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Editorial: Cleaning litter by developing and applying innovative methods in European seas

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Editorial on the Research Topic
Cleaning litter by developing and applying innovative methods in European seas

Introduction

In recent years, the issue of marine pollution due to plastic litter has gained significant attention, leading the European Union to allocate fund for a project within the Horizon 2020 framework known as "*Cleaning Litter by developing and Applying Innovative Methods in European seas*" (CLAIM; Grant Agreement number: 774586, under Topic BG-07-2017, which focuses on "Blue green innovation for clean coasts and seas"). Over the duration of 54 months from November 2017 to April 2022, CLAIM brought together a consortium of 21 partners from 13 European Union countries, together with Tunisia and Lebanon. The Hellenic Centre for Marine Research (Institute of Oceanography) served as the coordinating entity.

The primary objective of the CLAIM project was to explore and devise innovative, cost-effective and energy-efficient methods to mitigate plastic waste in the Mediterranean and Baltic Seas. Additionally, the project aimed to develop strategies to capture and degrade microplastics before they enter the sea, with a particular focus on river estuaries and wastewater treatment plants (WWTPs).

CLAIM used several enabling technologies to achieve its objectives, including a floating boom/barrier system (CLEAN TRASH[1], with Technology Readiness Level (TRL 9) that operates in river mouths and waterways, a small-scale thermal treatment device (pyrolizer) for use in vessels and ports (TRL 7), a low-cost, automated, self-cleaning filtering system (Waste & Water EcoPlex Microplastic Remover® (ECOPLEX)- TRL 8) to trap microplastics in WWTPs, a photocatalytic nanocoating device (Photocatalytic Reactor)[2] to further degrade microplastics using sunlight (TRL 6), and a seawater sampling device and passive flow-through filtering system (CLAIM Ferrybox[3] (FB) system) to provide information about marine microlitter distribution while operating on board ships of opportunity (TRL 9).

To better govern the complexity of marine litter, CLAIM adopted a multidisciplinary approach, and created, among others, plastics concentration maps and new distribution and assessment models to improve our understanding and insights into the spatial dispersion of macro- and microplastics, as well as scenarios to determine the efficiency of CLAIM's technologies. By forecasting potential environmental impacts, we are able to take certain mitigation measures. The project has also produced policy briefs with recommendations for the EU on the most promising policies to achieve its marine litter objectives, among others based on extensive key informant interviews with various stakeholders (Frantzi et al., 2021), including start-ups and emerging sustainable business models in industries related to marine plastics cleanup and processing (Dijkstra et al., 2020; Dijkstra et al., 2021; Dijkstra et al., 2022).

To determine the best way of implementing CLAIM technologies for reducing macro- and microplastics, a MCDA (multiple-criteria decision analysis) framework was proposed. An international survey of existing marine litter cleanup technologies resulted in an integrated assessment and prioritization of plastic cleanup technologies, including some of the CLAIM technologies, based on a cost-effectiveness and multi-criteria analysis (Brouwer et al., 2023). The project also assessed risks of innovation and business models to understand the implications of designing a business model for the CLAIM devices specifically, the exploitation of the CLAIM research and development results, and to provide insights on the uptake and upscaling of the new technologies. Additionally, different consumer profiles were developed based on a large-scale European survey of public perceptions of and attitudes to marine plastics pollution, and willingness to pay to implement measures to prevent and remove plastic pollution from European seas (Khedr et al., 2023; Van Oosterhout et al., 2023). Besides the articles included in this Research Topic, a wide variety of additional papers were published in other high-impact journals.

1 CLAIM's Litter Entrapping Autonomous Network Tactical Recovery Accumulation System Hellas

2 https://doi.org/10.1016/j.jhazmat.2020.124299; https://www.mdpi.com/2073-4344/9/10/819#; https://doi.org/10.1007/s10311-019-00859-z

3 The Ferrybox is a system of integrated hydrological and biogeochemical sensors installed on ships of opportunity (like ferries on fixed routes between Piraeus - Heraklion, Tunis-Marseilles, Tunis-Genoa and Tallinn – Helsinki) that measure parameters while the boat is underway. In these existing Ferrybox facilities, CLAIM added a seawater sampling device and passive flow-through filtering system to assist the collection of data on the distribution of microplastics and understand their impact on marine ecosystems.

