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Linking plastic ingestion research with marine wildlife conservation

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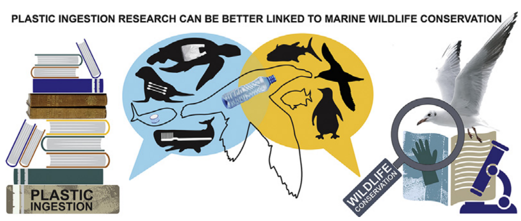
HIGHLIGHTS

- The number of studies documenting plastic ingestion in wildlife is accelerating.
- A disconnect exists between plastic ingestion research and wildlife conservation.
- Priority research questions involve identifying population-level impacts.
- A clearer pathway for integrating research into wildlife conservation is needed.

GRAPHICAL ABSTRACT



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ABSTRACT

Plastic is an increasingly pervasive marine pollutant. Concomitantly, the number of studies documenting plastic ingestion in wildlife is accelerating. Many of these studies aim to provide a baseline against which future levels of plastic ingestion can be compared, and are motivated by an underlying interest in the conservation of their study species and ecosystems. Although this research has helped to raise the profile of plastic as a pollutant of emerging concern, there is a disconnect between research examining plastic pollution and wildlife conservation. We present ideas to further discussion about how plastic ingestion research could benefit wildlife conservation by prioritising studies that elucidates the significance of plastic pollution as a population-level threat, identifies vulnerable populations, and evaluates strategies for mitigating impacts. The benefit of plastic ingestion research to marine wildlife can be improved by establishing a clearer understanding of how discoveries will be integrated into conservation and policy actions.

1. Introduction

Marine plastic pollution is a global environmental challenge that has been compared in significance to climate change (STAP, 2011). As of 2014, there was an estimated 93 to 236 thousand metric tons of plastic polluting the world's oceans (van Sebille et al., 2015). Despite local scale efforts to stem the flow of plastic into the oceans, the volume of marine plastic debris is increasing, with an estimated addition of 4.8 to 12.7 million metric tons every year (Jambeck et al., 2015). Plastic pollution is pervading ecosystems from the Arctic to the Antarctic, and affecting wildlife from zooplankton to whales, including many of the world's food resources (Barnes et al., 2009; Gall and Thompson, 2015). Beyond the numerous negative economic and social impacts of marine plastic pollution (Derraik, 2002; McIlgorm et al., 2011), plastic debris poses a

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threat to marine life through entanglement and ingestion (Kühn et al., 2015).

Over the past five decades, the number of publications documenting levels of plastic ingestion in marine wildlife has increased at an accelerating rate (Provencher et al., 2017). Many of these studies aim to provide a baseline against which future levels of plastic ingestion can be compared (van Franeker et al., 2011; Lusher et al., 2015; Lazar and Gračan, 2011; Boerger et al., 2010), and are motivated by an underlying interest in the conservation of their study species and ecosystems. However, we suggest there is a need to think creatively about how plastics research, conservation action, and policy could be better linked to achieve positive conservation outcomes for wildlife directly affected by plastic pollution (e.g., Hardesty and Wilcox, 2017).

Here, we present ideas to stimulate discussion about how plastic pollution research could inform effective conservation practices. This differs slightly from a recent and comprehensive list of research priorities for understanding plastic pollution impacts on marine species (Vegter et al., 2014), as we explore plastic ingestion research within the framework of informing conservation actions for wildlife specifically. We briefly summarize areas of research that are needed to elucidate the significance of plastic pollution as a threat, identify impacted populations, and evaluate strategies for mitigating impacts. We propose that existing international cross-sectoral working groups that include researchers, waste-management sectors, industry and decision-makers (e.g., the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection; GESAMP) could expand to include wildlife conservation practitioners and managers to improve our understanding of the ancillary benefits that reducing plastic pollution may have for species or populations vulnerable to marine plastics.

