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Aligning Ocean Plastic Pollution and Human Health a Co-benefits Approach

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1. INTRODUCTION

Coastal environments are some of the most ecologically and socio-economically important habitats worldwide with 40% of the global population living within 100km of the coast (Kaswani et al., 2016; Morrissey, 2017). The oceans and seas play an important role in human health, through the provision clean air, food, the water, while offering health-enhancing economic and recreational opportunities (Fleming et al., 2014). At the same time, human activity has resulted in the oceans and seas becoming the planet's biggest landfill, accumulating various types of waste including metals, glass, ceramics, textiles, paper and timber (Erikson et al., 2014; Schneider et al., 2018). Collectively referred to as marine litter or marine debris, the largest fraction of this litter is plastic pollution which is estimated to account for between 60-80% of marine litter (Xanthos & Walker, 2017; Schneider et al., 2018). In turn, up to 80% of this plastic is estimated to originate on land (Jambeck et al., 2015). Given the importance of the oceans and seas in global economic activity, the need to address the plastic problem is increasingly recognized with discussions on marine plastic pollution occurring at international fora such as the World Oceans Summit (WOS, 2017) and at recent meetings of the top seven and top 20 global economies G7 (G7, 2015; 2018) and G20 (Vince & Hardesty, 2018). However, while the Law of the Sea Convention provides a mandate for the prevention of marine plastic debris on a global scale the agreement focuses on the protection and preservation of the marine environment and does not extend to the terrestrial environments where the majority of plastic originates (Raubenheimer & McIlgorm, 2018). As such, there is presently no global plan of action to address the problem of plastic entering the ocean (Raubenheimer & McIlgorm, 2017; Vince & Hardesty, 2018; Ten brink et al., 2018). Instead, the regulation on plastic pollution has been largely left in the hands of over 125 coastal states with differing laws and policies (VanderZwaag & Powers, 2008; Raubenheimer & McIlgorm, 2017; Borrelle et al., 2017).

Common waste abatement policies to mitigate plastic entering the environment in the first instance include on the production side, bans on microbeads, and post production, bans on plastic bags (Xanthos & Walker, 2017; Willis et al., 2018). These country-by-country initiatives have had significant positive impact on reducing plastic usage and plastic on the coastline. For example, the plastic bag levy introduced in Ireland in 2002 saw the number of plastic bags found per 500m of coastline fall from 17 bags in 2001 (pre-levy) to around 10 bags in 2002 (the year the levy was introduced), 5 bags in 2003, and 2 in 2012 (Doyle and O'Hagan 2013). A recent ban on microbeads in the United States and France will prevent billions of plastic beads from entering watersheds daily. While country by country initiatives are important, two issues remain. First, like many environmental pollutants (such as greenhouse gases and ozone-depleting substances), plastic is not constrained by national boundaries (Liu et al., 2016). Although the vast majority of ocean plastic originates on land (Pettipas et al., 2016; Landon-Lane, 2018), the movement of plastic once in the marine environment is highly stochastic and is influenced not just by individual behaviors on land but also ocean and environmental factors such as tides and weather events. While considerable progress has been made in determining the amount and end location of plastic pollution in the marine environment (Jambeck et al., 2015), the points of entry into the ocean remain hard to identify (McIlgorm et al., 2011; Landon-Lane, 2018). Furthermore, given the long life of plastics and their ability to release toxins over time, the time frame at which the pollution occurs may be very different to the timeframe in which the impact occurs. Second, from a governance perspective, more than 50% of the ocean’s area sits beyond national jurisdiction (Borrelle et al., 2017). For the 50% under national jurisdiction, the ability to prevent and mitigate plastic pollution locally and nationally varies by nation and region because of resource availability for waste management (Borrelle et al., 2017).

This means that any mitigation efforts must be transboundary and regulated at the global level. These issues are implicitly highlighted in a number of recent papers that have examined the impact of various initiatives, including container deposit legislation (CDL) or disincentives such as plastic bag levies or disposal taxes, to reduce plastic usage entering the ocean (Nahman, 2010; Oosterhuis et al., 2014; Xanathos & Walker, 2017; Schnurr et al., 2018; Schuyler et al., 2018). While each study reported a certain amount of success in mitigating land based and as an extension ocean based plastic pollution, each paper concluded that the choice of an appropriate instrument is case specific, and largely depends on the source of pollution, the country's institutional characteristics and infrastructure, consumer preferences and habitual behaviors, and the economy's overall sectoral composition. Thus, large problems persist that require global rather local or even regional approaches to ocean plastic.

