

Response to reviewers: (Manuscript ID: os-2020-127)

Plastics in the Indian Ocean – sources, transport, distribution and impacts

We would like to thank and acknowledge the reviewer for their careful reading and constructive comments on the manuscript. We believe that we have addressed the issues raised by the reviewer and the proposed changes to the manuscript are detailed in this document. We trust that the reviewer and the editor will find that the suggested changes will make the manuscript suitable for publication.

Please note that the line numbers referred to in this document are those in the original manuscript commented by the reviewers.

| # | Reviewer comment | Author response |
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| | Abstract | |
| 1 | L33: “Some of the highest plastic-polluted rivers end up in the IO with all this...” – this sentence reads a little awkward to me. Suggest changing to something along the lines of “Some of the most plastic-polluted rivers empty into the IO suggesting the IO...” | We have changed this sentence to: “ Some of the most plastic-polluted rivers empty into the IO ” as suggested. |
| 2 | L48: slight issue with the phrasing, for example discuss vs discussed and identify vs identified. Pick one and be consistent throughout. | We have replaced all past-tense phrases with present tense phrases in the abstract. |
| | Introduction | |
| 3 | L33-46: The first paragraph is fascinating; however, it feels inappropriate for this paper (and journal - sorry) given these statements are focused on a historical account of the evolution of plastics in the late 1850s. Even if this were condensed significantly (which I would argue it needs to be, at 14 lines of text it feels too long and detailed – for example, “billiard balls” are mentioned five times), I’m still not convinced it’s the best fit. Instead, could you provide historical context for plastic usage in the SE Asia/IO region? I’ve not seen this information compiled/synthesised in other papers, so that would be a useful contribution. | We have shortened this section to: “ Historically, the motivation for the development of synthetic materials like plastics was for the conservation of elephants that inhabit countries along the Indian Ocean (IO) rim in southern Asia and Africa (Freinkel, 2011). The first plastic materials were advertised as saviours of the environment, because it would no longer be necessary to ransack the environment for scarce natural resources (Meikle, 1997). However, the production of plastic materials has increased exponentially since the 1950s (PlasticsEurope, 2019) and plastics have instead become a ubiquitous environmental pollutant (Law, 2017). ” |
| 4 | L49 (and some of the sentences in the paragraph above; also line 57 “35% of all plastic materials”): references are somewhat minimal and/or missing in a few places. For example, this sentence “Since a large percentage of all plastics are single use, “throwaway” packaging items, plastic waste has increased at a similar rate. | We have added in references where relevant. For example: “Since a large percentage of all plastics are single use packaging items (PlasticsEurope, 2019), plastic waste has increased at a similar rate (Geyer et al., 2017).” “Around 35% of all plastic materials produced globally have densities higher |

