Stakeholder perspectives on the roles of science and citizen science in Chesapeake Bay environmental management

Suzanne E. Webster[a, b] and William C. Dennison[a]

[a] Integration and Application Network, University of Maryland Center for Environmental Science, 425 Fourth Street, Annapolis, MD, 21401, United States (sspitzer@umces.edu, dennison@umces.edu)

[b] Maryland Sea Grant, University of Maryland Center for Environmental Science, 5825 University Research Court Suite 1350, College Park, MD, 20740, United States

Corresponding author: Suzanne (Spitzer) Webster, sspitzer@umces.edu, (630) 877-0324

Abstract

An extensive ecosystem restoration effort for Chesapeake Bay, launched in 1983, has more recently (2015) initiated a program to integrate volunteer monitoring into the overall monitoring program. We sought to understand Chesapeake Bay environmental stakeholders' perspectives about citizen science. Specifically, we explored stakeholders' perspectives on a) the roles of both science and citizen science in Bay management, and b) the level of influence that various stakeholder groups currently and ideally should have in Bay decision making processes. We employed a watershed-wide survey of over 350 Chesapeake Bay environmental stakeholders, including managers, scientists, educators, waterkeepers, and citizen scientists. Survey respondents felt that they should have more influence in environmental management decisions, but the degree of desired influence varied among stakeholder groups. Stakeholders broadly agreed that professional scientists should influence public policy, and that citizen scientists should influence policy to a lesser degree. Chesapeake environmental stakeholders had mixed perspectives on the utility of citizen science for Chesapeake environmental research and management, despite the clear potential that citizen science has in the Chesapeake Bay area. But it was recognized that citizen scientists can play an important role in protecting Chesapeake Bay, in that they can serve as advocates for change, help fill data gaps, and engage more community members. We provide evidence in support of expanded stakeholder engagement in Chesapeake Bay environmental research and decision making. Citizen science appears to be a promising new frontier that could help Chesapeake science and management develop more inclusive decision-making processes.

Keywords

volunteer monitoring, stakeholder engagement, community science, transdisciplinary, participatory research, knowledge integration

Introduction

Chesapeake Bay science and management are coupled tightly and have evolved substantially over the past hundred years. For simplicity, we have characterized Chesapeake science and management into four phases. The first phase of Estuarine Science was initiated in 1925 with the establishment of the Chesapeake Biological Laboratory in Solomons, Maryland. The basic physics, chemistry, geology and biology of estuaries was investigated with interdisciplinary research during this Estuarine Science phase. The next phase was initiated in 1972 after Tropical Storm Agnes caused the highest recorded freshwater flows into Chesapeake Bay (Davis 1977; Boesch and Goldman 2009). The realization that water quality degradation was affecting the Bay was brought into clear focus, stimulating the Eutrophication Science phase (Orth and Moore 1983). The United States Environmental Protection Agency, empowered by the passage of the Clean Water Act in 1972, funded a large multi-disciplinary study to discern the causes of Chesapeake Bay degradation (Costanza and Greer 1995).

In 1983, a regional partnership program known as the Chesapeake Bay Program was created, which led to the Integrated Monitoring and Modeling Science phase (Hood et al. 2021). A large physical model of Chesapeake Bay was built to investigate circulation patterns, along with a computational model of the watershed to better understand nutrient pollution sources (Trombley 2017). A coordinated, long-term monitoring program was established, and tracking Bay water quality and other features became possible (Hood et al. 2021). In 2010, the Total Maximum Daily Load (TMDL), also known as the “nutrient diet,” was established. The TMDL provided a regulatory framework to replace the voluntary approach that had not been achieving the desired results (Shenk and Linker 2013), and each jurisdiction enacted Water Quality Improvement Plans to outline their restoration strategy for meeting the newly-mandated nutrient reductions. The Citizen Science phase was initiated with the realization that the monitoring results were not sufficient in spatial and temporal scales to detect the efficacy of management actions taken in response to the TMDL. This stimulated the establishment of the Chesapeake Monitoring Cooperative in 2015 (Webster et al. 2021).

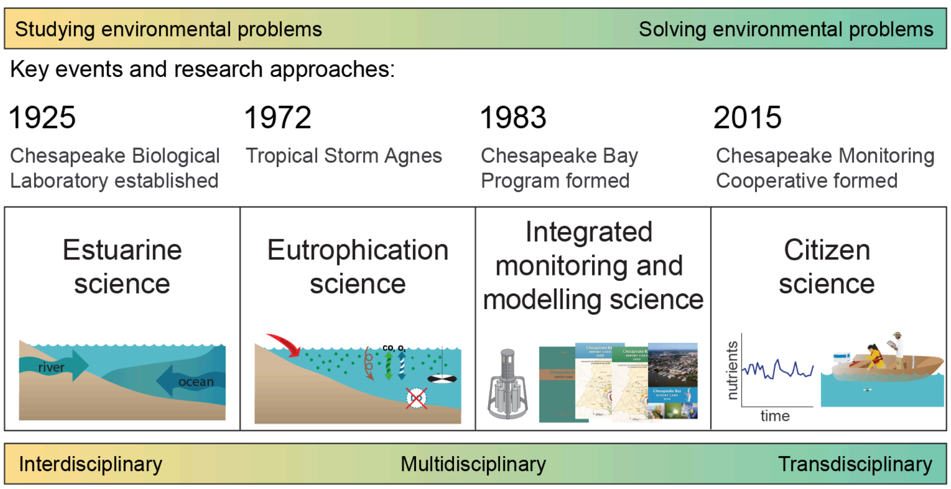


Fig. 1 The evolution of Chesapeake Bay science, broken down into four phases beginning in 1925. These phases represent a shift from studying to solving environmental problems as well as a shift from interdisciplinary science to multidisciplinary science and transdisciplinary science.

