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Review

Exploring Scientific Discourse on Marine Litter in Europe: Review of Sources, Causes and Solutions

Vilma Havas [1,2,*], Søren Løkke [2,*] and Lone Kørnøv [2]

[1] SALT Lofoten A/S, Havneterminalen, Fiskergata 23, 8301 Svolvær, Norway
[2] The Danish Center for Environmental Assessment, Department of Planning, Aalborg University, Rendsburggade 14, 9000 Aalborg, Denmark; lonek@plan.aau.dk
* Correspondence: vilma@salt.nu (V.H.); loekke@plan.aau.dk (S.L.)

Abstract: Marine litter is a transboundary environmental issue that affects all the world's oceans. Marine litter research is a young discipline but one that has exploded during the last five years. However, the increased knowledge of sources and underlying causes to marine litter, as well as knowledge regarding solutions, lack systematic review and synthesis. This study reviews the scientific discourses around plastic marine litter in Europe, and more specifically, in Norway and Denmark, and explores emerging discourse coalitions. Four main thematic storylines on the source-cause-solution causal relationship, as well as two emerging storylines within marine litter research, are found. This study concludes that in order to secure sustainability of solutions and to avoid risk transformation and greenwashing, more interdisciplinary research, including life cycle assessment and investigations of scientific and societal discourses, is needed.

Keywords: marine litter; scientific discourse; sources; causes; solutions; Europe

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1. Introduction

Plastic marine litter has been mentioned as an environmental threat in scientific literature as early as in the 1956′s, and already in the 1966′s and 75′s most of the negative impacts of marine litter were identified [1]. The number of scientific publications on marine litter increased exponentially between the 1956′s and 1985′s, but slowed down in the 85′s. The number of academic articles published on the topic is now increasing [1]; since 2015, the research on marine litter has exploded, leading to increased knowledge of the causes and solutions to marine litter [2]. The Norwegian researcher and adventurer, Thor Heyerdahl reported of not only oil spills, but also of "a large cluster of greenish rope, a plastic bottle, nylon-like material, a wooden box and a carton" during his Ra expeditions in the Atlantic Ocean in 1966 [3]. He concluded that "it is shocking to see how the Atlantic is getting polluted by Man". The findings under the Ra expeditions were reported to the United Nations International Maritime Organization and three years later, in 1969, the International Convention for the Prevention of Pollution from Ships, known as MARPOL (MARine POLlution), was ratified [4].

Now, 50 years later, marine litter is still an issue that concerns researchers and one that we have yet to solve. As marine litter research is a relatively young research discipline and a complex issue, there are still many knowledge gaps regarding causes and solutions to plastic pollution [5,6]. A study by Jambeck et al. [7], frequently referred to by scientific literature, policy makers and NGOs (see e.g., [8,9]), estimates that an amount between 4.8 and 12.7 million metric tons of plastic waste ended up in the oceans from land-based sources in 2010. This number is expected to increase by an order of magnitude by 2025 if no waste management improvements are made. In addition, Forrest [6] estimates that the leakage from land- and sea- based sources together is approximately 15 million metric tons per year. In addition to these rough estimates on marine litter inputs, an amount of up to five billion tons of plastic litter has accumulated in our oceans, soil, and air [6].

Even though the exact quantification of marine litter is a challenging task, the current knowledge on marine litter highlights the urgency of mitigation. The consensus of the scientific literature is that marine litter threatens the wellbeing of marine species and ecosystems through ingestion, entanglement, introduction of foreign species, and accumulation of persistent organic pollutants [10], to such a degree that millions of animals die from it annually [6]. In addition, marine litter affects coastal tourism and fishing industries negatively, due to lowered quality of the visitors' experience [11], gear damage, and decrease in catch [12]. Marine litter consists mainly of plastics, as 56 to 85 per cent of all marine litter is of plastic materials [13]. Plastic materials do not decompose in the marine environment, causing decade long damage potential [14,15].

The goal of this study is to analyze the scientific discourse and focus on plastic marine litter in Europe, with a specific focus on two Nordic countries, Norway, and Denmark. There are only very few studies of the marine litter discourses, one identifying temporal trends in ocean and coastal sustainability challenges and solutions in general [2], while the other is a text analysis of media attention to marine plastic pollution in the UK and related opinion and behavioral aspects [16]. In the former study, marine litter is identified as a topic that received increasing attention in the years between 2014-15, compared to earlier years, i.e., 2006-13. Through a systematic literature review process, we were also able to identify a similar trend as 92 of the 108 articles identified were published in 2014 or later. The following research questions have guided the investigation: How have sources, causes and solutions to marine plastic litter been represented in scientific discourse? Further, can these be grouped into emerging clusters of discursive representations of strategies?

Identification of temporal, geographical and strategic trends within the scientific literature on plastic marine litter helps to create a holistic image of the direction scientific research, as well as the development of environmental management strategies, are moving—and whether they are moving in the same direction. Ideally, political and management strategies are formed according to the best available knowledge, e.g., Thor Heyerdahl's findings that contributed to the ratification of MARPOL. The aim of this study is to contribute to the lacking discourse analysis around marine litter and to knowledge-based decision making.

However, the transferring of scientific knowledge to policy making is not a straightforward process of transferring objective knowledge to serve an optimized decision-making process and does not take place in a vacuum. This paper focuses on the output of scientific knowledge through scientific articles while acknowledging both the complex reality within the knowledge generation it takes place in, and the translation and interpretation processes that are involved when knowledge is taken further into the shaping of actions. The theoretical understanding of this field is based on two analytical stakeholder types that have been used in the study of the science-policy interrelations, namely the "Epistemic Community" concept as it is developed by Peter Haas [17], and the concept "discourse coalition" developed in the Argumentative Discourse Analysis framework by Marten Hajer and others [18,19].

2. Framework and Methods

The study is based on peer-reviewed articles published between 2000 and ultimo 2021. The analyzed scientific communication is used to identify the causes and solutions to marine litter, as well as the associated elements that potentially contribute to the creation of epistemic communities and discourse coalitions. Before presenting the methods chosen for the discourse analysis, Section 2.1 explains the theoretical framework further.

2.1. Theoretical Framework

The analytical framework targets understanding the construction of understandings and sensemaking of causes and solutions related to marine plastic litter. The aim is to identify possible patterns in the related explanations of what the problems are, what causes them, and how they are mitigated. Hence, the framework is not targeted at evaluating the scientific validity of claims made in the analyzed material, but rather at unravelling the dif-

ferent understandings of a complex problem field, i.e., marine litter, as these understandings are key elements in the shaping of policymaking processes [20,21].

The discourse analytical framework applied is inspired by two different approaches that focus on studying how policy is informed in a complex network of interrelations involving scientific knowledge, i.e., "epistemic communities" (EC) and "argumentative discourse analysis" (ADA). EC is a concept initially used in international politics, developed by John Ruggie [22], and further brought into the study of international environmental politics by Peter Haas [23]. An EC is an influential subgroup involving both scientific circles and stakeholders outside of science, including policy makers, non-governmental organizations and industries and businesses. An EC is defined by the sharing of both causal and principled beliefs, and by a shared knowledgebase as well as shared interests [24], and as outlined in Figure 1. In other words, it is a grouping that shares the same episteme, i.e., a shared vision of what reality is.