Although often treated in the literature as separate concepts, environmental sustainability and human health are interacting processes. The oceans and seas played an important role in human health, through the provision and quality of the air that we breathe, the food we eat, the water we drink, whilst offering health-enhancing economic and recreational opportunities. Understanding the full societal impact of ocean plastic pollution and incorporating its associated costs into decisions related to the design and evaluation of any plastics policy would almost certainly enhance social outcomes, while increasing the cost effectiveness of proposed policies. From a policy and planning perspective, the focus on human health in this paper is both pragmatic and important. Benefits to health readily attract public support for political action, as shown by experiences in which health benefits have dominated the externalities of environmental interventions such as clean air legislation in many countries (Haines et al., 2009). Within this context, this paper focuses on the need for economists and policymakers to look past the direct economic costs and benefits and focus on the indirect or co-benefits of ocean plastic mitigation. Specifically, this paper argues that aligning global public health outcomes and ocean plastic pollution is the key to providing a cost-effective argument for mitigation measures and a pathway to gain greater policy and public support. As such this paper addresses the gap in the literature on the co-benefits of ocean plastic pollution mitigation and brings the mitigation literature in this area

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up to date with other environmental agendas including air quality and climate change.

2. ECONOMIC IMPACT OF OCEAN PLASTIC POLLUTION

Given the importance of the oceans and seas in global economic activity, there is increasing concern about the economic cost of ocean plastic to the global economy. However, as the marine environment is a typical example of a public good, measuring the full economic cost of marine litter is complex due to the wide range of economic, social and environmental impacts, the range of sectors impacted by marine litter and the geographic spread of those affected. (McIlgorm et al., 2009; Newman et al., 2015). The few studies that have been conducted tend to examine the costs of clean-up campaigns and waste management systems or lost revenue to a sector as a proxy for economic costs (Ten et al., 2009; Mouat et al 2010; Newman et al., 2015). For example, research by McIlgorm et al., (2009) estimated that the cost of marine litter as US$1.26bn per annum (in 2008 terms) for 21 economies in the Asia-Pacific. Mouat et al. (2010) estimate that marine litter costs the Shetland islands (part of the UK) between €1–1.1 million on average per year. Furthermore, Mouat et al. (2010) estimate that removing marine litter costs U.K. ports and harbors on average €2.4 million per year.

In terms of research on the tourism sector, Ofiara and Brown (1999) determined that the losses in tourism revenues, as a result of a pollution debris event in 1988 in the New York Bight, in the USA, was $379.1–1597.8 million US$ (in terms of 1987$). Jang et al., (2014) estimated a $29–37M USD lose in revenue to the tourism industry that following a period of heavy rainfall in July 2011, which washed a large amount of marine debris was washed up on coastal beaches in South Korea. In coastal California, visitors are reported to travel longer distances to avoid beaches with more waste (Leggett et al., 2014), and in Brazil, a recent survey reports that 85% of beachgoers will avoid beaches with high litter loads (Krelling et al., 2017). Although these studies provide a good starting point, these studies do not take into account the intangible costs of any social and ecological impacts (Newman et al., 2015; McIlgorm et al. 2011; Lee, 2015; Latinopoulos et al., 2018) or the human health implications. Indeed, economic assessments of environmental policy more generally rarely include associated health co-benefits even though mitigation policies and technologies will have a direct influence on health by modifying health-related exposures such as non-GHG air pollutants, physical activity, and diet. Ignoring cost savings due to health impacts provides an unbalanced assessment of the net impacts of required mitigation activities (Nemet et al., 2010). From a health perspective, mitigating the impact of plastic pollution in the ocean may have a significant impact on future health outcomes and their associated health care costs. The next section provides a brief overview of the current evidence base of the impact of ocean plastic pollution.

