Marine Plastic Pollution - Evidence Review

Plain English Summary

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Summary

The UK Government has set out a pledge through its 25 Year Environment Plan to reduce ocean plastic. This issue has escalated from the simple aesthetic marine litter problem, to a ‘perceived’ global challenge. Whilst the accumulation of plastics in the marine environment is clear, the origins of the problem are nuanced, and complex. Identifying the policies and actions therefore requires a sound evidence and assessment. The issue has also gained considerable public interest through broadcast and social media, and also driven by emerging evidence gathered by both academic scientists and environmental NGOs. The challenge is therefore to understand the evidence and examine potential interventions against regulatory and policy needs.

The Marine Litter Policy team at Defra leads, and is consulted on, a wide range of interventions related to plastics and microplastics in the environment. Whilst the remit of Defra Marine is primarily litter in the marine environment, evidence relating to the underlying drivers and interventions on land are key to solving the problem.

This review has been prepared for the Defra Marine Litter Policy team to provide a summary of evidence of relevance in addressing marine plastic pollution, to identify evidence gaps and make recommendations for further work to support policy development.

Plastic Pollution in Context

Marine litter has been recognised as a threat to environmental quality for many years, with a range of potential impacts on wildlife, the economy and human-wellbeing. Plastic litter items have become the focus of attention in recent years, with the increasing amounts of ‘macro’-plastic litter being found in rivers, on coasts and the in open ocean, from the centre of ocean gyres to the deep ocean floor. Such items include single-use packaging, sanitary items, carrier bags, fishing gear, and shipping-related waste. However, it was the finding that microplastics, such as fibres and microbeads, as well as plastic pieces from fragmentation of larger plastic items are now present across our marine environment, that has caused widespread concern, with the potential for harm through entanglement and ingestion. Over 700 species are now known to encounter plastic litter in the marine environment including fish, shellfish, zooplankton and marine mammals.

This situation is exacerbated by an increasing amount of plastic waste entering the Ocean, in the range 4-12 million Tonnes around the world each year, driven by increasing consumption and ineffective waste management in some countries. However, although plastic is found in both freshwater and marine environments, much less is known about the underlying systemic causes and pathways to the environment, as well as the consequences to the marine ecosystem. This lack of knowledge is inhibiting progress towards several UN Sustainable Development Goals (SDGs), as the numerous positive and negative feedbacks have not yet been investigated

comprehensively and scientifically. Yet with over 400 papers published in 2018 using the term ‘microplastics’, the evidence base is seemingly growing fast. Therefore, this knowledge needs to be assessed to improve resource efficiency and support interventions to stop marine plastic litter.

Marine Plastic Evidence Review

This Evidence Review provides a snapshot assessment compiled in February to March 2019, drawing together and evaluating evidence from key scientific papers and reviews relevant to maritime and fisheries policy areas. The geographical scope of the review was centred on the UK and related convention areas (such as OSPAR) and the implications to UK marine policy in these areas. Therefore, publications focussing on data and evidence from other regions were included only where relevant to the UK situation, for example monitoring methods. The Evidence Review content was further discussed in a workshop held on 12^{th} and 13^{th} March in London, involving scientists from the UK, EU, Australia and South Africa, and representatives from the Defra Group. The main points for each of these theme areas within the review are summarised in the sections that follow.

Marine Plastic Monitoring and Methods

Plastics range in size from the ‘mega’ to ‘nano’, hence there is no ‘one size fits all’ method of monitoring such a diverse mixture of plastics, across a range of environmental compartments. Some methods may be highly technical, others may be designed to facilitate citizen science programmes. It is therefore important to determine exactly *why* the monitoring is being undertaken, for example: to assess environmental status and harmful effects; to determine critical thresholds and targets; source identification; or to measure the effectiveness of policy or other implemented measures. It is then necessary to design appropriate sampling protocols considering locations, equipment, number of replicates etc., to answer the specific questions. Unless this approach is adopted, it is unlikely that the monitoring programme will deliver reliable, relevant and ‘fit-for-purpose’ data, at an affordable cost. A summary of the monitoring protocols, including an assessment of their costs, technical requirements and the target plastic sizes is presented.