1.1. How can plastic ingestion research inform marine wildlife conservation?

There is a growing recognition in the research community that efforts need to shift from documenting plastic ingestion to investigating what the effects on wildlife may be (Nelms et al., 2015a; Skaggs and Allen, 2015; Vegter et al., 2014). This way, the impact of plastic ingestion relative to other threats can be assessed within a framework that considers multiple stressors (B. D. Hardesty *pers. comm.* 2018). Although, research has shown that ingestion of plastic can manifest as physical and toxicological symptoms that may be significant for individual organisms (Butler and Davis, 2010; von Moos et al., 2012; Wright et al., 2013; Rochman et al., 2013), the population-level impacts of plastic ingestion on marine wildlife are not yet well understood (Jemec et al., 2016; Nelms et al., 2015a; Rochman et al., 2016; Vegter et al., 2014).

Elucidating population-level effects can be challenging for several reasons, some of which are common to pollutant studies generally while others are specific to plastic. As the framework by Nisbet (1994) summarizes, to understand the general impact of pollutants at the population-level requires first understanding the degree to which animals are exposed to pollutants. This knowledge can then be used to investigate the effect of pollutants on the survival or reproductive performance of individual animals, which is governed by the pollutant's toxicity and biological factors, such as rates of uptake, anatomy and physiology (Nisbet, 1994). Only then can population-level effects be examined, for example by determining how the pollutant influences demographic characteristics, including reproductive fitness and mortality. Unfortunately, even when a pollutant represents unequivocal impacts, it can be challenging to measure effects at the population level, particularly for long-lived marine wildlife that have delayed sexual maturity (Warham, 1996).

Understanding the population-level effects of ingested plastic, specifically, is challenging because plastics are both a macro-contaminant (causing physical damage) and a micro-contaminant (due to the leaching of chemicals). Plastic toxicology studies are further complicated because plastic producers do not openly publish polymer recipes. Deciphering the negative impacts due to different modes of harm can be challenging, and cumulative effects are difficult to differentiate. As a result, many of the mechanistic linkages between plastic ingestion and health via physical or toxicological effects are not yet clear, even in taxa which have been extensively studied (Bakir et al., 2016; Rochman et al., 2016).

To date, most plastics ingestion studies involve single data points from necropsied individuals, and this has complicated efforts to identify causal relationships between plastic load and demographic parameters likely to impact populations. There is an obvious need for further research regarding the impacts related to microplastic debris, ideally involving experiments that truly measure ecological impacts at environmentally relevant levels (GESAMP, 2016). Research that establishes dose-exposure responses of individual animals to ingested microplastics alongside methods to quantify plastic loads in live animals (Hardesty et al., 2015) could enable plastic ingestion in wild animals to be tracked over time in relation to demographic rates.

In parallel with efforts to establish the significance of plastic ingestion at the population level, researchers should focus on improving our understanding of the factors that influence a species or population's susceptibility to ingesting plastic. Such information could facilitate predictions of a population's plastic ingestion risk (Dell'Ariccia et al., 2017; Savoca et al., 2016; Tavares et al., 2017; Wilcox et al., 2015), so that high-risk populations could be targeted for research and conservation actions. At present, our ability to predict plastic ingestion is limited by gaps in the literature and the use of non-standardized methods, which complicate comparisons (Avery-Gomm et al., 2016). This is a severe limitation that can be addressed by directing baseline research towards documenting plastic ingestion in understudied taxa and regions, and the widespread adoption of standardized methods for collection, analysis and reporting (Provencher et al., 2017).

We argue from the perspective that the most valuable plastic ingestion research provides information that will help us to better choose between actions or help us identify new actions to achieve positive conservation outcomes for species affected. Therefore, research that enables wildlife managers to answer questions such as; 'is plastic ingestion contributing to the decline of the population I manage?' 'How does it compare to other threats?' and 'Should I allocate resources to mitigating these impacts?' will be of greatest value.

1.2. Integrating plastic pollution research into wildlife conservation

Plastic pollution is accelerating and is expected to be a significant threat to at least some species in the future (Wilcox et al., 2015). As different countries will likely tackle plastic pollution as the most pressing conservation concern for different species at different times, it is reasonable to begin discussing mitigation and conservation options early.

One avenue that researchers and conservation practitioners may consider as a strategy to manage species in a highly-plasticized environment is compensatory mitigation, similar to the strategies that are used to manage species under climate change (Mawdsley et al., 2009; Saunders et al., 2013). Examples may include reducing threats to eggs and young either in situ or with head-start/hatchery programs (Eckert et al., 1999; Heppell et al., 1996), breeding site restoration methods (Friesen et al., 2017), or reducing threats at important feeding sites to bolster overall population growth. Where point-source pollution is identified, a compensatory offset approach could be explored (Wilcox and Donlan, 2007).