3. OCEAN PLASTIC POLLUTION & HUMAN HEALTH

Pollution is the largest environmental cause of disease and premature death in the world today (Landrigan et al., 2018). Responsible for an estimated 9 million premature deaths in 2015, pollution-related diseases cause productivity losses that reduce gross domestic product (GDP) in low-income to middle-income countries by up to 2% per year, with global welfare losses estimated to amount to US$4.6 trillion per year or 6.2% of global economic output (Landrigan et al., 2018). Although pollution takes many forms and includes industrial emissions, vehicular exhaust and toxic chemicals, most research has focused on the impact of carbon and air pollution on economic development and human health (Landrigan et al., 2017). In contrast, much less attention has been paid to the impact of pollution in our oceans and seas on human health. Ocean plastic pollution presents a number of public health and safety concerns including navigational hazards (Macfadyen et al 2009; Gold et al. 2013) and injuries to recreational users (Cheshire et al 2009), particularly when washed up on beaches (Campbell et al., 2019). For example, research in Tasmania found that even on beaches perceived to be 'relatively clean' by visitors, 21% of visitors receive injuries due to this litter (Campbell et al., 2016). Recent research in New Zealand found that anthropogenic beach litter poses a common and pervasive exposure hazard to all ages, with specific risk posed to young children (Campbell et al., 2019). The research found that anthropogenic beach litter injuries represented an average of 1.6% of all claims across New Zealand during the period 2007–2016. No claim of human mortality associated with beach litter was reported during this 10-year window, however 31 different causes of injury were reported (Campbell et al., 2019).

However, ocean plastic pollution poses a number of more nuanced indirect risks to human health (Gold et al. 2013; Galloway, 2015; Newman et al., 2015; Karbalaei et al., 2018). One clear pathway in which plastic pollution can impact human health is through the disruption of the marine food chain and water supplies (Karbealaei et al., 2018; Rochman et al., 2015; van Cauwenberghe and Janssen, 2014; Galloway, 2015; Barboza et al., 2018). Research has shown that shellfish (including crustaceans and bivalves), and many commercially important fish species are often contaminated with microplastics (van Cauwenberghe and Janssen, 2014). For example, out of the 25 species most commonly fished (FAO, 2016), 11 were found to contain microplastics. Van Cauwenberghe and Janssen (2014) estimated that in European countries with high shellfish consumption, consumers ingest up to 11,000 microplastic particles (size range 5–1000 μm) per year, whereas in countries with low shellfish consumption, consumers ingest an average of 1800 microplastics per year. With regard to water contamination, recent studies found microplastics in tap water (Kosuth et al. 2017) and bottled water (Schymanski et al. 2018). For people who food insecure in Sub-Saharan Africa and Asia, fish represents a rich source of protein, micronutrients and essential fatty acids (Beveridge et al., 2013) and in many instances is their only form of protein. Through disruption and degradation of fisheries, ocean plastic pollution will have the greatest impact on those who are socially and economically vulnerable.

The hard surface of plastics provides an ideal environment for opportunistic microbial

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colonisers to form biofilms which could act as an important vector for the persistence and spread of pathogens, faecal indicator organisms and harmful algal bloom species across beach and bathing environments (Gold et al., 2013; Kaswani et al., 2016; Barboza et al., 2018; Karbealaei et al., 2018). Chemicals used in the production of polymers can increase local concentrations of harmful toxins (Newman et al., 2015). Additives such as bisphenol A (BPA) and flame retardants, such as polybrominated diphenyl ethers (PBDEs), found in plastic waste, can dissociate in the ocean environment and are linked to endocrine disruption in both wildlife and humans (Gold et al. 2013). Both sources of chemicals increase the potential for bioaccumulation of toxins within food chains when ocean plastic is ingested by smaller organisms. Recent research has found that plastics in the marine environment are reservoirs for antibiotic and metal resistance genes (Yang et al., 2019). Despite the remaining uncertainties, a growing body of evidence shows that plastic pollution in the oceans negatively impacts human health. This evidence provides sufficient cause to invoke the Precautionary Approach. The precautionary principle attempts to account for the limitations of discounting practices in risk assessment by providing a moral and legal imperative to act to avoid impacts when there is some threat of harm (Gardner, 2006). The core of the principle is that the likelihood or even the consequences of harm need not be known precisely prior to action on risk avoidance (Challinor et al., 2018). This means that society should not wait until there is unequivocal and quantified evidence of the degree of impact before acting to reduce plastic inputs to the ocean. However, the question remains as to the mechanisms that may be used to mitigate ocean plastic pollution.

