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Steps Scientists Can Take to Inform Aquatic Microplastics Management: A Perspective Informed by the California Experience

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Abstract

Recent evidence suggests that microplastic particles are pervasive and potentially of great risk to both animal and human health. The California legislature has responded to this information by enacting two new bills that require quantification of microplastics in various media and development of new management strategies to address microplastic pollution. However, there are several scientific gaps that impede the development and implementation of necessary management strategies to address microplastic pollution. In this paper, we use the California experience as a case study to provide perspective on those science gaps, the current barriers to science affecting management, and the actions scientists can take to best ensure their efforts are of greatest value to policymakers and the management community.

Keywords

Microplastics, policy, management, California

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Introduction

As the amount of plastic in the environment has expanded, so has the number of legislative solutions intended to reduce that spread.[1–2] This trend has been very apparent in the State of California, which has enacted several policies to reduce inputs to the environment, including a statewide ban on carry-out plastic bags at grocery stores, a law requiring sit-down restaurants to only distribute single-use plastic straws to customers upon request, and regulations that limit the use of plastic microbeads in personal care products.[3–5] California has placed particular emphasis on protection of the aquatic environment, with the State Water Resources Control Board (SWRCB) adopting a trash policy that requires complete capture of all trash particles >5 mm from stormwater runoff, or demonstration that alternative approaches, such as public education, are as effective as capture control systems.[6] The California Ocean Protection Council (OPC) has incorporated directives into a broader management scheme in their Ocean Litter Prevention Strategy, which was jointly developed with the National Oceanic and Atmospheric Administration's Marine Debris Program.[7] The Ocean Litter Prevention Strategy outlines actions that stakeholders and OPC can take from 2018 through 2024 to prevent and reduce ocean litter in California.

These initiatives are largely focused on plastics larger than 5 mm.[6,7] However, recent evidence suggests that smaller plastic particles are pervasive and potentially of great risk to both animal and human health.[8,9] Microplastics are found in remote environments that are considered "pristine", suggesting more widespread exposure than previously understood.[10–12]

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Table 1. Requirements of recent California microplastics legislation.

Senate Bill 1422: California Safe Drinking Water Act – Microplastics
Senate Bill 1422 (Portantino, Chapter 902, California Statutes of 2018) charges the SWRCB with developing a monitoring strategy for determining microplastics concentration in drinking water, including:
Adopt a definition of microplastics in drinking water by July 2020
Adopt a standard methodology to test drinking water for microplastics by July 2021
Adopt requirements for four years of testing and public reporting of microplastics in drinking water
If appropriate, consider issuing a notification level or other guidance to aid consumer interpretations of the testing results
Accredit laboratories to analyze microplastics
Senate Bill 1263: Ocean Protection Council – Statewide Microplastics Strategy
Senate Bill 1263 (Portantino, Chapter 609, California Statutes of 2018) requires OPC to adopt a Statewide Microplastics Strategy and report to the legislature on implementation by 2025. The bill also requires OPC to develop a prioritized research plan to support the development of risk assessments in marine habitat types by 2021, including:
Develop standardized methodologies for sampling, detecting, and characterizing microplastics in the environment
Characterize ambient concentrations, effects, and sources and pathways of microplastics
Develop approaches to reduce the introduction of microplastics into the marine environment, including source control

The California legislature has responded by enacting two new bills (Table 1) that require quantification of microplastics in various aquatic media and development of new management strategies. Still, there are a number of scientific gaps that impede the development and implementation of responsive policies. Here, we use the California experience as a case study to provide perspective on those scientific gaps, the current barriers to science affecting management, and the actions scientists can take to best ensure their efforts are of greatest value to policymakers and the management community.

