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A Trip Upstream to Mitigate Marine Plastic Pollution – A Perspective Focused on the MSFD and WFD

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Developing and implementing effective legislation to combat plastic litter in the marine environment has proven a significant challenge. This is in large part due to an incomplete understanding of the sources and transport pathways of plastic litter and is manifested in Europe's current disjointed legislation that governs the aquatic environment. In this article, the authors present the perspective that marine plastic pollution in European waters cannot be mitigated without increased regional integration between the dominant legislative structures and must provide specific considerations for the role rivers and land-based activities play in the accumulation of plastic litter in the marine environment.

Keywords: marine litter, marine plastic pollution, MSFD, WFD, upstream, stakeholder

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INTRODUCTION

Plastic represents roughly 80% of all marine litter (Carney Almroth and Eggert, 2019). The past two decades have seen a dramatic increase in funding and research dedicated to understanding the characteristics of litter in the marine environment (Rochman et al., 2016; Dauvergne, 2018); yet examples of tangible reductions in marine litter, particularly plastics, are scarce. A myriad of reasons have stifled the mitigation of plastic litter. Notably, there are burgeoning concerns over the true sources and pathways of plastic litter, as well as the framing of the issue as one concentrated in the "marine" environment (Carlini and Kleine, 2018). Hartley et al. (2018) demonstrated that previously biased attitudes labeling plastics as a marine issue have restricted the full understanding of plastic pollution. For example, the majority of marine plastic pollution (MPP) originates from land-based sources and is transported by rivers to the ocean (Jambeck et al., 2015; Lebreton et al., 2017; Schmidt et al., 2017; Carney Almroth and Eggert, 2019). Many assert that the solutions to MPP lie on land. We now see that ineffective management responses to MPP are in large part due to a lack of knowledge concerning the sources and pathways of plastic pollution (Schmidt et al., 2017).

Considering Europe's emphasis on integrating ecosystem-based governance (Borja et al., 2010), and supported by the existing literature, the authors wish to draw attention to the constraints of legislative instruments for the environmental protection of aquatic resources in Europe, specifically the Marine Strategy Framework Directive (MSFD) (Directive 2008/56/EC) and Water Framework Directive (WFD) (Directive 2000/60/EC). The evidence currently suggests that the vast majority of plastic pollution originates from land-based sources, specifically rivers (e.g., Van der Wal et al., 2015). Research has established that rivers have acted as conduits for litter to the seas for over two decades (Galgani et al., 1995, 1996, 2000, 2011a,b; MSFD Technical Subgroup on Marine Litter [MSFD TSML], 2013; Sadri and Thompson, 2014; Bergmann et al., 2015; Schmidt et al., 2017). However, our knowledge concerning effective measures to address rivers' discharge of litter into the ocean is significantly lower than our understanding of plastic litter in the marine environment (Wagner et al., 2018).

Several EU regulations and policies, such as the Single-Use Plastics Directive (Directive (EU) 72 2019/904) and the EU Action Plan for the Circular Economy, are well placed to

turn off the tap on MPP and ultimately reduce plastic leakage into the environment. Indeed, the circular economy's emphasis on recycling and re-use of materials aims to reduce waste altogether (Abdallah et al., 2018). Furthermore, Member States (MS) monitor MPP beyond the MSFD (Gago et al., 2016) at regional seas level within programs under the OSPAR, HELCOM and Barcelona Conventions (Chen, 2015). Shaping effective measures, regulations or policies to reduce plastic influx into the environment requires adequate monitoring at or near the source of the pollution, e.g., EU riverine systems. At a global level, calls have been made to integrate and expand monitoring systems for plastics in all hydrological systems (Maximenko et al., 2019).

In the proceeding sections, we argue that current aquatic legislative instruments are limited in either their geographic scope, monitoring capacity, or implementation processes. Consequently, the legislative regime does not reflect the role that rivers play in MPP and is therefore incapable of reducing the quantity and hazard of marine litter at a European scale (Raubenheimer and McIlgorm, 2018). Rochman et al. (2016) maintain that further high-quality research is necessary for precise and accurate policy guidance; we believe such evidence is now emerging, pointing to rivers as primary transport vectors of MPP to the ocean. We present the perspective that a tactful re-examination of Europe's current environmental aquatic management regime, specifically the WFD and the MSFD, has the potential to improve cross-policy integration and identify interventions that effectively tackle plastic pollution in upstream surface and transitional waters.

