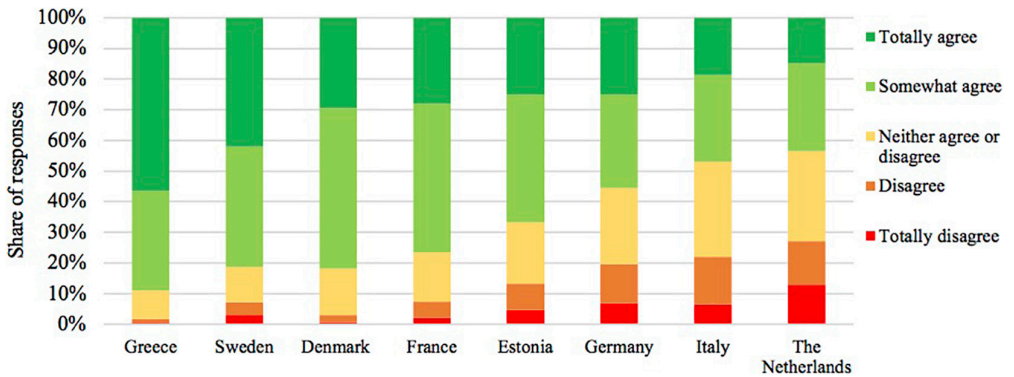


**FIGURE 9 |** Distribution of respondents feeling personally responsible to reduce marine plastic litter. Shares refer to response options ranging from 1 = totally disagree to 5 = totally agree to the statement "*I feel a personal responsibility to try to reduce plastic pollution*."

**TABLE 2 |** Comparisons of public responses on perception components by marine region.

| | Baltic Sea (1)–North Sea (2) | North Sea (1)–Mediterranean Sea (2) | Mediterranean Sea (1)–Baltic Sea (2) |
|---|---|---|---|
| **Observation and experience** | | | |
| *Frequency of seeing MPL* | ↓↓ | 0 | ↑↑↑ |
| *Amount of observed MPL* | 0 | ↓↓↓ | ↑↑ |
| *Size of observed MPL* | 0 | ↑ | 0 |
| **Concern and consequences** | | | |
| *Concern* | 0 | ↓↓↓ | ↑↑↑ |
| *Human health* | ↑↑↑ | ↓↓↓ | ↑ |
| *Marine organisms* | ↑↑↑ | ↓↓↓ | 0 |
| *Coastal Appearance* | ↑↑↑ | ↓↓↓ | 0 |
| **Responsibility and knowledge** | | | |
| *Responsibility* | ↑↑↑ | ↓↓↓ | ↑ |
| *Subjective Knowledge* | ↑↑↑ | ↓↓ | ↑↑↑ |
| *Objective Knowledge* | ↓↓↓ | ↓↓↓ | ↑↑↑ |

*↑ significantly higher mean score of group 1 compared to group 2 at $p < 0.05$; ↑↑ higher at $p < 0.01$; ↑↑↑, higher at $p < 0.001$; 0 no significant difference.*
*↓, significantly lower mean score of group 1 compared to group 2 at $p < 0.05$; ↓↓ lower at $p < 0.01$; ↓↓↓, lower at $p < 0.001$.*

comparisons can be made. General patterns in our results, regardless of the country of investigation, show that public knowledge about recyclability is low, but general concern about MPL is high, and the impacts of MPL are perceived to be most threatening for marine life. These findings about public concern and impacts of MPL are in line with previous findings. Forleo and Romagnoli (2021) found that Italians consider the threats of MPL for marine life most harmful, whilst Hartley et al. (2018) also confirm that the negative effects of marine litter on the marine environment are perceived more severe than for coastal appearance, human health and the fishing industry.

We also identified several differences across countries. In the present study, 70% of the respondents noticed the presence of MPL, with shares of respondents observing MPL ranging across countries from 54% in Estonia to 79% in Netherlands. These numbers are lower than those reported by Hartley et al. (2018), where 95% of the respondents in 16 European countries reported seeing litter when visiting the coast. However, our study asked about plastic litter specifically, whereas Hartley et al. (2018) considered all types of litter. Both studies found that a high prevalence of plastic was observed in European marine and coastal ecosystems, reiterating the scale of the MPL problem and need for action to reduce the amount of MPL. On the one hand, seeing marine litter did not influence respondents' concern or awareness of consequences. On the other hand, knowledge and personal responsibility to reduce MPL were affected by the presence of litter. These results could indicate that those who have more knowledge or feel more responsible are more aware of the presence of MPL, or vice versa. As argued by Rayon-Viña et al. (2019), seeing MPL could motivate the sense of responsibility and search for information about MPL.

