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1 **Proceed with caution: the need to raise the publication bar for microplastics research**

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15

16 **Abstract**

17

18 Plastic is a ubiquitous contaminant of the Anthropocene. The highly diverse nature of  
19 microplastic pollution means it is not a single contaminant, but a suite of chemicals that  
20 include a range of polymers, particle sizes, colours, morphologies, and associated  
21 contaminants. Microplastics research has rapidly expanded in recent years and has led to an  
22 overwhelming consideration in the peer-reviewed literature. While there have been multiple  
23 calls for standardization and harmonization of the research methods used to study  
24 microplastics in the environment, the complexities of this emerging field have led to an  
25 exploration of many methods and tools. While different research questions require different  
26 methods, making standardization often impractical, it remains import to harmonize the  
27 outputs of these various methodologies. We argue here that in addition to harmonized  
28 methods and quality assurance practices, journals, editors and reviewers must also be more  
29 proactive in ensuring that scientific papers have clear, repeatable methods, and contribute to a  
30 constructive and factual discourse on plastic pollution. This includes carefully considering the  
31 quality of the manuscript submissions and how they fit into the larger field of research. While  
32 comparability and reproducibility is critical in all fields, we argue that this is of utmost  
33 importance in microplastics research as policy around plastic pollution is being developed in  
34 real time alongside this evolving scientific field, necessitating the need for rigorous  
35 examination of the science being published.

36

37 **Keywords** – plastic pollution, environmental contaminants, standardization, harmonization,  
38 peer-review

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40

41 *1. Introduction*

42 Plastic pollution, because of its prevalence and persistence, is a defining pollutant of  
43 the Anthropocene. Plastic pollution, including microplastic, has been found from the  
44 Antarctic to the Arctic, and from urban landscapes to the deep sea (Cincinelli et al., 2017;  
45 Dris et al., 2015; Tekman et al., 2017; Woodall et al., 2014). Microplastics are most  
46 commonly defined as plastic particles  $>1 \mu\text{m}$  and  $< 5$  or  $1 \text{ mm}$  along their largest dimension  
47 (Hartmann et al., 2019; UNEP, 2014). We will use the  $< 5 \text{ mm}$  definition for our  
48 consideration of microplastics as this will include much of the literature. The number of peer-  
49 reviewed publications on microplastics has rapidly increased over the past decade  
50 (Cunningham and Sigwart, 2019), with studies finding microplastics across nearly all  
51 environmental systems (Güven et al., 2018), as well as in human food and beverages (Cox et  
52 al., 2019; Hernandez et al., 2019). While aquatic systems continue to be the most studied  
53 systems in terms of microplastics, studies in terrestrial systems are limited (de Souza  
54 Machado et al., 2018; Provencher et al., 2019; Rillig and Lehmann, 2020). The implications  
55 of microplastics in the environment, however are not clear, with some studies suggesting  
56 negative impacts to organisms, such as decreased growth rates, increased levels of  
57 contaminants, and deformities (Haegerbaeumer et al., 2019; Jeong and Choi, 2019), while  
58 others find neutral outcomes (Canniff and Hoang, 2018; Foley et al., 2018). This reported  
59 variability highlights the nature of microplastics as a diverse contaminant suite, with a range  
60 of polymers, particle sizes, colors, morphologies, and associated contaminants (Rochman et  
61 al., 2019). Coupled with the fact that microplastics often occur in patchy concentrations with  
62 complex mixtures of particle types, it is currently difficult to determine the ecological risk  
63 presented by microplastics in the environment (VKM et al., 2019). While further research is  
64 undoubtedly required, it is imperative that this research is rigorously reviewed and vetted

65 before publication to ensure reproducibility and applicability in the field, as well as  
66 appropriate interpretation by the non-scientist public.

67         The exponential increase in microplastic research and publications has generated  
68 attention by the media, NGOs, policy and decision makers and the public, leading to a  
69 growing number of strategies and policies to address plastic pollution (Connors et al., 2017).  
70 This has resulted in plastic pollution being recognized as a globally important contaminant by  
71 the United Nations Environment Program (UNEP), as a threat to biodiversity by the  
72 Convention on Biological Diversity (CBD), and as an emerging pollutant by the Arctic  
73 Council (AMAP, 2017; UNEP, 2014). This global recognition of the scale and potential  
74 impacts of plastic pollution is resulting in increased calls for research by regional and  
75 national funding bodies. For example, Canada has recently stated its intentions to create a  
76 regulatory framework for plastics by declaring them to be a toxic substance (ECCC, 2020,  
77 2019). Because of this attention, microplastics research must continue, but evolve to answer  
78 major questions about environmental and toxicological impacts.