SOURCES, PATHWAYS, AND POLICY RESPONSES

The discovery of large litter depositories in secluded regions of the ocean, e.g., Great Pacific Garbage Patch, demonstrated plastics' transportability in the marine environment (Lebreton et al., 2018). However, plastics' lightweight and durable properties also facilitate their transport in the terrestrial environment, where they can accumulate in freshwater systems (Blettler and Wantzen, 2019). In response, effective mitigation efforts that target plastic pollution at its source, i.e., preventative measures rather than downstream reactionary measures, require a comprehensive understanding of the issue's spatial and temporal variability (Lebreton et al., 2017).

A number of studies argue that rivers and terrestrial waterways facilitate the transport of discarded plastics from land to the ocean (Colton et al., 1974; Sheavly and Register, 2007; Munari et al., 2016; Willis et al., 2017; Crosti et al., 2018). Lebreton et al. (2017) estimated that river systems carry between 1.15 and 2.41 million tonnes of plastic litter to coastal and marine environments every year, with around 80% of MPP coming from land-based sources. This is certainly the case in Europe's regional sea basins (Van der Wal et al., 2015; Hurley et al., 2018). For example, the Danube River is estimated to release 530–1,500 tonnes of plastic into the Black Sea every year (Lechner et al., 2014), while the Rhine annually transports roughly 20–31 tonnes of plastic to the North Sea (Van der Wal et al., 2015). It is important to note, however, that scarce field-data for freshwater systems limit the robustness of estimates regarding the amount of plastics transported by rivers to the ocean (Blettler et al., 2018; Blettler and Wantzen, 2019). The literature presented here is but a small representation of the magnitude of river systems' contribution to plastic litter in Europe's coastal and marine environment (Schmidt et al., 2017; Wagner et al., 2018).

A clearer picture of the pathways by which plastics enter the marine environment enables the development of efficient prevention strategies for pollution (Schmidt et al., 2017). However, even with a richer understanding of MPP pathways, the nuanced multi-dimensionality of the problem requires a holistic governance regime (Vince and Hardesty, 2018). Indeed, there is no silver bullet for MPP. Rather, mitigating plastic pollution in the marine environment requires a collective governance and management regime that uses a mixture of international and national regulations, economic/market instruments, and community-based solutions (Ostrom, 2008; Vince and Hardesty, 2018). What follows then is a management framework that works within a transnational policy paradigm, yet is still capable of legal enforcement at a local and regional scale to ensure action that is understood and supported in the public domain.

The legislative structure of the European Union, which is intergovernmental in scope yet implemented and enforced at a national level, is conducive to implementing multi-tiered policies to effectively mitigate MPP. WFD and MSFD constitute an umbrella over European aquatic ecoregions. They are the most complete Directives with respect to aquatic ecological structure and environmental quality and are more integrative in terms of ecological assessment (Borja et al., 2008). However, as argued by Borja et al. (2010), the WFD and the MSFD must be fully and seamlessly integrated in order to serve as a catchment-to-coast management framework.

PRIMARY LEGISLATION GOVERNING THE FRESHWATER AND MARINE ENVIRONMENT

In Europe, the dominant piece of legislation governing the marine environment is the MSFD. Descriptor 10 specifically addresses litter in the coastal and marine environment, and MS actions are coordinated through the establishment of MSFD Good Environmental Status (GEnS)-Technical Subgroup on Marine Litter (TG ML). The TG ML has made a significant contribution by identifying the need for a harmonized monitoring approach across MS, as well as various short-term research priorities (Galgani et al., 2010). As a result, there has been a surge in research to understand the characteristics, drivers, and processes of litter at sea (Maes et al., 2019).

Moreover, the WFD aims to promote Europe's overall water quality through the reduction of hazardous emissions and pollutants, and to achieve near background levels of naturally occurring substances in the aquatic environment. The Directive focuses on achieving Good Ecological Status by monitoring a set of Biological Quality Elements (BQEs) (European Commission, 2000). In doing so, WFD positions ecological research on the

effects of pollutants at the forefront of EU MS's managerial decisions, codified in their respective River Basin Management Plans (RBMPs). The resulting legislative paradigm is one that, in theory, pursues an integrated land-sea management framework.