4. MECHANISMS FOR OCEAN PLASTIC MITIGATION

From an economic perspective, pollution occurs at greater levels than are socially optimal because markets fail to accurately relay the social costs of pollution to producers and consumers. In practice, there are essentially two varieties of legislation used to reduce waste in the environment (Schuyler et al., 2018). These include "command and control" measures, and market-based economic instruments (Oosterhuis et al., 2014). Command and control measures are defined as direct regulation of activities or unwanted items by legislation, such as bans on plastic microbeads in facial products or prohibitions on single use plastic bags. Economic instruments encourage behavior change through market signals rather than explicit control levels (Shortle & Horan, 2017) as a method to influence human behaviors. Economic instruments encompass a range of policy tools, from pollution taxes and marketable permits to deposit-refund systems and performance bonds (Oosterhuis et al., 2014; Ten Brink et al., 2009). The common element of all economic instruments is that they provide incentives to stimulate a change in the behavior of users by internalizing previously external costs (or benefits) into the prices of products or activities (Ten Brink et al., 2009; Vince & Hardesty, 2017; Shortle & Horan, 2017). Economic instruments focusing on financial incentives include deposit-refund schemes, subsidies, direct payments, price differentiation and preferential treatments (Mouet et al., 2009; Oosterhuis et al., 2014). Instruments focusing on financial disincentives aim to discourage behavior that may contribute to the problem of interest by applying a price tags on this activity. In contrast to a regulatory approach which makes specific behaviors or technical choices mandatory, it is assumed that an economic instrument approach allows more flexibility in how individuals or industries achieve environmental goals according to their budget constraints. It is believed that this flexibility achieves environmental goals at a lower cost than regulatory approaches (Shortle & Horan, 2017). Bohm & Russel (1991) not that to ensure the economic efficiency of an environmental instrument the following criteria are required:

1. Static efficiency, that is, minimum cost of achieving a given environmental goal;
2. Ability of the system to maintain a predetermined set of environmental standards when changes in exogenous parameters (such as tastes or technology) take place;
3. Effectiveness of the system in providing incentives so that, in the long run, adoption of new environment-saving technologies is facilitated;
4. Satisfaction of given distributional or ethical notions;
5. Informational requirements for the use of the implementation system; and
6. Cost of monitoring whether potential polluters comply with the given system and cost of enforcing the system in the presence of violators.

To fully understand these criteria, it is useful to examine a minimally complex problem as a point of reference. Such an example would involve a single, homogenous pollutant discharged deterministically at discrete points by known sources. The pollutant then follows a known route into the ocean or sea. In this example, not only is it easy to identify the polluter but also the ecosystem and individuals who are impacted by the specific polluter. In this instance, because the pollutant discharged is constant across time, producers of the pollutant can, without appreciable cost, provide the regulatory authorities with the required information on emissions. A single price can be calculated, and an appropriate economic instrument can be used to ensure that the goods and services produced are optimally priced from a societal perspective. Criteria 5 and 6 are met with all the required information is provided to a single agency with the authority and ability implement a single emissions price via the most appropriate instrument (e.g. a tax or a permit). Polluters in this setting, working with just one agency and with clear information on their discharge loads at all times and the environmental cost of their activity can respond to any regulation by adapting their processes to minimize their emissions and the social costs of pollution control (Criteria 3). In this instance, introducing and implementing an economic instrument or set of instruments that can induce changes in individual and collective behaviors to achieve environmental quality goals can be achieved at comparatively low costs, even if there are changes in production, to both the polluter and the regulatory authority (Criteria 1, 2).