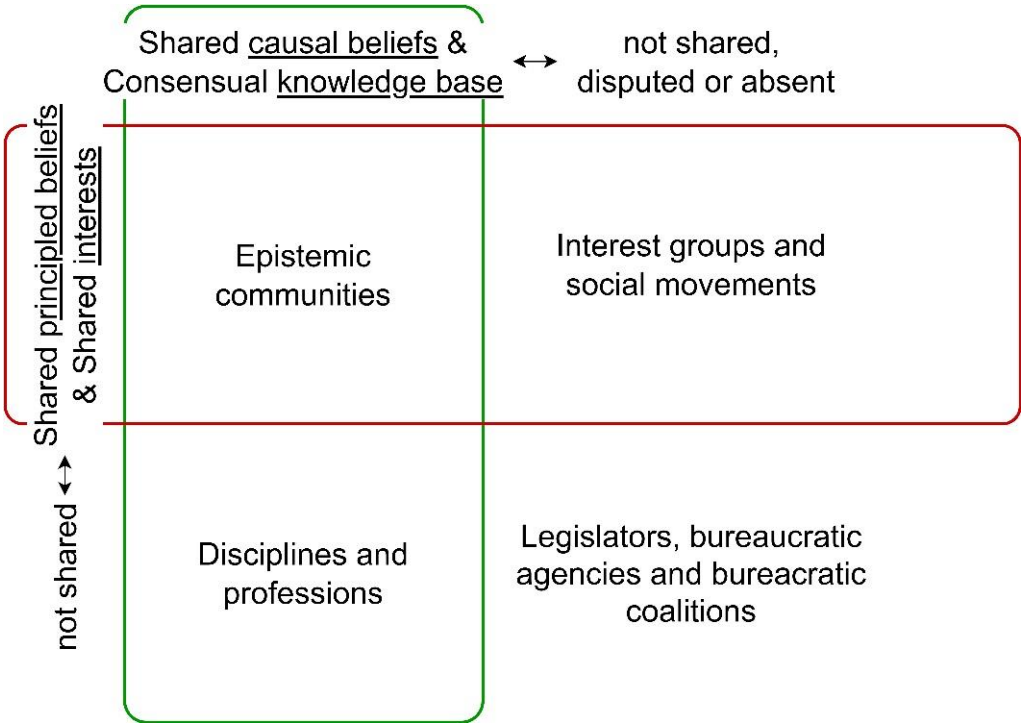

Figure 1. Contribution from the EC framework to the analytical framework. The green box indicate what aspects of potential ECs we map in this study. Based on [23,24].

Marten Hajer is one of the main architects behind the ADA approach [19] that focuses on a different main stakeholder grouping, namely "discourse coalitions". Hajer defines a discourse coalition as consisting of three elements: (1) a set of storylines, which is the "cement" of the coalition that allows for otherwise alienated actors or entities to have common points of understandings, (2) the actors who use the storylines, routinising these and who possibly may change practice, and finally, (3) the discourse coalitions are characterized by the practices that are derived from the discursive activities, that ultimately may lead to the institutionalization of the discursive practice. Several coalitions may co-exist, and dominance may shift between different discourse coalitions. A discourse coalition is dominant in a given political domain, if (1) the storylines dominate the language of the field, i.e., if "central actors are persuaded by, or forced to accept, the rhetorical power of a new discourse" (discourse structuration) and if (2) this leads to institutional practices related to the political domain, i.e., if actual policy processes follow the ideas expressed by the discourse coalition (discourse institutionalization). It is important to stress that a discourse coalition is distinct from a "traditional" coalition, as what defines a "discourse coalition" is shared discursive references (approximately the same as shared principled

beliefs) and not shared interests which defines a "coalition". The focus of this study is on the overall understanding of the problem field and identification of potential discourse coalitions based on sample analysis.

The most important difference between the two frameworks is how they conceptualize "interests"; the EC is defined as a grouping that shares interests, while participants in a discourse coalition do not necessarily share interests. In this way the EC concept shares elements from the traditional notions of political coalitions and alliances, whereas the ADA focuses on the construction of meaning as the constituent of consensual action. The two approaches share the notions of environmental problems as being socially co-constructed in complex science-society-policy networks, shaping human action related to environmental problems and challenges, and they share the position that nothing in these networks can be isolated from the social constructedness of reality, meaning that even at the conception of science, objectivity is an ideal which is embedded in social reality [22,25–27].

We argue that the discussion on shared or not shared interests are of lesser importance in the current context as we examine scientific communication that feeds into a larger sense-making process that involves all sorts of stakeholders, media representations, lobbyism, political agendas, bureaucratic rationalities, etc. Meaning may then be formed around ECs, which Haas convincingly has showed having decisive impact on environmental regimes such as the control of ozone depleting substances [25], control of the Bhopal crisis [28], and international governance of sustainable development in general [17,26]. The impact of discourse coalitions on European reactions to deforestation and, more generally, political modernization of European environmental policies has also been shown to be highly formed by the related discursive structures [19,27].

The goal of this study is not to unravel the full extent of epistemic communities and the discourse coalitions that are present or that are taking shape in relation to the marine litter problematique. Rather, the goal is to investigate a part of the overall picture, namely elements in scientific communication on the topic, that hint at the formation or existence of these types of analytical stakeholder types or social groupings. This research is intended to be used in studies of public media discussions and in policy discourse, on the topic of marine litter, for example. This enables integrative studies that extend from the single case study and which has been framed as one core challenge for studies of environmental policies [18]. Hence, this study analyses a sample of peer-reviewed, scientific publications to investigate to what extent these may be expressions of what Hajer [27] terms "discourse coalitions", and ultimately what Haas [23] terms "epistemic communities". The key analytical concepts in this investigation—the "building bricks" that may be constituting potential discourse coalitions and potential epistemic communities—are *storylines, metaphors,* and the *stakeholders* who express, reproduce, and co-produce the discursive understandings captured in the storylines, and *causal beliefs*, *principled beliefs*, and *knowledge base*, shared within an epistemic community. We see a large agreement between storylines of the ADA approach and especially the causal beliefs of the EC approach, as outlined above. However, the specific analysis applied here, will only be able to identify these elements to the extent they are present in the selected empirical material and there are certain limits to this as described by the end of this section.

We may comprehend the "epistemic communities" and the "discourse coalition" as stakeholders or agent-groupings where an EC may take part in one or more discourse coalitions, even though the shared beliefs and shared interest of EC increase the likelihood that there may be alignment with one alone. The definition of the EC makes it a strong and influential stakeholder-grouping. In this context it is important to be aware that the requirements defining the two groupings are fundamentally different. The requirement for the EC is quite stringent in terms of requiring shared interest, whereas the discourse coalition "only" requires that those adhering to the coalition use similar types of language (i.e., discursive constructions) in the communication related to the field or domain in question. In this way, an EC will in principle only belong to one discourse coalition and will only relate to more than one discourse coalition if these are not competing but

complimentary. Stakeholders outside of the epistemic community could possibly still be members of the same discourse coalition as the epistemic community. We will, in fact, argue that an EC is more likely to successfully shape policymaking if the community is also a part of a dominant discourse coalition, and vice-versa, and that the development of a dominant discourse coalition is more likely if it is constituted also by an EC. In our perception, the combination of the EC approach with the ADA approach enhances the study of science-policy relations, which is a less developed part of the literature using the ADA approach.

When investigating a field using the ADA approach, the central output is a discourse coalition that consists of a storyline or a system of connected storylines, as well as the actors who express these. A key aspect of the approach is that these actors or stakeholders do not have to share interests but rather it is the formation of a common language which shapes common understandings, and which creates a basis for action and policymaking in complex problem fields such as environmental problem solving.

In this study we use ADA and the EC concepts for the exploration of strategies for handling the problem field: (discussions of) what (anthropogenic) marine litter is, why it occurs and what can or should be done to reduce, mitigate or remove the problem. These discussions take place at many different sites and arenas in society, hereunder in scientific literature, newspapers, radio and TV broadcasts, social media, books, policy-documents, speeches, and other types of formal and informal forms of communication, of which we only investigate the first type. Figure 2 sketches out how different discourse coalitions may co-exist and eventually overlap in the same problem field. At the core of each discourse coalition, there is a storyline which is the key sense-making device being expressed and reproduced by the stakeholders belonging to the discourse coalition in various medias. Over time such discourse coalitions will change and some will tend to dominate, which is referred to as an institutionalization process where the dominance of certain understandings of the problem field enables political processes to deal with the problems in accordance with the understandings. Furthermore, Figure 2 reflects how the EC can be seen as a particularly strong coalition of actors within a discourse coalition. I.e., this actor group may be a subgroup that also refers to metaphors and storylines that defines a discourse coalition. We identify potential discourse coalitions and ECs, which can be further investigated using the results from this paper in combination with further investigations involving sources beyond the scientific research articles, as described above. What we do in the present work corresponds to the first steps of Hajer's [29] ten-step methodology. In the following method-section we describe the detailed procedure for selecting and analyzing the relevant scientific literature covering the problem field, using systematic literature review and qualitative text analysis, identifying key perspectives on sources, causes and solutions to plastic marine litter.

