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Stakeholder Perceptions of Microplastics Management in Oregon

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THESIS:

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Abstract

There is currently no federal policy in the United States that specifically addresses microplastics (MPs) pollution. However, states are beginning to act on this issue; California's SB 1422 initiates measurement of MPs in drinking water resources and Senate Bill 1263 requires the state to adopt a strategy to reduce the ecological impact of MPs in marine ecosystems. Other West Coast states like Oregon and Washington are expected to follow California's example. It is important to know what the actors who are a part of shaping MPs policy in Oregon would see as barriers and opportunities to doing so. We conducted semi-structured interviews with a group of stakeholders in Oregon with interests in microplastic pollution and evaluated baseline attitudes towards management. This provides our community partner, Ocean Conservancy, with detailed information on the landscape and priorities for managing MPs pollution in Oregon. Discerning what challenges and data gaps there are to addressing pollution reduction will inform future endeavors to manage MPs in Oregon waterways.

Acknowledgements

This project and paper would not be possible without the help of each of my committee members. A huge thanks to Dr. Sarah Carvill, Dr. Elise Granek, and Dr. Britta Baechler for their guidance and mentorship throughout the project. I would also like to thank the Applied Coastal Ecology Lab, and particularly Summer Traylor, my project partner, for their support throughout the project. Finally, I'd like to thank the Nielsen-Pincus & Carvill Lab for their support as well.

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1. Introduction

Microplastics (MPs) are a contaminant in marine ecosystems for which there is a lack of standardized management protocol in the United States. Microplastics are defined as a polymer material with chemical additives that is between 0.001 and 5000 micrometers in dimensions (State Water Resources Control Board, 2020). Concern has grown not only about effects of microplastics on the environment, but also for their potential to affect human health. Microplastics have been found in seafood products available for consumption along the West Coast (Rochman et al., 2015), and in oysters and razor clams collected on the Oregon Coast (Baechler et al., 2019). In other studies, fish and fish larvae ingesting microplastics have been shown to experience toxicity, reduced growth rates, and increased mortality (Pannetier et al., 2020). A study on rats found that MP exposure was associated with defective ovarian function (Haddadi et al., 2022). A study on microplastic exposure in mice showed evidence of potential gut toxicity from MPs, which suggests they may be toxic to humans as well (Deng et al., 2020). While the long-term human health effects of MPs are largely unknown, we do know that they can end up in tissues in the body, including the lungs and even in the blood stream (Campanale et al., 2020, Amato-Lourenco et al., 2021, Leslie et al., 2022), and given the negative health effects on test organisms, there is concern that similar effects may ultimately be found to occur in humans.

The main sources of marine microplastic pollution include but are not limited to large plastic litter, cleaning products, tire wear particles, medicines, and textiles (Browne, 2015). Fragmentation is one pathway by which plastic litter enters ecosystems. Large pieces of plastic debris degrade into smaller pieces from photolysis (i.e., sun exposure), biological degradation (i.e., bacteria), or physical abrasion (i.e., wave action). Microplastics can also enter the environment through wastewater. Personal care products such as toothpastes and facewashes can contain small abrasive plastic pieces called microbeads, which wash off into municipal wastewater after use. Similarly, medicine capsules are often made of plastics that may not degrade during metabolism and are excreted from humans and animals or washed down drains to wastewater (Browne, 2015). Sewage and wastewater contain synthetic microfibers from the washing of clothes and textiles that many sewage treatment plants are not equipped to effectively remove (Browne et al., 2011).

Despite the growing body of knowledge on MPs, there has been very little legislation to target this suite of pollutants. At the federal level, the Microbead Free Waters Act is the only adopted microplastics related legislation. There have been many bans on specific single-use plastic items in states and municipalities (State Plastic Bag Legislation, 2021), but this captures only one pathway by which microplastics enter the environment. In 2018, California became the first state to pass legislation that aims to address MPs specifically and comprehensively. Since Pacific Coast states often collaborate and set an example for one another on marine issues, Oregon and Washington are expected to follow suit in the next several years to address MP pollution[1]. West Coast states have a history of aligning their approaches and coordinating to address issues that they have in common, such as ocean health (West Coast Governors' Alliance on Ocean Health).

However, Oregon differs from California in many important respects, and it is not necessarily the case that policies adopted and implemented in California will be supported or effective in Oregon. The purpose of this project is to understand the landscape for managing microplastics in Oregon. To do this, we conducted semi-structured interviews with microplastics stakeholders to understand their baseline attitudes toward the issue, and specifically the priorities, concerns, and barriers to addressing MPs in Oregon.

1.1. U.S. Plastic Policy

Only one statute specifically targeting microplastics at the federal level exists, the US Microbead-Free Waters Act of 2015. This limits the use of microbeads in personal care products, but these are not contributing a significant amount to marine plastic pollution and make up only 0.1-4.1% of MP entering marine habitats (McDevitt et al., 2017).

Congress has made some attempts to address the problem comprehensively, most notably the Break Free from Plastic Pollution Act (BFFPPA) of 2020, but this bill failed to pass. The BFFPPA, which was reintroduced in March 2021, would 1) set requirements for plastic

[1] While this is not documented in literature, it has been anecdotally referenced over the course of my project as a commonly observed phenomenon in the environmental field on the West Coast. An example of this is the West Coast Governors Alliance on Ocean Health, which is a regional collaboration between the Governors of California, Oregon, and Washington to advance goals relating to coastal and ocean protection and enhancement (West Coast Ocean Alliance). Another example is the West Coast Ocean Acidification and Hypoxia Science Panel, which was a scientific collaboration between Oregon, Washington, California, and British Columbia that assessed actions to address OAH threats across the entire region (Chan et al., 2016).

producers to be responsible for the collection and recycling of the products after consumer use; 2) begin to phase out single use plastic items; 3) require plastic items to meet a minimum required content of recycled material; 4) set a temporary moratorium on new plastic production; and 5) set limitations on export of plastic waste to other countries and guidelines for recycling and compost receptacles to make them more usable to the general public (Lowenthal, 2020). This is a comprehensive approach to plastics management, and it incorporates and extended producer responsibility framework, meaning that it would incentivize plastics producers to manage their products from cradle to grave. Because of these features, it is regarded as an effective method to address sources of plastic pollution (Eastwood et al., 2020), and although the bill passed the House of Representatives, it failed to pass the Senate when originally introduced. After being re-introduced in 2021, it was referred to a subcomittee on Environment and Climate Change and has yet to pass in either chamber.

A national level policy that aims to reduce plastic waste could be useful in facilitating national reductions, however state level management has advantages too. State level management can address state-specific issues and is also often quicker to implement than federal regulations. In addition, states can provide innovative and unique solutions to issues in the absence of federal policy (Fiorino and Weted, 2021). Innovative, state-level ideas can later be adopted by other states and eventually push national standards to be stronger (Vogel, 1999).

Existing state-level legislative efforts to address plastics pollution can be divided into two categories: bans targeted at specific, single-use plastic items (e.g., straws and bags) and targeted MPs legislation. Many states have banned the use of single-use plastic bags, starting with California, and now including Connecticut, Delaware, Hawaii, Maine, New York, Oregon, and Vermont. Many other states (see Appendix 2) have local bans or fees on single-use plastic bags and other single use items like carryout containers, Styrofoam, and straws. However, seventeen states (see Appendix 2) have made it illegal to ban single-use plastics, in other words banning the ban on plastics (Gibbens, S. Nat Geo, 2019)[2]. Bans on single use plastic products do not address

[2] The lobbying of the fossil fuel industry has driven the banning of plastics bans, since the fossil fuel industry also benefits from the production of plastic because most plastics are made from petroleum (Gibbens, S. Nat Geo, 2019). Over 99% of plastics are made with chemicals derived from fossil fuels, and in addition many gas companies also own plastic producing companies (*Fueling Plastics*, 2017). Companies like DowDuPont, ExxonMobil, Shell, Chevron, BP, and Sinopec are integrated companies that produce fossil fuel as well as plastics (*Fueling Plastics*,

the major sources of MPs pollution. Significant sources for MPs include macroplastics that are found in freshwater and marine environments (e.g., fishing gear), as well as tire wear particles shed from tires and delivered from roads via runoff and aerial deposition, microfibers from synthetic clothes and other textile washing, and plastics manufactured in small particles, such as nurdles (Boucher & Friot, 2017). Source-focused legislation for MPs would likely take these delivery pathways into account and address the information needs associated with emerging contaminants that are difficult to measure and whose sources and effects are not well understood.

The only U.S. example of a MP-specific, state-level policy are the two bills passed by the state of California in 2018. California's Senate Bill 1422 initiates the preliminary measurement of MPs in drinking water sources. The state set a standardized measurement technique in late 2021 (California Safe Drinking Water Act: microplastics, Senate Bill-1422, 2017-2018). The other bill (SB 1263) requires the state to adopt a strategy to reduce the ecological impact of MPs in marine ecosystems. In response to California acting on certain environmental management issues, other West Coast states like Oregon and Washington are likely to follow California's lead. While neither bill removes MPs from state waters nor prevents MPs from entering the water in the first place, they are a step towards understanding the current levels so that future action can be taken to address the contaminant. California's efforts can serve as a jumping off point for other states that may wish to classify microplastics as a contaminant and develop their own regulation framework as they do not have to invest as much time developing a definition and standardized measurement system.