There are several features of the Chesapeake Bay region that promote an engaged citizenry (Tillman 2009). The geography of the Chesapeake Bay watershed, with a myriad of dendritic streams and rivers, allows ready access to a waterway that is ultimately connected to the Bay (Oxnam and Williams 2001). In addition, the Bay and its tributaries have over 12,900 km (8,000 mi) of shoreline (Boesch and Goldman 2009). These features of the watershed and shoreline means that people in the Chesapeake Bay region are geographically connected to the Bay. Another feature of the Chesapeake Bay watershed that promotes citizens' connection with the landscape is the high biological productivity of the watershed and the Bay. The watershed includes highly fertile soils that support productive agriculture, and the Bay is highly productive in terms of fish and shellfish production (Roman et al. 2005; Houde 2011). This productivity has supported people in the Chesapeake Bay region for thousands of years.

The Chesapeake Bay watershed includes the Appalachian mountains, a ridge and valley system, a piedmont region of soils eroded from the mountains, and a coastal plain of low lying soils adjacent to Chesapeake Bay (Gillelan et al. 1983). This diversity of landforms is characteristic of a watershed that spans different physiographic regimes. These different landforms have promoted a diversity of traditional cultural groups in the region, which include people living in the Appalachian Mountains, farmers in the valleys and coastal plain, fishers along the Chesapeake Bay shoreline and on islands in the Bay, and traders who use the waterways for commerce. These cultural groups have remained relatively intact since European settlement and the resulting cultural diversity gives rise to different motivations and capabilities of citizen scientists in the region.

The Chesapeake Bay Program, launched in 1983, initially focused on integrated monitoring within the Bay. This monitoring program was eventually expanded into the watershed (Ator et al. 2020; Moyer and Langland 2020). In spite of this extensive and sustained monitoring effort, the spatial resolution and sampling frequency of the monitoring program can only detect long-term changes over large areas. This is one of the key factors why the Chesapeake Bay Program has embraced the establishment of citizen science monitoring.

Citizen science refers to research collaborations between scientists and volunteers, who work together to collect scientific data and answer real-world, locally-relevant questions (Dickinson et al. 2012; Aceves-Bueno et al. 2015). Also known as volunteer monitoring, this movement to include volunteers in environmental research has expanded around the world over the last three decades (Whitelaw et al. 2003; Conrad and Hilchey 2011). In the Chesapeake Bay, scientists and environmental managers have started to explore citizen science as an option for augmenting the temporal and spatial sampling intensity of the Chesapeake Bay Program's formally-established monitoring program. More localized sampling intensity would provide more responsive feedback on various management actions (Zhang et al. 2018). Another factor contributing to the rise of citizen science in the Chesapeake Bay region is the growing awareness of the social and economic inequities amongst the watershed residents. In order to understand and address the environmental justice issues associated with disadvantaged communities, citizen science programs can help detect inequities and empower citizens to act on this information.

Chesapeake Bay watershed residents have participated in volunteer environmental monitoring efforts for decades (Rubin et al. 2017). Various volunteer monitoring programs exist across the watershed, and have traditionally operated independently of one another, each with its own project scope, research goals, and scientific processes. In the Chesapeake Bay region, volunteer-collected data has historically been underused in management and policy-making contexts due to challenges such as low data comparability between monitoring programs, inadequate quality assurance, and potentially a misunderstanding or bias against citizen science on the part of Chesapeake Bay scientists, managers, and decision makers. In 2015, the Chesapeake Bay Program established a new coordinated effort called the Chesapeake Monitoring Cooperative in order to address some of these challenges (Chesapeake Bay Program 2018) and make citizen science data more broadly usable. Despite this progress, there are other challenges that need to be addressed in order for citizen science to reach its full potential in the Chesapeake Bay region.

In the present study, we explored Chesapeake Bay environmental stakeholders' perceptions of how power currently is and ideally ought to be distributed across the socio-political landscape of Chesapeake Bay environmental science and management. We surveyed members of the Chesapeake Bay environmental community to investigate stakeholders' level of familiarity and overall perspectives of the entities of science, management, and citizen science in the Chesapeake Bay region. One objective of this analysis was to gain insight into stakeholders' characterization and delineation of these overlapping concepts. We also asked Chesapeake Bay environmental stakeholders to share their perceptions on the role of science and stakeholder engagement in the management of the Bay. This analysis provided deeper understanding of stakeholders' valuation of science and scientists, as well as their feelings of empowerment or disempowerment in science and management discourse. Finally, we synthesized stakeholders' perspectives of the value of citizen science and the role of citizen scientists in both environmental science and management. Our results provided evidence that encourages continued and expanded stakeholder engagement in Chesapeake Bay environmental research and decision making. We also laid out several recommendations for how the broader Chesapeake Bay environmental community can leverage participatory research to empower non-scientists to contribute to future scientific knowledge production and Chesapeake Bay environmental discourse.