While levels of objective knowledge hardly differ across countries, ratings of subjective knowledge vary considerably. An illusion of knowledge was most evident among Italian and Greek respondents, as were high levels of concern about MPL and its associated negative effects, with almost 90% of the Greek and Italian respondents indicating concerns about MPL. These findings suggest that considering yourself knowledgeable about MPL contributes to feelings of concern. However, more research is needed to further explore the causality of these relationships.

With regard to responsibility, significant differences were found, not only in terms of responsibility to reduce MPL, but also to clean-up MPL. Although less than half of the respondents in Netherlands and Italy confirmed feeling responsible to reduce MPL, up to 90% of the respondents acknowledged this in the other investigated countries. In general, companies, consumers and the EU were identified as being responsible to clean up MPL, while the tourism and fishing industry are considered least responsible for the perceived littering. These findings correspond to some extent to the results by Hartley et al. (2018), who found that retailers, industry and government were perceived as main responsible for littering. The general public believed that consumers carry responsibility for cleaning up MPL, but it is not exactly clear whether they consider themselves part of this group. It is remarkable that respondents from all countries ascribe low responsibility to fisheries, although the fishing industry is widely recognized to be a significant contributor to MPL entering the oceans. For example, Consoli et al. (2018, 2020) found that derelict fishing gear represented 32% of the overall litter in a coastal area of the central Mediterranean Sea, and 97% on the seabed of the deep water of Malta, which is exploited by local fisheries using fish aggregation devices. Furthermore, we detected some differences in perceptions of assigning responsibility across countries: Germany and Estonia have a somewhat different view as they ascribe more responsibility to governmental institutions and agencies, such as the EU, national governments and waste management companies, and significantly less to private actors, including companies and consumers.

## Limitations and Future Research

This study presents a unique database allowing for geographical comparisons of MPL perceptions, but it also has some limitations. First, despite the fact that the survey was distributed online by a professional survey company and completed anonymously, we must recognize that self-reported answers may lead to social desirability biases, potentially resulting in higher and more favorable results related to public perceptions. Moreover, variabilities in sample size and gender distribution of the national respondent groups, as well as cross-cultural survey response patterns, may influence the survey outcomes. For example, van Herk et al. (2004) found that respondents in the Mediterranean countries generally scored higher on acquiescence and had more extreme response styles than those in the Northwestern European countries. Other external factors possibly influencing responses could be the fact that the survey was carried out in times of a global pandemic. Concerns about the impact of the COVID-19 pandemic could either crowd out an individual's worry about other issues, also referred to as the Finite Pool of Worry (Weber, 2010; Botzen et al., 2021), or lead to a spill-over effect by generalizing one's concern to other worries, referred to as the Theory of Affect Generalization (Johnson and Tversky, 1983). The exact impact of the pandemic on the general public's concern toward environmental problems is as of yet unknown and needs to be explored more empirically.

Additionally, it must be noted that visual perceptions of MPL cannot be compared with data about actual presence of MPL. Comparisons with observed MPL could improve the understanding of an individual's processing of visual perceptions and allow for further examination of the influence of psychological and external components on one's own observations and experiences. Since our study did not ask for specific locations of litter observations, such as coordinates, we cannot compare observations with monitored amounts of MPL. Furthermore, while this study covers a range of EU countries, when it comes to MPL, a global strategy to prevent and reduce MPL is needed. Research into public perceptions in countries outside Europe, such as the study of Arulnayagam (2020) focusing on public perceptions of MPL in Sri Lanka and the research by Van Rensburg et al. (2020) examining beachgoers perception of single-used plastic (SUP) use in South Africa, contribute to a more thorough understanding of regional differences and similarities in perceptions of MPL.

Finally, the results of this study already point to differences in perceptions not only between but also within countries.

Therefore, future research should explore these intra-country differences in more detail to contribute to a better understanding of the differences between the interests, attitudes, behaviors and information needs of different social groups, which could lead to more specific communication and engagement initiatives to further incentivize participation in the fight against MPL.