Integration and impact of the results and findings

This work describes the outcomes of the scientific research conducted within the CLAIM project, focusing on the Mediterranean and Baltic Seas. The articles included in the Research Topic provide an in-depth presentation of the research work in these regions.

In the Eastern Mediterranean Sea, over the period 2014-2020, 84 samples were collected from open waters, coastal waters, and enclosed gulfs to investigate the distribution patterns and sources of microplastic pollution. The study by Adamopoulou et al. revealed a high degree of variability in microplastic concentrations, with sea surface slicks found to be a crucial factor in their distribution. The majority of microplastics were fragmented and 2mm or smaller in size, with polyethylene, polypropylene, and polystyrene being the most abundant types of polymers. The proximity to coastal population centers influenced the properties, size, and polymer types of microplastics. The results suggested that local oceanographic conditions significantly affect microplastics concentrations, posing risks to sensitive habitats. The study provides insights into a better interpretation of floating microplastics data from systematic monitoring activities.

To track the pathways and fate of plastics from major land-based sources in the Mediterranean, Tsiaras et al. used a hydrodynamic/particle drift model, considering different size classes/types of micro- and macroplastics. The model incorporated processes such as advection, stokes drift, mixing, sinking, wind drag, and beaching, as well as biofouling-induced sinking as a possible mechanism of microplastics removal from the surface. The results of an 8-year simulation identified potential accumulation patterns of micro and macroplastics in the surface layer, water column, seafloor and beaches. The near-surface distribution of micro- and macroplastics were closely related to their sources (i.e., rivers and WWTPs for the micro- and rivers and coastal cities for the macroplastics), with microplastics being more abundant near metropolitan cities and heavily populated areas, while macroplastics were more abundant near important riverine inputs and highly populated coastal areas. The study's sensitivity experiments showed that vertical mixing had the most effect on smaller size particles, biofouling/sinking decreased the abundance of microplastics in the surface layer, and wind/wave drift had a stronger effect on larger size classes that are more prone to direct drift and beaching. The distribution of macroplastics on beaches follows the predominant wind/wave direction, showing higher concentrations in some areas along the Algerian and Eastern Levantine coasts.

Ben Ismail et al. investigated microplastic pollution in the Gulf of Gabes in the Southern Mediterranean Sea, an area of high ecological value but poorly studied. The researchers found high levels of microplastics in surface water samples, with seasonal variability, but low frequencies of plastic ingestion by marine species. The study expands our understanding of the pollution levels of microplastics in the Gulf of Gabes, and the results confirm the ubiquitous nature of microplastics in the marine environment, highlighting the need for further and long-term investigations. With the severe anthropogenic pressure existing in the area, future work is recommended to define plastic pollution levels in the area and its reliable threat to marine ecosystems, which are essential to set effective management measures to face this emerging global threat.

The study conducted by Tsiaras et al. aimed to investigate the properties and abundance of microplastics in sea surface water samples collected from four coastal areas in the Mediterranean Sea, namely Saronikos Gulf, Ligurian Sea, Gulf of Lion and Gabes Gulf. Two sampling campaigns were conducted throughout 2018-2019 and used coupled hydrodynamic/particle drift model simulations with basin-scale Mediterranean and high-resolution nested models to better understand the variability of microplastics in the four areas.

The model simulations considered different size classes of microplastics and took into account biofouling-induced sinking as a possible mechanism of microplastics removal from the surface. The model simulations provided insights into the key processes controlling the microplastics distribution in the marine environment, including the impact of waves drift and advection of microplastics from non-local sources. Additionally, it was found that smaller size classes of microplastics were more likely to sink near source inputs in coastal areas, while larger (floating) microplastics were able to travel longer distances in the open sea.

The study found that the Mediterranean Sea is a hotspot for the contamination of microplastics, which is consistent with previous studies. The Gabes Gulf showed the highest mean microplastics abundance, followed by the Ligurian Sea, Saronikos Gulf and Gulf of Lion. The variability in microplastics abundance and size distribution were reasonably well-reproduced by the model simulations in the four different areas, except for an overestimation of small-sized microplastics in Saronikos Gulf. It was also found that the contribution of microplastics inflowing from remote areas was particularly high in Gabes Gulf, suggesting that most microplastics originate from offshore areas and are mainly (floating) larger size classes, as suggested by the quite small contribution of size <1mm particles.