Science has the potential to inform both policymakers and managers, but we concentrate here on the connection to managers. Policymakers, such as legislators and gubernatorially appointed agency leaders, focus on determining which issues to prioritize. In California, the recent legislative actions have already defined policy directions for microplastics, and the baton has been passed to managers who must now implement actions necessary to achieve those directives. Legislators have great interest in ensuring that there are measurement programs that characterize risk, but less interest in determining the specific techniques used to achieve that end. In contrast, managers have greater immediate need to interact with scientists to ensure validity and effectiveness of their actions to implement policy directives.

Research Gaps

Both California bills require significant scientific advances in the field of microplastics within a limited timeframe. These science needs fall into three broad categories. The first is development of standardized measurement methods, following the adage that, "you cannot manage what you cannot measure". Management strategy development requires monitoring to assess the relative contributions of multiple sources and assess the progress toward source reduction, a framework that is currently being tested in major urban areas around the world, such as San Francisco, USA,[13] Melbourne, Australia,[14] and Toronto, Canada.[15] Such assessments are of little value if they are confounded by incomparability of measurements among matrices or over time, a problem that has hampered management efforts for the environment (e.g., Great Lakes, USA)[16] and drinking water (e.g., Denmark).[17] Also, placing results from regional studies into context of other geographies is important, but only if analysis methods used across geographies are consistent enough to warrant such comparisons.[18] A principal hindrance in the comparability of measurements is the lack of standardization for microplastics sampling and analysis methods,[19] and, until recently, the lack of quality standards for reporting measurement data.[20,21]

A few studies have been conducted to compare results among measurement methods.[22–26] In addition, several groups, including the Japanese Ministry of the Environment on behalf of an international consortium, have published standardized methods.[27,28] However, those efforts have been focused on single or limited media, such as seafood or the water column, or have focused on only a subset of required standardization activities, such as field collection methods, microplastics extraction, or measurement technology. The recent changes in California law (Table 1) create a need to build on this work and develop standardized methods for the entirety of the monitoring process, including sampling, extraction, detection, and characterization of microplastics.

The second science need is application of the methods to characterize the problem, such as source attribution, spatial distribution, and trends both within and outside areas where management actions have been implemented. Method standardization is an important part of meeting that need, but another part of the characterization challenge is defining thresholds. Scientists have made great progress on elucidating the ubiquitous nature of microplastic pollution,[29] but foundational epidemiological and toxicological questions remain, including at what point microplastic concentrations become harmful, rather than just a nuisance.[30,31] A large majority of studies testing toxicological effects of microplastics suffer from lack of test method standardization, making them less reproducible and therefore less reliable.[32–34] This problem has, in large part, occurred due to a lack of guidance on quality assurance and quality control practices for toxicological effects studies, a problem which has only recently been significantly addressed.[34]

The third science need is developing science-based solutions. There are a number of possible managerial or policy directions that could be considered, including: reduction of source material inputs, which is currently being pursued for intentionally, and unintentionally added microplastics in the European Union;[35,36] or ways to remove materials from the ambient environment, such as floating interception technologies,[37] which are being implemented around the world, such as in Jamaica, Indonesia, and Los Angeles, California,[38,39] or more novel, bio-based approaches such as remediation using clams[40] or fungi[41] techniques which have not been applied at scale and for which additional research is needed to understand effectiveness.[42] Even within a broad category such as source reduction, there are multiple available strategies such as removal at the source, removal in the conveyance system, or even limitations at the producer level that would affect the chemical nature of the source material. Selection among such strategies requires a firmer understanding of which chemical classes and size groups present the greatest environmental risk and which strategies are most appropriate to those risk groups.

Barriers to Overcome

As scientists work to help fill these needs, it is important to recognize what divides scientists and managers. First, managers often overestimate the speed with which scientists can answer questions and may be pressured to act before the necessary science is available. Most managers have little appreciation of the complexities of microplastic characterization methods, the continual challenges posed by sample contamination,[43] and the high costs and extensive skill required for the methods that exist.[44] Thus, there is a burden on scientists to help managers understand that developing standardized methods requires much investigation into how the intricacies of method permutations affect results.