The development and reporting of laboratory quality control processes is emerging and needs to be promoted widely. Following sampling, analytical processes are critical to support the generation of ‘reliable’ environmental data, for example using techniques from other scientific disciplines such as flow cytometry.

The broad policy drivers for monitoring originate from commitments under the Marine Strategy Framework Directive, and relevant Marine Conventions. However, the specific requirements and purpose of the monitoring are not defined. There is a clear need to ensure that monitoring for macro and microplastics is coordinated, and applies the most appropriate monitoring methods and programmes

Sources and Pathways of Marine Plastic Pollution

Policy makers and other stakeholders need to establish the scale of plastic pollution, and to develop effective prevention strategies. Understanding the sources of litter items, and their relative importance to the marine environment is a critical prerequisite. This is particularly relevant for plastics as they have a range of properties (e.g., durability, strength, thermal and electrical insulation, and barrier capabilities) and can take many forms (e.g., rigid or flexible solids, including films and sheets; fibres and cloths). These properties influence their use and application into products, and therefore likelihood of escaping waste management processes, as well as their ultimate fate and impact in the environment.

A broad range of macroplastics has been identified in the marine environment, but the relative importance, in terms of quantities and risk to different environmental compartments, remains elusive. Macroplastics entering the marine environment range from disposable single use items from inland and coastal communities, to marine fishing gear and lost goods from shipping. There is also a critical distinction between *primary* microplastics (manufactured to be between 100nm and 5mm in size and directly released to the environment), and *secondary* microplastics generated by the fragmentation and degradation of macroplastics in the environment. This distinction influences the ultimate fate and risk to the marine ecosystem, and what prevention strategies can be developed. From available data, there is compelling evidence that preventing land-based sources of plastics reaching the wider environment needs to be a clear focus.

Pathways of plastics to the environment include from rivers and direct littering at the coast, as well as fishing gear lost whilst at sea. Both macroplastics (for example wet-wipes, cotton buds), and microplastics (microbeads, microfibres) from the human population have been found in final effluent discharges from wastewater treatment works. Effluents should be seen as 'pathways' and not sources, unless the wastewater treatment works is creating plastic waste. Pathways will also vary over time, for example in high flows where plastic litter is washed out of river catchments, and on the coast when storms will bring coastal plastic onshore.

The input rates of plastic waste to the Ocean at UK locations needs to be aligned to local waste management to obtain a robust quantitative estimate of the relative importance of various sources. By understanding this, the appropriate interventions can then be developed, targeted to the specific elements of the formal, and informal, waste management system.

Transport and Fate of Marine Plastic Pollution

Plastic and microplastic debris are ubiquitous marine contaminants with a global distribution, across ecological compartments, including surface waters, the water column, the seafloor, shorelines, sea ice and biota. Given that approximately two thirds of all plastic produced is negatively buoyant in sea water, it is expected the seafloor represents the largest reservoir for plastic. Environmental concentrations are hugely variable, with average microplastic concentrations in the order of 0.1-1 particles/m^3 for surface waters, and 10^3-10^4 particles/m^3 for sediments

Plastic debris can be transported vast distances, primarily driven by physical forces such as currents, wind and eddies. However, vertical profiling of microplastics in the North Atlantic gyre showed surface mixing is limited. For many countries, the debris washing up along coastlines will predominantly stem from their own relatively local waste leakage. However, oceanic currents can result in the redistribution of plastic. Debris from the UK may be transported into the Arctic region within two years. The relative importance of physical and biological processes in controlling the spatial distribution and fate of plastic remain unclear. Fundamental uncertainties remain regarding the flux of marine plastic debris between ecological compartments.