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| | | <p>than that of seawater (PlasticsEurope, 2019)”</p> <p>“Plastics also accumulate biofouling while in the ocean, which can change the overall density and lead to plastics moving vertically in the water column (Lobelle & Cunliffe, 2011; Long et al., 2015; Kooi et al., 2017).”</p> |
| Section 2 Sources | | |
| 5 | L97-100 – no reference(s) provided | <p>We have added references as follows:</p> <p>“Plastic waste enters the ocean from coastal sources transported by wind and tides (Jambeck et al., 2015), from sources far into the hinterland transported by rivers (Lebreton et al., 2017; Schmidt et al., 2017; 2018), and directly from ocean-based sources (Richardson et al., 2019).”</p> |
| 6 | <p>L102 – “the total amount of plastic waste produced in 2010 by the USA and China” Here and elsewhere, how do these values such as these compare to more recent (2015) estimates?</p> <p>http://advances.sciencemag.org/content/advances/3/7/e1700782.full.pdf</p> | <p>We have added:</p> <p>“More recently, Kaza et al. (2018) estimated that the total amount of plastic waste produced by IO rim countries in 2016 was around 24 million tonnes, compared to 34 million tonnes by the USA and 39 million tonnes by China.”</p> |
| 7 | L110-114 – suggest providing more information on how and when this error was identified, and more importantly, how it has been rectified (this could potentially be included as Supp Info). The level of detail provided here is a little lacking. For example, what exactly is the error originating from the World Bank Data? | <p>We have changed this part to contain more detailed information and the corrected estimate of plastic waste input from coastal populations in Sri Lanka as follows:</p> <p>“However, it is likely that the estimated amount of plastic waste entering the ocean by Jambeck et al. (2015) for Sri Lanka is incorrect. Jambeck et al. (2015) based their estimate on a reported 5.1 kg of municipal solid waste generated per person per day in Sri Lanka (Hoornweg and Bhada-Tata, 2012). The updated report by Kaza et al. (2018) and dataset available through the World Bank (What A Waste Global Database) indicates that only 0.34 kg of municipal solid waste is generated per person per day in Sri Lanka; this number is also more in line with the amount of waste generated in other developing countries. Using this correction, the amount of plastic waste entering the ocean from Sri Lanka through coastal populations is estimated between 0.021 and 0.057 million tonnes in 2010, instead of between 0.24 and 0.64 million tonnes as reported in Jambeck et al. (2015).”</p> |

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| <p>8</p> | <p>L123-124 “The estimates of the amount of plastic waste entering the oceans through rivers by Lebreton et al. (2017) and Schmidt et al. (2017) agree relatively well with each other. In contrast, the estimates by Jambeck et al. (2015) of the amount of plastic waste entering the oceans through coasts are an order of magnitude higher” – it’s useful to synthesise these 3 studies like this, but I’m left wondering what the take home message is beyond what you’ve stated here. Could the authors make some sort of recommendation on how the plastics community should move forward, in light of this? Do we need another of these modelling papers to try and figure out who is “most right” or is the more useful path forward to fill an obvious data gap that would help refine one of the existing models? As the authors are aiming to synthesise information and “recommend future research strategies” it would be useful to answer the “now what” question.</p> | <p>Two new papers have been published with estimates of the amount of plastic waste entering the ocean through rivers since we submitted this manuscript. We have included these two papers in our new manuscript:</p> <p>“More recently, Meijer et al. (2021) estimated that between 0.80 and 2.7 million tonnes of macroplastics (defined by Meijer et al., 2021 as larger than 5 mm) enter the global ocean per year. In this estimate, Meijer et al. (2021) took into account the spatial variability of mismanaged plastic waste generated within a river basin, as well as more advanced climate and terrain characteristics than considered in the estimates of Lebreton et al. (2017) and Schmidt et al. (2017). They calibrated their estimates based on visual sampling of macroplastics at river mouths around the world.”</p> <p>We have also expanded this section to recommend some future research strategies:</p> <p>“The estimates of the amount of plastic waste entering the oceans through rivers by Lebreton et al. (2017), Schmidt et al. (2017), and Meijer et al. (2021) agree relatively well with each other. In contrast, the estimates by Jambeck et al. (2015) of the amount of plastic waste entering the oceans through coasts are an order of magnitude higher. In even starker contrast, Weiss et al. (2021) re-evaluated the estimates of Lebreton et al. (2017) and Schmidt et al. (2017) and suggested that only 6.1 thousand tonnes of microplastics (defined by Weiss et al., 2021 as smaller than 5 mm) enter the ocean through rivers each year, which is 2 to 3 orders of magnitude smaller than previous estimates. These differences highlight the extreme uncertainty involved in determining the amount of plastic waste entering the ocean from land-based sources. These estimates are based on few measurements of plastics entering the ocean (in the case of Jambeck et al., 2015, only on data from the San Francisco Bay; in the case of Lebreton et al., 2017;</p> |
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| | | <p>Schmidt et al., 2017; Meijer et al., 2021; and Weiss et al., 2021, on 30 to 340 samples from 13 to 89 rivers around the world). None of these samples were taken in IO rim countries or in rivers that empty into the IO. Expanding on these datasets will likely help improve these estimates, especially for the IO. However, as Weiss et al. (2021) demonstrate, to reduce extreme errors it is essential to use comparable sampling methodologies and to collect not only data on the amount of plastics sampled but also on their weight. Furthermore, Meijer et al. (2021) emphasize the importance of sampling plastics at river mouths to get a more reliable estimate of the amount of plastic that actually enters the ocean. However, sampling plastics further upstream in addition to the river mouth, can help improve models of the probability for plastic to reach the ocean from inland areas.”</p> |
| 9 | <p>L135 – I find the wording of this sentence to be in an odd order, sorry “Although the International Convention prohibited the dumping of waste from vessels in 1988 for the Prevention of Pollution from Ships (MARPOL)”</p> | <p>We have rephrased this sentence as: “In 1988, the International Convention for the Prevention of Pollution from Ships (MARPOL) prohibited the dumping of waste from vessels. However, accidental losses and illegal dumping still contribute to plastic debris.”</p> |
| 10 | <p>L136 – what about ghost nets in Carpentaria, do you have any information on whether some could make their way across to the IO? https://www.sciencedirect.com/science/article/pii/S0016718516302603</p> | <p>Gulf of Carpentaria is a sink. During the monsoon period (Austral summer) the winds are from the south-west to westerly along the north-west coast of Australia and Indonesia – thus the net movement is into Gulf of Carpentaria. However, when the winds reverse to south-easterly they do not have much impact on the transport of debris out of Gulf of Carpentaria.</p> |
| 11 | <p>L149 – “Commonly used type categories are plastic fibres, fragments, films, and pellets” this is a brief and somewhat uninformative statement as it lacks references and other information. For example, why are these the commonly used categories (why does this matter to the reader)? Consider this paper, or others like it: Serra-Gonçalves, C., Lavers, J.L., Bond, A.L., 2019. Global review of beach debris monitoring and future recommendations. Environ. Sci. Technol. 53, 12158-12167.</p> | <p>We have rewritten this section and now refer to relevant existing review papers instead: “Samples of plastic debris consist of different plastic polymers and are generally classified into different type and size categories. Size and type categories can vary widely between authors but it is beyond the scope of this review to discuss these different categories. Instead, we refer to recent review papers by Gigault et al. (2018) and Frias & Nash (2019) discussing plastic size categories, and</p> |