Similarly, managers may not be cognizant of the need for more science investment to address the public and environmental health impacts. The extent to which microplastics findings have been extensively reported on in the popular press[45] belies the poor underlying state of science and creates false expectations for both policymakers and managers. Policymakers and managers want to take the steps necessary to protect public health, wildlife, and inhabitats from microplastic pollution as soon as they can, but must be made aware of the state of the science in the face of demand for action.

On the scientist's end, the most prominent need is an appreciation for the value of scientific consensus. Managers are hesitant to implement programs around a shifting scientific landscape or where there are competing approaches. Developing management initiatives is a challenging process, and managers want to see overarching agreement within the scientific community on a topic before developing their directions. As such, they are less likely to take action on a single scientific manuscript, particularly one reflecting the thoughts of a small number of researchers, no matter how groundbreaking the work. Scientists must work collaboratively toward an agreed endpoint, as managers are generally not interested in choosing among differing scientific viewpoints. Additionally, they must provide understandable and easily accessible information that managers can use to answer policy-relevant questions; synthesis documents such as recent reports from the World Health Organization[31] and Canadian government[46] are particularly useful.

Another necessary recognition is that the goal is not to create approaches that are achievable only by the most proficient experts, but approaches that are transferable and repeatable among a wide array of laboratories, some of which will be introduced to microplastics for the first time as a result of legislation. The needs from a management perspective can differ from that of an academic; academic experts might be satisfied with harmonized methods, but standardized methods are an essential requirement for labs processing samples in a regulatory context. Finally, methods must be detailed enough so that managers can establish expectations from an Environmental Laboratory Accreditation Program that ensures the generation of environmental and public health data are of known, consistent, and documented quality.

Once a clear understanding of the sources, pathways, and effective mitigation strategies for plastic into the environment are established, successful intervention strategies are contingent on the establishment of holistic, multinational approaches due to the nuanced multidimensionality of the problem,[47,48] and the global scale of the environmental threat.[49] Such a multinational management framework is being implemented in the European Union, in which a transnational policy is enforced at local and regional scales, ensuring action is understood and supported in the public domain.[50] In West Africa, 12 out of 16 countries have instituted single-use plastic reduction policies (bans); however, coordination is not as effective as in Europe.[51] In multinational, and even single states, seamless integration between multiple agencies is critical to providing a successful catchment-to-coast management framework.[52]

While these challenges are real, California presents an ideal opportunity for scientific-management exchange. California policymakers and managers recognize the value of science to inform effective management strategies. The state's legislative demand for science products creates an opportunity for scientists to contribute their work to directly inform management of microplastic pollution and subsequent future policy development.