For coastal populations that are vulnerable to plastic pollution, waste management actions that address local sources of plastic pollution could be considered as an indirect approach for reducing wildlife exposure to plastic pollution (IUCN, 2016, p. 7). Although peer-reviewed studies documenting the successful reduction of plastic pollution in the marine environment following waste management practices are sorely needed, there is some evidence (Xanthos and Walker, 2017). For example, efforts to reduce industrial plastic pollution in the North

Sea in the 1980s appear have reduced industrial plastic pollution in the region over the past three decades (van Franeker and Law, 2015). If reduced exposure to local source pollution is shown to benefit wildlife populations then such an approach could be considered as a wildlife conservation action.

Wildlife populations face an array of threats. Many of these are better understood than plastic pollution (e.g., over-exploitation, incidental catch, habitat destruction), and are obvious priorities for near-term conservation interventions. However, there is little chance that plastic pollution is having *no* impact on wildlife (GESAMP, 2016). If we assume that further study will reveal plastic ingestion to have measurable, negative impacts on some populations, it is logical to think creatively about how impacts may be addressed.

1.3. Cross-sectoral communication

Although there are no legally binding international regulations on marine plastics (Borrelle et al., 2017; Xanthos and Walker, 2017), several waste abatement campaigns and policies have made progress towards reducing the flow of plastics into the environment (Willis et al., 2017), and working groups re being established to coordinate plastic pollution reduction a (e.g., Plastic Pollution Coalition). Another example is the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection under the United Nations Environmental Program that aims to bring together experts to provide interdisciplinary advice regarding the protection of the marine environment. While we support these working groups and the cross-sector engagement many of these have, there is a need to better integrate those who work on wildlife conservation to ensure the flow of information between those interested in plastics in the environment and those working in wildlife conservation.

The disconnect between policy makers and practitioners is not new or unique to the world of plastics research. The science-policy gap is firmly entrenched in conservation (Jarvis et al., 2015; Lemieux et al., 2018), leading to some describing the science-policy interface as dysfunctional (Sutherland et al., 2012). Indeed, Lemieux et al. (2018) found that managers used international agreements, grey literature (e.g. working group documents), and indigenous knowledge the least in protected area management in Canada. To prevent this gap in the emerging plastic pollution-conservation field we propose that existing international cross-sectoral working groups should include conservation practitioners from their initial development. This early engagement between plastic pollution working groups and wildlife conservation could improve the degree to which research to elucidate the ecological impacts of microplastics is integrated into policy in a way that benefits marine wildlife conservation.

Specifically, this would help plastic pollution working groups refine specific questions related to the health of the marine environment. For example, although directions for future research have been articulated, further work is needed to clarify how efforts will benefit wildlife. Policies to ban bags are a popular mechanism for raising awareness and reducing the use of plastic bags, but whether local levels of plastic pollution reflect the change remains to be seen (Xanthos and Walker, 2017). And, while a reduction of plastic bags in the marine environment may reduce plastic ingestion in sea turtles (González Carman et al., 2014; Nelms et al., 2015b), other marine wildlife may be more susceptible to other forms of plastic (i.e., hard plastic, microplastics or nanoplastics). Therefore, within these cross-sectorial working groups, engaging with conservation practitioners and wildlife managers will be key to expediting policy actions on plastic pollution, and providing the legislative support needed to achieve conservation goals for impacted species.

2. Conclusion

Addressing pollution of the world's oceans by plastic debris require will require global cooperation to define specific, measurable, time-bound targets to reduce plastic emissions into our oceans (Rochman et al., 2013; Vince and Hardesty, 2017). It is likely this will take years, possibly decades to achieve (Borrelle et al., 2017). The plastic ingestion research conducted to date has helped to raise the profile of plastic as a pollutant of emerging concern, and numerous national governments and global organizations have now listed understanding the effects of plastics on the environment as research priority (e.g., IUCN, USA, Australia). The benefits of plastic ingestion research will increase when informed by a broader community (i.e., cross-sectoral working groups, inclusive of wildlife conservation practitioners and managers) with a clear understanding of how research can be integrated into conservation and policy actions.

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