Methods

We developed a survey to explore environmental stakeholders' perspectives on environmental science, management, and citizen science within the Chesapeake Bay watershed. We provided definitions of key terms used throughout the survey (Figure 2). The term 'environmental stakeholder' was used to refer to people who 1) have an interest in or a concern for the environment, 2) are impacted by decisions or changes that affect the environment, and/or 3) are influential in making such decisions or changes. Each respondent was asked to consider their own role as an environmental stakeholder, and self-categorize themselves as a member of one of nine listed stakeholder groups. These groups included 1) program managers, 2) environmental managers, 3) scientists within academia, 4) scientists outside of academia, 5) environmental educators, 6) volunteer monitors and citizen scientists, 7) policy makers, 8) environmental consultants, and 9) Waterkeepers and volunteer coordinators. Respondents were also given the option to indicate that they did not identify as a member of any of the listed stakeholder groups and provide a description of their role. In these cases, respondents were assigned to a listed stakeholder group if their description clearly fit into one of the roles. For example, respondents who described themselves as a “scientist within the federal government” and a “private sector social scientist” were both labeled as “Scientists outside of academia.” In cases where stakeholders’ descriptions did not clearly match with one of the listed roles, such as “Military officer” or “Land use attorney,” the responses were labeled as “Other.”

Environmental stakeholder
Someone who 1) has an interest in or a concern for the environment, 2) is impacted by decisions or changes that affect the environment, and/or 3) is influential in making such decisions or changes

Environmental science
The study of Earth's environments and how humans interact with the environment

Environmental management
Making decisions and taking actions that influence how environmental resources are used, protected, modified, and valued

Citizen science
Research partnerships between scientists and volunteers that provide opportunities for community members to contribute to scientific research and access scientific information

Fig. 2 Definitions for key terms that were used throughout the survey. Respondents were given these definitions before they were asked to provide their perspectives.

Respondents were asked a series of Likert-scale (multiple choice) and sliding scale questions, and were permitted to skip questions throughout the survey if they felt uncomfortable answering a particular survey item or were unable to provide answers for any reason. To start, stakeholders indicated their level of familiarity with various concepts and processes related to Bay research and management. A Likert scale ranging from 1 to 5 was provided for these questions (1=Not at all familiar, 2=Slightly familiar, 3=Moderately familiar, 4=Very familiar, 5=Extremely familiar). Respondents were also asked questions about the relationships between Chesapeake Bay science, management, and citizen science, as well as the roles of various stakeholder groups in these contexts. A Likert scale ranging from 1 to 4 was provided for these questions (1=Not at all, 2=Very little, 3=Somewhat, 4=To a great extent). For these questions, stakeholders were also given the option to select "I do not know" from the list of response choices. This option was provided in order to minimize low quality data resulting from forced responses. Additionally, the survey requested that stakeholders share their perspectives on how much influence various stakeholder groups– including their own– currently and ideally should have on Chesapeake Bay science and management. A sliding scale ranging from 0 to 100 was provided for these questions (0=No influence, 100=Very high influence). We indicated to respondents that for the purpose of this study, signs of having influence, or power, include having control over environmentally-focused policy making, research priorities, funding decisions, or conversations.

To analyze the quantitative data, we first removed all returned surveys that were less than 50% complete. A mean response and corresponding standard deviation was then calculated for each Likert scale and sliding scale question, using all available responses. In cases when respondents selected "I do not know," their answers were excluded from aggregate calculations of the mean response and treated as missing data for statistical analyses that required paired responses. Finally, we conducted two-tailed paired t-tests to determine whether or not the difference between the mean responses of two related questions was statistically significant. For example, related questions were those that compared stakeholders' current and ideal levels of influence or the ideal level of influence for two distinct stakeholder groups. The sample sizes for all t-tests were equal to the number of respondents who answered both of the questions under comparison for each individual test. For t-tests that were missing more than 5% of the total possible paired responses ($n<353$), we concluded that the missing-ness appeared to be approximately equally distributed across stakeholder groups and so randomness was assumed.

The survey also contained several free response questions. Respondents were asked to share three words that came to mind when they thought about Chesapeake Bay research, management, and citizen science, sequentially. We compiled all survey responses into a single list for each of the three key terms. We then standardized similar words that were used by multiple respondents to create clean lists of the most-shared words. For example, all usages of the words ‘volunteers’ and ‘volunteering’ were changed to match the frequently-used root word, ‘volunteer.’ We did not alter conceptually-similar terms such as ‘volunteer’ and ‘non-professionals,” nor did we combine terms with overlapping words, such as ‘water’ and ‘water quality.’ The website WordItOut was used to create a word cloud for each key term, using the 20 most-used words from each of the three lists of survey responses. Finally, respondents were encouraged to provide additional comments at the end of each grouping of Likert-scale survey items. All written responses were analyzed using qualitative data analysis techniques, which involved inductively sorting free response text from each question into emergent themes in a spreadsheet and then coding the text fragments to identify core ideas that were shared by many respondents and representative quotes.