Overall, the modeling tools proposed provide useful insight to gain a better understanding of microplastics dynamics in the marine environment and assess the current status of plastic pollution on a basin and regional scale. The study's findings can be used to develop environmental management action for the mitigation of plastic pollution in the Mediterranean Sea.

The pollution of micro- and macro-plastics is increasingly becoming a threat to marine biodiversity, ecosystem functioning, and human well-being. To explore this issue in marine protected areas (MPAs), numerical models have been developed that take into account the sources of plastics and simulate their dispersal characteristics (Hatzonikolakis et al.). In the latter study, a Lagrangian plastic drift model was used to predict plastic accumulation zones in protected areas of the Mediterranean Sea. The model considered various sizes and types of plastic litter originating from major land-based sources, such as coastal cities and rivers. The results showed that the size of plastic litters plays a crucial role in their dispersion and ultimate destination, with larger litter traveling longer distances. The study revealed that most of the Mediterranean countries studied (13 out of 15) had at least one national MPA with over 55% of macroplastics originating from sources beyond their borders. This finding suggests that local efforts to reduce plastic pollution in protected areas would be insufficient, particularly for macroplastics management. Therefore, transboundary collaboration among Mediterranean countries is critical for the successful implementation of management plans against plastic pollution in their territorial waters and specifically in MPAs.

Mishra et al. presented a sea surface microplastics monitoring in the eastern Baltic Sea from 2016 to 2020 using a Manta trawl at 16 sampling stations, and investigated the statistical pattern of the microplastics. The study found that the concentrations varied from 0.01 to 2.45 counts/m^3 with a mean of 0.49 counts/m^3. The share of fragments and fibers in the samples was approximately equal. Higher mean values were observed in the Baltic Proper and the Gulf of Finland, while lower values were found in the Gulf of Riga and Väinameri Archipelago Sea. The difference in values between the sub-basins can be explained by the degree of human pressure in the catchment areas. Microplastics concentrations were higher in autumn than in summer due to the seasonality of biofouling and sinking rate of particles. The wind speed had a weak negative correlation with microplastics concentration in the central Gulf of Finland and a positive correlation in the shallow area near the Pärnu river mouth. Upwellings and downwellings, wind mixing, and (sub)mesoscale processes affected the variability of microplastics concentrations. The authors concluded that further studies are needed to improve the understanding of microplastics pathways and fluxes.

The increasing concern over marine plastic pollution's impact on marine ecosystems and wildlife underscores the importance of understanding the sources, sinks, and pathways of land-based plastic pollution for effective marine conservation. In Murawski et al. study, a three-dimensional model was developed to simulate the transport and accumulation of microplastics in the Baltic Sea. The model accounted for wave- and current-induced transport, biofouling, sinking, and sedimentation processes. Using a multi-year simulation of microplastic pollution from 2014-2019, the model was tested and compared with observations. The simulation considered three types of microplastics: small-sized tire wear particles, medium-sized and large-sized particles from WWTPs. The results showed that the model successfully reproduced the seasonal and spatial patterns of observed microplastic pollution but encountered difficulty simulating very high concentrations associated with flooding and sub-mesoscale transport. The study concludes that the model can be a useful tool for assessing microplastic transport and accumulation patterns in the Baltic Sea, and further improvements in resolution and synoptic source information are needed to capture the variability of microplastic concentrations accurately.

Frishfelds et al. used a two-way nested three-dimensional model to track the transport of microplastics from rivers and lakes to coastal waters and the open sea, with a model resolution of 90 m to resolve inland waters. The model was verified with observations in the Gulf of Riga and a backtracking algorithm was developed to determine the most likely source of pollutants. It was found that the concentration of microplastics decreased as the drift time from the Daugava estuary increased, and that river retention of microplastics improved the correlation with experimental data in the Gulf of Riga. The study emphasizes the importance of Lagrangian drift assessments as a large portion of microplastics are released in sewer overflow events in wastewater treatment plants with a considerable concentration of microfilms.

Data uncertainties in marine microplastic measurements have been a big issue when using different microplastic datasets for model validation. They were examined in She et al. study, including sampling and analysis errors, mesh sizes, and consistency in multiple observation datasets. There were analyzed 27 datasets on surface marine microplastics with particle size >100 μm in the Baltic Sea. Results showed spatiotemporal sampling errors of 25% for microlitter concentration, 36% for microplastic fiber concentrations, and 40-56% for microplastic particle concentration. It is discussed the impact of surface currents and wave-induced Stokes drift on sample volume estimation and datasets identified with significant differences in microplastics due to analysis methods and sampling techniques. Consistency within individual datasets and between different datasets was also examined.