Oregon currently bans some common single-use plastics and is considering further action of this type. In 2019, the state legislature passed a bill prohibiting retailers from providing single use checkout bags to customers (Oregon HB 2509, 2019). Another 2019 bill made it illegal for restaurants and other food and beverage providers to distribute single-use plastic straws unless they are specifically requested by customers (Oregon SB 90, 2019). The state considered legislation that would have prohibited the use of polystyrene (Styrofoam) for food (HB 2883), but this failed to pass on the Senate floor. Another bill under consideration prohibits construction, expansion, or modification of chemical recycling facilities (HB 2811), which could

2017). These special interest groups fuel support for the bans on plastics bans and lobby to keep single-use plastics available.

be used to "recycle" plastics using methods that are environmentally harmful (e.g., incineration). Similar to plastic bag and straw bans, these reduce the use of some plastic products but do not address the major sources of MPs pollution. Oregon also recently passed the Plastic Pollution and Recycling Modernization Act (Senate Bill 582), which was signed in 2021 and is being implemented via a task force that will update Oregon's outdated recycling system[3] (Oregon Senate Bill 582, 2021). Within Oregon, there are also city bans on polystyrene, for example in Portland (City of Portland, Title 17 Public Improvements 2019). Although these bills are important to reducing waste from persistent plastic products, they target plastic products that are only singular sources of pollution and neither focus specifically on MPs pollution.

1.2. Relevant Oregon Regulatory Frameworks

The Oregon DEQ is responsible for regulation of toxic material and water quality in Oregon. Since this agency has jurisdiction over other contaminants, it may be the most obvious agency to have jurisdiction over MPs in the future. The DEQ has programs to manage water quality, including the National Pollutant Discharge Elimination System (NPDES) permitting program, which implements the Clean Water Act by regulating discharges into water bodies (Water Quality Permitting Program Review). DEQ is also responsible for approval of solid waste disposal methods, and under SB 582 is also required to review coordination plans for producer responsibility organizations and determine if recycling goals have been met (SB 582).

In addition, DEQ is responsible for overseeing safety of water resources for drinking water, recreation, agriculture, and fish health (Water Quality Monitoring, DEQ). A key regulatory framework for controlling pollutants from both point source and non-point sources in the water are Total Maximum Daily Loads (TMDLs), required under the federal Clean Water Act and implemented by DEQ. Regularly monitored water bodies are assessed to determine whether they are impaired, specifically if the contaminant impairs the beneficial uses of fisheries, aquatic life, drinking water, recreation, and irrigation. If it does, a TMDL must be established to determine the total amount of the pollutant that can be present in the waterbody at any given time and meet water quality standards (Oregon Department of Environmental Quality, 2001). These

[3] SB 582 will include a 'Truth in Labeling Task Force' that aims to make recycling easier for the public by evaluating misleading and confusing labelling on packaging products. The bill will also expand access to recycling services and upgrade the facilities for sorting of recyclables. This will include plastics manufacturers being held financially responsible for recycling improvements (SB 582).

set load allocations by water body for each designated pollutant and provide a basis for subsequent monitoring conducted by the DEQ to ensure that pollution limits are being met (DEQ Water Quality Monitoring Strategy, 2021). For example, there are TMDLs for increased water temperature and pH levels that require monitoring and reduction of impairment to certain levels.

Oregon Health Authority (OHA) would likely be another state agency to have jurisdiction to address MPs given their responsibility for drinking water standards. OHA's Drinking Water Services division is responsible for enforcement of drinking water quality standards that comply with the state and federal standards. This includes microbial and inorganic contaminants, organic chemicals, and radiological contaminants. The OHA sets standards and requires samples from water suppliers for contaminants and chemicals (Oregon Drinking Water Quality Standards, 1998).

Another state agency with a potential role in addressing MPs in Oregon is the Department of Fish and Wildlife (ODFW), which has jurisdiction to clean up waste that washes up on state beaches. ODFW is also responsible for the management of commercially fished species in state waters. In addition, Oregon Watershed Enhancement Board (OWEB) funds projects to conduct research and implement solutions to protect and restore healthy watersheds. For example, a research project relating to MPs could be funded by them to study microplastics in a specific watershed and investigate sources or reduction methods.

Given these existing management frameworks in Oregon and the potential for them to be applied to MPs pollution, there are a variety of possibilities for which agencies might be drawn into MPs management due to their existing mandates. There are by extension a variety of different regulatory and non-regulatory tools that can be leveraged to address MPs. A comprehensive MPs strategy might draw on any number of these tools. Oregon stakeholders have choices to make based on what they would like to see in MPs management for the state. Given these choices, we wanted to know what the major stakeholders (i.e., government and nongovernment actors whose advocacy, interest, and responsibilities may shape MPs management in Oregon) that would likely be involved in implementing plastics management perceive as barriers to doing so.

Research Questions:

How do Oregon stakeholders perceive the potential for management of microplastics in Oregon?

Specifically, what do stakeholders see as the priorities, concerns, and barriers to microplastics pollution in Oregon?

2. Methods

We conducted semi-structured interviews with a variety of water quality stakeholders in Oregon[4] to learn about their perception of microplastic pollution and possible management strategies. Our semi-structured interview questions were prefaced by a short, multiple-choice survey which primed the interviewees to think about and recall their knowledge of MPs pollution prior to answering open-ended questions. Semi-structured interview questions presented participants with potential management strategies that they otherwise might not have known about, while also having an open-ended format to let them discuss perceptions of the issue. In our study, stakeholders are defined as individuals employed by organizations/industries that are, or are likely to be, directly affected by MPs or engaged in control. In order to gain a better understanding of the tools available to government and industry to address MPs, we spoke with people with experience in the implementation or policy realm of environmental contaminants rather than the general public.

We stopped contacting potential stakeholders once we got close to 30 participants. While this was not saturation, the timeframe to conduct interviews and perform data analysis was limited. Follow up work will attempt to reach more stakeholder groups and fill in gaps that we did not have time to address.

We conducted recruitment by sending a short introductory email describing the project and asking for participation and approval of the consent form. Consent forms included the purpose of the research, potential risks to interviewees, and a statement that they would remain anonymous in any reports of the research. The consent form and expected interview questions were approved by the PSU Institutional Review Board (IRB) and we received exemption from

[4] One of the 28 total interviewees was based in Washington but worked in a capacity that connected them to Oregon. For example, some environmental NGOs have a regional scope of work that includes both Oregon and Washington.

IRB review (IRB protocol #217266-18). In the analysis below, interviewees are identified only by the type of organization they worked for to protect their identities.

Initial interviewees were identified through professional networks of the research team members who had connections with relevant stakeholder group representatives. A "Stakeholder Advisory Panel", formed through the Oregon Sea Grant SEED project that funded this work, provided a group of individuals in Oregon with relevant experience and suggestions for potential interviewees. I also "cold-called" and emailed potential organizations of interest as I found and identified them through internet research. Once an organization was identified as a "stakeholder" or as representing a stakeholder group, we contacted members of the organization via email, or completed a general contact form on their website, to find a willing participant. We used a mix of snowball and purposive sampling to continue identifying interviewees throughout data collection from different types of stakeholder groups. We asked initial respondents to suggest additional potential interviewees after speaking with them. A total of 28 interviews were conducted over Zoom. Most interviewees were from state agencies (14), environmental advocacy groups (6), and fishing and seafood industry (4) sectors (Figure 1). The other four interviews included academic, engineer [5], and a state policy specialist. We were not able to get anyone from the apparel industry to agree to participate in the study despite persistent outreach.

Interviews began by reviewing the study consent form with the interviewee. Any questions about interview participation were answered. Once the participant gave their consent to participate, we noted this and proceeded. We asked the participant to fill out a short, seven question survey, where questions focused on categorizing participants' awareness and concern for MPs pollution among other significant marine threats, such as ocean acidification, overfishing, marine heatwaves, and marine disease. This type of question is common in other social science studies on MPs and precedent for asking participants to categorize environmental threats can be found in other studies (Thiele & Hudson, 2021). The survey was included to prime

[5] Originally, we had engineers in the interviewee pool because we wanted to develop a sense of technical MP solutions that are available/may become available soon and the barriers and opportunity to scaling them. However, this strategy was abandoned early in the project since we identified engineer collaborators earlier than anticipated that could work on a follow up project. Since we spoke with the engineer for different reasons than the other interviewees, most of the analysis does not include the engineer's interview unless explicitly noted.

participants to think about microplastics and what they know about it in the Oregon context. A limitation of the survey is that the group of interviewees is not representative of a larger sample and the numbers of interviewees from a particular group are not large enough to support statistical analysis or characterize the population as a whole (e.g., n=6 environmental advocacy participants).

We waited in real time for the respondent to take the survey on Zoom, and then continued with in-depth, semi-structured questions. Interviews included nine questions asked to every participant, then specific question sets depending on the type of organization the interviewee was a part of (e.g., fishing industry-specific questions). Questions were stratified in this manner to target organization-specific understandings of the MPs issue. These covered topics relating to the participants' knowledge of microplastics pollution and their thoughts on potential management strategies. The nine questions that all interviewees were asked are listed in the appendix (Appendix 1).

Between May and October 2021, to avoid COVID-19 exposure, we conducted interviews via Zoom, which rapidly became accepted practice in social science studies (Roberts et al., 2021). The interviews, which lasted 30-60 minutes, were recorded in Zoom and then uploaded to a transcription service (Otter.ai) for automatic voice to text transcription. I edited transcripts for errors by listening to the audio while reading through the transcription and correcting mistakes. Transcribed interviews were loaded into MAXQDA 2021/22 software for coding.