2.2. Method

The systematic literature review was conducted to map the sources, causes and solutions to plastic marine litter in Europe, and more specifically, Norway and Denmark. This review resulted in a sample of 108 articles that were analyzed in detail.

2.2.1. Systematic Literature Review

A systematic literature review "strives to comprehensively identify, appraise, and synthesize all the relevant studies on a given topic" [30]. Development of the systematic literature review was conducted in five steps, as adopted from Pietzsch et al. (2017), and in correspondence with the recommendations of the updated PRISMA systematic review approach (the term "article" is used interchangeable with the term 'study' used in the PRISMA-approach) [31]:

1. Defining the research objective;
2. Database selection;
3. Keyword identification;
4. Selection of compatible articles;
5. Data extraction

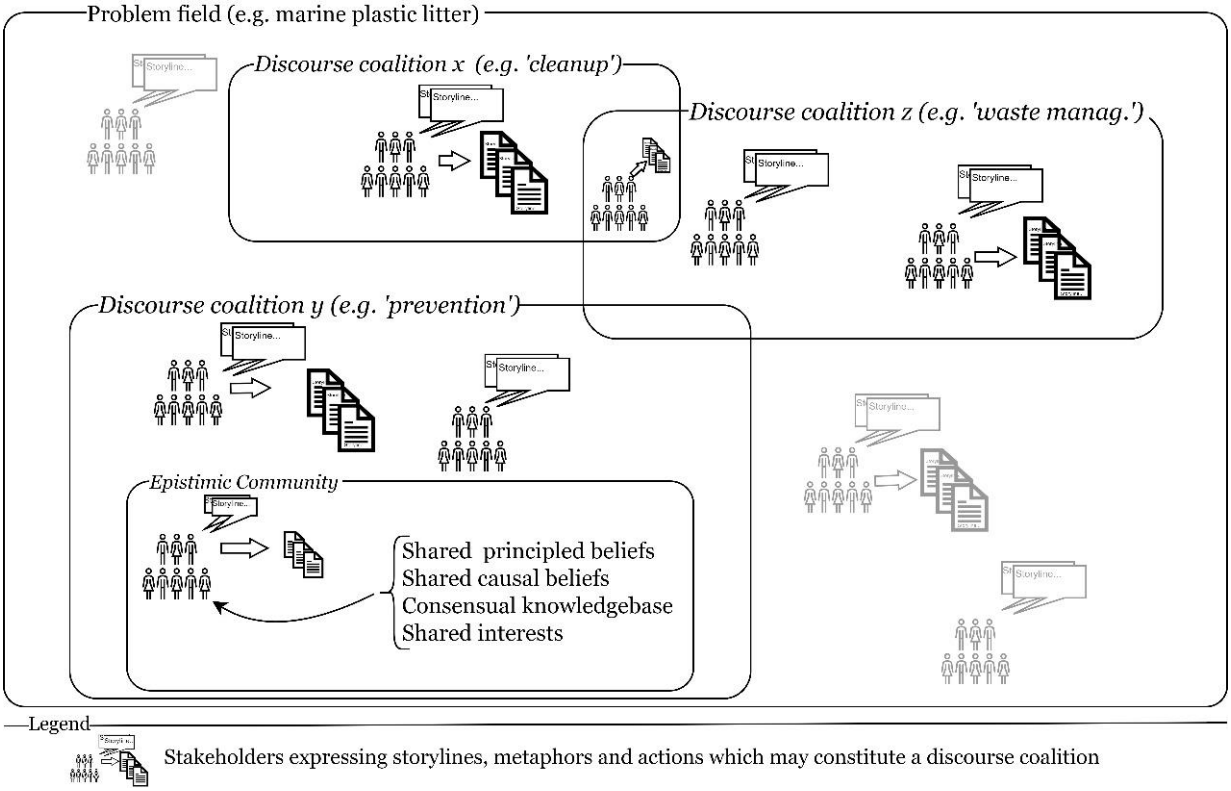

Figure 2. Overview of the theoretical framework combining Argumentative Discourse Analysis (ADA) and the Epistemic Community (EC) concept for the exploration of strategies for the understanding and handling of marine litter. The figure presents the epistemic community as referring to storylines belonging to one discourse coalition exclusively, but this may not necessarily be the case, as reality often imply ambiguity. Discourse coalition x, y, and z are competing coalitions identified by storylines and the stakeholders expressing these. Each discourse coalition may refer to more than one sub-storyline, and the constellation may change over time. Some stakeholders may refer to more than one storyline if these are not conflicting. Persons symbolize stakeholders, and documents and speech bubbles symbolize their utterances that contains shared storylines and metaphors.

Firstly, the research objective was defined, this being to gain an overview over the sources, causes and solutions to plastic marine litter in Europe, with focus on Norway and Denmark, presented in scientific literature. This limitation allows for comparison of the scientific discourse in the two neighboring countries, one of which is a part of the European Union (EU) and one that is not. The European studies were included as the European context is important regarding environmental regulation, especially in Denmark that is a part of the EU. Secondly, Scopus and Web of Science (WoS) were selected as the databases to be used, as these are the two most extensive databases for peer-reviewed articles (Mongeon and Paul-Hus 2016). The search was limited to articles published between 2000 and ultimo 2021. No restrictions were made with respect to language, but the keywords may have limited the search to cover only English results. The Boolean operation was used to limit the search to the geographical region of interest, i.e., Europe, Norway, and Denmark. The keywords used are (Marine AND litter AND Europe), (Marine AND debris AND Europe), (Marine AND litter AND Norway), (Marine AND litter AND Denmark), (Marine AND

debris AND Norway), (Marine AND debris AND Denmark). Both Marine debris and Marine litter were included as these terms are used interchangeably when describing "any anthropogenic, manufactured, or processed solid material (regardless of size) discarded, disposed of, or abandoned in the sea by rivers, sewage, storm water, waves, or winds" (UNEP and NOAA 2012). This search resulted in a total of 527 articles.

The screening of the records and exclusion of non-compatible articles was done in three stages. Firstly, based on the title and abstract, those articles that did not focus on plastic marine litter or plastic marine debris were excluded (e.g., articles that focus on organic debris). Secondly, all duplicates were excluded. Finally, the remaining 108 articles were read thoroughly, to identify whether they included information about sources, causes and/or solutions to plastic marine litter. Out of these remaining articles, those that did not mention sources of, causes for, and/or solutions to plastic marine litter were excluded. The concrete eligibility evaluation of the sample, as defined in PRISMA 2020, is described in detail in the Supplementary Materials, with categories of exclusion criteria. Furthermore, the database contains specific explanation for every study excluded, plus details of the analysis of the studies included in the review.

2.2.2. Description of the Sample

The sample of 108 articles was divided according to whether they suggest solutions to marine litter and/or if they describe sources and/or causes, or if they mention neither of these. To be included in the solutions-group, the article must suggest a concrete solution or solutions that are recommended above other solutions, e.g., prevention in the form of banning single-use plastics. To be included in the sources and causes-group, the article must describe a specific cause or source of marine litter which, in the specific space and time the article focuses on, was the dominating cause or one of the dominating causes to marine litter. The context of the sources, causes and solutions are not analyzed in detail, i.e., the goal of our analysis is not to give an overview of the "ranking" of sources, causes and solutions to marine litter, described in scientific literature, but rather identify the discourses in general. Sources and causes were analyzed together, as they are often interlinked (categorizing method is explained in more detail in Section 2.2.3 below).

A total of 44 articles describes sources and/or causes to marine litter and 42 describe solutions. 21 articles describe both sources, causes and solutions and 51 describe neither of these or focus on non-European areas, mapping, monitoring method development, or impacts of littering, and were therefore excluded. The articles were also categorized according to country or region of study, source of funding, and whether they are based on empirical or conceptual method. Only 18 out of the total 108 articles are conceptual studies of which one was excluded.