Nevertheless, there are a number of discrepancies between the WFD and the MSFD that restrict their integration, starting with the fact that the WFD, the primary legislative mechanism for maintaining the quality of the aquatic environment, does not address plastic litter. Inherently, the MSFD and the WFD espouse different approaches to assess the status of aquatic environments within their jurisdiction (Borja et al., 2010). The MSFD focuses on 11 descriptors which together portray the systems functions. Rather, under the WFD, the various BQEs are examined separately before merging the separate assessments into an overall evaluation of the aquatic environment (Borja et al., 2010). This certainly presents barriers to potential comparable integration of plastic litter and microplastic monitoring within WFD. For example, MS are currently obligated to monitor priority substances such as di(2-ethylhexyl)phthalate, nonylphenol, or octylphenol, that can be found in plastic; however, their occurrence does not necessitate plastic or microplastic as their source (SAM, 2018).

Furthermore, the WFD centers on the management of freshwater systems, including transitional and coastal waters, while the MSFD applies to marine and coastal waters and divides all EU marine areas into four marine regions according to hydrology, oceanography and biogeography. At first glance the objectives of the WFD to reach and maintain good ecological status based on BQEs, and the MSFD functional ecosystem approach to reach and maintain GEnS based on 11 descriptors, seem compatible; both refer to achieving "good status" (Karamfilov et al., 2019). Quantitative and qualitative elements of both WFD and MSFD can indeed support assessments in overlapping geographic areas for specific purposes e.g., assessment of seagrass as shown in Karamfilov et al. (2019). Issues arise when one takes a closer look at aspects of the Directives that fall within the spatial overlap of river basins and marine regions, such as MPP.

Currently, the WFD and the MSFD govern their respective boundaries as two distinct systems, i.e., a river basin and a marine region, rather than a contiguous complex system (Bigagli, 2015). For example, the WFD includes transitional and coastal waters inside the river basin, and extends to territorial waters (up to 12 nm offshore), but only for chemical aspects, while the MSFD includes coastal waters, but only for aspects not already addressed through the WFD (Bigagli, 2015). In relation to MPP, this suggests that plastic litter in WFD/MSFD overlapping geographic areas should be monitored based on MSFD requirements, but not in areas that fall solely under the WFD. WFD's focus on biological and chemical elements to give an indication of good ecological status means the scope for inclusion of litter and plastics is incredibly limited. In turn, the MSFD seems to have a limited capacity to effectively coordinate with existing legislation (Salomon and Dross, 2013; Bigagli, 2015). In addition, the MSFD text does not, according to Bigagli (2015), incorporate explicit prioritization of GEnS over, for example, sectorial objectives. This presents an issue for regions where WFD and MSFD overlap; WFD, despite incorporating ecological considerations, lacks the appropriate definitions and prioritizations that the MSFD provides for MPP – or indeed other descriptors (Bigagli, 2015).

Furthermore, there are important differences with regards to how the WFD and MSFD incorporate public participation. The WFD maintains a strong commitment to the involvement of citizens in the development and implementation of the Directive, especially in the preparation of the RBMPs (De Stefano, 2010; Jager et al., 2016). In contrast, the MSFD provides an opportunity for the public to comment on the marine strategies developed – although Fletcher (2007) has highlighted the ambiguity surrounding stakeholder engagement and public participation in the implementation of the MSFD. The role of the societal/stakeholder voice is significant in addressing socio-ecological challenges; marine litter, fisheries by-catch, climate action are all examples of instances where increased levels of public awareness have led to responses by the scientific, regulatory and policy communities (Fischer et al., 2015).

In the case of the RBMPs, stakeholders from the public have the opportunity to articulate the key issues for their particular catchment, and are likely to prioritize and support actions aligned to these issues. Environmental policies and legal instruments have been shown to need public support in order to be successful (Eriksson et al., 2006; Sundblad et al., 2007; de Groot and Schuitema, 2012). This not only supports an argument for stakeholder engagement during development and implementation of relevant policies, but also highlights the importance of clear and appropriate communications in the public domain and with policy and decision makers. Based on current research (Hartley et al., 2018), public awareness may be low regarding catchment level inputs as a contribution to MPP. Thus, if plastic pollution – which has the potential to become MPP – is not viewed as a catchment issue, the level of priority and likelihood for intervention is significantly lessened. Moreover, it is clear in the case of water quality, public actors are aware of the implications of nutrient run-off for coastal waters, and actions are taken at terrestrial/catchment side that support achieving GEnS in coastal and marine waters. Therefore, the interplay between public participation, public awareness and the implementation framework for each Directive plays a significant part in the effectiveness of tackling MPP.