The minimally complex example pollutant provided originally by Shortle & Horan (2017) here is a typical example of a point source pollutant. Point sources of pollution are those that emit pollutants from a fixed or readily identifiable point. With point-based pollution, the policymaker has sufficient (in theory, perfect) information, regarding the emissions or pollutants generated by each potential polluter. That is, the source, the size and the distinctive characteristics of the emissions can be identified with sufficient accuracy at a non-prohibitive cost. In contrast, non-point source (NPS) pollution such is ocean plastic pollution refers to the form of pollution where neither the source nor the size of specific emissions/pollutants can be observed and identified with sufficient accuracy (Shortle & Horan, 2001; Xepapadeas, 2012). In this instance, the actions of individual polluters can be hidden from policymakers and the problem becomes predominantly an informational problem (Xepapadeas, 2012). It is no longer possible to meet the criteria outlined by Bohm & Russel (1991) necessary to ensure the effectiveness of any economic instrument.

Although considerable progress has been made in determining the amount and end location of plastic pollution in the marine environment (Jambeck et al., 2015), there points of entry and when and how much entered from each point remains hard to identify (McIIgorm et al., 2011; Landon-Lane, 2018). The negative impacts of ocean plastic are just as likely to be experienced in outside their point of origin. Furthermore, given the long life of plastics and their ability to accumulate toxins overtime, the time frame at which the pollution occurs may be very different to the timeframe in which the impact occurs. As such, a suite of international policies and regulation would be required to successfully implement and administer economic instruments to address the flow of plastic into the marine environment. In this situation, standard economic instruments such as emission taxes and tradable emission permits are demoted from first-best to second-best economic incentives (Shortle & Horan, 2001; Xepapadeas, 2012). Relaxing the static, deterministic assumption outlined in the minimally complex example above, introduces the fundamental challenge of ocean plastic pollution: metered emissions are not possible, and an optimal incentive design becomes a complex mix of different instruments (e.g., taxes, subsidies, permit market).

When policy debates are framed in terms of cost minimization, it is clear that economic instruments as a means to mitigate ocean plastic pollution are not cost-effective, the planning, implementation and administration of the suite of instruments required is too large. At the same time, a global governance approach is unlikely in the necessary timeframe to administer the necessary system, while at the national level the pace progress is piecemeal and not commensurate with the pace of plastic emissions (Borrelle et al., 2017). Usually treated in the literature as separate concepts, the marine environment and human health are linked processes (Fleming et al., 2015). However, the literature reviewed in Section3 demonstrates the increasing evidence base that ocean plastic pollution is and will impact on human health. Within this context, this paper argues that aligning the debate on ocean plastic pollution with human health offers two important opportunities. First, mitigating ocean plastic is going to be costly and from an economic perspective most interventions will not be cost effective in the truest sense. However, understanding the benefit’s and savings to public health and health services is an important accounting exercise to present the real cost of ocean plastic pollution. Second, aligning the discussion between the two areas, opens what is currently an environmental debate up to a much wider audience. Indeed, the environmental literature more broadly is increasingly framing environmental issues around human health to increase the pace in which environmental issues enter mainstream political and public debate (Haines et al., 2009). Given these issues, the next Section introduces the case for aligning the ocean plastic pollution debate with global public health through the concept of co-benefits.