2.2.3. Data Analysis

The analysis of papers was based on three rules. Firstly, the authors used full texts to analyze the relevance, rather than using abstracts only. Secondly, papers could be allocated more than one discourse. Thirdly, papers were included in the scientific discourse category if they mentioned sources, causes and/or solutions in any form. For each paper, discourses were identified based on the description and argumentation of; (1) sources of and causes for marine litter and (2) solutions offered. For labelling and categorizing reasons, a system for categorizing the litter was adopted. The system, with slight alterations, is based on the categorization of marine litter used in the study by Falk-Andersson et al. [32] see Table 1.

Table 1. Framework for categorizing sources of marine litter. Variables on one row are merged into the variable on the right-hand side (e.g., "Plastic bags", "Food and drink" and "Smoking" are merged into "On the go").

Sub-Categories			Labels
Plastic bags	Food and drink	Smoking	On the go
Domestic	Sanitary	Wearables	Domestic
Fishing	Netting	Ropes	Fishing
Industrial	Agricultural	Construction	Industrial
Not a specific product	Other		Other

The sources to marine litter were identified in each article, based on the labels listed in Table 1. The labels represent a user area, e.g., whether the products are used for consumption of food and drink outside ("on the go") or most likely source from use within households, such as cotton buds and other sanitary products ("domestic"). Litter sourcing from industries is divided into fisheries and other land- based industrial waste. The articles that do not mention a specific product or product category, but do mention a user area, are categorized under "other". Also, products that do not fit into any of the other categories and recreational products are included in the "other" category.

For analyzing the sources further, they are categorized according to the underlying causes to littering, as presented in Table 2. The categories were developed during the analysis of the sample, i.e., the underlying causes described in the articles determined the categories described in Table 2.

Table 2. Framework for categorizing underlying causes for marine litter.

Underlying Causes	Description
Lack of awareness and/or bad behavior	Conscious or unconscious dumping of plastic litter, e.g., cigarette butts on a beach
Lack of infrastructure and/or technology	Lacking or poor waste management systems on land or at sea, e.g., open landfills.
Design	Features of the plastic product are the primary cause to pollution, e.g., loss if fishing gear during regular activity
Unknown	Source to the pollution is identified, but the reason to pollution is unknown or not mentioned

The solutions were first divided into whether they are suggested to be applied up- or downstream, i.e., prevention of influx of marine litter or mitigation methods of marine litter already leaked into the environment, as presented in Table 3. The coding phase for the discourse analysis entailed identifying solutions to marine litter as signified through language use.

Table 3. Framework for categorizing solutions to marine litter.

Solutions and Strategies for Marine Litter	Labels
Prevention	Technology and/or infrastructure Policy and/or regulation Awareness and/or Behavioral change Product development and/or design Research and/or data gathering None Other?
Clean-up	Onshore clean-up Offshore clean-up Clean-up in general Other None

3. Results

The articles were categorized according to the above-mentioned criteria and analyzed within the categories. Firstly, any trends or popular themes were identified, or the lack of them. If any relatively often mentioned themes appeared, these were analyzed further to find out whether the themes appear often due to, for example, referencing to the same publication, or whether all the analyzed articles have come to the same or similar conclusions through their own, independent studies.

Below in Table 4, we present an overview of the analyzed articles, showing the total number of articles before and after exclusion of non-compatible articles, and divided into source-, cause-, and solution-categories. The overview shows that the topic only quite recently started gaining traction in scientific literature in Europe, and more specifically, Norway and Denmark (i.e., since 2017). The main sources of litter reported are fishing gear and different types of food packaging and single use items. The main underlying causes for marine litter are described as undesirable behavior or lacking or missing knowledge of cause, and the main solutions are indicated as being changes in behavior and development of policies that prevent marine litter influx. A lesser but more constant focus is at improved technology and infrastructure, mainly improved waste management. Emerging solutions to marine litter are connected to the development of a circular plastics economy and, more specifically, improved design of plastic products.

Table 4. Overview of the sources, causes, and solutions to marine litter mentioned in the analyzed scientific publications. The highest numbers in each year (where applicable) is marked in bold. Details of the dataset can be found in the material available at the journal website. The data is extracted from the review database which is available as Supplementary Materials.

		2000–5	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
	Exclud.+includ. articles	2	1	1	1	2		1	1	1	4	7	4	12	15	**22**	19	15
	Included articles		1		1			1		1	3	2	2	6	12	**15**	6	4
Upstream solutions	Improved tech/Infrast.		1		1								1	2	3	3	3	2
	Policy/regulation		1		1					1	**2**	1		**4**	3	**6**	3	3
	Increased Awareness		1		1					1	1			**4**	**6**	2	2	2
	Improved design															3	1	1
	Research (solution)									1	1	1	2	2	3	**6**	3	2
	Other/upstream											1					1	
Downstream solutions	Onshore CU														2	2		
	CU offshore														1			
	CU in general													2		1		
Cause of littering	Lack of awareness/ bad behav.												1	2	4	2	1	1
	Lack of infrast./technol.												1	2		1	1	2
	inexpedient design																1	1
	Cause unknown/diffuse				1			1			2		1	2	**5**	**6**	1	
Source	Land				1						2	1	1	3	**7**	**6**	2	3
	Sea				1			1			1	1	2	3	4	4	1	4
Source label	On-the-go				1						1			3	**7**	**6**	1	1
	Fisheries				1			1			1		1	3	3	**5**	2	2
	Industrial										1				1	1		
	Domestic													1	1	2		
	Other											1	1	1	2	1	1	2

3.1. Sources and Causes

In this study, the sources of marine litter identify the user areas from which the plastic litter is leaked, e.g., fishing or consumption of food or drinks "on the go", whereas the "underlying causes" define the reason why litter is leaked into the environment from these sources. Both "on the go" plastic and plastic waste from fisheries is mentioned by 18 articles as main sources to marine litter. In contrast, only three articles focus on industrial waste and four on domestic litter.

The underlying causes of marine litter, as described in the articles, are described below. 19 articles either did not mention the underlying cause to litter or could not identify the source of the litter. The second largest category, "lack of awareness or bad behavior", comes in second place with 11 articles that define these as major causes to marine litter. "Design of either products or systems" is only mentioned by six articles, while "insufficient or lacking waste management infrastructure or technology" is only mentioned by four.

Unknown/not mentioned: In most articles, the underlying cause for marine litter is not mentioned or unknown. These articles were included in the analysis as they identify the source of the litter, which helps to understand the causality to some extent. For example, knowing that litter sources from fisheries, can help policy makers pinpoint some mitigative measures that can reduce influx from this industry or highlight the need to support research that aims at identifying the underlying causes of pollution from the industry. The high representation of articles where the underlying cause of littering is unknown or not mentioned, indicates a need for an increased focus on cause identification in future studies. Most of the articles where the underlying causes are unknown, focus on fishing and/or pinpointed fishing as a major source to marine litter. As litter from fisheries is the second most common type of marine litter, after single-use plastics in Europe [33], identifying the causes to leakage of litter from this industry is important to combat marine litter in the region.

Lack of awareness/bad behavior: This is the next most common underlying cause to marine litter. Most studies that identify awareness and/or behavior as the main cause to marine litter focus on the "on the go" category, i.e., on single use plastics and cigarette products. For example, Axelsson and van Sebille [34] identify shoreline and recreational activities as the main source for litter, as registered by the International Coastal Cleanup. They also highlight cigarette buts' role as a major source to marine litter, as "up to four trillion cigarette buts are improperly disposed of globally each year". Šilc et al. [35] also identify coastal and recreational activities as a source to marine litter, most of which belong to the on-the-go category, e.g., plastic bags and bottles. Kanstrup and Balsby [36] pinpoint a recreational activity, hunting, as a major source to marine litter in some Danish coastal areas and call for more responsible practice to avoid accumulation of litter from ammunition. Gomiero et al. [37] note that "irresponsible human behavior during disposal of used plastic material has resulted in large masses of single use plastics being released into nature", together with limited waste management infrastructure and microplastics from washing of clothes.