We used the combination of a thematic analysis framework (Braun & Clarke, 2006) and a general inductive analytical approach when coding and identifying themes (Thomas, 2006). Analysis began with open coding and transitioned to focused coding as themes began to emerge. Themes were identified as information that stood out as especially important to interviewees, or ideas and concepts that were mentioned consistently throughout the interviews. The themes presented were some of the most prominent identified from the coding process.

2.1. Reflexivity

In order to situate the researcher within the study, it is important to know my background. As a master's student in Environmental Science and Management, I have been working on plastics use research for about 3 years including in my undergraduate studies. A strong concern

for MP pollution and the health of aquatic and marine environments has drawn me to the topic. Throughout the interview, coding, and data analysis process, I did my best to keep personal beliefs about MPs management to myself to prevent bias in the results below.

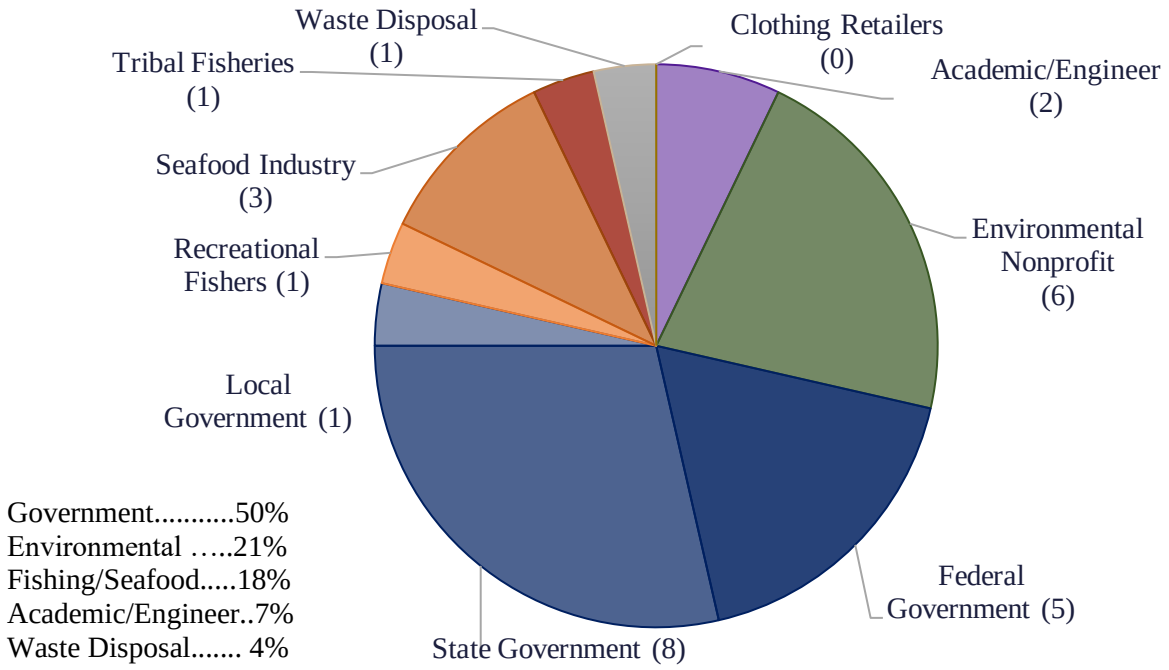

Figure 1. Organization sectors of the 28 Oregon Stakeholders from 2021 Surveys and Interviews. The majority of interviewees were from Government and Environmental sectors.

3. Results & Discussion

3.1. Survey

The results from a survey characterized the stakeholder's perception of the issue, level of concern, and attitudes towards state policies on microplastics, displayed in the following figures. The results of this study are not representative of a larger group, but rather reflect the perspectives of the study participants and what they think about MPs pollution.

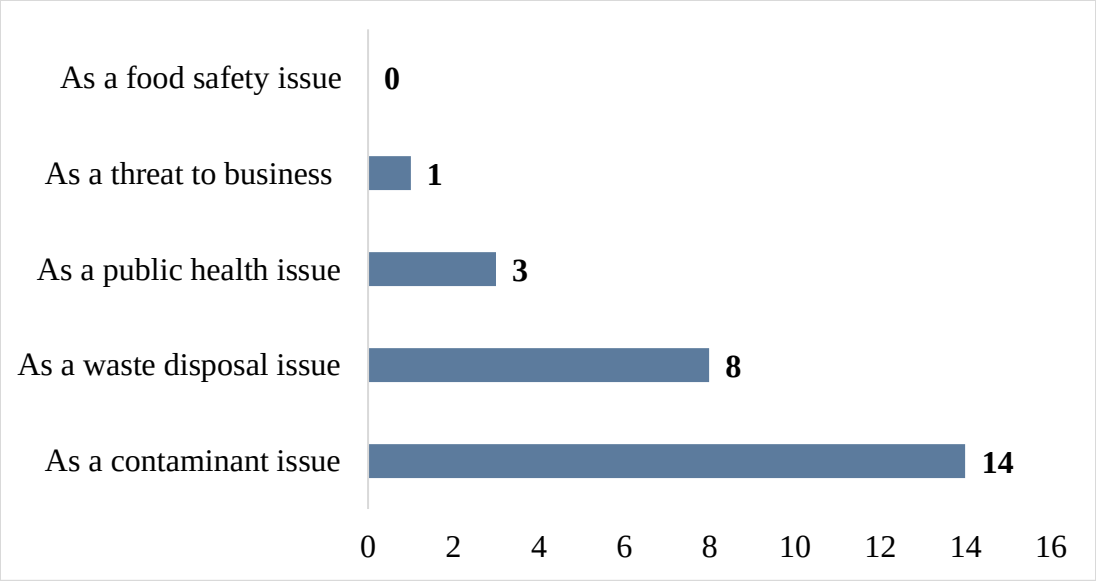

Figure 2. Oregon Stakeholders Classification of MP Pollution from 2021 survey. Participants were asked to select one classification of microplastics pollution to gauge their perception of the issue.

Given a choice between different ways of thinking about MPs, a majority of participants (53.8%) chose the “contaminant” framing, followed by "waste disposal” (30.8%) and “public health” (11.5%). No participants chose to classify microplastic pollution as a food safety issue (Figure 2).

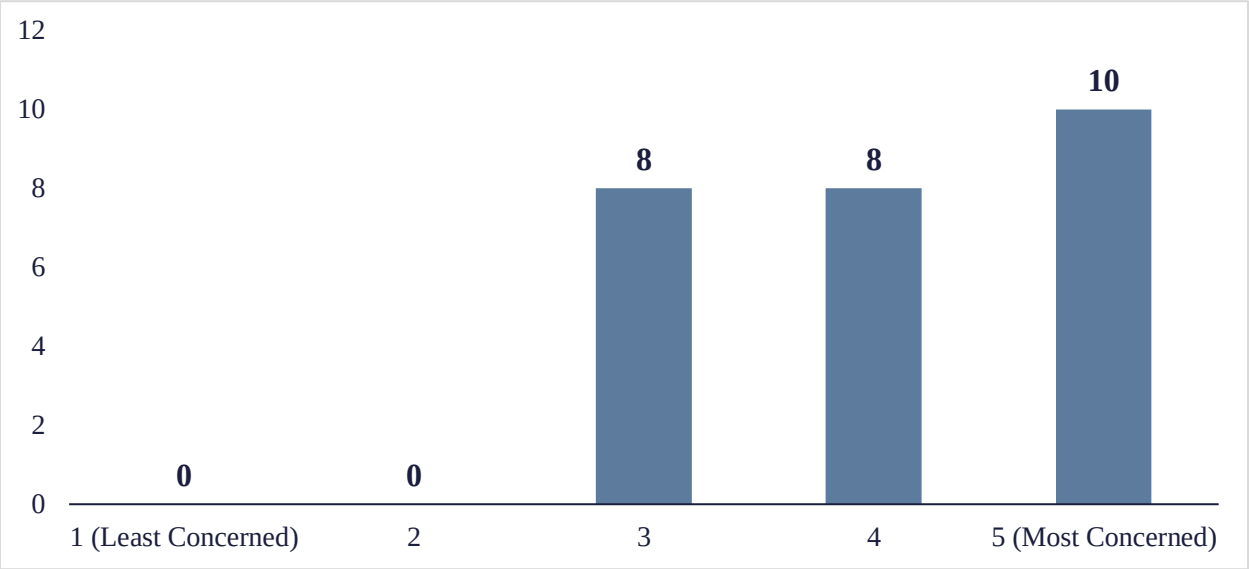

Figure 3. Personal Level of Concern of Oregon Stakeholders about MPs from 2021 survey. Participants ranked on a scale of 1 to 5, with 1 being the least concerned and 5 being the most concerned, their personal level of concern about microplastics pollution.

Interviewees expressed a neutral to high level of personal concern about MPs, with a plurality (38.5%) reporting the highest level of concern (Figure 3). No participants chose the lowest levels of concern (1 and 2).