5. ALIGNING HUMAN HEALTH & OCEAN PLASTIC POLLUTION: A CO-BENEFIT APPROACH

The mitigation of ocean plastic promises to be a costly and complex enterprise. As with many environmental issues, vested interests will use the large cost of mitigation and potential decrease in economic growth and employment as an argument to continue business as usual. In response, the term 'co-benefits' has exploded in in both academia and official policy documents (Nemet et al., 2010; Mayrhofer & Gupta, 2016). The co-benefits concept implies a 'win–win' strategy to address two or more goals with a single policy measure (Nemet et al., 2010). The concept of co-benefits makes the economics of pollution mitigation feel comfortable to the public. The Co-benefits framework takes the economic concept of double dividends away from its typical revenue generating definition (Mayrhofer & Gupta, 2016) and focuses on a much wider range of welfare measures such as social justice and human health (Mayrhofer & Gupta, 2016). In the global policy arena, the concept of co-benefits is seen as a means of valuing both the direct and indirect impact of environmental policies. In terms of climate change abatement, the influential Intergovernmental Panel on Climate Change reports now feature 'co-benefits' as a central concept (IPCC, 2007; IPCC, 2014a; IPCC, 2014b). While, the co-benefits of clean air initiatives and chemical regulations are already well established. For example, air quality improvements in the high-income countries have been proven to not only increase air quality but also to reduce deaths from cardiovascular and respiratory disease and yield substantial economic gains. In the USA, an estimated US$30 in benefits (range, $4–88) has been returned to the economy for every dollar invested in air pollution control since 1970, which is an aggregate benefit of $1.5 trillion against an investment of $65 billion (Landrigan et al., 2017). Similarly, the removal of lead from gasoline has returned an estimated $200 billion (range, $110 billion–300 billion) to the US economy each year since 1980, an aggregate benefit of over $6 trillion through the increased cognitive function and enhanced economic productivity of generations of children exposed since birth to only low amounts of lead (Landrigan et al., 2017). While a recent review of the cost- benefit effects of international air quality, transportation and diet policies, found that the studies consistently demonstrated that the health co-benefits of mitigation policies and technologies offset a significant portion of their implementation costs (Chang et al., 2017).

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However, the focus on human health is not just about making a cost-effective argument for ocean plastic pollution mitigation. Benefits to health readily attract public support for political action, as shown by experiences in which health benefits dominated the debate about other environmental interventions, such as clean air legislation (Haines et al., 2009; Orset et al., 2015). As such, the environmental literature is increasingly considering the impact of environmental issues on human health as a means to (i) provide scientific evidence that environment and health should be considered jointly and (ii) increase recognition for environment in the wider policy agenda. This is particularly true for climate change where the focus on the health impacts of climate change has arguably helped embed the climate change agenda in the wider public health research (Costello et al., 2009; Workman et al., 2018). For example, comprising a multidisciplinary consortium of researchers the Lancet Commission on Climate Change and Health (Watts et al., 2015) aims to provide specific recommendations to government to enhance climate action, and monitor, assess and report on progress of health in the climate change agenda (Workman et al., 2018). From a co-benefit perspective, framing or at least aligning environmental policy with public health have been used in China as a means to reduce emissions [Holdaway, 2013; Green and Stern, 2107], while in the USA, health co-benefits are publicly communicated as a key selling point in the climate change debate in an attempt to pursue climate action despite the politically toxic nature of the climate change debate (Jacob, 2016). The strength of the co-benefits concept lies in its positive framing and its advocacy potential because it can help to align the temporal and spatial costs and benefits of climate policy and support by providing strong empirical evidence with a convincing financial price tag (Mayrhofer & Gupta, 2016).

6. CONCLUSION

The health of the environment and human health and wellbeing are intimately linked, and the environment affects our health in a variety of ways (Fleming, 2015). Previous research has found that mitigating environmental hazards presents unrivalled opportunities for improving both the economic and health wellbeing of a country (Landrigan et al., 2017). While research on the impact of ocean plastic pollution is in its infancy, early evidence indicates that ocean plastic pollution will impact human health via food security and nutrition, water security and access to health services and medicine. It is expected that as with all environmental issues, these impacts will be felt across the globe but will have a disproportionate negative effect in developing countries and vulnerable populations. Aligning other challenging, cross boundary environmental challenges such as climate change and air quality has proved to be a successful mechanism to account for the costs associated with mitigation. Furthermore, there is evidence that linking environmental policies to human health increase public acceptance of proposed environmental policies.

From a co-benefit perspective, mitigating the impact of plastic pollution in the ocean will have a wide variety of effects that are not only related to the costs saved in clean-up operations.

However, aligning the debate about plastic pollution with human health is not a panacea. Estimating the human health costs of ocean plastic or remediation is a difficult task as there are no institutional data systems designed to collect the relevant information. A much wider evidence base is required, particularly around environmental justice and equity. The long latency of many pollution-related diseases, insufficient information about pollution's enormous economic and social costs and the vested interests of large industry coupled with the belief that pollution is an unavoidable consequence of economic development has meant that the impact of pollution on human health has long been neglected from a policy perspective. In conclusion, while many questions remain, this paper makes it clear that protecting human health should be a primary goal of any environmental policy focused on ocean plastic.

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