Insufficient infrastructure/technology for waste management: Four articles identify the lack of waste management infrastructure and/or technology as a major cause to marine litter influx. As Axelsson and van Sebille [34] describe, "[Open] landfilling near the coast can allow for plastic leakages into the ocean". Nelms et al. [38], on the other hand, point out sewage as a source to land-based litter, while Gomiero et al. [37] state that "limited and/or inappropriate waste management practices" cause the release of single-use plastic into nature, along with irresponsible human behavior. The lack of agreement on where infrastructure should be improved suggests the potential for improvement in several areas of plastic waste management: from improved sewage treatment to elimination of open landfills and better practices.

Design: Only seven articles specify design of either systems or products as a cause to marine litter influx. Deshpande et al. [39,40] focus on the leakage of fishing gear into the oceans and highlight the need to find ways to reduce the leakage of plastic materials from the industry, through design for recycling, as well as the development of circular systems for these fractions. Veiga et al. [41], Leal Filho et al. [42], Agamuthu et al. [43], Calleja [44], and Fossi et al. [45] also call for a paradigm shift towards circularity, i.e., redesign of the plastics economy.

A summary of the categorization of the articles can be found below in Table 5.

Table 5. Sources and underlying causes to plastic marine litter described in the articles analyzed. "label" denotes types of underlying causes. "source" denotes the activity type related to the littering.

Label	Source	Article
Lack of awareness/ bad behavior	On the go	Axelsson and van Sebille (2017) [34]; Prevenios et al. (2018) [46]; Loizidou et al. (2018) [47]; Chen et al. (2021) [48]
	On the go, fishing, domestic	Nelms et al. (2017) [38]
	On the go, domestic	Gomiero et al. (2019) [37]
	On the go, fishing	Falk-Andersson et al. (2019) [32]
	On the go, other, industrial	Šilc et al. (2018) [35];
	Fishing	Deshpande et al. (2020a; 2020b) [39,40]
	Other	Veiga et al. (2016) [41]; Kanstrup and Balsby (2018) [36]
Insufficient infrastructure/ technology for waste management	On the go	Axelsson and van Sebille (2015) [34]
	Other	Veiga et al. (2016) [41]; Bishop et al. (2020) [49]; Chen et al. (2021) [48]
	On the go, fishing, domestic	Nelms et al. (2017) [38]; Deshpande and Haskins (2021) [50]
	On the go, domestic	Gomiero et al. (2019) [37]
Design	Fishing	Deshpande et al. (2020a; 2020b) [39,40]; Deshpande and Haskins (2021) [50]
	Other	Veiga et al. (2016) [41]; Leal Filho et al. (2019) [42]
Unknown/not mentioned	On the go	Puig-Lozano et al. (2018) [51]; Urban-Malinga et al. (2018) [52]; Urban-Malinga et al. (2020) [53]
	On the go, fishing	Koutsodendris et al. (2008) [54]; Pham et al. (2014) [55]; Arcangeli et al.; (2018) [56]; Nyka (2019) [57]; Calleja (2019) [44]; Gerigny et al. (2019) [58]
	On the go, fishing, other	Maes et al. (2017) [59]; Zeri et al. (2018) [60]
	Domestic	Turrell (2019) [61]
	Industrial	Lechner et al. (2014) [62]
		Murray and Cowie (2011) [63]; Moriarty et al. (2016) [64]; Gutow et al. (2018) [65]; García-Barón et al. (2019) [66]; Enrichetti et al. (2020) [67];
	Fishing	Buhl-Mortensen and Buhl-Mortensen (2017) [68]
	Other, on the go, industrial	Schulz et al. (2019) [69]

3.2. Solutions

The solutions identified in the articles were divided into solutions upstream (prevention) and solutions downstream (clean-up of marine litter). The preventative measures were further divided up into specific initiatives or strategies (i.e., improvement of technology and/or infrastructure for waste management, policy development and more stringent regulation, increased awareness and change in behavior, improved product and system design and more research on marine litter). The articles where clean-up was mentioned as the prioritized strategy or a supplementary effort in addition to prevention, were further categorized according to whether the clean-ups should take place on- or offshore, or if the articles suggest clean-ups in general, without specifying the environmental compartment.

All the articles suggest a combination of strategies, such as increased awareness/change in behavior and policy development [34,40,43,54,59,70–73] and/or a combination of increased awareness/change in behavior and improvements in technology and infrastructure [39,40,43,45,46,54,60,70]). This signals the need for a holistic approach to the issue

of marine litter and specifically a need to include multiple stakeholders in the process of reducing the influx and well as the stock of marine litter.

The suggested measures are summarized in Table 6 below. Most articles pointed out the need to stop the influx of marine litter through preventative efforts, with focus on policy and regulation being the largest category (23 articles), followed by call for more awareness and change in behavior (20 articles) and more research and data gathering (17 articles). 11 articles identified improved waste management infrastructure and technology as a solution, while the need for improved design of systems and/or products was only mentioned by five articles.

Table 6. Overview of solutions to marine litter in categories, and the articles supporting these.

Label	Categories	Article
Prevention	Technology/ infrastructure	Storrier and McGlashan (2006) [70]; Koutsodendris et al. (2008) [54]; Auta et al. (2017) [73]; Axelsson and van Sebille (2017) [34]; Prevenios et al. (2018) [46]; Zeri et al. (2018) [46]; Loizidou et al. (2018) [47]; Adam et al. (2019) [74]; Leal Filho et al. (2019) [42]; Agamuthu et al. (2019) [43]; Deshpande et al. (2020a; 2020b) [39,40]; Fossi et al. (2020) [45]; Barcelo and Pico (2020) [75]; Chen et al. (2021) [48]
	Policy/regulation	Storrier and McGlashan (2006) [70]; Koutsodendris et al. (2008) [54]; Depledge et al. (2013) [71]; Lechner et al. (2014) [62]; Loizidou et al. (2014) [72]; Eerkes-Medrano et al. (2015) [76]; Auta et al. (2017) [73]; Axelsson and van Sebille (2017) [34]; Maes et al. (2017) [59]; Nelms et al. (2017) [38]; Steensgaard et al. (2017) [77]; Penca (2018) [78]; Zeri et al. (2018) [46]; Aanesen et al. (2018) [79]; Molina et al. (2019) [80]; Agamuthu et al. (2019) [43]; Black et al. (2019) [81]; Calleja (2019) [44]; Gerigny et al. (2019) [58]; Leal Filho et al. (2019) [42]; Nyka (2019) [57]; Deshpande et al. (2020a) [39], Fossi et al. (2020) [45]; Barcelo and Pico (2020) [75]; Chen et al. (2021) [48]; Dabrowska et al. (2021) [82]
	Awareness/behaviour	Storrier and McGlashan (2006) [70]; Koutsodendris et al. (2008) [54]; Depledge et al. (2013) [71]; Loizidou et al. (2014) [72]; Auta et al. (2017) [73]; Axelsson and van Sebille (2017) [34]; Maes et al. (2017) [59]; Nelms et al. (2017) [38]; Šilc et al. (2018) [35]; Prevenios et al. (2018) [46]; Hartley et al. (2018) [83]; Loizidou et al. (2018) [47]; Kanstrup and Balsby (2018) [36]; Zeri et al. (2018) [60]; Agamuthu et al. (2019) [43]; Calleja (2019) [44]; Gerigny et al. (2019) [58]; Deshpande et al. (2020a; 2020b) [39,40]; Fossi et al. (2020) [45]; Barcelo and Pico (2020) [75]; Chen et al. (2021) [48]
	Product development/design	Leal Filho et al. (2019) [42]; Agamuthu et al. (2019) [43]; Calleja (2019) [44]; Deshpande et al. (2020b) [40]; Fossi et al. (2020) [45]; Deshpande and Haskins (2021) [50]
	Research/data gathering	Depledge et al. (2013) [71]; Lechner et al. (2014) [62]; Eerkes-Medrano et al. (2015) [76]; Moriarty et al. (2016) [64]; Veiga et al. (2016) [41]; Auta et al. (2017) [73]; Nelms et al. (2017) [38]; Hartley et al. (2018) [83]; Loizidou et al. (2018) [47]; Gutow et al. (2018) [65]; Molina et al. (2019) [80]; Gerigny et al. (2019) [58]; Falk-Andersson et al. (2019) [32]; Haarr et al. (2019) [84]; Schulz et al. (2019) [69]; Panti et al. (2019) [85]; Fossi et al. (2020) [45]; Bishop et al. (2020) [49]; Dabrowska et al. (2021) [82]; Deshpande and Haskins (2021) [50]
Clean-up	Onshore clean-up	Šilc et al. (2018) [35]; Kanstrup and Balsby (2018) [36]; Haarr et al. (2019) [84]; Gerigny et al. (2019) [58]
	Offshore clean-up	Loizidou (2018) [47]
	Clean-up in general	Axelsson and van Sebille (2017) [34]; Panti et al. (2019) [85]; Auta et al. (2017) [73]