79         Early microplastics research focused primarily on its environmental presence,  
80 especially in the marine environment and marine biota. This work was vital to establishing  
81 the extent of contamination and was critical to the foundation of our understanding of  
82 microplastics in the environment. Early microplastics studies could only hypothesize about  
83 the potential impacts of microplastics on environmental health, such as the potential  
84 accumulation of particles in food webs and by concentrating pollutants from the environment  
85 (Cole et al., 2011; Teuten et al., 2007). In some cases, these hypotheses are stated as facts by  
86 both popular media and scientific experts despite a lack of rigorous evidence, such as  
87 microplastic accumulation and magnification in food webs, or conflicting evidence and  
88 ongoing debate, as in the case of the complexities associated with the bioavailability and  
89 toxicity of polymers, monomers, additives, and sorbed chemicals associated with

90 microplastics (Rochman et al., 2019). As the field of microplastics has moved beyond ‘first  
91 time reported’ papers, and further develops while continuing to shape policy, it must also be  
92 improved through more rigorous vetting by researchers, manuscript reviewers and journal  
93 editors.

94         There is a lack of quality assurance and quality control protocols for microplastics in  
95 this developing field (Cowger et al., 2020), but we argue that this also extends into the  
96 statements used by authors in their publications in relation to environmental and human  
97 health risks. This problem has developed due to the lack of a standard framework to ensure  
98 the findings and statements of studies are peer-reviewed in the context of what we know, and  
99 what we can know, rather than past unproven speculation. For example, some peer-reviewed  
100 studies lack field and laboratory blanks needed to identify the occurrence of sample  
101 contamination (VKM et al., 2019). Other studies overstate their conclusions about  
102 widespread presence, absence, or effects of microplastics when their experimental design and  
103 resulting data do not support such interpretations. This has subsequently resulted in  
104 misleading headlines in the press that are accurate based on the language used in the article,  
105 but factually inaccurate relative to the data presented. Examples such as this are detrimental  
106 to the progress and reputation of microplastics research, and can negatively impact the  
107 credibility of the microplastics research field.

108         Our knowledge of environmental impacts is further limited by variation in research  
109 methods and quality of reporting that have been adapted for a variety of research questions,  
110 yet often lack harmonization and comparable outputs (Brander et al., 2011; Hermsen et al.,  
111 2018; Renner et al., 2018). With rapid growth in this field generating a variety of methods, it  
112 is imperative that robust quality assurance/quality control and reporting criteria are included  
113 with each newly published study (Cowger et al., 2020; Dehaut et al., 2019). Microplastic  
114 researchers must continue to explore techniques and tools to quantify microplastics in the

115 environment and answer a range of questions, but as this field evolves the rigor of research  
116 and the manuscript review process must improve with it. This requires that researchers, co-  
117 authors, manuscript reviewers, and editors are aware of the ongoing evolution of this research  
118 field and are also willing to hold each other accountable to the most recent advances that  
119 ensure only scientifically sound research is published. In addition, when editors are not  
120 knowledgeable, editors must ensure that a manuscript is allocated to a knowledgeable person  
121 who is familiar with the current field, can make hold authors to the standards of the field.  
122 Some examples would be requirements for the use of standard nomenclature, method  
123 validation, contamination control, inclusion of standard protocols (if available), thorough  
124 reporting of all methods and techniques used, and clear and explicit discussion of the studies  
125 limitations (Cowger et al., 2020). Importantly, given the public interest, press, and rapid  
126 growth of policies based on published science, authors, peer-reviewers and editors must  
127 ensure that the language, especially in titles and abstracts, accurately reflects the work done,  
128 data generated and the broader literature in this field. Collectively, as a field of researchers,  
129 reviewers, editors, and publishers, we must lift the entire field to ensure that sound science is  
130 available to inform decision makers on plastic pollution policy. This paper provides  
131 recommendations to guide and improve the review and publication process for microplastic  
132 pollution research.