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References

1. C.S. Lam, S. Ramanathan, M. Carbery, et al. "A Comprehensive Analysis of Plastics and Microplastic Legislation Worldwide". Water Air Soil Pollut. 2018. 229(11): 345.
2. D. Xanthos, T.R. Walker. "International Policies to Reduce Plastic Marine Pollution from Single-Use Plastics (Plastic Bags and Microbeads): A Review". Mar. Pollut. Bull. 2017. 118(1–2): 17–26.
3. A. Padilla, K. de Leon, R. Lara, et al. "SB-270 Solid Waste: Single-Use Carryout Bags". https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201320140SB270 [accessed June 26 2020].
4. I. Calderon, R. Bloom. "AB-1884 Food Facilities: Single-Use Plastic Straws". https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB1884 [accessed June 26 2020].
5. R. Bloom. "AB-888 Waste Management: Plastic Microbeads". https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB888 [accessed June 26 2020].
6. State Water Resources Control Board Ocean Standards Unit. "Water Quality Control Plan: Ocean Waters of California". 2015. https://www.waterboards.ca.gov/water_issues/programs/ocean/docs/cop2015.pdf [accessed June 19 2019].
7. California Ocean Protection Council and National Oceanic and Atmospheric Administration Marine Debris Program. "California Ocean Litter Prevention Strategy: Addressing Marine Debris from Source to Sea". 2018. http://www.opc.ca.gov/webmaster/_media_library/2018/06/2018_CA_OceanLitterStrategy.pdf [accessed June 19 2019].
8. R. Lehner, C. Weder, A. Petri-Fink, et al. "Emergence of Nanoplastic in the Environment and Possible Impact on Human Health". Environ. Sci. Technol. 2019. 53(4): 1748–1765.
9. E. Besseling, P. Redondo-Hasselerharm, E.M. Foekema, et al. "Quantifying Ecological Risks of Aquatic Micro- and Nanoplastic". Crit. Rev. Environ. Sci. Technol. 2019. 49(1): 32–80.
10. S. Allen, D. Allen, V.R. Phoenix, et al. "Atmospheric Transport and Deposition of Microplastics in a Remote Mountain Catchment". Nat. Geosci. 2019. 12(5): 339–344.
11. I. Peeken, S. Primpke, B. Beyer, et al. "Arctic Sea Ice is an Important Temporal Sink and Means of Transport for Microplastic". Nat. Commun. 2018. 9: 1505.
12. C.L. Waller, H.J. Griffiths, C.M. Waluda, et al. "Microplastics in the Antarctic Marine System: An Emerging Area of Research". Sci. Total Environ. 2017. 598(15): 220–227.
13. R. Sutton, D. Lin, M. Sedlak, et al. Understanding Microplastic Levels, Pathways, and Transport in the San Francisco Bay Region. Richmond, CA: San Francisco Estuary Institute, 2019.
14. L. Su, S.M. Sharp, V.J. Pettigrove, et al. "Superimposed Microplastic Pollution in a Coastal Metropolis". Water Res. 2020. 168: 115140.
15. J. Grbić, P. Helm, S. Athey, et al. "Microplastics Entering Northwestern Lake Ontario are Diverse and Linked to Urban Sources". Water Res. 2020. 174: 115623.
16. M.R. Twiss. "Standardized Methods are Required to Assess and Manage Microplastic Contamination of the Great Lakes System". J. Great Lakes Res. 2016. 42(5): 921–925.
17. H. Løkkegaard, S. Woldum Tordrup, M. Køcks, et al. "Partnerskab om mikroplast I spildevand [Partnership on Microplastics in Wastewater]". Environmental Protection Agency, Odense, Denmark. 2017. https://mst.dk/media/143341/partnerskab-om-mikroplast-i-spildevand-2017.pdf [accessed June 8 2020].