Plastic degradation processes were studied prior to the assembly of the cleaning devices, as plastic products pose a significant threat to the environment and biota despite their low cost, durability, and resistance to degradation (Hamd et al.). In the review, the use of advanced oxidation processes (AOPs) is discussed, specifically photocatalysis and Fenton processes are effective in breaking down microplastics, with TiO_2 and ZnO nanoparticles being commonly used as photocatalysts. Characterization of microplastics can be done through various techniques, including gel permeation chromatography (GPC), nuclear magnetic resonance (NMR), scanning electron microscopy (SEM) and Fourier transformation infrared (FTIR) spectroscopy. Photocatalytic reactors have been studied at a pilot plant scale, and the use of compound parabolic collector (CPC) technology turned out to be most suited for scaling beyond.

Furthermore, a study by Piazza et al. utilized the photo-Fenton process to remove microplastics from water, achieving high degradation efficiency of polypropylene and polyvinyl chloride microplastics, and evaluated potential risks to the ecosystem. Ecotoxicological experiments on aquatic organisms showed no toxic effect from the degradation by-products, indicating the process is a viable method for removing microplastics from water sources. This process has promising implications for large-scale WWTPs to sustainably remove microplastics before they are discharged into the environment.

The CLAIM project resulted in the development of two systems, the ECOPLEX filtering system for WWTPs and the CLEAN TRASH system in river estuaries, to address the issue of marine pollution mainly caused by plastic litter. As discussed in Gkanasos et al., the ECOPLEX filtering system reduces the number of large microplastics of various types before entering the photodegradation system, with an efficiency rate of 96.67% in lab tests. Meanwhile, the CLEAN TRASH system uses floating barriers to prevent macroplastics from entering the sea, and it was found to be 90% efficient at blocking macroplastics. Numerical models showed that the implementation of these systems in all rivers and WWTPs in Athens, Greece, for a period of two years, could reduce the concentration of plastics in the sea by reducing macroplastics by 13-43.5% and microplastics by 87%. In certain areas with high importance for marine life conservation, tourism, and aquaculture activities, the reduction was even more significant. However, the efficiency of these systems in real conditions could be limited by weather conditions, river water outflow, and bulky litter carried away, requiring constant online monitoring to maintain their effectiveness. Further development and testing are needed to improve the efficiency rates and address any design failures that may arise during long-term application. Overall, the CLAIM project's devices show significant potential to contribute to a plastic-free sea.

The management of marine litter cleanup and disposal is becoming increasingly important due to heightened public scrutiny, government regulation, and stakeholder initiatives. As Christensen et al. discuss, limited financial and economic resources necessitate a scientific framework that integrates multiple perspectives to optimize decision-making and consider the effects of investments. This framework must account for physics, environmental engineering, science, and economics and incorporate input from marine litter transport modelling, ecosystem functioning, and cleanup technology effectiveness. To address these challenges, the authors propose a spatial cost-benefit optimization framework that prioritizes limited cleanup efforts within a regional spatial network of marine litter sources. Using real data for litter transport and cleanup technology, they illustrate this framework in case studies of the Baltic and Mediterranean Seas. The framework allows for systematic extensions, with different objective functions and solutions based on cost minimization and benefit maximization. The study demonstrates that including litter transport simulation is essential to maximize ecosystem benefits in marine litter cleanup.

Van Oosterhout et al. examined public perceptions of marine plastic litter (MPL) across eight European countries and sea regions. They identified and classified relevant components of public perceptions of MPL, including observation, perceived consequences and concern, and knowledge and responsibility. The results show high levels of concern about MPL throughout the EU, and the general public held companies and themselves as consumers most responsible for cleaning up MPL. The study also found that this sense of self-responsibility to reduce MPL varied considerably within and across countries. Based on these findings, the study suggests that decision-makers should tailor national strategies to educate the public and increase awareness to minimize plastic consumption and littering.