CONCLUDING THOUGHTS AND FUTURE DISCUSSION

In this article, the focus is on the potential for improved mitigation of MPP through better connectivity between the MSFD and WFD; however, it is worth noting that other initiatives (e.g., Single Use Plastics Directive, Packaging and Packaging Waste Directive, Urban Waste Water Treatment Directive) have a role in reducing the introduction of plastic to the marine (and wider) environment. Nevertheless, as with the case of the MSFD and WFD discussed here, the challenge is to best integrate the suite of relevant policy and legal instruments to overcome compartmentalization, overlap, and piecemeal approaches. Such issues have thus far dogged marine environmental policy and

management in the EU (Boyes and Elliott, 2014) and have presented challenges to those tasked with their implementation. It is therefore pertinent to explore opportunities to include plastic monitoring through the WFD, e.g., as part of an iterative planning cycle looking at the pressure and impacts analysis of the 3rd RBMP cycle and through the 2019 revision of the Directive (SAM, 2018).

We believe the current legislation requires further examination and needs to respect the *trans*-spatial flow of plastic litter, thereby recognizing the geographic connectivity that facilitates the transport of plastic litter from land to sea. In the WFD, RBMPs provide the structure for integrating a geographically holistic framework that recognizes the land-sea interface as a complex interconnected system and moves away from the traditional land-sea regulatory dichotomy; WFD, however, pays no regard to plastic litter. Instead, MPP is only recognized, from a legislative perspective, once it enters the regional jurisdiction of the MSFD.

In addition to providing EU MS with a monitoring and mitigation policy framework for upstream plastic prevention, incorporating plastics into aquatic monitoring frameworks could catalyze much needed research into riverine pathways of MPP (Hering et al., 2010; Maes et al., 2019). As Van der Wal et al. (2015) point out:

> "Since the Water Framework Directive (2006/06/EC, WFD), does not include litter, plastic litter in freshwater systems is not included in any of the EU freshwater legislation. This also explains why. there are no long-term, systematic monitoring programs in place for litter items in the riverine or marine environment (p. i–ii)."

Overall, our current understanding of plastic pollution in freshwater environments is poor compared to our understanding of marine plastics. As of 2018, only 4% of publications related to plastic pollution have included a freshwater perspective, despite the fact that the majority of marine plastics are land-based (Wagner et al., 2018). Consequently, the robustness of estimates regarding the amount of plastic transported from rivers to the ocean (e.g., Lebreton et al., 2017; Schmidt et al., 2017), are limited by scarce field-data for freshwater systems (Blettler et al., 2018; Blettler and Wantzen, 2019). Schmidt et al. (2017) argue that, for the reasons presented here, efficient prevention strategies for MPP must be based on clear, geographically representative understanding of pollution sources, pathways and fate. Therefore, substantial improvements to MPP mitigation efforts could be made by expanding the spatial scope and interconnectivity of the EU's monitoring and legislative framework, connecting river basin management to coastal and marine water management.

Currently, WFD substance monitoring does not facilitate the identification of sources and pathways of MPP, nor does it enable iterative assessments to evaluate if potential mitigation measures are indeed effective. That being said, if plastic pollution were recognized as a barrier to meeting WFD environmental objectives, a strong argument could be made for legal mechanisms that integrate plastics monitoring. This requires additional targeted research in relation to environmental impact of plastics and microplastics in aquatic environments covered by the WFD, with results disseminated to the policy and regulatory communities relevant to the WFD.

In addition to policy considerations, future research that examines upstream intervention points are critical for MPP mitigation efforts to be successful. Such intervention points relate to human behavior (Science Advice for Policy by European Academies [SAPEA], 2019) because human activities are the sole cause of plastic litter, and result from misguided attitudes and behaviors (Wyles et al., 2014; Pahl and Wyles, 2017). Upstream intervention points are, therefore, a manifestation of human behavioral changes upstream. While the public's awareness and motivation to reduce marine litter has increased (Hartley et al., 2018), behavioral change models suggest that attitudinal shifts are non-linear, and require a system of motivations and pressures, e.g., social, and institutional, in order for people to commit to new behaviors (Stern, 2000; Bamberg, 2013). If upstream interventions are to be successful, regulations, along with continued social incentives, must work in concert to drive shifts in behavior.

AUTHOR CONTRIBUTIONS

JB, KK, and CO'M contributed conception and design of the study. JB wrote the first draft of the manuscript. All authors wrote sections of the manuscript, contributed to manuscript revision, and read and approved the submitted version.

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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.

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