## 133 *2. Words matter*

134 While standardized methodology may not be necessary for the harmonization of  
135 microplastics research, standardization of reporting and terminology is essential. For every  
136 emerging field the development of suitable, common nomenclatures is critical in order to  
137 promote constructive and productive scientific discourse. Clear, accurate, consistent, and  
138 specific language is essential in science. Firstly, for the work to be interpreted correctly by  
139 those in the field who are looking to test the ideas presented and build on the work published

140 (Hartmann et al., 2019). Secondly, for non-expert readers who are trying to expand the work  
141 on microplastics to other biota or compartments. And lastly, for scientific papers to be  
142 interpreted correctly by non-researchers such as policy makers and the media who are often  
143 tasked with summarising complex science findings in only a few lines.

144         There have been many discussions by experts over the last few years about  
145 microplastic terminology relating to size classes (Hartmann et al., 2019) and microplastics  
146 (GESAMP, 2019). Given the legislated definition of microplastics in some regions, and the  
147 ongoing discussion about the size classes, it is imperative when researching microplastics that  
148 manuscripts define microplastics, explicitly stating numeric size classes. This enables the  
149 media, and more importantly researchers, to integrate and synthesize data from a variety of  
150 studies across disciplines and publishing eras - regardless of the terms used for plastic  
151 pollution.

152         As the field currently lacks standardized definitions, studies should clearly define all  
153 terms that they use that could be misinterpreted by readers less familiar with the field.  
154 Recently, there have been calls for applying a more ecotoxicological framework of  
155 terminology when referring to plastic pollution in biota (Provencher et al., 2019). This  
156 includes the difference between the intake (ingestion) of microplastics, and the accumulation  
157 (when ingestion exceeds the rate of excretion) of microplastics. Furthermore, while plastic  
158 pollution has been shown to accumulate in the gastro-intestinal tract of animals, there is little  
159 evidence to date demonstrating that the most commonly measured sizes of microplastics  
160 (>100  $\mu\text{m}$ ) accumulate in the tissues of animals as traditionally defined by ecotoxicology.  
161 Therefore, additional terms or qualifiers may need to be established traditional toxicological  
162 frameworks to account for accumulation in different compartments of the body (Lusher et al.,  
163 2017; Provencher et al., 2019). Synchronization and consistent terminology use are essential  
164 to compiling the most robust data available on microplastics; therefore, authors, editors and



165 reviewers must critically assess manuscript submissions to ensure accurate reporting so that  
166 results can be meaningfully interpreted in the correct context.

167         Most importantly, studies must explicitly report all the details of the methodologies  
168 they have used and clearly present any limitations (Dehaut et al., 2019; Hermsen et al.,  
169 2018). These limitations should also be evident in the titles and abstracts of published studies,  
170 such as the size range and types of particles detected by the study. For example, reporting that  
171 no plastics are found in an organism or habitat is very different from reporting no plastics  
172 over a certain size (i.e. > 50  $\mu\text{m}$  or > 425  $\mu\text{m}$ ). While these differences can be difficult to  
173 state clearly in a title, the abstract of a paper should be as specific as possible so that even  
174 those skimming the abstract do not come away with the wrong conclusions (i.e. Bourdages et  
175 al., 2019). Another avenue that should be taken with caution for microplastics research is the  
176 use of beach survey data, and other data sets collected by volunteers. While we are supportive  
177 of citizen science, and the strength of citizen science has a very strong place in plastic  
178 pollution science, the role of citizen science in microplastic research needs to be critically  
179 considered. The limitations for citizen science need to be recognized as cross-contamination  
180 of samples for microplastics < 1mm is common and occurs easily (Connors et al., 2017;  
181 Hermsen et al., 2018).

182         These issues of language and reporting presented above may seem pedantic, but they  
183 are important to the integrity of the field, and the fast-evolving policies that are drawing on  
184 the published research. Global policy makers are looking to researchers to answer health  
185 related questions regarding microplastics, and we must have reliable data to answer with.  
186 Given that sampling in remote areas, such as the polar regions, is extremely difficult and  
187 repeat sampling may not occur for almost a decade in these regions (i.e. Baak et al., 2020;  
188 Poon et al., 2017; Provencher et al., 2009), it is extra critical that rigorous protocols, reporting  
189 and terminology are used.