The web-administered survey was distributed to approximately 800 individuals via email, from July 31 to September 9, 2020. To develop the list of potential respondents, we began with our list of nine stakeholder roles. For each stakeholder role, we created a list of organizations across the watershed where individuals within that particular stakeholder group might be employed or otherwise affiliated. For example, to target volunteer coordinators, we compiled a list of volunteer monitoring organizations, waterkeeper associations, and environmental outreach programs that varied in scale and geographic location. To target policy makers, we compiled a list of city, county, and state-level political organizations, as well as various multi-jurisdictional legislative groups, such as the Chesapeake Bay Commission. We then contacted a sample of individuals who were listed on each organizations' staff webpages, using publicly-available email addresses. We supplemented these initial lists with names and email addresses sourced from contact sheets that are provided to attendees at regional conferences, particularly those that draw diverse stakeholder participation, such as the Chesapeake Watershed Forum. Furthermore, we also contacted individuals listed as board members of regional environmental organizations, members of various environmentally-focused advisory committees, and a selection of other organizations. Throughout the whole process, our aim was to be as inclusive as possible and ultimately contact a representative sample of all Chesapeake Bay environmental stakeholders.

Results

Demographics

We received a total of 381 questionnaire responses from Chesapeake Bay environmental stakeholders. We chose to exclude responses that were less than 50% complete, resulting in 372 qualifying responses. From this number, we calculate that our overall questionnaire response rate was approximately 46.5%, with 96% of returned questionnaires completed in full. Respondents represented at least 190 organizations from across the watershed (Appendix 1), ranging in scale from regional environmental committees to state-level governments to hyper-local community organizations. Respondents held a wide diversity of environmental stakeholder roles, including scientists, policy makers, program managers, volunteer monitors, waterkeepers, consultants, educators, managers, and other roles that were not pre-defined on our questionnaire, such as funders, non-profit directors, policy advisors, and environmental lawyers (Table 1). Collectively, respondents indicated that they spent the majority of their time on activities related to program management, outreach, education, and scientific research. Finally, the environmental stakeholders also had a large array of career experience in their stakeholder roles, ranging from early-career professionals with only a few months of experience in their current positions, to individuals who have worked in the same role for over 45 years.

Respondent characteristic	Number of responses	Percentage of study respondents
Stakeholder role		
Program manager	89	23.9
Environmental manager	44	11.8
Scientist outside of academia	40	10.8
Scientist within academia	39	10.5
Environmental educator	35	9.4
Volunteer monitor or citizen scientist	25	6.7
Policy maker	25	6.7
Environmental consultant	20	5.4
Waterkeeper or volunteer coordinator	16	4.3
Other	39	10.5
Years in current stakeholder role		
< 2	44	11.8
2 to 5	130	34.9
6 to 10	71	19.1
11 to 15	44	11.8
16 to 20	28	7.5
21 to 30	27	7.3
31 to 40	13	3.5
> 40	7	1.9
No response	8	2.2
Total	372	100.0

Table 1. Respondent demographics by their self-described stakeholder roles and the number of years in their current role.

Familiarity

We asked respondents to describe Chesapeake Bay science, management, and citizen science, and then reflect on their own level of familiarity with each of the three concepts. Participants' responses provided support for our hypothesis that Chesapeake Bay environmental stakeholders share a rather sophisticated understanding of Bay science and management (Figure 3). As an aggregate group, stakeholders claimed a moderately high level of familiarity with the processes involved in researching the Bay (Figure 3D), emphasizing Bay science's focus on water quality and monitoring for the purpose of research, as well as the importance of ecology, models, and nutrients (Figure 3A). Stakeholders claimed a slightly higher level of familiarity with the processes involved in managing the Bay and the same level of familiarity with the role that environmental science plays in Chesapeake Bay management (Figure 3D). Their descriptions of Bay management drew attention to the emphasis that management places on protection, regulation, and conservation, and stakeholders once again mentioned the importance of water quality, but this time for the purpose of restoration and policy (Figure 3B).

When describing citizen science, stakeholders again emphasized the importance of monitoring, but this time with a distinct focus on community, engagement, and education (Figure 3C). Stakeholders also called attention to the fact that citizen science involves volunteers, differentiating it from both science and management. Interestingly, despite the fact that 66% of respondents indicated that they had participated in a Chesapeake Bay citizen science effort within the last five years, environmental stakeholders had somewhat lower levels of familiarity with citizen science efforts in the Bay (Figure 3D). Compared to their level of familiarity with the role of traditional science in environmental management, stakeholders were significantly less familiar with the role that citizen science plays in managing the Chesapeake Bay ($p<0.0001$)(Figure 3D).