The EU Marine Strategy Framework Directive requires the quantification of non-market benefits of marine litter reduction in monetary terms for cost-benefit analysis. However, the available evidence is insufficient to derive country-wide policy implications for the evaluations required by the Directive, as Stoever et al. discuss. Only seven out of 22 reviewed studies provide information for eight EU Member States, and quantitative evidence on the societal benefits of micro litter is lacking. Benefit estimates from non-EU countries can inform specific benefits for a subgroup of users, but to comprehensively assess the societal benefits of reducing marine litter, future research should consider the values non-users attach to such reductions, account for interdependencies between individual indicators of marine litter reduction and explore co-benefits for other descriptors.

Nguyen and Brouwer explore the impact of marine litter on a fishery economy and propose a dynamic optimization model to demonstrate how it causes inefficiencies in this sector. The study finds that neglecting the marine litter externality leads to increased fish harvest and further ocean deterioration. To address this issue, they suggest a "fishing-for-litter" market, where marine litter can be traded, and fishermen are incentivized to recover and repurpose plastic waste. This approach can effectively tackle the global marine litter problem while promoting a more sustainable and efficient fishery sector. The authors acknowledge that the specific utility function employed in the study might have constrained the obtained results. They propose the exploration of alternative models in subsequent research endeavors, which could potentially encompass the incorporation of the costs incurred from damage caused by marine litter on catch rates.

Cunha et al. employed a Delphi method to identify the most important factors to consider when evaluating new technologies for reducing and processing marine litter. Plastic pollution in the oceans is a global issue, and the use of appropriate technologies is essential to reverse the current trend. The study provides guidelines for future work in the field by proposing a comprehensive list of statements that characterize various aspects, including environmental, economic, socio-economic, political, and technical operations. Respondents from 22 countries, including administrations, marinas, ports, associations, companies, universities, and research centers, participated in the survey. The results revealed that environmental issues are the most important for all types of stakeholders, and technical operation is highly valuable for companies, universities, and research centers. The study concludes by acknowledging that the results depend on the thresholds used for statistical analysis, and the need for more research in this emerging field.

In their systematic review, Santos et al. analyzed 20 studies that utilized multicriteria decision analysis (MCDA) to address plastic waste management. The primary objective of MCDA was to identify the most appropriate end-of-life disposal option for plastic waste, including recycling, incineration, or landfilling, in order to prevent the contamination of marine environments. The authors observed that different MCDA methods were used, with the Analytical Hierarchy Process (AHP) being the most frequently employed. The criteria weighting was primarily done by consulting experts or decision-makers, with little involvement from affected communities or other stakeholders.

Overall, the authors found MCDA to be an effective approach for evaluating alternatives that encompassed environmental, socioeconomic, and operational factors. They also highlighted its transparency and potential for stakeholder engagement. Nonetheless, the authors noted that MCDA can be constrained by the availability of data and resources for implementation, as well as the changing perspectives of experts and stakeholders. In most instances, the authors were able to determine a winning alternative, which occasionally involved a combination of various strategies.

Conclusions

The CLAIM project has been a ground-breaking multidisciplinary initiative, bringing together expertise from different fields and countries, developing and demonstrating a range of cutting-edge tools and technologies aimed at enhancing our understanding of the dispersion of plastics in the marine environment, and help us more effectively retain plastic waste at its main entry sources (river estuaries and wastewater treatment plants), thus minimizing the amount of plastic pollution that makes its way into our oceans.

One of the most important achievements of the project was the development of technologies that are now available for immediate installation and replicability all over the world. These technologies have the potential to significantly improve our ability to manage plastic waste, not just in the Mediterranean and Baltic Seas, but in oceans and waterways worldwide.

The CLAIM project has also highlighted the critical need for transboundary cooperation in addressing plastic pollution in MPAs. The research has shown that plastic pollution in a country's MPAs may originate from sources beyond its national jurisdiction. Therefore, effective management of plastic pollution within Mediterranean MPAs requires collaboration not just among EU Member States, as specified by the Marine Strategy Framework Directive 2008/56/EC, but also beyond EU borders. By leveraging the tools and technologies developed by the CLAIM project and working together across borders, we can begin to make meaningful progress in tackling this urgent environmental issue.

Ecosystem services are crucial for sustaining human well-being and our society heavily relies on the functioning of healthy ecosystems. Understanding the value of these services is crucial for making informed decisions about resource management and ensuring that the benefits provided by nature are not lost. To achieve this, various methods and technologies have been developed to mitigate potential environmental impacts, including forecasting models and scenario analysis. These tools help to identify potential threats and take appropriate actions to preserve ecosystem functioning and services.