190 3. *Quality matters*

191 In a growing field such as that of microplastics, there is a need to balance novelty and  
192 innovation in methodology against accessibility to a wide diversity of traditional and citizen  
193 scientists, and at the same time meet a necessary standard of reporting, reproducibility and  
194 quality of methodology. According to a recent assessment by the Norwegian Scientific  
195 Committee for Food and Environment (VKM et al., 2019), which reviewed the state of  
196 knowledge on microplastics (less than 1mm), in relation to environmental and human health  
197 (n = 171 publications from 33 journals from 2016 to 2018), a large proportion (60%) of the  
198 scientific microplastic papers in the peer-reviewed literature were not of sufficient quality to  
199 include in the data analysis review. A closer look at the data, specifically related to  
200 environmental levels of microplastics revealed that the two most highly cited journals,  
201 *Marine Pollution Bulletin* and *Environmental Pollution*, are also responsible for a large  
202 proportion of the poor quality publications (both journals had over 30% poor quality  
203 publications). Of the 33 journals examined in this review, 12 failed to publish any articles  
204 that received acceptable scores (VKM et al., 2019). None of the top three journals with the  
205 most publications (*Marine Pollution Bulletin*, *Environmental Pollution*, and *Science of the*  
206 *Total Environment*) had any publications that ranked excellent quality condition (VKM et al.,  
207 2019).

208 This indicates that there is widespread publication of poor-quality research in the field  
209 of microplastics. While some of these exclusions may be due to changes in methodologies as  
210 the field has progressed, the number of recent publications excluded, indicate a contemporary  
211 lack of rigorous scientific method and protocols being applied (Fig 1). This lack of quality in  
212 peer-reviewed microplastic publications is leading to the exclusion of many of these papers  
213 from synthesis assessments (VKM et al., 2019), as well as making it difficult to make firm  
214 conclusions based on these assessments. While we recognize that the field is emerging, and

215 harmonization is not always going to be possible, the lack of an increase in excellent papers  
216 in the last few years is concerning (Fig 1). Given the challenges recognized in science with  
217 repeatability and standard reporting it is the synthesis of data from many publications that  
218 are the most useful in making evidence-based decisions (Roche et al., 2019). To ensure that  
219 peer-reviewed publications meet their full potential in contributing to informing our  
220 understanding of microplastics it is critical that microplastic papers are reviewed with a  
221 critical eye to methods, findings and conclusions. We discuss each and how they can be  
222 improved in publications below.

#### 223 *4. Inter-comparability matters*

224 One of the fundamental needs in the study of any environmental contaminant is the  
225 inter-comparability of findings across studies (Cowger et al., 2020). The above examples  
226 highlight the confusion related to this that currently exist in the field of microplastics.  
227 Moving forward, we suggest that these issues can be solved through a better understanding  
228 and application of some key ideas and how they work together, including standardization,  
229 harmonization, validation, and optimization.

230 In general, methods in peer-reviewed publications must first be optimized via  
231 development and fine-tuning to make them as effective as possible for the type of sample at  
232 hand. These methods assist in producing high quality results but require validation in order to  
233 ensure them. For example, methods with KOH have been fine tuned to work with blue  
234 mussels (Thiele et al., 2019). A method can be considered validated when there have been  
235 sufficient QA/QC procedures implemented to ensure the results generated meet predefined  
236 quality criteria. These methods produce high quality data but may be different from other  
237 approaches that have been used in the field. For example, with microplastics, methods are  
238 tested for extraction efficiencies, and recovery of spiked polymers, the impact on polymers,  
239 as well as potential for background contamination (Hurley et al., 2018). Specifically,

240 validation of applied methods must be included in all research outputs. Method validation,  
241 such as extraction efficiencies, must be performed for all studies and include a variety of  
242 microplastic morphologies and polymers reflecting those previously observed in the target  
243 matrix. Variable recovery rates have been reported in the literature (e.g. Hurley et al., 2018;  
244 Jung et al., 2018) which may need to be adjusted for in order to prevent false estimation of  
245 microplastic quantities

246         Once methods have been optimized and validated for specific samples types, the gold  
247 standard for the study of contaminants would generally require standardization.

248 Standardization refers to the application of certain methods according to robust criteria, with  
249 limited flexibility, to allow for comparability between laboratories. This has the significant  
250 limitation of restricting the scientific freedom of method development, but is commonly  
251 applied for standard analytical procedures, such as the International Organization for  
252 Standardization (ISO) and General Laboratory Practices (GLP) ecotoxicological approaches.  
253 While the benefits of standardization are clear, we suggest that in its current state,  
254 microplastics research does not require, and would in fact be hindered by, standardization,  
255 but would rather benefit the most from harmonization.