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| | | <p>Hartmann et al. (2019) discussing different categories of polymers, sizes, shapes, colours, and origins.”</p> <p>We refer to the suggested paper in the paragraph following it; see our response to review comment #27 for this.</p> |
| 12 | <p>L151 – “Size categories as defined by...” this is actually a very complex and actively debated issue that is often over-simplified. GESAMP may have been (one of) the original groups to define these categories, but there’s been much development and learning in the 12 years since the report was published. For example, see Gigault et al. 2018. Current opinion: What is a nanoplastic? Environ. Pollut. 235, 1030-1034.</p> | <p>We have rewritten this section so that it does not contain any specific size categories, but refer to existing review papers discussing this matter in detail instead (see our response to comment #11 for the changes we have made in the manuscript to address this).</p> |
| 13 | <p>L207 – definition of Convergent flows isn’t provided until line 210, after it’s first mention. This is a little confusing for readers not familiar with this concept</p> | <p>We have included a brief description of what convergent flows are: “Physical processes that lead to convergent flows, where ocean currents flow towards each other, are one of the most important features for the transport of buoyant plastics.”</p> |
| | Section 4 | |
| 14 | <p>Sections 4.1 to 4.3 – these are well-written and referenced sections. The level of detail is high, explanations are clear, and I found this useful and enjoyable to read. However, it stands out against other sections which, in comparison, are brief and sometimes feel incomplete (or a little unnecessary). I’m not suggesting you write more elsewhere as your article is already 18 pages – instead, is it possible to focus the paper more on these sections where the author’s clearly have a wealth of knowledge and experience? (and less on the tangential topics, many of which have already been covered in other papers).</p> | <p>Thank you. We have shortened this section a bit. We have also added the relevant information from section 5 here and removed section 5 (fate), see also our response to comment #15.</p> |
| | Section 5 (fate) | |
| 15 | <p>This 1st paragraph is redundant with earlier sections which also talk about buoyant plastics (e.g., line 181-186) and sinks (e.g., line 59, 80-84, and 174). L391-395 – an example of one of the brief sections that seems “thrown in” at the last minute (sorry). While this is interesting and does indeed occur, you either need to provide more information on the mechanism of how this actually occurs, or disregard this entirely and focus on other fates. Two refs that you may want to consider: Cartraud et al. 2019. Plastic ingestion in seabirds of the western Indian Ocean. Mar. Pollut. Bull. 140, 308-314. Fujieda et al. 2008. Ingestion case of plastics by black marlin and lancetfish caught in the east Indian Ocean. Memoirs of Faculty of Fisheries 57, 47-48.</p> | <p>We have removed section 5 (fate) because, as you say, there was a lot of duplicate or irrelevant (for the purpose of this paper) information. We have added the relevant information from this section to section 4. As these changes are quite extensive, we will not list them all here. Instead, please see the manuscript with tracked changes.</p> |
| 16 | <p>Section 5.1 – well-written, however I’m not entirely convinced this section adds anything new as it essentially</p> | <p>Agreed, we have removed this section and kept only a few summary sentences in</p> |