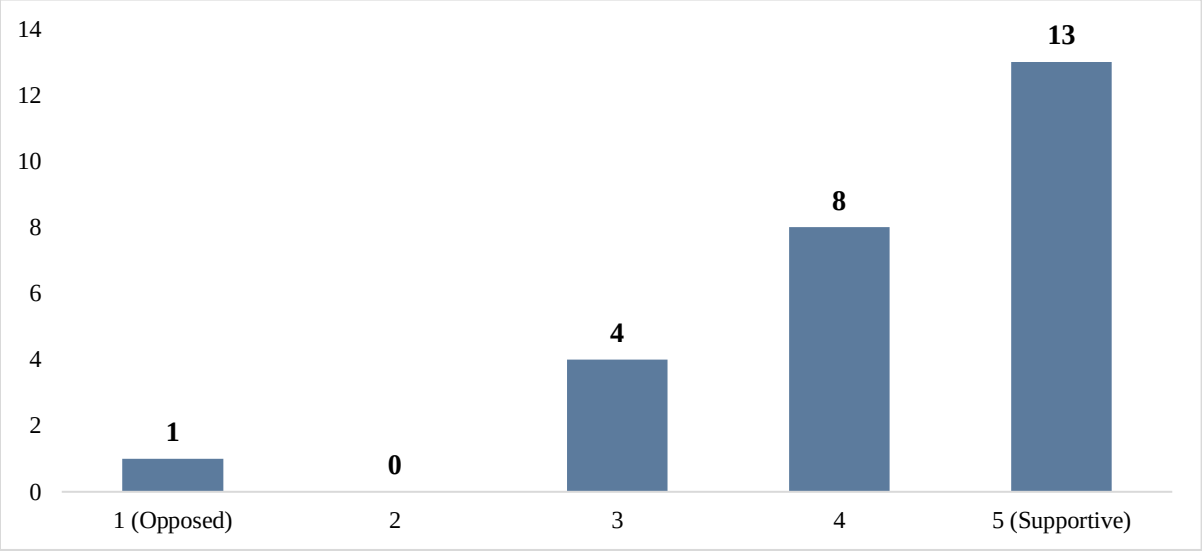

Figure 4. Personal Attitude of Oregon Stakeholders Towards State Policies to Address MPs Pollution in 2021 survey. Participants ranked on a scale of 1 to 5, with 1 being opposed and 5 being supportive, their personal attitude towards a state policy on microplastics pollution.

Interviewees' personal attitudes towards state policies to address MPs were mostly supportive. The majority (50%) marked themselves as being supportive to such policies, but one interviewee marked 1, or opposed, to this (Figure 4). A plurality of participants (46%) marked neutral to intermediate levels of support towards a state policy to address this.

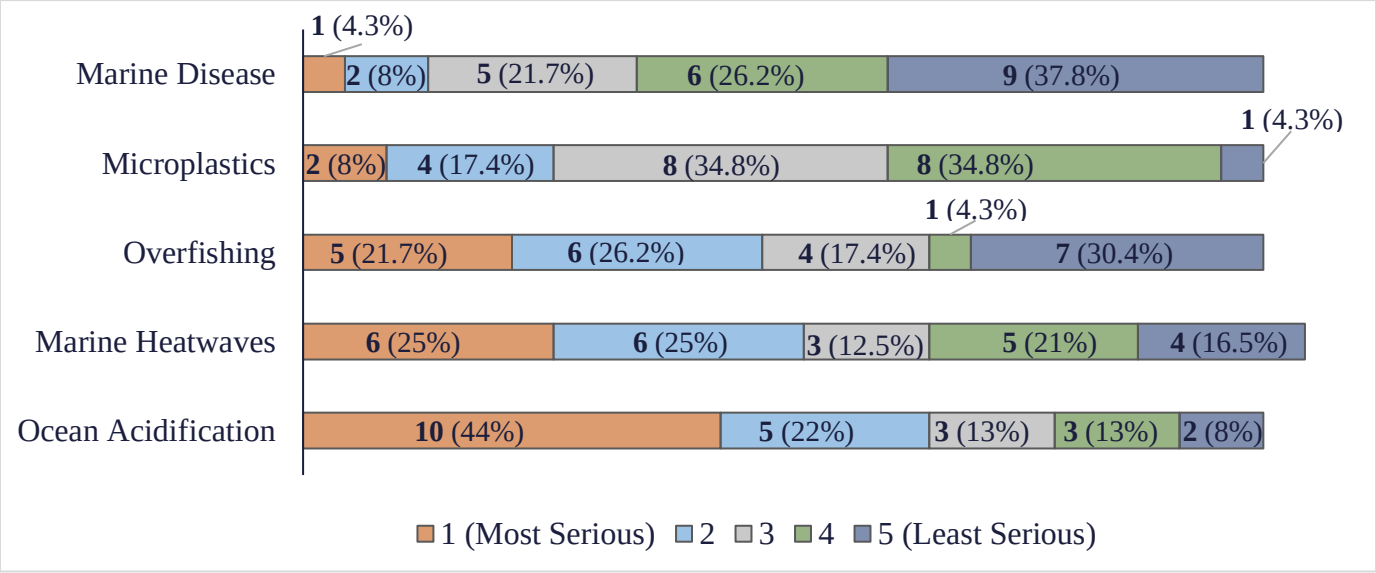

Figure 5. Oregon Stakeholders' Ranking of Major Threats to Marine Ecosystems from 2021 survey. Participants ranked 5 major threats to marine ecosystems on a scale of 1 to 5, with 1 bieng the most serious and 5 being the least serious.

Respondents ranked MPs compared to 4 other major threats to marine ecosystems on a scale of 1 to 5, with 1 being most serious and 5 being the least serious. Most participants rated MPs around 3 or 4 in terms of seriousness, and issues like Ocean Acidification and Marine heatwaves as most serious (Figure 5). Comparing these results with Figure 3, it is interesting to note that, although respondents are indentifying themselves as having a high level of concern for MPs, they do not see it as the most significant threat to marine ecosystems.

A study evaluating the major threats to marine ecosystems determined that the greatest threats are increasing temperature, destructive fishing, and point-source organic pollution, according to 135 experts (academic, agency, and non-governmental scientists) in 19 countries (Halpern et al., 2007). While this study found increasing temperatures to be the greatest threat among respondents, ours identified ocean acidification as the greatest threat. This result may

have to do with the areas of expertise for our respondents as well as geographic location. Microplastics were not specifically identified in the other study, but might have been considered under the umbrella of point-source pollution.

Responses to the other three survey questions are shown in Appendix 3. Participants rated their organization's level of awareness regarding MPs (Figure 6), with all levels being above the lowest level of awareness (1). All participants marked 2 or higher level of awareness, with the largest percentage (34.6%) rating their organization at a level of 3 out of 5. No participants marked their organization as having a level of 1 in awareness of MPs. We also asked participants to rate their organization's level of concern for MPs, and the majority (44%) rated their organization at a level of 3 for concern, followed by 28% marked for a level of 2, and the rest spread between levels 4 and 5 (Figure 7). No participants marked their organization's level of concern at the lowest level of 1. Finally, we asked respondents to rate their level of interest in collaborating with other stakeholders to address MPs pollution (Figure 8). Most participants had strong interest in this, with 73% of them marking 4 or 5. Only 2 participants showed little interest in this type of collaboration.

3.1. Interview

The interview results are organized into points of agreement, where there was consistency in similar answers among interviewees, and points of disagreement, where interviewees had varying or opposing responses.

3.2.1. Points of Agreement

The interviews demonstrated consensus on several themes, which included lack of information distribution on MPs, a preference for source reduction, government agencies lacking the authority to address MPs, connecting the issue to human health, and dependence on plastics materials. This section summarizes the findings in each of these key areas of agreement.

Information Distribution on Microplastics

Stakeholders identified lack of information on MPs as a barrier to action. Broadly, stakeholders cited a need for scientific studies that show the presence and sources of MPs in Oregon. Many noted the need for research and public education on MPs. Their interviews imply that more information on occurrence and sources would demonstrate the need for microplastics

management in the state. Most interviewees had a similar view, explaining how more knowledge of MP sources in Oregon is needed before further efforts begin. While some studies of MPs in specific marine species and sources of pollution have been conducted in Oregon (Baechler et al., 2019, Horn et al., 2020, Valine et al. 2020), several stakeholders did not appear to be aware of this and admitted that they were uninformed of relevant studies in the state. The specific types of information that participants perceive as missing appear to be Oregon-specific information on MP effects on ecosystems, prevalence/density, and sources.

Interviewees from environmental advocacy groups note a lack of information on quantities of MPs present in Oregon's waterways and information on the effects of the pollutant:

> We need more data on actual [...] microfibers and their actual impact […] it will just make our arguments a lot stronger in order to get the policies changed, if we had stronger data in that regard.
>
> […] I think one of the first things is we need to start getting assessments of microplastic density and identifying [...] origins of them in Oregon waters in ways that I haven't seen yet.

These participants noted that they were missing important information that would provide stronger support for policy needs. One interviewee from a state agency said:

> You know, those are the kinds of tools that I have, but at this point, we don't have information, you know, to support a reduction in take by either the commercial or the recreational fisheries.

This participant explains that further research would elucidate what management measures can be taken, and these would potentially have repercussions for statewide fisheries. In the meantime, they don't believe there are currently tools available to them to manage MPs. This exemplifies how the perceived lack of scientific knowledge is a significant barrier to getting policy in place for MPs, and more information on it may allow stakeholders to support policy. Some state agency participants pointed to the overall lack of understanding and argued that it is holding their organization back from properly addressing the issue:

> […]a big challenge is just knowing where they're coming from, what the sources are of the pollution.

> I don't think that we have a good handle on the sort of extent and breadth of the problem to be able to choose one of those [management options] versus another to do a better job of addressing things.