256         Harmonization occurs when the methods used by different studies have been  
257 rigorously tested to the point that results can be viewed as comparable despite differences in  
258 methodologies. In this sense, harmonization is possible through standardization, but  
259 standardization is not a requirement. For the case of microplastics, methods -optimized and  
260 validated- can be compared to ensure they work the same or in a similar manner in different  
261 institutions so that the outcome can be used together more easily. This means that data can be  
262 generated across institutions using different, but similar, methods. The limitations of each  
263 method are known, comparison coefficients can be defined, and the different activities/data  
264 generated can be combined. Importantly, instead of requiring standard methodology,

265 harmonization includes a diverse suite of investigatory techniques, and for reports to be  
266 comparable a minimum list of reportable metrics (i.e. size, polymer type, etc.) as well as  
267 complete/exact methods reporting must be presented in comparison to other studies.

268         Examples already exist where harmonization rather than standardization has led to  
269 useful information about microplastic contamination of the environment. For example, in the  
270 North Sea, the northern fulmar (*Fulmarus glacialis*), a common seabird, is used as a  
271 biological indicator of plastic pollution levels in the environment (Provencher et al., 2017).  
272 Throughout the North Sea, the Convention for the Protection of the Marine Environment of  
273 the North-East Atlantic (the OSPAR Convention) has a standard protocol for the collection  
274 and examination of fulmars to track trends in environmental plastic pollution (> 1 mm) in the  
275 region (van Franeker et al., 2011). The North Sea protocol is based on beached birds being  
276 examined for ingested plastics pollution (van Franeker et al., 2011). Since the early 2000s,  
277 the protocol has been applied to regions outside of the OSPAR, but often in regions where  
278 beached bird surveys are not possible (Provencher et al., 2017). In regions such as Arctic  
279 Canada, collections depend on local Inuit hunters to collect carcasses from local colonies or  
280 on fishers submitting fulmar incidentally caught in their nets. While the collection methods  
281 are different, researchers in the region have worked with international colleagues to ensure  
282 the methods are harmonized and thus can contribute to reporting standardized data that can be  
283 compared across the northern hemisphere (Provencher et al., 2017). Similar approaches are  
284 now emerging for invertebrates, such as the investigation of 100 sites in the Nordic countries  
285 looking at microplastic presence in bivalves (Bråte et al., 2020).

## 286 *5. Conclusions matter*

287         Alongside the vocabulary of microplastics, there is the terminology of reporting new  
288 information. Wording of titles and conclusions also warrant attention in the developing field  
289 of microplastics where scientific papers are quickly turned into popular science articles. As in

290 all new fields, there are many reports of ‘firsts’ and areas ‘free from ...’. This type of  
291 statement is critically important as policies regarding human health and the impacts of  
292 microplastics are under review. In a field that is emerging in a time where hundreds of  
293 journal articles are released each month, the language of findings should be critically  
294 considered. For example, a recent publication declared the offshore surface waters around  
295 Antarctica “free of floating microplastics” (Kuklinski et al., 2019). Given that the surface  
296 waters of Antarctic consist of thousands of kilometers of ocean encircling the continent and  
297 the study only examined 10 sites, declaring the waters “free” of microplastics is misleading at  
298 best, and ignores findings of microplastics in the Antarctic by other studies documenting  
299 microplastics in the region (Cincinelli et al., 2017; Isobe et al., 2017; Lacerda et al., 2019;  
300 Munari et al., 2017; Reed et al., 2018; Waller et al., 2017). A more critical assessment and  
301 appropriate terminology would have been to state that given the sampling regime, no floating  
302 microplastics were detected using this specific set of techniques and in these locations. While  
303 a single study may not detect microplastics over a certain size as dictated by the methods,  
304 papers that declare species or areas ‘plastic-free’ can be misleading to policy and decision-  
305 makers. It is important to be extremely specific regarding the size range of possible  
306 microplastics are detected or not, as the paper above could have easily missed the smaller end  
307 of the microplastics size spectrum due to their filtration size.