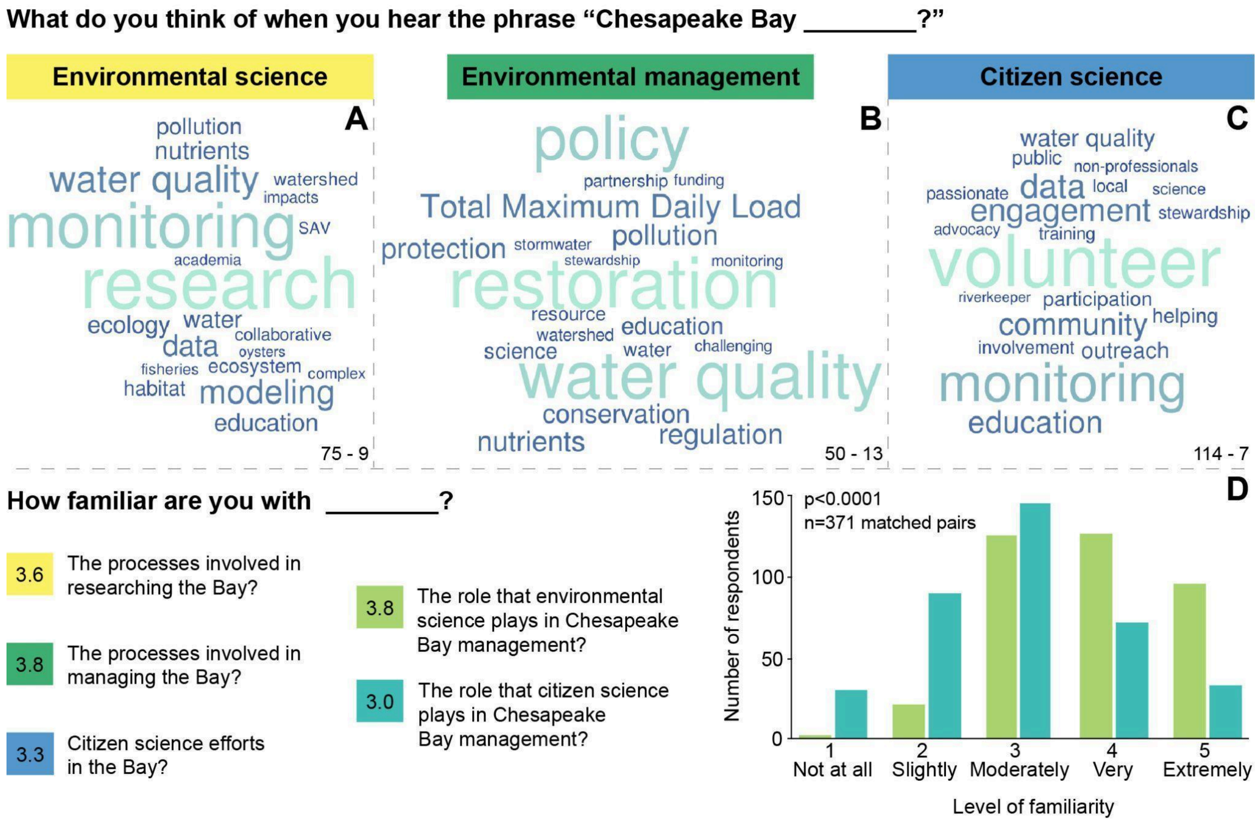


Fig. 3 Word clouds provide a visual representation of stakeholders' conceptualization of Chesapeake Bay environmental science (A), management (B), and citizen science (C). Each word cloud shows the 20 words or phrases that were most frequently listed by stakeholders in response to the corresponding survey question. Words in larger and lighter-colored text were listed the most frequently; smaller and darker-colored words were listed less often. The numeric ranges provided at the bottom of the word clouds represent the number of respondents that listed the most often-used and least often-used words shown on each cloud. Respondents' mean self-reported level of familiarity with various processes associated with researching and managing the Bay is specified (D)(n=371). Standard deviations ranged from 0.9 to 1.1. Most stakeholders reported that they were either 'moderately' or 'very' familiar with the role that traditional science plays in management, but significantly less familiar with the role of citizen science (t-test; $p < 0.0001$).

Perspectives on the role of science and scientists in Bay management

We found that stakeholders were generally enthusiastic about the utility and power of Chesapeake Bay science in the context of environmental management. In fact, an overwhelming 91% of respondents said that public policies should be based on the best available science "to a great extent." Although stakeholders largely agreed that scientific research should play some role in environmental policy and management, stakeholders shared varying perspectives regarding the degree to which science (and scientists) should ultimately be able to influence policy decisions. Many respondents argued in their written responses that science should be “front and center” and dictate management decisions, and likewise specified that scientists should have the “primary voice” in policy development, with the power to vet all management decisions before their implementation. On the opposite side of the spectrum, other respondents believed that “scientists should focus on their research” rather than become directly involved in management processes, and shared a number of concerns over emphasizing science when making management decisions. For example, some respondents argued that the utility, novelty, and even the credibility of scientific research is limited because the scientific community follows funding priorities that are influenced by politics. Respondents professed that this dependence on funding can lead to an “outsized influence” of certain types of research, such as computer modeling, and can cast doubt upon scientists’ ability to be “objective” in their research and resulting management recommendations.

The majority of respondents, however, fell in the middle of these two extremes, saying that “science should guide public policy, not dictate it” and that scientists, like other stakeholder groups, should have a specific role and accompanying responsibilities associated with Bay management. Many respondents specified that scientists should serve as subject matter experts for politicians. One respondent explained this division of labor, saying “Scientists are there to tell us the closest thing there is to absolute truth, and policymakers are there to decide what to do with that information.” Other stakeholders believed that scientists should not be restricted to the role of information providers and “nonpartisan observers of the decline of the Chesapeake Bay.” Instead, some stakeholders argued that scientists should be encouraged to “speak up” and advocate for Bay protection, perhaps by serving as members of a government-mandated scientific committee that is consulted about policy involving the Bay. Finally, one of the most often-shared perspectives about the role of scientists in management was that “Scientists should have as much influence as anyone else at the table;” therefore, while science should inform policy, “Final decisions should be part of the democratic representative system.”