These participants, similar to others, have a desire to know more about the pollution sources for MPs here in Oregon. They imply that having access to these data would likely allow them to address MPs pollution. Their responses suggest that they do not have enough information to use management tools available to them to address the problem. Without knowing specific information, for example, the source of MPs pollution in Oregon, the respondents don't believe they can make a strong case to legislators to change policies to target MPs. Based on these responses, it appears many of the interviewees are not easily finding or are unaware of the existence of information on MPs pollution in Oregon, which is preventing their organizations from further addressing it.

One participant from the fishing industry said "I have no idea what the state would or could do" in regard to addressing MPs pollution. Their uncertainty of approaches to MPs by the state government is notable and suggests that they don't have enough information to know what kind of policy approach would be best for this type of contaminant.

These responses show that recent attention to MPs in the marine and environmental science community has not necessarily broken through even to the Oregonians who are most likely to be involved in or impacted by future efforts to manage MPs. While participants were referred to the research team because of their awareness of, interest in, or knowledge of the issue, many described themselves as having limited knowledge of MPs, and some appeared to be unaware of relevant recent research findings (for example, noting an absence of Oregon-specific studies on MP presence in marine organisms, even though such studies have been published in recent years). They also suggested that public awareness and understanding of the issue is lacking, which seems likely given that information isn't even reaching participants with relevant knowledge of state water pollution issues. These findings suggest a need to convey key emerging findings on MPs sources, pathways, and impacts to people who are mostly likely to shape, implement, and/or be impacted by MPs management efforts in the state. While we did not collect data on the best way to deliver this information to respondents and similarly situated stakeholders, studying appropriate pathways is a potential follow up project.

At the same time, some interviewees warned that efforts to increase public awareness of MPs run the risk of creating unnecessary panic over the issue or driving unhelpful responses. Specifically, these respondents voiced concern that people may misunderstand the pollution issue and stock up on bottled water, as has happened with other water pollution issues that get widespread media attention. This type of response would be particularly inappropriate in this case since MPs are also found in bottled water. Any potential educational campaigns should be careful to communicate the ubiquity of MPs in our water resources in a way that does not incite panic by the public. These results suggests that connecting MPs stakeholders with emerging science would be a useful strategy, since it directs information to people whose experience and expertise would help put information into context for management solutions.

Prevention at the "Source"

One of the most widely noted themes resulting from the interviews was participants' desire for MP management that focused on reducing new inputs of MPs pollution as close to the "source" of these inputs as possible. Participants appeared to have different understandings of the meaning of "source" throughout the interviews. About two thirds of the interviewees noted preference for prevention of MPs entering the environment in the first place, but where they noted this prevention could happen varied. An environmental engineer interviewee preferred to see a MPs management policy that focuses on this:

> I'd like to see […] source-driven policy, instead of like the retroactive […] trying to scoop up all the microplastics in the ocean for example.

This suggests that less energy should be focused on cleaning up legacy MPs, and rather we should focus energy on keeping MPs from entering the environment, although where to intercept the MPs is vague. A respondent from an environmental non-profit organization noted:

> Microplastic pollution, […] the sources of it, by my understanding, are the places where we should be focusing more effort than on the end user and consumer end of the effort of […] managing plastic pollution in general, and microplastics as well.

This respondent suggests that the focus should be on the supply chain upstream instead of on consumers changing buying habits. They agree that MPs pollution should be managed at the source rather than focusing on managing pollutants at the end of their life. Another

environmental non-profit respondent explained that the most successful MPs approach would be reducing the sources:

> I think if there were a statewide microplastic […] control strategy, I think it would most successfully be addressing it at source.

This reinforces the consistent theme that respondents would like to see preventative reduction of MPs pollution. A tribal fisheries organization respondent indicated that they would like to eliminate contamination sources as opposed to agencies like OHA warning people to not eat seafood species due to contamination levels:

> I would rather see the sources of that contamination stopped, rather than telling people to stop eating foods that are healthful.

This is another example of preferring a preventative management approach rather than retroactive management of pollutants in food. In this case, the respondent prefers preventative measures to setting limitations on fish consumptions. State agency respondents also showed preference for preventative solutions:

> […] it's great to control a problem kind of as far upstream […] and probably in the manufacturing process as possible so that you don't have consumer goods that are a source of microplastics in the first place.

This response provides a more specific location to focus prevention (at the plastic manufacturers). One interesting response from a local government interviewee noted that the idea of "microplastics policy" would not be appropriate to truly address the sources of the issue:

> […] I think a microplastics policy […] you're at the wrong end. […] the policy should be further up in addressing the kinds of products that produce microplastics, as opposed to trying to deal with the problem that has become microplastics

They point out how targeting microplastics as the contaminant to be managed is not looking at the greater issue, which is where the contaminant comes from in the first place. These responses regarding source management provide insight into how most respondents think this issue should be managed, but further studies should clarify exact source location respondents see as best to intercept pollution. The varying definitions of the "source" may be related to and reinforce the lack of information that stakeholders have on MPs pollution in Oregon. The attraction to "source" framing of MPs suggests that a potentially successful messaging strategy for advocates of MPs policy may be one that references controlling MPs "at the source".

Lack of Authority to Address Microplastics

Another perceived barrier to MPs management is the lack of authority of various agencies to put management tools in place. Many government stakeholders felt their agencies did not have a statutory mandate to address MPs pollution.

> ... [it] may not be our agency's authority to deal with when you look at state statutes and our - the constitution on what our funding is intended for, it may not be a good fit for our funding programs.
>
> And microplastics just has not yet come up, we have no state water quality standards associated with microplastics. And […] no toxicity standards or anything along those lines. So we don't have any explicit requirements to address.

These comments suggest that state agency staff see MPs as outside of the scope of what they can work on in the absence of legislative direction. While agencies can adopt regulations that have the force of law, those regulations must be within the scope of the agency's authority as defined in statutory law. The interviews with state agency employees show that these stakeholders almost uniformly situate action on MPs as outside of their existing jurisdiction. Agency participants repeatedly explained that MPs are not within their agency's purview and could not be addressed by them without direction from the state legislature or federal government.

Although many of these stakeholders had strong concern for MPs pollution, they did not perceive an avenue for their organizations to address it with their existing authority. Two interviewees from state agencies noted:

> […] we're not the ones who develop that public health guidance, we rely on that federal framework to develop the […] best available science or to determine the best available science that we then implement.
>
> But we have not been mandated by the legislature to […], we aren't really steering into the research and development side of things.

The first interviewee explains that their agency does not have authority to create public health guidance, and that the federal government creates this framework that they can implement. The second interviewee similarly explains that they carry out their work as directed by the legislature and do not have the authority to decide what they research. These quotes

emphasize that state agencies may not have the authority to create MPs guidance or conduct research on MPs.

Some federal government respondents had similar responses, however most federal interviewees explained that their agency does not have a regulatory role and managing contaminants is not in their scope. The responses from state government individuals suggest that new state legislation would be needed for an effective effort in microplastics management. State agencies can implement initiatives mandated by legislation; however, no legislation exists to direct state agencies to reduce microplastic contaminants. The management tools available to many state agencies cannot be utilized to address MPs unless there is action by the legislature to mandate their involvement.

It is important to note that legislation expanding agency mandates to address MPs need not create new regulatory programs. For example, California SB 1422 requires initial testing and reporting of contaminants in state drinking water resources. While regulations could eventually be adopted to reduce MPs found in the water, there is no regulation of sources happening under current law; rather, a measurement program is being developed. CA SB 1263 requires the adoption and implementation of a Statewide Microplastics Strategy to understand the scale and risk of MPs to ocean health (SB 1263 Senate Rules Commentary). Again, no regulatory program is involved; this legislation mandates further study to understand the extent of the issue and the threats it poses to marine health. This could be an effective method to initiate research, collaboration, and resource-sharing on MPs in Oregon without establishing new regulatory frameworks or shoehorning MPs into existing programs.

Connecting the Issue to Human Health

Another notable theme was participants' attraction to a drinking water standard as a policy tool, and the rationale they provided for this preference. When asked what approaches to MP management they preferred, one state agency participant said:

> I really like those style of approaches [drinking water standards] because it centers it around human health [...] I know that's like incredibly human centric, which is not what all the plastic should be about. But I do think it is impactful in driving solution[s].

This quote suggests that interviewees are aware of and care about the effects of MPs on ecosystems and non-human species. However, they believe the best way to build support for

action on MPs among decisions makers and the public is by emphasizing their potential human health impacts. This leads them to gravitate toward drinking water standards as a policy tool. An interviewee from an environmental advocacy organization said:

> [A] Drinking water [management approach is] certainly important from a human health impact. But [we] want to make sure we're also addressing stuff that's going into […] the waterways and ecosystems.

They approve of management approaches that focus on the effects of MPs on humans, but also emphasize that management needs to address the entire ecosystem and not solely humans. These data indicate how many respondents agree on human health concerns as an effective method of urging the public as well as legislators to care about the issue and make effective decisions to prevent pollution.

Public health may be an effective way to increase attention to MPs and encourage management efforts. Interviewees suggest that since the general public will likely be concerned about microplastics in their drinking water and bodies and that this should be relatively straightforward to legislate, since concern for human health is a shared concern for most if not all legislators. While research on the human health effects of MP is still emerging, it is becoming increasingly clear that MPs are in our bodies and have the potential to do harm.

Some respondents noted that a drinking water standard has limitations, which include only addressing MPs in water sources meant for drinking water. These results suggest that a strong policy strategy for MPs would leverage human health considerations into a broader management strategy, rather than simply reducing human ingestion of MPs.