3.2.1. Upstream Solutions

Policy/regulation: Focus on policy development and more stringent regulation is mentioned in most articles. Depledge et al. [71] describe the needfor bringing the issue of marine litter to the attention of the public, policymakers, and politicians in general, while Maes et al. [59] state that a reduction in the number of observed plastic bags in the Greater

North Sea "suggests that behavioral and legislative changes could reduce . . . marine litter within decades". Nelms et al. [38] call for better legislation to stop mass pollution events, such as balloon releases, in addition to awareness creation, design of alternatives to certain plastic products and more research on leakage from both land- and sea-based sources. Zeri et al. [60] focus also on a specific pollution problem and suggest banning of single-use plastics to reduce the amount of floating plastics in the Adriatic Sea. Aanesen et al. [79] highlight the need to better regulate fishing in the Norwegian Arctic to reduce marine litter. Steensgaard et al. [77] go a step further and suggest a variety of regulative tools: polymers should be categorized according to whether they have the same monomer constitutes, and plastics should have the same level of monitoring and reporting requirements as hazardous waste through the entire life cycle. In addition, Steensgaard et al. [77] call for more stringent regulation from the EU in the form of more ambitious recycling and recovery targets, and expansion of regulation on consumption of lightweight plastic carrier bags to apply also to heavyweight plastic carrier bags. Lastly, they call for inclusion of plastic waste as an impact in water quality in the Marine and Water Framework Directives. Black et al. [81] state that the main solution to marine litter in Europe is "increased regional integration between the dominant legislative structures" and that these "must provide specific considerations for the role that rivers and land-based activities play in the accumulation of plastic litter in the marine environment". Axelsson and van Sebille [34] are on a similar track, calling for "cooperation between regional and communal policy makers to create holistic solutions", to create stricter laws and fines on littering and to, for example, ban smoking in certain public areas and increase taxes on cigarettes to cover clean-up efforts. Leal Filho et al. [42] point to producers, by calling for Extended Producer Responsibility (EPR) measures, to achieve the existing EU waste targets, as well as the newer targets in the EU Circular Economy Package. Interestingly, this is the only article that highlights the need for EPR as one of the main mitigative strategies.

Policy development is never suggested as a stand-alone effort, but rather as a pillar that supports other efforts, such as awareness creation and improvement of waste management infrastructure, and which is being supported by research within marine litter to ensure knowledge-based decision-making. As described by Fossi et al. [45]: "The way forward must go through forging partnerships for action that amplifying the impact of the work of individual actors in Government, Civil Society, a multi-disciplinary Scientific Community, Private Sector, and International Organizations to effectively promote prevention and reduction measures, technological solutions, education and awareness raising, research in order to fill in knowledge gaps and support effective decision-making".

Awareness/behavior: The second most common category focuses on changing behavior and increasing awareness as a tool against marine litter. Storrier and McGlashan [70] and Depledge et al. [71] call for more education on the issue of marine litter, while Axelsson and van Sebille [34] suggest complementing the improvement of regional recycling systems with local educational programs. Nelms et al. [38] propose an increase in efforts to quantify marine litter sources, to be able to develop more effective efforts, such as awareness increasing campaigns and better waste management systems. Prevenios et al. [46] also suggest a combination of awareness creation and improvement of waste management schemes. Maes et al. [59] assume a relationship between reduction in plastic bags in the Greater North Sea and change in behavior, and suggest that behavioral, together with legislative, changes "could reduce marine litter within decades".

Need for increased awareness and change in behavior seems to be a complementary strategy that anchors the policy and waste management infrastructure development in the local population and visitors. There are no clear references as to who should be responsible for increasing awareness and what form the information campaigns should take, e.g., whether this is an effort that should be included in school curriculums and financed by the public sector, or if companies that put plastic on the market should include information campaigns about correct waste disposal as a part of their corporate social responsibility efforts.

Research/data gathering: Of the 21 articles that focus on the need to increase research and data gathering efforts, Lechner et al. [62], Moriarty et al.[64], Nelms et al. [38], and Falk-Andersson et al. [32] call for increased efforts to quantify sources to marine litter influx to stop the problem at its source, while Haarr et al. [84] add that increased understanding of marine litter accumulation can improve the efficiency of removal of marine litter from nature. Molina Jack et al. [80] and Lechner et al. [62] also highlight the need for standardized data gathering that allows international comparison of marine litter quantities. Eerkes-Medrano et al. [76], on the other hand, highlight the lacking knowledge of microplastics in the freshwater systems.

Technology/infrastructure: A total of 16 articles mention the need to develop waste management technologies and infrastructures, to fight marine litter. Already in 2006, Storrier and McGlashan [70] call for development of sufficient waste management systems, in combination with education and law enforcement, to tackle marine litter. Koutsodendris et al. [54] focus on a more specific source of marine litter and suggest improvements of sewage waste treatment facilities. Axelsson and van Sebille [34], Loizidou et al. [47], and Adam et al. [74] propose the development of better sewage systems, to be able to gain better control over extreme rainfall events and to reduce the amount of microplastic leaking into the waterways. In addition, improvement in recycling facilities and adaptation of circular economy principles, in general, are suggested [34,39,40,43,48,75,86].

Product/system development/design: Only five articles discuss the role of product and/or system design as preventative methods, from varying aspects. Nelms et al. [38] mention the possibility to mitigate marine litter issues through replacing polystyrene foam and plastic food packaging with cardboard. Leal Filho et al. [42] discuss the issues related to lacking extended producer responsibility in Europe and highlight the need to design plastic products so that they can be recycled, e.g., use of single polymers instead of multi-layer and multi-component packaging. The study by Leal Filho et al. [42] argue that the negative environmental impacts caused by mismanaged plastic waste could be avoided if plastic products were designed according to circular economy principles. Agamuthu et al. [43] highlight the need to make the plastics economy more circular, as this is the "only sustainable, long-term solution to marine litter". Other mitigative actions, such as beach and marine clean-ups and conventions and regulations that focus on assessment, reduction, prevention, and management of marine debris are described as merely short-term, unsustainable solutions to the problem [43]. Calleja [44] agrees with the previous authors, as the article concludes that "The New Plastics Economy" must be a circular economy which eliminates waste, maximizes value, and uses plastic efficiently". Not only will the shift to a circular economy reduce the influx of marine litter, but it will also reduce greenhouse gas emissions from plastics production [44]. Deshpande et al. [40] call for more accurate quantification of abandoned, lost or otherwise discarded fishing gear, in order to be able to build circular end-of-life solutions for fishing gear. Fossi et al. [45] discuss the potential of replacing plastic materials with biodegradable plastics in the aquaculture and fisheries sectors but point out the challenges related to biodegradation in marine environments, that are yet to be solved.

Most of these few articles that focus on redesign of systems or specific products to reduce the influx of plastic into the oceans point out the underlying issue of the linearity of the current system. This trend signals a need to address several issues along the plastics' life cycles to create a system that ensures long-term reduction of marine litter and other harmful environmental impacts caused by the excessive and increasing demand for plastics.