308         Concluding statements in microplastics research should also be examined critically as  
309 many decision-makers and policymakers are asking for science recommendations in real time  
310 - whilst many studies are underway. For example, studies that suggest the use of certain  
311 animals as potential bioindicators for microplastic contamination of the environment, despite  
312 not measuring any microplastics in the environment as a comparison (Garcia-Garin et al.,  
313 2019), studies that report microplastics in the environment or biota but did not use material  
314 verification methods or report identification error rates (i.e. Saley et al., 2019; Villagran et al.,

315 2020), and studies that claim to have found bioaccumulation and biomagnification in  
316 organisms despite a lack of proof according to ecotoxicological standards (Saley et al., 2019).

### 317 *6. Reviews matter*

318 A critical component of the peer-review system are the editors and the reviewers that  
319 dedicate time reviewing manuscripts to ensure accepted manuscripts contain rigorous  
320 research. The review process includes consideration of the most recent literature that relates  
321 to a specific topic. Editors should ensure that reviewers are selected who will understand the  
322 nuance and pace of change in the field of microplastics, and that journals publish only papers  
323 that meet the current standards of the field. This includes seeking reviewers that are active in  
324 the field, have experience in reviewing as well as publishing peer-reviewed research, or can  
325 be supported by someone who is. Reviewers should conduct thorough reviews and provide  
326 feedback to authors on how to improve studies, including pointing to papers that promote  
327 harmonized protocols and reporting guidelines. Given widespread reporting of unprofessional  
328 comments during reviews (Gerwing et al., 2020), we specifically encourage reviewers to  
329 provide critical and constructive reviews, so that authors are encouraged to address comments  
330 to improve manuscripts, rather than feeling discouraged. Additionally, to help editors make  
331 informed decisions about the rigour of submitted manuscripts, reviewers should also include  
332 that information directly in the comments to the editors with references so that the editors can  
333 understand the context of comments based on technical developments in the field. This will  
334 assist editors with publishing decisions while helping authors meet currently accepted rigor  
335 that will improve their papers and citation potential. With the increase in papers in the field of  
336 microplastics research there are many manuscripts being submitted for review, but the quality  
337 of science should not be compromised by shorting the length of the review period. In this  
338 emerging field where outputs are of immediate policy interest, the publication process  
339 remains critical. Therefore, we stress that reviewers must perform rigorous reviews, and

340 expect the same in return from their peers. Taken a step further, editors must also consider  
341 reviewers comments critically, in most cases senior reviewers will have more current  
342 knowledge of the topic than the editor; but this can be clouded by junior less experienced  
343 reviewers.

#### 344 *7. Recommendations for raising the microplastic publication bar*

345 While we recognize the research that has led to the prominence of microplastics  
346 research today, we propose that in order to produce the most robust science for evidence-  
347 based decision-making the level of standards for microplastics must be increased in the peer-  
348 reviewed literature. The following recommendations are provided in the context that they will  
349 improve the field of research and push us all to deliver high quality science on microplastics  
350 which will benefit the field, and the policies derived from the research.

351 I. **Clear protocols, Quality Assurance/Quality Control and**  
352 **methodological limitations recognized** – As discussed above the use of out-dated  
353 methods, lack of quality assured and quality-controlled approaches (or at least  
354 documentation to prove otherwise) are an ongoing challenge in the field. While the  
355 need to tackle each of these methodological constraints are addressed by other studies  
356 (i.e. GESAMP, 2019; Lusher et al., 2017; Provencher et al., 2017), we argue that it is  
357 the responsibility of authors, editors and publishers to improve transparency and the  
358 overall quality of future published studies. Data should be held in an open-access  
359 repository (Cowger et al., 2020). The use of online supplemental material should be  
360 considered for details that are not of immediate relevance to the study but are of  
361 utmost importance for comparing microplastic results to other studies. Where  
362 investigations have been performed prior to the requirement of full QA/QC measures,  
363 researchers must be open and address all limitations. Those investigations shouldn't  
364 be discouraged but should be clearly communicated.



365                   II.           **Critical reviews applied via a reviewer checklist** – As methods and  
366 approaches evolve, researchers must also evolve accordingly, rather than following  
367 the blueprint in an older paper that used methods now considered substandard.  
368 Researchers must work to have an understanding of the key questions within the field,  
369 whether they be ecological, toxicological, or hydrodynamic in nature, and ensure that  
370 their research plays a role in finding answers to these questions. Reviewers must hold  
371 authors accountable to this, and clearly and concretely articulate these concerns to  
372 editors. Editors themselves should be familiar with the state of the literature to not  
373 waste the time of reviewers when papers clearly do not meet current standards. We  
374 propose the use of a microplastics research checklist for authors, editors, and  
375 reviewers to help ensure that the best science possible is being considered and passed  
376 through the peer-review process (Table 1).