Many respondents noted that scientists have a key responsibility to effectively communicate their findings to managers, policy makers, and the public. Most stakeholders agreed that management decisions should take science into account to some degree; therefore, it follows that scientists should keep policy makers and managers informed on the latest Bay science in order to enable timely and evidence-based management decisions. Through communicating about their research, scientists play a crucial role in closing the gap between research and management by minimizing the “disconnect between current scientific understanding and how fast that science is incorporated into management and policy decisions.” Furthermore, respondents indicated that scientists should also share their science with broader audiences, specifically Bay communities affected by environmental management decisions. Respondents suggested that in order to do this effectively, scientists must heed the pithy advice of marine conservationist Jacques Cousteau and remember that "People protect what they love". Therefore, scientists should work to “shape stories that people can connect with” and communicate the relevance and importance of their work in a way that respects community values and motivates people to do their part in supporting environmental decisions that help the Bay.

Perspectives on stakeholders participation in Bay management

Respondents expressed strong support in favor of increasing the degree to which stakeholders and stakeholder perspectives are included in Chesapeake Bay management decisions. Most stakeholders shared the belief that Bay management currently somewhat takes into account a wide diversity of stakeholders’ concerns; however, as an aggregate group, respondents said that stakeholder perspectives should ideally be considered to a significantly greater extent than they are now (p<0.0001) (Figure 4). Indeed, in their written responses, many individuals expressed feelings of frustration or resignation at the current state of stakeholder involvement in Bay management. One respondent wrote, “Stakeholders are often asked to participate in conversations, some of which involve a lot of time and effort, but my experience has been that most of the suggestions, ideas, and information presented during those dialogues doesn't find its way into policy”. Respondents also noted that incorporating a greater diversity of people into the environmental management community “would improve management discussions and plans as more perspectives and lived experiences would be brought to the table” and result in environmental policies that have “equitable and truly resilient outcomes,” as well as increased public acceptance.

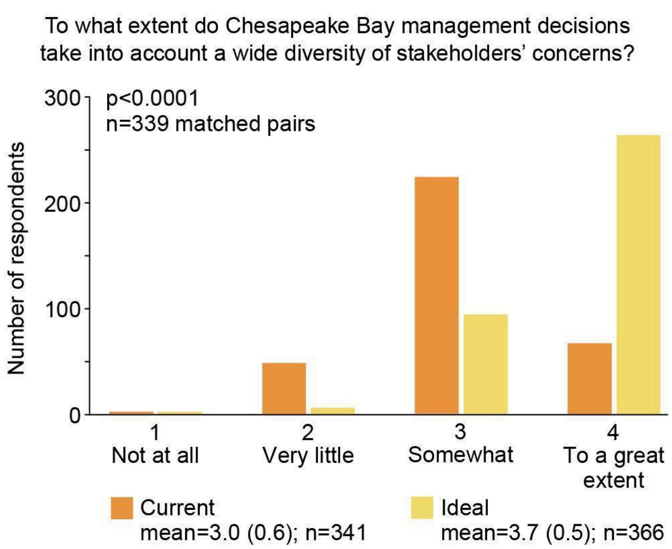


Fig. 4 Respondents indicated that they would like to see diverse stakeholder concerns be taken into account to a significantly greater extent than they are currently, when making management decisions (t-test; p<0.0001). The mean responses for each question, along with corresponding standard deviation in parentheses, are reported in the figure legend.

Respondents were also asked to reflect on their own involvement in Bay management. Specifically, respondents were asked to quantify the level of influence that they, as well as others with the same stakeholder role, currently have in Bay management. They were also asked to identify how much influence they should have, ideally. Across the board, within every stakeholder group, respondents perceived that they should be significantly more influential in Bay management, by an average of 19.2 points on a scale of 100 (p<0.0001) (Figure 5).