3.2.2. Downstream Solutions

There are only eight articles that propose the use of marine litter clean-ups as a complementary strategy to preventative efforts and only one of them mentions offshore clean-ups as a solution to marine litter. This article, by Loizidou et al. [47], however, refers to the Fishing for Litter (FFL) scheme, where fishers can deliver marine litter caught under regular fishing activity to appointed marinas for free. FFL does not, in other words, target marine

litter in specific, but facilitates for collection and management of marine litter bycatch. Four of the articles suggest clean-up activity onshore [35,36,58,84] while three articles do not specify the environmental compartment where the clean-ups should be implemented [34,73,85], while one article focuses on solutions that has not been implemented yet, i.e., the use of microorganisms to degrade microplastics in the environment [73]. A summary of the categorization is found above in Table 6.

3.2.3. From "Sources", "Causes" and "Solutions" to Shared Causal Beliefs and Storylines

The study reveals a few main storylines that are distinct, and which can be constructed from the sources, causes and solutions identified above. The existence of differences in the emphasis of sources and causes naturally reflect differences in the types of marine litter that are observed and collected, whereas the identification of causes and solutions depends on increasingly complex investigation designs, thus increasing the potential for interpretation. In the material analyzed, we see a large agreement with respect to sources and to some extent with respect to causes, but high variations with respect to proposed solutions, which leads to a large variation in the potential storylines.

The main storylines can be synthesized into the following seven storyline-elements (see Figure 3):

1. "The main sources of marine litter are on-the-go plastics and plastic from fishing activities",
2. "the prevalent causes of littering are lack of awareness"
3. "the prevalent causes of littering are due to diffuse or unknown causes"
4. "a main solution to avoid marine litter is increase of awareness"
5. "a main solution to avoid marine litter is establishment of policy and regulation"
6. "a main solution to avoid marine litter is to build better waste infrastructure"
7. "More research is needed to achieve a better problem understanding and better solutions"

These seven fragments combine into four distinct main storylines (a–d):

a. 1 + 2 + 4 = "The main sources of marine litter are on the go plastics and plastic from fishing activities", "the prevalent causes of littering are lack of awareness" and "A main solution to avoid marine litter is increase of awareness"
b. 1 + 3 + 5 = "The main sources of marine litter are on the go plastics and plastic from fishing activities", "the prevalent causes of littering are due to diffuse or unknown causes" and "a main solution to avoid marine litter is establishment of policy and regulation"
c. 1 + 3 + 6 = "The main sources of marine litter are on the go plastics and plastic from fishing activities", "the prevalent causes of littering are due to diffuse or unknown causes" and "A main solution to avoid marine litter is to build better waste infrastructure"
d. 7 = "More research is needed to achieve a better problem understanding and better solutions"

Among these storylines there is potentially competition between a. (focus on informing citizens to behave better), b. (focus on creating structural change through policies), and c. (focus on technological fixes for reducing leakages from waste management systems). However, these strategies also reflect different disciplinary approaches and lack of integration between them indicates that the field of marine litter research is young. Thus, it is expected that negotiations and network creation are likely to have an impact on increased consensus building, as there seems to be no important barriers for the formation of an overarching discourse coalition balancing the different strategies. The fourth storyline is compatible with the first storylines and focuses on the need for further research.

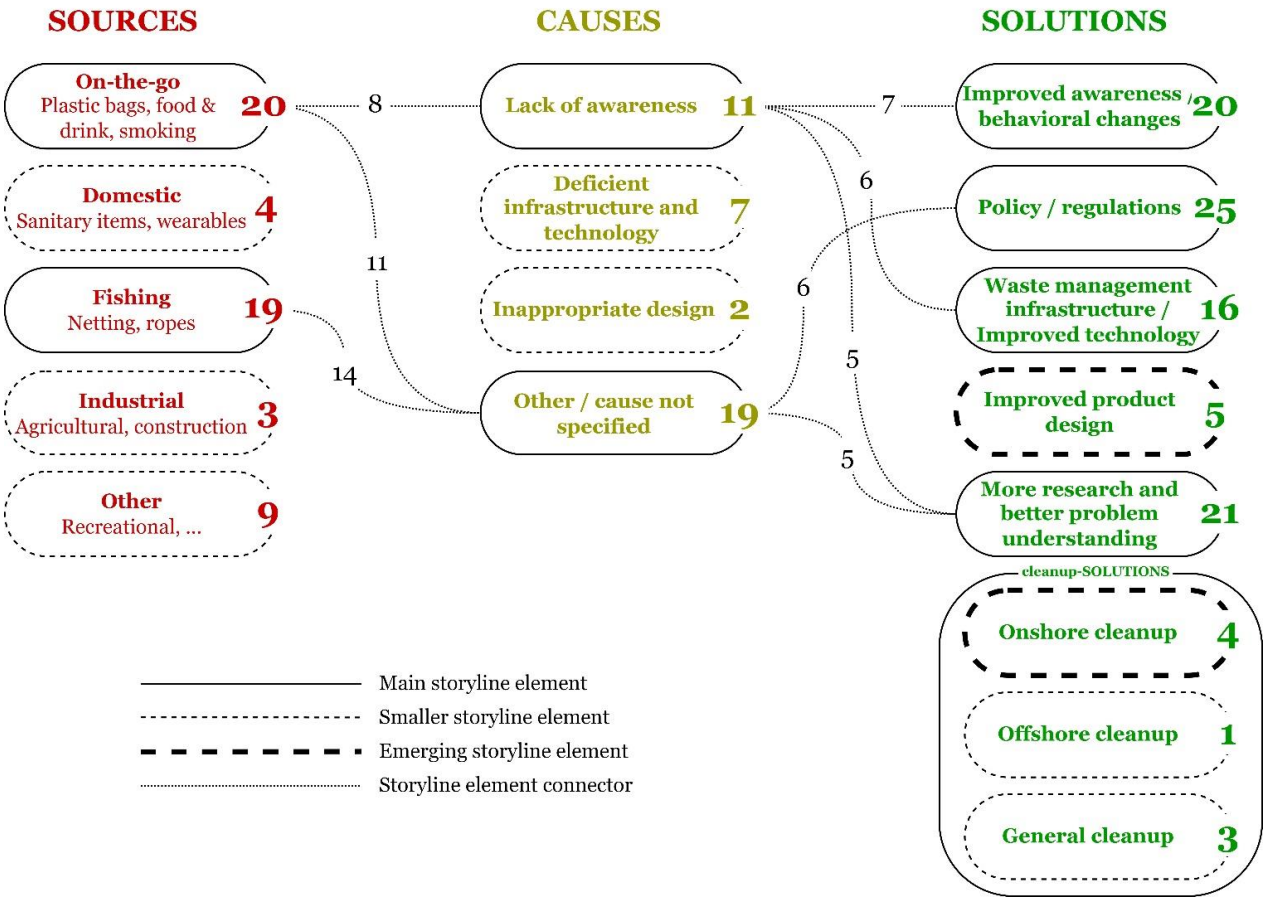

Figure 3. Building bricks to storylines: Main storyline elements are connected by lines, also showing the number of articles connecting these. Emerging topics in are marked with bold frames. Number of articles referring to the topic is marked on the topic-box. Details of the data including a full connection matrix can be found in the material available on the journal website.

Two types of upcoming storylines, at the solution level, are emerging from the study: product design according to circular economy principles and clean-up. The emerging storyline of a product design discourse is strongly linked to the idea and principles of circular economy. Its proponents argue that the new plastics economy requires circularity addressing all part of the life cycle [43,44], based upon system-wide analysis [40], and supporting efficient recycling [42]. A specific product category where the need to develop circular solutions is identified, is fishing gear [40]. Within this storyline, we also find the proposal of designing biodegradable plastic in aquaculture and fisheries sectors [45]. Circular solutions and sustainable product design may be specifically needed in fishing industry, as fishing gear cannot be removed from the market through bans in the same way as, for example, several single-use plastic products can.