Environmental monitoring efforts have increased dramatically in recent years, but for many areas of the world there remains little or no data describing how much plastic is present. Numerical models have been used extensively as a cost-effective means of supplementing and scaling up environmental data to estimate the global budget of plastic. However, as models are predictive, it is essential that uncertainties relating to model outputs, and validation of these models, are reported. Mapping the overlap between the distribution of marine organisms and plastic hotspots could identify areas “at risk”, and recognising that coastal waters are likely to be the biomes where plastic debris will have the greatest ecological and economic impact, and therefore where exposure to macro- and micro-plastic will be of the greatest concern.

Impacts of Marine Plastic Pollution on Biota and Ecology

A broad range of marine organisms (from plankton to whales) has been shown to become entangled in, or ingest, plastics. Physical encounters through entanglement and entrapment by marine debris (nets, ropes and crab pots; to car air filters and polythene bags) have been widely reported for marine mammals. There is also clear evidence that critical life processes, including metabolism, growth, reproduction and behaviour (and mortality) are affected by ingestion of plastic across marine species. However, the degree of risk at population levels remains elusive. Fundamentally, there is no agreed convention for hazard assessment of plastics and microplastics, such as is used in assessing ecotoxicity for chemical risk assessment. Moreover, the concentrations of microplastic particles used in laboratory exposure studies can exceed those found in the environment.

Further work is now required to elucidate the bioavailability and effects of fragments and fibres, the relative sensitives of different species and life-stages, to better understand the mechanisms by which microplastics cause toxicity, and explore the risk nanoplastics pose to marine life. In addition, the effects on marine ecology need to be better understood, so that the wider implications of marine plastics can be assessed, for example , uptake of plastic up the food chain, and biochemical cycling.

Ecosystem Service and Economic Impacts of Marine Plastic Pollution

A healthy Global Ocean is vital to human health and well-being, providing an array of ecosystem services with wide-ranging societal benefits. The marine environment can be considered as a stock of natural assets (biota, habitats, ecosystems and ecological processes) that provides ecosystem services of direct benefit to society, including food, regulation of climate and oxygen production, and cultural benefits, that can be economically valued giving them weight in policy decision making. In the absence of chemical hazard and risk paradigms, considering ecosystem services as the means to focus policy action is both pragmatic and attractive since it aligns with the economic valuation principals of 'natural capital'.

A recent publication suggests that economic costs of marine plastic, as related to marine natural capital, are conservatively conjectured at between $3,300 and $33,000 per tonne of marine plastic per year. However there is a need for more UK-relevant case studies that provide the cost:benefit evidence for specific economic sectors potentially impacted by plastic pollution, and which would then underpin policy measures.

Behaviour Change in People and Business Towards Plastic Pollution

Since 2016, there has been considerable influence by media and political leaders, in parallel to scientific communication, on the public 'discussion' relating to plastic pollution. The evidence suggests that emotive visual images (for example, beaches covered with waste; dying whales on beaches) and portrayed by trusted media sources has driven public attention to this issue, and that topics are intensified by social media peer-to-peer sharing.

There appears to be consensus between different stakeholder groups, with little indication of plastic pollution deniers. However, research on public knowledge and awareness has so far focused on macro-plastics rather than micro- and nano-plastics, for which little is known about the perceptions of pathways and impacts other than on wildlife. There is also evidence of co-responsibility in the public and a willingness to make change where they feel it is possible, and there is evidence of citizen and stakeholder initiatives that are actively engaged in campaigns and projects. There is a clear opportunity for policy makers to harness the positive public support for relevant measures.

Behaviour change programmes can be faster and more cost-effective at achieving changes in motivation and awareness than policy tools. However, policy measures are important to reduce situational barriers, otherwise motivational change may not lead to behavioural change, and the desired environmental outcome. Research is therefore needed to support the development of policy proposals, that identifies and quantifies behaviours, and analyses feasibility, acceptability and impact on reducing plastic pollution.