Dependence on Plastic Materials

Another notable theme was societal dependence on plastic products, which poses a challenge to eliminating microplastic pollution sources. A local government respondent pointed out how managing this type of pollutant is not just a matter of state policy, but is a much larger issue that relates to our society and culture of using disposable products:

> I mean, you're trying to change the status quo of a consumer driven society […] that relies on cheap and easy products that are fundamentally considered to be disposable. And I think that is wide scale societal change, not policy.

Their response suggests that to effectively address the use of plastics altogether, we need to implement societal change, not just policies. Prevention "at the source" may be challenging in this regard since plastics are so engrained in our society.

All four of the seafood/fishing industry participants brought up the issue of dependence on plastics. One of the seafood/fishing industry participants explained:

> I can't get out of plastics, I can't create […] a meal kit that can ship for two days in a UPS supply chain with gel packs with paper packaging, it just destroys [it]. So, I'm left with plastics – we don't like plastics. I try to do everything I can at home to recycle plastics, but as a business owner, it's really hard.

While they would prefer to not use plastic, seafood industry participants note that plastic packaging keeps the seafood fresh and prevents food waste, and there are no affordable alternatives that work as well and are environmentally friendly. Another seafood/fishing industry representative also brought up this challenge:

> I don't even know how much we heavily rely on plastic for our shipping issues, but the biggest concern […] or the only thing that [would] draw us back, is if it were to compromise our ability to do business.

They acknowledge their business' reliance on plastic and explain how an effort to reduce plastic use would be a difficult for them to support if it made it harder for them to transport food safely. These considerations of seafood/fishing industry representatives are important to understanding the full picture of current attitudes towards MPs pollution.

All four of the seafood/fishing industry participants mentioned their reliance on this material and the challenges with getting rid of plastic products altogether. Their responses suggest hesitancy towards any types of management approaches that ban materials or cause their industry to have to pay an increased amount for alternative packaging sources. This provides insight into the policy landscape for the fishing/seafood industry and indicates that any management approach should consider the impacts on industries that rely on plastic materials.

When asked about barriers to statewide policy action on MPs or the single most important thing relating to MPs from their perspective, seafood/fishing industry respondents tended to point out how they must use plastic materials. To be clear, we were not implying or suggesting that they were responsible for MPs pollution, but they tended to jump to their own culpability at some point in the interview when asked about the broader issue. This indicates that

the seafood/fishing industry stakeholders may make an unprompted association between MPs and their own plastic use.

This is important to know for approaching the seafood/fishing industry in the future regarding potential management endeavors. When advocates for MPs policy reach out to the seafood industry, they should avoid implying blame for MPs pollution and clarify the goals and methods of policy since many common strategies for MPs management (e.g., washing machine filters, wastewater treatment capabilities, stormwater infrastructure optimized to capture MPs, measurement in drinking water, extended producer responsibility) do not situate the seafood industry as the problem and would not force them to identify and use substitute materials for plastics.

It appears stakeholders from this industry have a sense of remorse and feel obligated to try to reduce their plastic use, and they identify part of the problem is the limited availability of alternative materials that they can afford to package their products in. One tribal fishery organization voiced their concern for their industry being associated and taking blame for plastic pollution in their products:

> […] is the food that they're selling […] commercially going to be conflated with this idea of microplastic contamination?

Another seafood/fishing industry participant expressed how they feel beholden to address their industry's use of plastics:

> I personally feel a sense of remorse and obligation to deal with the fact that my industry, the restaurant industry produces so much plastic [….] I don't want to - customers don't want it […] I really want to have better choices.

Their response explains that neither them nor the people buying seafood want to be consuming plastic materials, but this is the only option they seem to have. This suggests they need a higher authority to mandate production of alternative materials (or reclamation and recycling of plastics where alternatives cannot be identified) and facilitate the transition. Another fishing and seafood industry respondent pointed out their concern for a state policy to prevent MPs pollution:

> I think the problem with policy is how to not penalize […] people for using it but create incentives to find alternatives.

This participant wants to find methods to incentivize reduction of plastic use that will help support the fisheries in this transition.

3.2.2. Points of Disagreement

Interviewees showed differing perspectives on several issues. In general, these responses suggest that stakeholders are uncertain how to address microplastics pollution in Oregon and still need many questions answered before they can suggest the best approach.

Potential Management Approaches

One of our interview questions proposed three types of management approaches for MPs and asked respondents which they thought would be most effective. These included a voluntary initiative, potentially pushed by a non-profit organization, in which willing organizations take specified steps to reduce plastics pollution on a voluntary basis. This type of voluntary management is often used in combination with or in lieu of regulatory approaches to reduce pollution (Brouhle et al., 2004). Another proposed management strategy was a regulatory drinking water standard for MPs (i.e., a limit on allowable MP concentrations in drinking water, to which the kind of testing requirements in California's SB 1422 would be a precursor). The last management strategy we proposed to interviewees was a Total Maximum Daily Load (TMDL) by the Department of Environmental Quality (DEQ), in which a daily limit on MPs levels in designated waterways would be set, and point/non-point sources would reduce MPs output in the waterways.

The voluntary initiative approach received mixed responses, with most interviewees thinking it would not be an effective way to specifically address MPs pollution, but that it may be effective at spreading awareness. A federal government participant explained how voluntary initiatives could help to build public awareness but may not be able to address the pollution issue:

> I think that's a really effective way […] to ramp up public awareness of an issue, whether or not it's functionally going to stop microplastics from getting in into the environment- I have my doubts.

A participant from an environmental advocacy organization was concerned that even with work from non-profits, a volunteer approach still may not gain public awareness:

> I am wary that a volunteer initiative would be able to get traction with the public, even if pushed by nonprofits.

These responses show skepticism for the effectiveness of a voluntary approach for preventing MPs from getting into Oregon's natural environments, but a few stakeholders did express interest in this type of approach. An interviewee from the fishing industry explained that they would prefer a voluntary initiative and think it would lead to better understanding of the issue.

> So probably the volunteer would [be] the best [approach], it would take a lot more outreach at the beginning to provide answers as to why this is good, why it's needed, what you can do, you know, how this will affect change. And, you know, the benefits, how it's going to help the processors. And you probably get more buy in from them that way, too.

This respondent suggests that a voluntary initiative would further educate their industry about MPs pollution and build support for management. They see this approach in particular as effective for their industry and they would likely be more supportive of this non-regulatory management.

Non-regulatory approaches, like voluntary initiatives, are typically used in combination with regulatory management strategies in order to create a multi-pronged approach to pollution regulation. Given the responses from most interviewees that voluntary initiatives may not be effective on their own, this could be a possible method for creating more public awareness and distributing information on MPs pollution in Oregon in combination with a regulatory management solution. There was hesitancy by the seafood industry to embrace a regulatory approach, and specifically, the cost appears to be an important consideration for potential regulatory management. The cost of implementation can be a significant barrier to businesses, so offering state or federally funded solutions could be a method to make this accessible to businesses. Another concern of the seafood/fishing industry is that it will situate them as the problem for using MPs as a packaging material that can eventually cause MPs pollution and require high costs to use alternative products.

Voluntary approaches, while not an effective solution on their own, may be valuable for spreading awareness. Research on the effectiveness of voluntary programs on pollution reduction have been studied and there are established methods that can be applied to the area of plastics

pollution in order to effectively reduce plastic production, which can in turn have the effect of reducing plastic pollution downstream (Bui and Kapon, 2012; Uchida and Ferraro, 2007)

Regulatory Approaches

While a few participants saw advantages to a voluntary initiative, most government participants preferred regulatory approaches. For example, a state agency participant said:

> […] definitely regulatory approaches I think are necessary. The TMDLs and water regulation intrigued me.

Other participants also voiced their preference for this, such as a waste management participant:

> Well, I think the most effective is going to be a regulatory approach.

A respondent from an environmental non-profit suggested that their organization may be able to propose and advocate for legislation for a drinking water approach:

> And it's an easier one for us to kind of legislate first. Because people need to connect to it. Right? And so it's a little harder to connect to a fish, I might not eat fish.

They suggest that the public and legislators will be able to connect to the issue since everyone drinks water and uses this MP-affected resource, whereas an approach centered on MPs in certain types of food (e.g., meat) would not be as universally relatable since not everyone eats this product. This relates to the emphasis on human health concern for MPs as being a pathway to build support, as something that everyone can have a shared concern about.

Notably, government interviewees voiced concerns and challenges associated with a TMDL for microplastics, such as a longer time frame to implement the TMDL. This type of approach would depend on the EPA listing MPs as a contaminant and raises the challenge of identifying exact sources of MPs pollution in the state, which could also be time consuming. A major issue is that significant sources of microplastics come from non-point sources, like tire-wear particles, which result from road wear on car tires, that are delivered to waterways through urban runoff. Despite the weaknesses identified with a TMDL approach, most of the interviewees preferred a regulatory approach to MPs, as an enforceable approach that would be the most effective to limiting pollution in their opinion.

Several participants pointed out advantages and issues with the TMDL approach. Two state agency participants had opposing viewpoints on TMDLs as an effective approach for MPs pollution:

> […] it's interesting you say that, because […] I do kind of see how a TMDL could work for it, because that's allocating responsibility for reduction of – in this case, it would be microplastics - to different entities that are responsible for some portion of the pollution problem.
>
> But if you can't pin exceedance of a TMDL on a particular activity by a particular entity, then you can't regulate it, and you can't affect change. So having a TMDL doesn't help you.