## Policy Implications

The findings of this study have several policy implications. First, since knowledge is an important predictor of perceptions and actions (Vicente-Molina et al., 2013; Soares et al., 2021), enhanced educational initiatives aimed at increasing the general public's understanding of MPL could translate into notable changes in desirable individual behavior. Results of this research have shown that the general public's understanding of recyclability of plastics is particularly low in all surveyed countries, which indicates a clear international need for more information dissemination on this topic. Increased knowledge on recyclability could stimulate pro-environmental behavior and increase support for implementation of existing and new European policies, such as the EU Directive 2015/720, which sets targets to reduce the consumption of lightweight plastic carrier bags, and the upcoming EU Directive 2019/904, also known as the SUP ban.

Second, variations in levels of self-responsibility to reduce MPL across countries indicate that some nations should increase efforts to enhance citizen's sense of personal responsibility and to facilitate their engagement in tackling marine litter. The Dutch and Italian government authorities, in particular, should design engagement programs that address the key role of citizens' contributions to combat marine litter, since the sense of self-responsibility is particularly low in these countries. Moreover, Estonians and Germans appear to rely on and potentially wait for actions taken by the EU and their national government. Although governmental actors must indeed take their responsibility in developing strategies, setting targets and making policies, they should also take steps to make citizens and companies aware of their contribution and to incentivize them to prevent and reduce MPL.

Third, since the results showed that high levels of responsibility are ascribed to companies producing and using plastics, extended producer responsibility measures should be promoted. The upcoming single-use plastic ban (European Commission, 2019/904) includes extended producer responsibility schemes covering the costs to clean up litter, as well as the costs of awareness raising measures to prevent and reduce marine litter. These measures apply to various products, such as tobacco filters, balloons, and fishing gear and are not only in line with the polluter pays principle, but, as our research shows, also in line with the general public's opinions. The fact that the public holds companies responsible supports the EU's efforts to develop extended producer responsibility schemes to encourage innovation, product development and the use of sustainable alternatives.

Finally, since certain perceptions are similar across nations, such as lack of knowledge of recyclability, decision-makers could collaborate to develop joint strategies to target regions as a whole. For example, the content of particular educational initiatives could be shared throughout EU Member States. However, decision-makers should also be cautious to use a "one-size-fits-all" approach, since similarities in perceptions do not necessarily mean that strategies and measures can successfully be duplicated or have similar impacts in different countries. Differences in perceptions across surveyed countries indicate a need for the development of differentiated national strategies, tailored to match the needs of the general public in specific countries and regions. However, previous studies (e.g., Soares et al., 2021) have shown that, in additional to one's nationality, other socio-demographic and -economic factors also influence individuals' perceptions. Therefore, insights in perceptions across countries are an important initial step, but not a final one, for developing international and country-specific policy and communication efforts to encourage community participation in addressing MPL pollution.

# CONCLUSION

This study aimed to explore perceptions of MPL across European countries and sea regions. We introduced a three-prong definition of perception in order to cover a variety of components that contribute to perception, namely observation of and experience with MPL, perceived consequences and concern, and knowledge and responsibility. These variables have all been studied in previous literature and described as related to perception. However, this is the first study that analyses all of the aforementioned variables in one research endeavor to create a more holistic picture of MPL perception across different EU countries. The benefit of a comprehensive definition of perception lies in the ability to tailor specific strategies or behavior change campaigns based on the differing perception results. Our results suggest that perception is not homogenous or nationally determined and differs significantly between countries and regions. Based on these obtained results, decision-makers should differentiate and tailor national strategies to educate the general public and increase their awareness, with the goal of minimizing plastic consumption and littering.

# DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because it contains information that could compromise the privacy of research participants. Requests to access the datasets should be directed to LO.

# ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and

institutional requirements. The patients/participants provided their written informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

LO: conceptualization, methodology, formal analysis, data curation, and writing–original draft. HD, KR, and RB: conceptualization and writing–review and editing. PB: conceptualization, writing–review and editing, and supervision. SK and SD: writing–review and editing. All authors contributed to the article and approved the submitted version.

## FUNDING

This work was funded under the EU project CLAIM (Cleaning Litter by developing and Applying Innovative Methods in European Seas) H2020 Grant agreement ID: 774586.

## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2021.784829/full#supplementary-material

## REFERENCES

Ankamah-Yeboah, I., Xuan, B. B., Hynes, S., and Armstrong, C. W. (2020). Public Perceptions of Deep-Sea Environment: Evidence From Scotland and Norway. *Front. Mar. Sci.* 7:137. doi: 10.3389/fmars.2020.00137

Arulnayagam, A. (2020). Public Perception towards Plastic Pollution in the Marine Ecosystems of Sri Lanka. *Am. J. Mar. Sci.* 8, 6–13.