18. C.M. Rochman, F. Regan, R.C. Thompson. "On the Harmonization of Methods for Measuring the Occurrence, Fate, and Effects of Microplastics". Anal. Methods. 2017. 2017(9): 1324–1325.
19. F. Barbosa, J.A. Adeyemi, M.Z. Bocato, et al. "A Critical Viewpoint on Current Issues, Limitations, and Future Research Needs on Micro- and Nanoplastic Studies: From the Detection to the Toxicological Assessment". Environ. Res. 2020. 182: 109089.
20. W. Cowger, A. Booth, B. Hamilton, et al. "Reporting Guidelines to Increase the Reproducibility and Comparability of Research on Microplastics". Appl Spectrosc. 74(9): 1066–1077.
21. A.A. Koelmans, N.H. Mohamed Nor, E. Hermsen, et al. "Microplastics in Freshwaters and Drinking Water: Critical Review and Assessment of Data Quality". Water Res. 2019. 155: 410–422.
22. J.F. Cadiou, O. Gerigny, Š. Koren, et al. "Lessons Learned from an Intercalibration Exercise on the Quantification and Characterisation of Microplastic Particles in Sediment and Water Samples". Mar. Pollut. Bull. 2020. 154: 111097.
23. A.P. Barrows, C.A. Neumann, M.L. Berger, et al. "Grab vs. Neuston Tow Net: A Microplastic Sampling Performance Comparison and Possible Advances in the Field". Anal. Methods. 2017. 9(9): 1446–1453.
24. M. Lares, M.C. Ncibi, M. Sillanpää, et al. "Intercomparison Study on Commonly Used Methods to Determine Microplastics in Wastewater and Sludge Samples". Environ. Sci. Pollut. R. 2019. 26(12): 12109–12122.
25. O. Setälä, K. Magnusson, M. Lehtiniemi, et al. "Distribution and Abundance of Surface Water Microlitter in the Baltic Sea: A Comparison of Two Sampling Methods". Mar. Pollut. Bull. 2016. 110(1): 177–183.
26. Y.K. Song, S.H. Hong, M. Jang, et al. "A Comparison of Microscopic and Spectroscopic Identification Methods for Analysis of Microplastics in Environmental Samples". Mar. Pollut. Bull. 2015. 93(1–2): 202–209.
27. Y. Michida et al. "Guidelines for Harmonizing Ocean Surface Microplastic Monitoring Methods. Ministry of the Environment Japan". 2020. http://www.env.go.jp/en/water/marine_litter/guidelines/guidelines.pdf [accessed June 26 2020].
28. A. Dehaut, A.L. Cassone, L. Frere, et al. "Microplastics in Seafood: Benchmark Protocol for their Extraction and Characterization". Environ. Pollut. 2016. 215: 223–233.
29. Z. Akdogan, B. Guven. "Microplastics in the Environment: A Critical Review of Current Understanding and Identification of Future Research Needs". Environ. Pollut. 2019. 254(Pt. A): 113011.
30. K. Bucci, M. Tulio, C. Rochman. "What is Known and Unknown About the Effects of Plastic Pollution: A Meta-Analysis and Systematic Review". Ecol. Appl. 2020. 30(2): e02044.
31. World Health Organization (WHO). "Microplastics in Drinking-Water". 2019. http://edepot.wur.nl/498693 [accessed December 16 2019].
32. J.D. O'Connor, A.M. Mahon, A.F.R.M. Ramsperger, et al. "Microplastics in Freshwater Biota: A Critical Review of Isolation, Characterization, and Assessment Methods". Global Challenges. 2020. 4(6): 1800118.
33. European Center for Ecotoxicology and Toxicology of Chemicals. "An Evaluation of the Challenges and Limitations Associated with Aquatic Toxicity and Bioaccumulation Studies for Sparingly Soluble and Manufactured Particulate Substances". Technical Report No. 132. 2018. http://www.ecetoc.org/wp-content/uploads/2018/12/ECETOC-TF-132-Aq-tox-particulates.pdf [accessed June 9 2020].