Through the development and application of innovative methods and technologies, we have focused on managing the growing problem of macro and microplastics in the marine environment. By demonstrating the effectiveness of these technologies and sharing the results of simulation models, we aim to foster the protection of ecosystems and promote conservation efforts sustainably for future generations.

Committed to disseminate information about these efforts to a wide range of stakeholders, including young children, mature stakeholders, and decision-makers, and engaging with these groups, we hope to inspire a sense of responsibility and promote conservation efforts at all levels of society. Our ultimate objective is to influence policy-making processes and advocate for sustainable practices, working towards a future where ecosystem services are cherished and safeguarded for generations to come. In line with our commitment to maintain a strong connection between CLAIM and society for the preservation of healthy ecosystems, we have established a spin-off company called MINDS (Marine INnovations, Depollution & Services) that aims to effectively utilize the research results and expertise generated within the CLAIM project. Its focus is on developing and implementing comprehensive solutions for the protection of aquatic ecosystems, including both marine and inland waters, with a particular emphasis on combating pollution, especially plastics (macro & micro).

Author contributions

GTriantaf: CLAIM project Coordinator, modelling the pathways of plastic pollutants in the Mediterranean, and determining the impact of marine litter on the environment and ecosystem services. AP: contribution to the development of novel technologies for river estuaries, wastewater treatment plants (WWTPs), and microplastics monitoring filter devices, critical reading, and summary of each referred article. GTriantap: CLAIM's project manager, contribution to the assessment of potentially threatened ecosystem services in the Mediterranean Sea and investigation of relevant technology features using a Delphi method. JS: Leading CLAIM-WP1, development of advanced modelling for predicting the movements of micro- and macro-plastics in the Baltic Sea. JD: leading CLAIM-WP2, development of innovative green nanocoating for the mineralization of polymers found in microplastics for the WWTPs. MF: leading CLAIM-WP3, assess the efficiency and environmental impact of the microplastic cleaning devices, and perform microplastics monitoring in water and fish specimens from the key study areas. MS: leading CLAIM-WP4, assess the influence of marine litter on ecosystem services. RB: leading CLAIM-WP5, socio-economic analysis of innovative marine litter reduction technologies, and development of business models. PS: Leading CLAIM-WP6, project dissemination & communications activities, Data Management Plans, critical reading, and comments on the editorial. All authors contributed to the article 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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References

Brouwer, R., Huang, Y., Huizenga, T., Frantzi, S., Le, T., Sandler, J., et al. (2023). Assessing the performance of marine plastics cleanup technologies in Europe and north America. *Ocean Coast. Manage.* 238, 106555. doi: 10.1016/j.ocecoaman.2023.106555

Dijkstra, H., Beukering, P., and Brouwer, R. (2020). Business models and sustainable plastic management: a systematic review of the literature. *J. Cleaner Production* 258, 120967. doi: 10.1016/j.jclepro.2020.120967

Dijkstra, H., Beukering, P., and Brouwer, R. (2022). Marine plastic entrepreneurship; exploring drivers, barriers and value creation in the blue economy. *Sustain. Technol. Entrepreneurship* 1 (3), 100018. doi: 10.1016/j.stae.2022.100018

Dijkstra, H., van Beukering, P., and Brouwer, R. (2021). In the business of dirty oceans: overview of startups and entrepreneurs managing marine plastic. *Mar. pollut. Bull.* 162, 111880. doi: 10.1016/j.marpolbul.2020.111880

Frantzi, S., Brouwer, R., Watkins, E., van Beukering, P., Conceição Cunha, M., 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. pollut. Bull.* 170, 112611. doi: 10.1016/j.marpolbul.2021.112611

Khedr, S., Rehdanz, K., Brouwer, R., Van Beukering, P., Dijkstra, H., Duijndam, S., et al. (2023). Public preferences for marine plastic litter management across Europe. *Ecol. Economics* 204 (A), 107609. doi: 10.1016/j.ecolecon.2022.107609

Van Oosterhout, L., Dijkstra, H., Borst, D., Duijndam, S., Rehdanz, K., and van Beukering, P. (2023). Triggering sustainable plastics consumption behavior: identifying consumer profiles across Europe and designing strategies to engage them. *Sustain. Production Consumption* 36, 148–160. doi: 10.1016/j.spc.2022.12.023