The pro-clean discourse is another emerging storyline; all the eight articles that mention marine litter clean-up as a mitigative strategy, are published between 2017 and 2019, indicating this as an emerging focus within the scientific literature. However, the articles have varying approach to marine litter clean- ups; Haarr et al. [84] discuss the importance of mapping marine litter accumulation zones onshore, to be able to make beach clean-up efforts more efficient, Kanstrup and Balsby [36] focus on a specific littering problem along the Danish shoreline; plastic litter from shotgun ammunition and awareness creation amongst hunters. In other words, Haarr et al. [84] wish to combine clean-up activities with improved knowledge, while Kanstrup and Balsby [36] call for more responsible practices from the hunters operating along the shoreline. Loizidou [47], on the other hand, is the only one that mentions offshore clean-ups as a mitigative method. The scheme Loizidou

refers to is FFL; a scheme where fishers deliver marine litter caught under regular fishing activity to appointed marinas without cost. An important aspect of the pro-clean elements in the investigated literature is that the positions largely are in line and not conflicting with the more preventive strategies, as cleaning for litter is seen as a partial solution that needs to be combined with preventive measures.

The material analyzed in this study only allows for limited identification of the formation epistemic communities, which is closely related to the immature status of the field as described above. We can see that shared causal beliefs are established with respect to the sources of littering, as well as with respect to the relative importance of prevention and mitigation. The relatively strong link between lack of awareness and waste management as a solution strategy could indicate the existence of an epistemic community around the connection between waste management and prevention of marine litter. However, this most likely reflects a well-established scientific community around waste management technologies which is a very well developed and mature scientific field. Furthermore, when it comes to more specific solution strategies, beyond the need to avoid leakage from waste handling, we do not see evidence of potential epistemic communities yet, indicated by a general lack of a connected consensual knowledge base.

4. Discussion

This study has presented the scientific discourses around causes and solutions to marine litter in Europe, and more specifically, Norway and Denmark. The study includes peer-reviewed, scientific articles, published in WoS and Scopus between the years 2000 and 2021. Even though the scientific literature analyzed in this study widely agrees on the harmfulness of marine litter and on prevention being the most effective way to combat the issue, there seems to be pronounced uncertainty about how to stop the influx of marine litter in the most effective way [5]. Four main storylines that potentially can constitute different discourse coalitions emerge from the discourse analysis. At the same time, the contours of two new emerging storylines are drawn. Regarding the sources of marine plastic litter, there are consenting discourses of "on the go" and "fishing" being the main sources. The main causes in the scientific discourses are found to be "lack of awareness"—and in many cases simply not specified. Regarding solutions, most of the articles analyzed in this study recommend the development of policies and awareness creation as preventative measures. However, the need to gather more information about marine litter through research, and especially the quantification of sources to marine litter that allows for efficient influx prevention, is highlighted [32,38,62,64].

In contrast, none of the analyzed articles suggest marine litter clean-ups as the most effective solution but clean-up is nevertheless found to be one of the two emerging storylines. As there already is a considerate stock of marine litter in the environment, removing litter from the nature is suggested as a necessary, complementary strategy to prevention [84]. The need to gather more information on the accumulation of marine litter, as well as the spatial and temporal variations of the accumulation, to streamline clean-up efforts is called for in recent literature [84,87]. Currently, the negative environmental impacts caused by marine litter clean-up activities are also understudied, highlighting the need for a holistic assessment of the economic and environmental cost-benefit relationship of clean-up efforts to ensure a net-positive impact [87]. In addition, collected marine litter is identified as a growing waste problem, as there is currently little knowledge and facilitation of end-of- life alternatives for these fractions [88]. Therefore, a more holistic view on the issue of marine litter has increased the knowledge of the challenges associated with the removal of marine litter from the environment, and the general awareness of the urgency to stop the influx of marine litter.

As the public is becoming increasingly aware of the magnitude of the issue of marine litter, the need for a transition to a circular plastics economy is getting increased attention in the scientific literature, representing the second emerging storyline (e.g., [7,39,40,43,45]), and this storyline is likely to constitute an emerging discourse coalition. The current

plastics economy is highly linear, as only nine per cent of all plastics ever made have been recycled [89]. In addition, in the last three decades, OECD countries have been exporting their plastic waste to countries with insufficient or lacking waste management infrastructure, such as China, for recycling [90]. In 2018, China imposed the National Sword Policy banning the import of scrap plastics. As a result of this ban, up to 111 million metric tons of plastic waste can be displaced by 2030 [90]. In addition, in the wake of the ban in China and other Asian countries, several new regions for plastic waste imports are emerging many of which are already struggling to manage their own plastic waste, or which are being controlled by corrupt or criminal actors (INTERPOL 2020).

These dynamics in the global waste trade highlight the need to move towards a more transparent and circular plastics economy [87,90]. The COVID-19 pandemic also highlighted the need to construct plastics value chains that are based on fair trade, flexibility, and cooperation [87].

Fiscal policies and regulatory frameworks are being implemented in the EU to make the necessary shift from a linear to a circular economy more efficient. Circularity principles are in the core of EU's "Green New Deal" that aims at developing the region's economy towards sustainability with respect to climate change and environmental degradation [91]. In addition, EU's Plastic Strategy aims at increasing the regional plastics recycling capacity and through e.g., requirements for recycled and recyclable contents in plastic products, strengthens the regional, circular plastic value chains [33]. The United Nations Sustainable Development Goals (SDGs) also act as a policy response and support the prevention of marine littering and pollution [92]. These regulatory and policy frameworks will hopefully strengthen the development of truly circular plastic economies further.

5. Conclusions

Marine litter is a complex problem, combatting of which requires value chain cooperation. Plastics' value chains can involve extremely high numbers of stakeholders, increasing the complexity of a system change, as highlighted by the study by Friant and colleagues; a discourse network analysis of 211 stakeholder organizations [93]. The mobilization of different actors is to some extent reflected in the reviewed literature. Especially the importance of educational programs and awareness raising is prominent in the articles ([34,45,70,71]). Axelsson and van Sebille [34] further refer to the need for stronger cooperation between the regional and municipal policymakers, while Fossi and colleagues [45] emphasize the importance of partnerships.

Due to the complexity and the range of necessary solutions (reflecting e.g., short-term, and long-term solutions, and interventions of political, regulative, educational and management nature), there is space for more research focusing on the issue of marine litter on a system level. The connection of sources to underlying causes for littering and the suggestion of relevant solutions is currently weak in the scientific literature. The improved understanding of underlying causes seems to be a key parameter when policy makers are to support and set frames for the circular economy. In addition, when suggesting solutions to marine litter, the source-cause-solution causality and cost-benefit relationships must be understood from a lifecycle perspective. More specifically, by using a holistic assessment method, i.e., life cycle assessment, we can reduce the risk of suggesting and implementing solutions that merely contribute to replacing one environmental or societal externality with another, rather than removing it [94].

Future research should also focus on the marine litter discourse outside of the scientific literature to examine how scientifically generated knowledge is used in policymaking processes and in public debates ([16,95] are for the present solitary examples of such analyses). This recommendation is twofold. Firstly, we recommend that researchers pursue the understanding of marine litter with an interdisciplinary approach, which is needed to resolve the complex, societal challenges related to marine litter. The interdisciplinary approach is a pivotal precondition for sound policymaking and should be applied especially in scientific research. We see that interdisciplinarity is gaining attention in scientific literature, through

for example the recent call for interdisciplinary, science-based solutions to plastic pollution in One Earth Voices [96]. Here, the need for coordinated research across natural, social, and applied sciences to solve the complex problem of marine litter is emphasized. Secondly, we recommend that the field of marine litter is researched to observe the evolvement of policy responses and their connection to scientific, as well as other public discourses. Gaining an overview over the degree to which, and how, scientific, societal, and public discourses impact policy development will help to identify whether the current plastic marine litter policies are developed based on best available scientific knowledge. In addition, discourse analyses can help to unveil how this knowledge is being translated and raise the flag if the construction of knowledge into action is biased or suboptimized due to opinion-based private interests or the lack of essential knowledge in the opinion- and policymaking process [97], which may lead to suboptimal policy making and politics.

Supplementary Materials: The following supporting information can be downloaded at 10.5281/zenodo.6757492: review data set (interactive) analysis based on SIGMA principles.

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