34. V.N. De Ruijter, P.E. Redondo-Hasselerharm, T. Gouin, et al. "Quality Criteria for Microplastic Effect Studies in the Context of Risk Assessment: A Critical Review". Environ. Sci. 52(18): 10230–10240.
35. European Chemicals Agency. "Annex XV Restriction Report Proposal for a Restriction: intentionally added microplastics. Version 1.2. (Proposal 1.2)". 2019. https://echa.europa.eu/documents/10162/05bd96e3-b969-0a7c-c6d0-441182893720 [accessed January 2 2020].
36. S. Hann, C. Sherrington, O. Jamieson, et al. "Investigating Options for Reducing Releases in the Aquatic Environment of Microplastics Emitted by (but Not Intentionally Added in) Products". 2018. https://www.eunomia.co.uk/reports-tools/investigating-options-for-reducing-releases-in-the-aquatic-environment-of-microplastics-emitted-by-products/ [accessed June 26 2020].
37. B. Dommergues, R. Brambini, R. Mettler, et al. "Hydrodynamics and Capture Efficiency of Plastic Cleanup Booms: Part II—2D Vertical Capture Efficiency and CFD Validation". Presented at: ASME 2017 36th International Conference on Ocean, Offshore and Arctic Engineering, American Society of Mechanical Engineers Digital Collection. 2017.
38. The Ocean Cleanup. "The Ocean Cleanup Unveils Plan to Address The Main Source of Ocean Plastic Pollution: Rivers". Press Release. 2019. https://theoceancleanup.com/press/press-releases/the-ocean-cleanup-unveils-plan-to-address-the-main-source-of-ocean-plastic-pollution-rivers/ [accessed June 9 2020].
39. The Ocean Cleanup. "The Ocean Cleanup Wins $1M Award from Benioff Ocean Initiative to Combat River Plastic Waste in Jamaica". Press Release. 2020. https://theoceancleanup.com/press/press-releases/the-ocean-cleanup-wins-1m-award-from-benioff-ocean-initative-to-combat-river-plastic-waste-in-jamaica/ [accessed June 9 2020].
40. S. Arossa, C. Martin, S. Rossbach, et al. "Microplastic Removal by Red Sea Giant Clam (*Tridacna maxima*)". Environ. Pollut. 2019. 252(Pt. B): 1257–1266.
41. C. Sánchez. "Fungal Potential for the Degradation of Petroleum-Based Polymers: An Overview of Macro- and Microplastics Biodegradation". Biotechnol. Adv. 2020. 40: 107501.
42. M. Padervand, E. Lichtfouse, D. Robert, et al. "Removal of Microplastics from the Environment. A Review". Environ Chem Lett. 2020. 18(3): 807–828.
43. C. Scopetani, M. Esterhuizen-Londt, D. Chelazzi, et al. "Self-Contamination from Clothing in Microplastics Research". Ecotoxicol. Environ. Saf. 2020. 189: 110036.
44. S. Primpke, S.H. Christiansen, W. Cowger, et al. "Critical Assessment of Analytical Methods for the Harmonized and Cost-Efficient Analysis of Microplastics". Appl Spectrosc. 2020. 74(9): 1012–1047.
45. C. Völker, J. Kramm, M. Wagner. "On the Creation of Risk: Framing of Microplastics Risks in Science and Media". Global Challenges. 2020. 4(6): 1900010.
46. Environment and Climate Change Canada, Health Canada. "Draft Science Assessment of Plastic Pollution". 2020. https://www.canada.ca/content/dam/eccc/documents/pdf/pded/plastic-pollution/Science%20Assessment%20Plastic%20Pollution.pdf [accessed June 26 2020].
47. J. Vince, B.D. Hardesty. "Governance Solutions to the Tragedy of the Commons that Marine Plastics Have Become". Front. Mar. Sci. 2018. 5: 214.
48. United Nations Environment. "Combating Marine Plastic Litter and Microplastics: An Assessment of the Effectiveness of Relevant International, Regional and Subregional Governance Strategies and Approaches". 2017. https://papersmart.unon.org/resolution/uploads/unep_aheg_2018_inf3_full_assessment_en.pdf [accessed June 26 2020].
49. P. Villarrubia-Gómez, S.E. Cornell, J. Fabres. "Marine Plastic Pollution as a Planetary Boundary Threat: The Drifting Piece in the Sustainability Puzzle". Mar. Policy. 2018. 96: 213–220.
50. J.E. Black, K. Kopke, C. O'Mahony. "A Trip Upstream to Mitigate Marine Plastic Pollution: A Perspective Focused on the MSFD and WFD". Front. Mar. Sci. 2019. 6: 689.
51. I. Adam, T.R. Walker, J.C. Bezerra, et al. "Policies to Reduce Single-Use Plastic Marine Pollution in West Africa". Mar. Policy. 2020. 116: 103928.
52. Á. Borja, M. Elliott, J. Carstensen, et al. "Marine Management–Towards an Integrated Implementation of the European Marine Strategy Framework and the Water Framework Directives". Mar. Pollut. Bull. 2010. 60(12): 2175–2186.