These quotes suggest the potential effectiveness of a TMDL, since it provides a way to put responsibility on polluters to reduce their pollutant output into waterways. But the second quote points out the challenge of being able to identify where MPs are originating and resulting challenge in regulating it. If we cannot find the non-point sources of MPs, then a TMDL would not be effective in reducing the contaminant. A seafood/fishing industry interviewee also identified the dependence of a TMDL approach on identifying the exact sources of MPs in the state:

> Regulatory TMDL is... I don't know, I think that sounds great. But […] it depends on if it's point source, or nonpoint source and whether or not that would actually even be measurable and regulatable.

This reinforces the many uncertainties regarding sources of MPs that would need to be resolved for a TMDL to be an effective approach. Another potential issue with a TMDL management approach is that explained by an interviewee from an environmental non-profit organization:

> […] you can't do a TMDL until you have the waterbodies listed in the 303(d) list […] So the thing about that [TMDLs] is that will take some time.

Given that the Environmental Protection Agency would have to list microplastics as a contaminant for waterbodies, and Oregon DEQ would have to add waterbodies with MP contamination to the state list of impaired waters, known as the 303d list, before development of TMDLs for individual waterways (which is often a multiyear process) could even begin, this process would take an extended period of time to achieve and might not be in place for many

years in Oregon. A TMDL would take much longer to implement than other potential management like a drinking water approach or voluntary approaches. Many respondents showed favor for a potential drinking water approach that focuses on the human health threat of MPs.

The uncertainty among respondents regarding effectiveness of approaches indicates how many stakeholders have a strong degree of uncertainty in how to approach MPs and emphasizes the need for increased education and information distribution on MPs pollution.

Perceived Responsibility

We asked respondents about who they saw as responsible for addressing MPs. Many respondents interpreted the question differently. Some interpreted the question as relating to jurisdiction, while others interpreted the question as who should be held responsible in a MPs policy. Most participants identified state agencies as appropriate entities to address the issue, provided they were given the direction to do so by the legislature. In addition, the federal government was mentioned as an entity that could help address the issue. A participant from a tribal fishery organization said:

> I think this is a federal problem as well as a state problem. So the DEQ makes sense to me.

The participant sees MPs as an issue both state and federal government should be dealing with. Specifically, they see Oregon Department of Environmental Quality as an agency that should be managing the pollutant. The Oregon DEQ implements state water quality and toxics policies and has a role in implementing federal environmental laws such as the Clean Water Act. A state agency respondent mentioned a few agencies that they thought should be charged with working on this issue:

> We have to work with the Oregon Health Authority in the state to deal with the interface with human health, with the Oregon Department of Environmental Quality, which really regulates the pollutants and water quality.

This response suggests that the OHA and ODEQ are responsible state agencies for regulating pollutants in drinking water. While many participants mentioned state agencies, some participants mentioned that responsibility for the issue should be put on plastic manufacturers. An interviewee from the fishing/seafood industry said:

> I would put the onus on manufacturing to develop better products so that we have more choices.

This participant is getting more at the question of "who should be targeted by MPs policy" rather than "who has the jurisdiction". Another seafood/fishing industry respondent said:

> […] we're not causing it [MPs pollution], you know, how can we be part of something when […] it's a few steps behind us that is the problem.

These seafood/fishing industry participants are pointing out that the cause of the problem is the packaging that is available and affordable to them. Again, their response gets at the question of who should or should not be targeted by MPs management rather than who has the jurisdiction to address it. These respondents prefer to seek a management approach that does not make their industry liable for what they see as the manufacturer problem. One academic respondent noted the effectiveness of approaches that target manufacturers:

> I think one thing that they've done in Canada that's been effective is putting it on the manufacturers, to […], develop strategies for end of life of their products. And put the burden on them.

This participant is identifying a strategy that could address the problem that the seafood industry participants are reporting— that is, that they inherit a problem from further up the supply chain. This position also suggests who MPs policy should target in order to reduce pollution.

While most respondents saw some type of government as responsible, be it federal, state, or local, respondents also mentioned non-profits, businesses, plastics producers, and consumers as responsible parties for MP pollution. This suggests some interviewees see the parties who create and use the product as partly responsible to manage the pollution. Most aquatic contaminants in Oregon are currently managed by the Oregon Department of Environmental Quality. The federal Environmental Protection Agency sets certain thresholds for pollutants that the state DEQ will manage.

Requiring plastics producers to have end of life plans for their products is becoming a more popular approach: in Canada, the Ocean Plastics Charter places responsibility on plastics producers to manage the plastic waste their products generate (Government of Canada, 2021). In addition, the Break Free from Plastic Pollution Act, which was reintroduced to Congress in 2021,

would hold plastics producers in the US responsible for managing the waste their products create. Potential state level legislation in Oregon also focuses on extended producer responsibility (EPR). Senate Bill 582 requires packaging producers to join "extended producer responsibility programs" and prohibit confusing packaging that is deceptive about recyclability (SB 582). EPR forces producers of environmentally damaging products to take responsibility for the environmental costs of their products throughout their lifecycle (i.e., including not only manufacturing, but also end of life), which incentivizes the design of products with fewer harmful environmental effects (Hickle, 2014). In the case of MPs, that might mean plastics manufacturers producing products that are easier to recycle, since they would bear more responsibility for seeing that those products are recycled.

These results suggest that state and federal government as well as plastics producers are seen as the major responsible parties to address MPs pollution in Oregon, and extended producer responsibility approaches may be an effective way for these parties to address pollution.

4. Limitations

Our project struggled with balancing the diverse respondent groups in the sample. We attempted to get a more balanced sample from tribal organizations and apparel industry on this issue, but time constraints prevented us from developing many (or, in the case of the apparel industry, any) contacts in these groups. Although we tried to reach out to tribal organizations for interviews, we were not able to find someone who was willing to be interviewed. Another group we tried to target with our outreach was the clothing/apparel industry in hopes of getting their perspective on MPs pollution since clothes and textiles shed microfibers when washed (Boucher & Friot, 2017). However, we were not able to speak with anyone on the record; prospective participants who declined to be interviewed often explained that our request would have to be cleared through other departments and this approval was not likely possible. Future research should follow up on this aspect of the project. Another member of the research team is currently working to made inroads to with these groups.

We learned from this that speaking with this industry would require further outreach to carefully navigate their concerns about publicity on MPs problems. The limited balance of the sample in this study reflects our time constraints on participant outreach and the challenge of finding willing participants.

It is also important to note some challenges with constructing appropriate interview questions given participants' relative lack of familiarity with the emerging issue that was the focus of this study. In seeing participants perspectives on management tools, we offered three examples (a TMDL, drinking water regulation, and voluntary approaches) and asked participants which they thought would be the most feasible of the three. This is not an exhaustive list of potential ways to manage MPs; it served as a starting point for respondents to provide ideas about ways to address the issue. We suggested these three approaches as it helped respondents think about and discuss different ways to manage MPs. In pre-test surveys, we found that interviewees struggled to identify management tools or solutions with an open-ended question, so we decided to provide more structure in the question. These options capture three very different approaches to managing pollutants and the interview question provided rich discussion. We worded the questions so that respondents had an open-ended opportunity to bring up any other management approaches they might think of. However, the suggestion of these three management approaches may have biased respondents to only think of these types of approaches and so the interview responses do not reflect all possible approaches to the issue.

Other possible approaches to MPs management that would be interesting to discuss include a wastewater focused approach that centers around filtration of MPs out during treatment processes, and an extended producer responsibility approach that puts the responsibility on plastics producers to manage their products entire lifecycle. These both target microplastic reduction in different locations to intercept pollution, and a multifaceted approach such as this may be needed to effectively remove and prevent MPs pollution.

5. Conclusion

The results suggest that better pathways to get MPs information to stakeholders are needed prior to steps towards management. Some potential methods to improve information pathways include creating informational events open to the public, and robust outreach efforts to market these events to stakeholder organizations. Formats of outreach materials may include peer reviewed articles, news articles, PowerPoint presentations, educational videos, informational pamphlets, etc. Future research is needed to determine what formats work best for stakeholders to receive information on MPs.

A recent study on public knowledge of microplastics suggested that greater public dissemination is needed for effective management of the problem, in both formal and non-formal education programs. Public information campaigns and school curriculum that includes microplastics pollution are some ways to establish stronger public understanding of the issue (Garcia-Vasquez, 2021). Most people receive information on microplastics from the media, however this can be problematic. The images of charismatic species entangled in larger plastic waste may confuse them as to what the issues are surrounding smaller particles like microplastics (Henderson & Green, 2020). Better public engagement should be cautious and thoughtful about the storytelling and images used, in a way that effectively communicates what the problem is and what individuals have the power to change. The improvement of science communication will help the public know what to prioritize and put pressure on government to address (Garcia-Vasquez, 2021).

Stakeholders showed a preference for prevention methods focused on "source", and further investigation can help pinpoint the best points of intervention. Follow up work could also find out where exactly stakeholders think would be most effective to manage MPs pollution, for example, at the output of washing machines and dryers, at wastewater treatment plants, or before it enters waterways in the first place may be potential locations to intercept MPs pollution. There are filters available to install on washing machine output that have shown high efficiency in testing, but further evaluation is needed to determine how practical and effective these are for the average person to use long term (Brodin et al., 2018). In addition, electric clothes dryers are another source of microfibers, which are released in dryer vents and lint, which are not currently managed for (Kapp & Miller, 2020). Recent studies have investigated the efficiency of wastewater treatment processes to filter out microplastics during tertiary treatment and understanding is growing on methods of filtration, flocculation, and coagulation that effectively remove MPs fragments and fibers (Na et al., 2021; Lapointe et al., 2020).