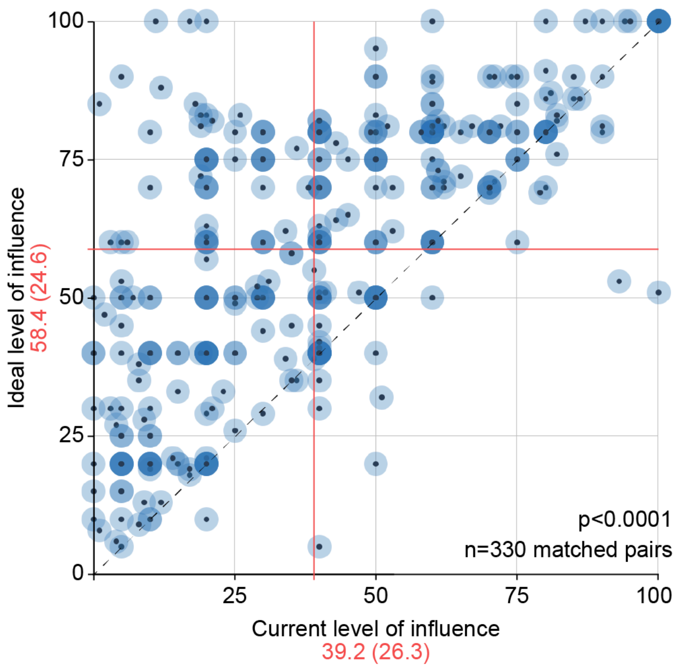


Fig. 5 There was a statistically significant difference in respondents' current and ideal levels of influence in Chesapeake Bay management (t-test; $p<0.0001$). Dots depict the level of influence that stakeholders believed they and others who share their stakeholder role currently (x-axis) and ideally (y-axis) have in Bay management. All dots above and to the left of the diagonal line represent respondents who think they should have more influence than they currently do. Darker-colored dots indicate multiple overlapping responses. The mean response for each variable is reported in red text, along with the corresponding standard deviation in parentheses. The mean difference between stakeholders' current and ideal level of influence was 19.2 on a scale of 100, meaning that stakeholders would like to see a 49.0% increase in their amount of influence in Chesapeake Bay management.

Although these feelings of disempowerment were evident across all respondents as an aggregate group, there were some compelling differences between stakeholder groups (Table 2). For example, we found that scientists within academia and waterkeepers or volunteer coordinators experienced the highest degrees of disempowerment, meaning that these stakeholders perceived the greatest mean difference between their ideal and current levels of influence ($p<0.0001$ and $p=0.0027$, respectively). Environmental managers and policy makers perceived the smallest mean difference between their ideal and current levels of influence, and also reported the highest levels of current influence out of all the stakeholder groups. This suggests that while these stakeholders believe that they should have more influence than they do, they feel the most empowered of all the listed stakeholder groups. Finally, through their written responses, many respondents also drew attention to other stakeholder groups that they believed have a lot of potential to contribute towards environmental management but are currently unempowered or undervalued, including environmental educators and members of the business community.

Stakeholder role	**Current influence**	**Ideal influence**	**Difference between ideal and current influence**	**95% Confidence limit for the difference**	**T-test p-value**
Scientist within academia (n=35)	34.4 (23.7)	60.7 (23.4)	26.4 (17.9)	20.2 - 32.5	<0.0001
Waterkeeper or volunteer coordinator (n=13)	33.9 (24.8)	57.5 (28.4)	23.6 (22.6)	9.9 - 37.3	0.0027
Environmental consultant (n=20)	38.4 (24.1)	61.7 (22.9)	23.3 (23.5)	12.3 - 34.3	0.0003
Program manager (n=78)	42.2 (26.2)	62.9 (22.3)	20.6 (20.0)	16.1 - 25.1	<0.0001
Scientist outside of academia (n=35)	42.0 (27.2)	60.3 (21.6)	18.3 (25.9)	9.4 - 27.2	0.0002
Environmental educator (n=29)	34.5 (25.1)	51.6 (25.3)	17.1 (18.2)	10.2 - 24.1	<0.0001
Volunteer monitor or citizen scientist (n=22)	20.4 (21.0)	35.9 (23.5)	15.5 (16.2)	8.3 - 22.7	0.0002
Policy maker (n=24)	47.0 (31.8)	61.8 (28.1)	14.8 (22.7)	5.2 - 24.4	0.0040
Environmental manager (n=41)	49.8 (25.5)	61.5 (23.7)	11.7 (16.9)	6.4 - 17.0	<0.0001
Other (n=34)	34.5 (23.8)	55.6 (25.9)	22.0 (21.3)	14.5 - 29.5	<0.0001
All respondents (n=330)	39.2 (26.3)	58.4 (24.6)	19.2 (20.6)	17.0 - 21.5	<0.0001

Table 2. Stakeholder reflections on their own level of influence in environmental management, broken out by stakeholder role. Using a scale of 0 to 100, stakeholders were asked to indicate the degree of influence that they, along with others with their stakeholder role, currently have and should ideally have in Chesapeake Bay management. Mean responses are reported, along with corresponding standard deviations in parentheses. The variable n represents the number of responses included in the paired t-test.

Interestingly, many respondents suggested in their written responses that the integration of people and ideas into environmental management should be facilitated, or even spearheaded by scientists, perhaps partly due to their above-average current levels of influence. Respondents indicated that they would like to see environmental scientists directly reaching out to elevate and empower other stakeholder groups, especially local communities. Specifically, stakeholders suggested that scientists should take the initiative to "coordinate with a broad spectrum of stakeholders to help identify knowledge gaps and the most important questions," and be actively engaged in understanding others' perspectives. Repeatedly, respondents stated that effective environmental management should pair environmental science alongside local and cultural knowledge, community-based participatory research, and approaches from other disciplines, such as socio-economics and behavioral science.