377                   III.           **Contextualised hypothesis-driven research questions** – given that  
378 microplastics research has been published in some taxa since the 1960s (in fish and  
379 seabirds), and more broadly since the 2000s (Andrady, 2017; Cole et al., 2011;  
380 Provencher et al., 2017), there is a need for the field as a whole to move towards more  
381 hypothesis driven research that is based on prior findings and within the context of the  
382 larger study system. While exploratory and opportunistic sampling have built a  
383 foundation of microplastics research, there is now a need for hypothesis driven  
384 research to generate a deeper understanding of microplastics as a contaminant, and the  
385 implications for the environment. Thus, every microplastics paper should now be  
386 examined in the context of prior work on microplastics in the region and  
387 environmental compartment, and any paper claiming to be the ‘first report’ should be  
388 carefully considered before publication. Additionally, baseline sections of journals

389 should be expanded in to accommodate studies that report microplastics in the  
390 environment via monitoring programs.

391

## 392 *8. Conclusion*

393 We need to continue to encourage and establish rigorous, tested, validated and robust  
394 data within the field of microplastics. While we need to foster and support exploratory  
395 methods and discovery of techniques and sampling types, because the science on  
396 microplastics is being incorporated in real-time into policy by decision-makers, there needs to  
397 be extra attention in this field to rigorous review of methods and conclusions. No longer can  
398 we publish microplastic papers in silos. We must move microplastics research to the next  
399 level to provide the best available evidence for decision and policy makers.

400 Regardless of the effects, many agree that there are large knowledge gaps in our  
401 understanding of microplastics, and that more research is needed on both the fate and effects  
402 of microplastics. Therefore, the work must be transparent in the reporting, and include  
403 discussions of caveats in the description of the methodologies, so the results are useful to the  
404 field. Only then can the scientific community know how to appropriately assess the results in  
405 each study, and incorporate them into literature review and meta-analyses. When vague terms  
406 are used, methodologies are not reported in detail in the context of other papers in the field,  
407 and bold statements are made using terms like ‘free from plastics’, papers are contributing to  
408 the confusion of both the researchers in the field, as well as to the non-experts who will  
409 interpret results based on the title and abstract of the publication.

410 In conclusion, we suggest that authors, editors and publishers need to turn a more  
411 critical eye to microplastic publications to ensure peer-reviewed publications are producing  
412 the best science possible in this time of rapid policy adoption on this emerging environmental  
413 issue. Microplastic research now receives significant global attention from the media and

414 policymakers, yet lower quality or out of context research has the potential to discredit the  
415 field and limit timely and science-based discussion and mitigation of microplastic  
416 contamination of the environment. Microplastics science has a unique opportunity to directly  
417 inform policies as they are being developed for the first time in many places. Thus, it is  
418 critically important that we balance testing and sharing new ideas with the need for rigorous  
419 standardized methods.

420

## 421 **Acknowledgements**

422 We are very grateful to all researchers who are publishing on microplastics in the  
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425