Since state agency stakeholders perceive that they lack authority to address MPs, there is a need for a state-wide policy to initiate measurement and management. Follow up studies should explore what other types of management strategies are preferred by stakeholders and which would be the most effective for Oregon. In addition, asking stakeholders opinions on types of approaches other than the three we discussed, such as extended producer responsibility, would

be informative to future policy. Stakeholders suggest that an effective way to enhance concern about MPs with the public and legislators is to relate it to human health, so this is an avenue for policymakers to consider for future advocacy.

Seafood and fishing industry representatives emphasized their dependence on plastics materials as a barrier to reduction. Our findings suggest that policy managers should be aware of fishing and seafood industry perceptions of this issue. Their industry may be unsupportive of management efforts if policymakers do not consider the effects of microplastics and plastics management on their businesses.

Finally, participants indicated a general preference for regulatory approaches to manage MPs but were uncertain in suggesting a particular method, further highlighting the need for more information distribution as well as education on Oregon-specific MPs studies. While stakeholders are uncertain how exactly to address the issue, most see state and federal government as responsible for addressing MPs.

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Appendix 1

Below is the interview guide from the study.

All Oregon Stakeholders

1. Are you involved with any efforts to address or mitigate microplastics pollution at this time?
   If yes:

   a. Tell me more about what you have been doing.

   b. If not clear from response to 7a: Are you doing this because it is a priority of your organization/company/agency, or did you decide to prioritize this issue independently?

   c. What have you learned from participating in these activities?

   If no:

   d. Is there a particular reason why not? Has microplastic pollution lower in priority that other pressing issues?

   e. Are there any incentives that could help you to do so?

   f. If provided with the opportunity to be involved in efforts to mitigate MP pollution, would you do so?

2. Some possible solutions to reducing microplastics include a drinking water regulation approach similar to CA, a voluntary initiative, TMDLs, etc. Which is the best approach? Do you think that approach is feasible? Why or why not?
3. What do you see as the major challenges to addressing microplastics pollution in Oregon?
4. Do you have concerns about a statewide microplastic policy?
   If yes:

   a. What about that idea concerns you?

   b. What do you think would be a barrier to statewide policy action on this issue?

   c. Do you think your organization/industry would support a MP policy?

5. If Oregon were to develop a MP control strategy, what aspects of the problem would you most like to see addressed by that? (e.g., washing machine, stormwater, etc.)
   a. Probe if they cannot answer: Given that we cannot address it overnight, what do you see as the most important aspect of the issue or impact to address first?

   b. What would a successful MP program look like?

6. Do you have any interest in participating in efforts to develop a MP control strategy for the state of Oregon, such as workshops or focus groups?
7. What do you think is the single most important thing I should know about addressing MP pollution, from your perspective?
    - Or what do you know about this issue that would be most valuable to share?
8. Is there anything that we haven't discussed that you think is important to understanding this issue?
9. Is there anyone else whom you think I should talk to about these issues/events?

    Probe: How about state agency personnel, environmental groups, or seafood industry?

Appendix 2

States with local bans or fees on single-use plastic items: Utah, Wyoming, New Mexico, Colorado, Minnesota, Arkansas, Florida, Ohio, Maryland, DC, North Carolina, South Carolina, New Jersey, New York, Connecticut, Rhode Island, Vermont, New Hampshire, Massachusetts, and Maine [1]

States that may make it illegal to ban plastic bags: Idaho, Arizona, Texas, Colorado, North Dakota, Oklahoma, Minnesota, Iowa, Wisconsin, Missouri, Tennessee, Mississippi, Michigan, Indiana, Florida, Delaware, and New York. [2]

[1,2] Gibbens (2019) *National Geographic*, "Planet or Plastic?"

Appendix 3

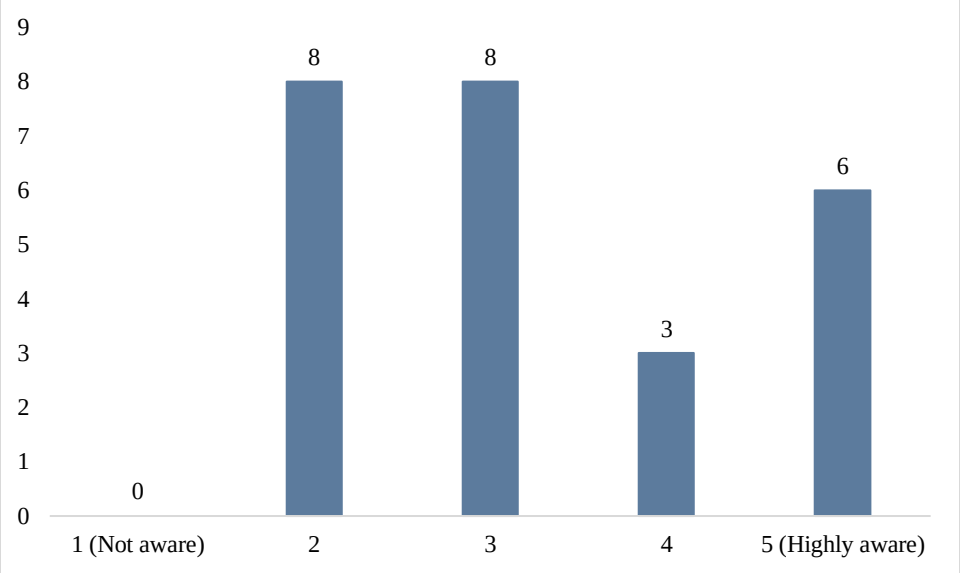

Figure 6. Oregon stakeholders ranking of their organization's awareness of microplastics from 2021 survey.

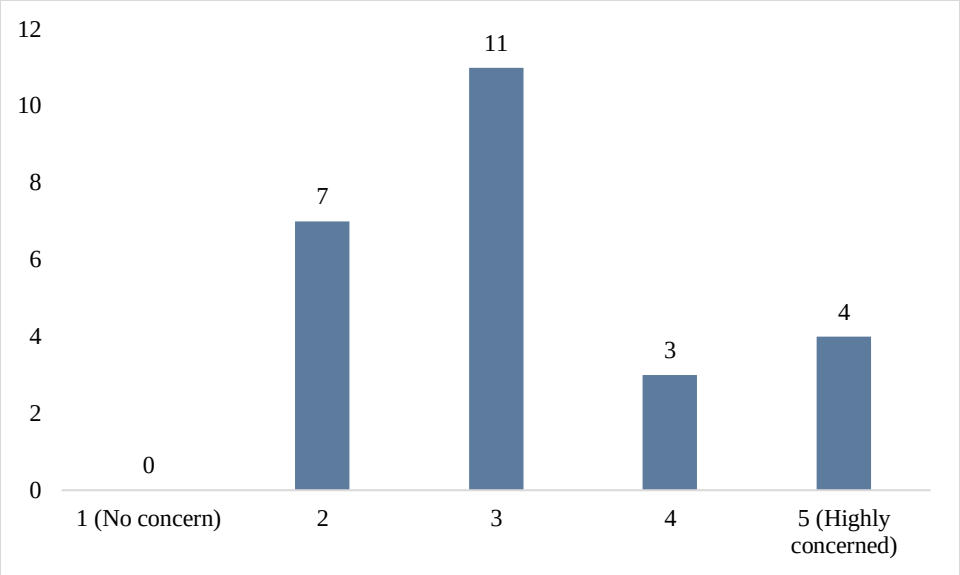

Figure 7. Oregon Stakeholders ranking of their organizations level of awareness regarding microplastics from 2021 survey.

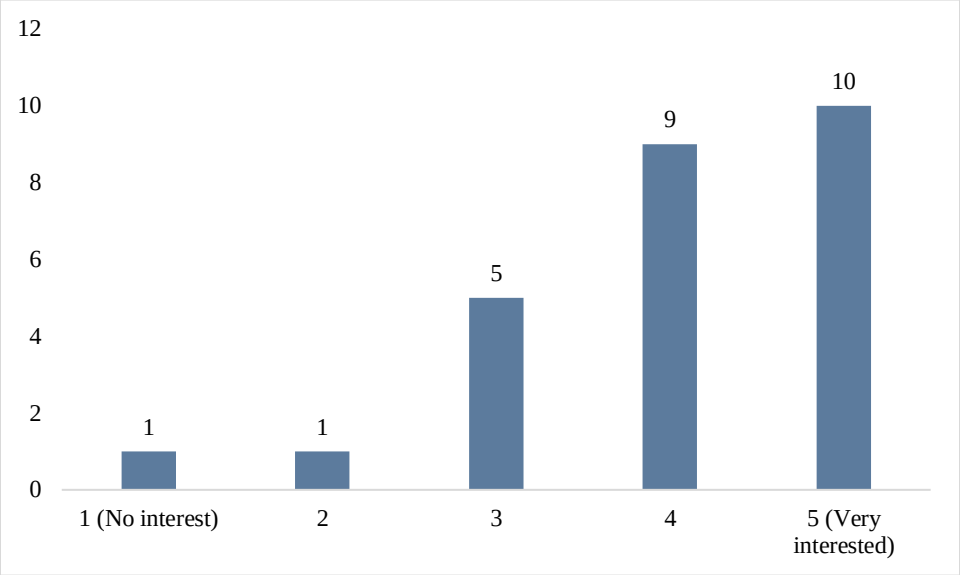

Figure 8. Oregon stakeholders ranking of their level of interest in collaborating with other water stakeholders in Oregon to address microplastics pollution from 2021 survey.