Barnes, D. K. A., Galgani, F., Thompson, R. C., and Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosop. Transact. R. Soc. B Biol. Sci.* 364:205. doi: 10.1098/rstb.2008.0205

Boothe, R. G. (2002). *Perception of the Visual Environment*, 1st Edn. New York, NY: Springer-Verlag, doi: 10.1007/b97382

Botzen, W., Duijndam, S., and van Beukering, P. (2021). *Lessons for climate policy from behavioral biases towards COVID-19 and climate change risks*. Amsterdam: Elsevier Ltd, doi: 10.1016/j.worlddev.2020.105214

Brouwer, R., Hadzhiyska, D., Ioakeimidis, C., and Ouderdorp, H. (2017). The social costs of marine litter along European coasts. *Ocean Coast. Manage.* 138, 38–49. doi: 10.1016/j.ocecoaman.2017.01.011

Consoli, P., Falautano, M., Sinopoli, M., Perzia, P., Canese, S., Esposito, V., et al. (2018). Composition and abundance of benthic marine litter in a coastal area of the central Mediterranean Sea. *Mar. Poll. Bull.* 136, 243–247. doi: 10.1016/j.marpolbul.2018.09.033

Consoli, P., Sinopoli, M., Deidun, A., Canese, S., Berti, C., Andaloro, F., et al. (2020). The impact of marine litter from fish aggregation devices on vulnerable marine benthic habitats of the central Mediterranean Sea. *Mar. Poll. Bull.* 152:110928. doi: 10.1016/j.marpolbul.2020.110928

Dilkes-Hoffman, L. S., Pratt, S., Laycock, B., Ashworth, P., and Lant, P. A. (2019). Public attitudes towards plastics. *Resour. Conserv. Recycling* 147, 227–235. doi: 10.1016/j.resconrec.2019.05.005

Efron, R. (1969). "What is perception?," in *Proceedings of the Boston Colloquium for the Philosophy of Science* 1966/1968, eds R. S. Cohen and M. W. Wartofsky (Dordrecht: Springer), 137–173. doi: 10.1007/978-94-010-3378-7_4

European Commission (2008). *Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy* (Marine Strategy Framework Directive). *Off. J. Eur. Union* L164, 19–40.

European Commission (2019). *Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment* ('the Single Use Plastic (SUP) Directive'). *Off. J. Eur. Union* L155, 1–19.

European Environment Agency (2020). *The European Environment: State and Outlook 2020. Knowledge for transition to a sustainable Europe*. Luxembourg: Publications Office of the European Union.

European Parliament Research Service (2018). *Briefing EU Legislation in Progress: Single-Use Plastics and Fishing Gear—Reducing Marine Litter*. Rue Wiertz: EPRS.

Forleo, M. B., and Romagnoli, L. (2021). Marine plastic litter: public perceptions and opinions in Italy. *Mar. Poll. Bull.* 165:112160. doi: 10.1016/j.marpolbul.2021.112160

Frantzi, S., Brouwer, R., Watkins, E., van Beukering, P., Cunha, M. C., Dijkstra, H., et al. (2021). Adoption and diffusion of marine litter clean-up technologies across European seas: Legal, institutional and financial drivers and barriers. *Mar. Poll. Bull.* 170:112611. doi: 10.1016/J.MARPOLBUL.2021.112611

Galgani, F., Hanke, G., and Maes, T. (2015). "Global Distribution, Composition and Abundance of Marine Litter," in *Marine Anthropogenic Litter*, eds M. Bergmann, L. Gutow, and M. Klages (Cham: Springer International Publishing), doi: 10.1007/978-3-319-16510-3_2

Gelcich, S., Buckley, P., Pinnegar, J. K., Chilvers, J., Lorenzoni, I., Terry, G., et al. (2014). Public awareness, concerns, and priorities about anthropogenic impacts on marine environments. *Proc. Natl. Acad. Sci.* 111:1417344111. doi: 10.1073/pnas.1417344111

Geyer, R., Jambeck, J. R., and Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Sci. Adv.* 3:e1700782. doi: 10.1126/sciadv.1700782

Hartley, B. L., Pahl, S., Veiga, J., Vlachogianni, T., Vasconcelos, L., Maes, T., et al. (2018). Exploring public views on marine litter in Europe: Perceived causes, consequences and pathways to change. *Mar. Poll. Bull.* 133, 945–955. doi: 10.1016/j.marpolbul.2018.05.061