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617 **TABLES AND FIGURES**

618

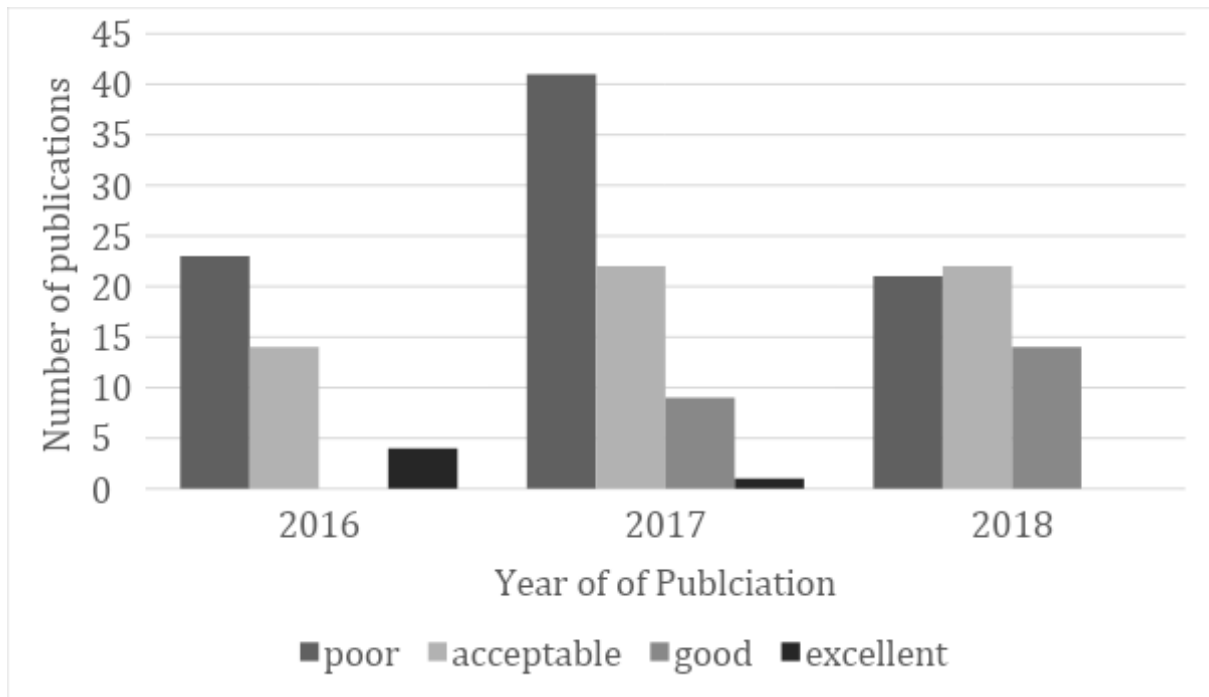
619 Table 1: Critical aspects to address when formulating, reviewing and publishing microplastic  
620 research that should be considered by authors, reviewers and editors.

621

<b>Aspect</b>	<b>Explanation</b>
Main claims	<ul style="list-style-type: none"> <li>- How significant are the claims of the paper?</li> <li>- Does the paper add further information to the understanding of the topic, or are they just another report of occurrence?</li> <li>- Is the chosen journal a suitable option for said claims?</li> <li>- Is this more relevant in a baseline section?</li> <li>- Are first report of microplastics in a species/region considered in context?</li> </ul>
Methodological approach	<ul style="list-style-type: none"> <li>- Are all instruments and materials clearly described with sources of error?</li> <li>- Were methods tested/validated before analysis?</li> <li>- Are the limitations of the approach addressed?</li> <li>- First use of a new technique?</li> <li>- Were replicates used and treated appropriately?</li> </ul>
Quality assurance	<ul style="list-style-type: none"> <li>- Were procedural controls, carried out and treated appropriately?</li> <li>- Were positive controls used to test methods?</li> <li>- How were the field and laboratory blanks dealt with in processing data?</li> <li>- Data adjustments or limits of detection considered?</li> </ul>
Terminology	<ul style="list-style-type: none"> <li>- How are plastic polymers determined?</li> <li>- What size classes are examined and what terminology is used for sizes?</li> <li>- Are microplastics confirmed as polymer or just anthropogenic?</li> </ul>
Detection limits	<ul style="list-style-type: none"> <li>- Are the detection limits clearly defined?</li> <li>- Are the methodological limitations clearly stated in the abstract?</li> </ul>
Reporting	<ul style="list-style-type: none"> <li>- Is data made available?</li> <li>- Is an appropriate analysis carried out?</li> </ul>
Understanding of recent literature	<ul style="list-style-type: none"> <li>- Has enough modern literature been included, or does the manuscript reply heavily on early publications from the research field that are no long state-of-the-art (i.e. protocols which are no longer fit for purpose)?</li> <li>- Are the citations of methods up to date, or explained in the context of why methods are used</li> </ul>
Reviewer expertise	<ul style="list-style-type: none"> <li>- Is the manuscript within your area of expertise?</li> <li>- Do you have enough experience reviewing?</li> <li>- If not, can you work with a mentor to review the manuscript with you and help you develop this skill?</li> </ul>

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625 Figure 1 – Rating of the quality of microplastics (poor, acceptable, good, excellent)

626 publications over a three-year period in peer-reviewed journals (source of data VKM 2019).

627