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| | summarises the findings of one paper written by the authors (van der Mheen et al. 2019). | section 4. See also our response to comment #15. |
| 17 | L490 - Abandoned, lost, and discarded fishing gear (ALDFG) already defined on line 136 | Thank you, we have replaced this with the abbreviation ALDFG . |
| Section 6 | | |
| 18 | section 6.1 (ghost nests) is 2 paragraphs, but only one sentence (line 489) contains information or direction refers to the Indian Ocean – can you replace some of this with information more specific to the region? | <p>We have added some more information relevant to the IO in this section:</p> <p>“Data from genetic analyses of Olive Ridley turtles entangled in ghost nets in the Maldives showed that the individual turtles originated from populations nesting in India and Sri Lanka (Stelfox et al. 2020b). This shows that impacts on charismatic marine species that drive tourism can impact multiple economies in the IO rim simultaneously.”</p> <p>“Recent interviews of fishers by Richardson et al. (2021), which included fishermen from Indonesia along the IO rim, showed that the main reasons for gear loss reported were bad weather and interactions with wild life respectively. Illegal and deliberate gear discard on the other hand was reportedly low. Furthermore, over half of fishermen interviewed across the world reported being “concerned” or “very concerned” about ALDFG, whereby economic losses scored highest (54%) as an issue of concern followed by environmental harm (41%). The reported loss prevention strategies that scored highest were gear maintenance and training crew in gear management, which provide clear avenues for targeted programs to educate and raise awareness around ALDFG in low income fisheries, such as in many IO rim economies (Richardson et al., 2021).”</p> |
| Other | | |
| 19 | Acknowledgements - Australia nPostgraduate Award | Thank you, we have corrected this. We have also corrected a few other mistakes in the Acknowledgements section. |
| 20 | Figure 7 – the brown arrows and red boundaries are a little difficult to distinguish (perhaps even more so when the image is reduced in size during printing). Can you select another colour, being mindful of folks with colour blindness https://www.ascb.org/science-news/how-to-make-scientific-figures-accessible-to-readers-with-color-blindness/ | We have changed the brown arrow to green. |

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| 21 | Table 1 – some entries seem incomplete, plastic size and type data is available at least for Cocos, yes? | We have corrected this and filled in all available information in Table 1. We have also reorganised Table 1, in our response to a comment by another reviewer. |
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