Hartley, B. L., Thompson, R. C., and Pahl, S. (2015). Marine litter education boosts children's understanding and self-reported actions. *Mar. Poll. Bull.* 90, 209–217. doi: 10.1016/j.marpolbul.2014.10.049

Henderson, L., and Green, C. (2020). Making sense of microplastics? Public understandings of plastic pollution. *Mar. Poll. Bull.* 152:110908. doi: 10.1016/j.marpolbul.2020.110908

Hynes, S., Norton, D., and Corless, R. (2014). Investigating societal attitudes towards the marine environment of Ireland. *Mar. Policy* 47, 57–65. doi: 10.1016/j.marpol.2014.02.002

Jefferson, R. L., Bailey, I., Laffoley, D. D. A., Richards, J. P., and Attrill, M. J. (2014). Public perceptions of the UK marine environment. *Mar. Policy* 43, 327–337. doi: 10.1016/j.marpol.2013.07.004

Johnson, E. J., and Tversky, A. (1983). Affect, generalization, and the perception of risk. *J. Personal. Soc. Psychol.* 45:20. doi: 10.1037/0022-3514.45.1.20

Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika* 39:BF02291575. doi: 10.1007/BF02291575

Niva, M., and Timonen, P. (2001). The role of consumers in product-oriented environmental policy: can the consumer be the driving force for environmental improvements? *J. Consumer Stud. Home Econom.* 25, 331–338. doi: 10.1046/j.1470-6431.2001.00204.x

Park, C. W., Gardner, M. P., and Thukral, V. K. (1988). Self-Perceived Knowledge: Some Effects on Information Processing for a Choice Task. *Am. J. Psychol.* 101, 401–424. doi: 10.2307/1423087

Pereira, S. (2019). *Plastic perceptions: surveying public opinion of plastic pollution in Rhode Island*. Ph. D. Thesis. Rhode Island: University of Rhode Island, 1480.

Pomerantz, J. R. (2006). "Perception: Overview," in *Encyclopedia of Cognitive Science*, 1st Edn, ed. L. Nadel (Chichester: John Wiley & Sons, Ltd), doi: 10.1002/0470018860.s00589

Rayon-Viña, F., Miralles, L., Fernandez-Rodríguez, S., Dopico, E., and Garcia-Vazquez, E. (2019). Marine litter and public involvement in beach cleaning: disentangling perception and awareness among adults and children, Bay of Biscay, Spain. *Mar. Pollut. Bull.* 141, 112–118. doi: 10.1016/j.marpolbul.2019.02.034

Soares, J., Miguel, I., Venâncio, C., Lopes, I., and Oliveira, M. (2021). Public views on plastic pollution: knowledge, perceived impacts, and pro-environmental behaviours. *J. Hazard. Mater.* 412:125227. doi: 10.1016/j.jhazmat.2021.125227

Steel, B. S., Smith, C., Opsommer, L., Curiel, S., and Warner-Steel, R. (2005). Public ocean literacy in the United States. *Ocean Coastal Manage.* 48, 97–114. doi: 10.1016/j.ocecoaman.2005.01.002

United Nations Environment Programme (2009). *Marine Litter: A Global Challenge*. Nairobi: UNEP, 232.

van Herk, H., Poortinga, Y. H., and Verhallen, T. M. M. (2004). Response Styles in Rating Scales. *J. Cross Cult. Psychol.* 35:0022022104264126. doi: 10.1177/0022022104264126

Van Rensburg, M. L., Nkomo, S. L., and Dube, T. (2020). The 'plastic waste era'; social perceptions towards single-use plastic consumption and impacts on the marine environment in Durban, South Africa. *Appl. Geogr.* 114:102132. doi: 10.1016/j.apgeog.2019.102132

Veiga, J. M., Vlachogianni, T., Pahl, S., Thompson, R. C., Kopke, K., Doyle, T. K., et al. (2016). Enhancing public awareness and promoting co-responsibility for marine litter in Europe: The challenge of MARLISCO. *Mar. Poll. Bull.* 102, 309–315. doi: 10.1016/j.marpolbul.2016.01.031

Vicente-Molina, M. A., Fernández-Sáinz, A., and Izagirre-Olaizola, J. (2013). Environmental knowledge and other variables affecting pro-environmental behaviour: Comparison of university students from emerging and advanced countries. *J. Cleaner Prod.* 61, 130–138. doi: 10.1016/j.jclepro.2013.05.015

Weber, E. U. (2010). What shapes perceptions of climate change? *Wiley Interdiscipl. Rev. Clim. Change* 1:41. doi: 10.1002/wcc.41

**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.