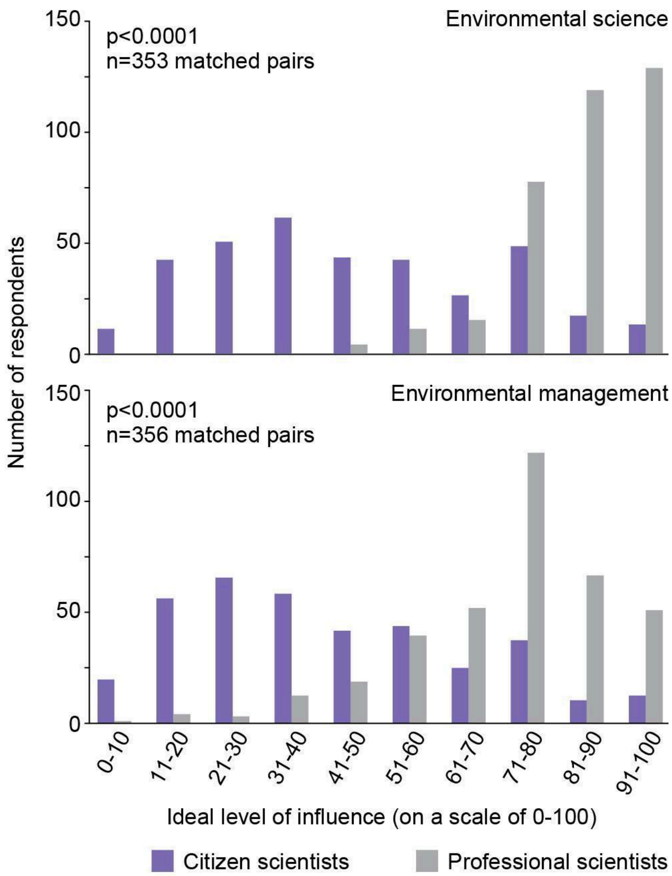
Perspectives on citizen science

Following up on our questions about the influence of science, scientists, and other environmental stakeholders in Bay management, we were interested in understanding stakeholders' perspectives on Chesapeake Bay citizen science, as a potential avenue for interested members of the public to contribute to the science and ultimately the management of the Bay. As an aggregate, respondents said that citizen scientists and volunteer monitors 'somewhat' increase scientific understanding of the Bay, with an average score of 3.1 points on a scale of 4 (n=365). Stakeholders' responses to various survey questions revealed that as an aggregate, the Chesapeake Bay environmental community believed that .

In both their written and multiple-choice responses, stakeholders as an aggregate group agreed that citizen scientists should have some influence in both Bay science and management; however, stakeholders shared diverse perspectives about the specific role and level of influence that volunteers ought to have in scientific research. For example, stakeholders had differences in opinion about the overall utility of citizen science with respect to Chesapeake Bay environmental science. Some stakeholders suggested that while citizen science augments other scientific research efforts in the watershed, it is currently underutilized, in part due to the fact that other environmental stakeholders – especially professional scientists – lack trust for volunteers or have personal biases against their contributions. Other stakeholders' responses confirmed these suspicions. These stakeholders argued that citizen science should only be used in situations where professionals are unable to conduct the study themselves, and that citizen scientists' role should be strictly limited to data collection for the purpose of supporting professional scientists' research. Some stakeholders held a more absolute view, arguing that science should be strictly reserved for professionals because they have "spent years in school to adequately learn how to sample," and therefore have the authority over that line of work. One responder hinted at this territoriality and competitive mentality, commenting that "there is nothing more frustrating than investing time, research, and money into a profession and then having volunteers squeeze you out because they do what you could do for free".

Furthermore, some respondents expressed concern about the quality of volunteer-collected data, saying that volunteers' contributions "should not be valued as much as research conducted by scientists who stick to protocols." Other stakeholders opposed this view and argued that "Science is science" and therefore, assuming volunteers are trained, "there is no reason their data is different from those collected by someone with a formal science education." Finally, stakeholders also shared different perspectives about the impact that citizen science has had, or could have, on Bay science. For example, some respondents were concerned that volunteers might “use science as a political weapon” and generate flawed data to support their own agendas, which “could potentially undermine the objectivity and legitimacy” of not only their research, but the institution of science. On the opposite end of the spectrum, other stakeholders perceived that citizen scientists are undervalued and have already increased the capacity of the scientific community by expanding data collection efforts across the watershed. These respondents recognized citizen scientists’ contributions, saying that “Most of the current scientific research on the Bay would not have been possible without countless hours of volunteer effort.”

Perhaps unsurprisingly, stakeholders as an aggregate believed that citizen scientists should have a significantly lower level of influence in environmental science than their professional counterparts, with a mean difference of 38.1 out of 100 ($p<0.0001$) (Figure 6). Respondents’ assessments of how much influence volunteers should ideally have in Chesapeake Bay environmental science echoed the wide diversity of perspectives that were shared in the free response questions. While the majority of stakeholders agreed that professional scientists should have high levels of influence in environmental science, stakeholders expressed a notably larger range of perspectives about the ideal role of citizen scientists in environmental science, with responses ranging all the way from 0 to 100 and a centralized median of 50.



Science	49.2 (23.3); n=355	87.3 (11.4); n=366
Management	44.5 (23.5); n=357	74.4 (16.9); n=370

mean (std dev); sample size

Fig. 6 The level of influence that citizen scientists and professional scientists should have in Chesapeake Bay science (top) and management (bottom), according to the broader stakeholder community. Mean responses are reported in the legend, along with corresponding standard deviations in parentheses.

On average, stakeholders assessed that citizen scientists should ideally have even less influence in environmental management than they should have in science ($p<0.0001$, n=353), though responses again ranged across the board (Figure 6). Respondents also agreed that volunteers should have a comparatively lower level of influence in management than professional scientists ($p<0.0001$), with a mean difference of 29.9 out of 100 between the two stakeholder groups. Regardless of stakeholders' perspectives on the relative influence of volunteer and professional scientists in environmental management, respondents as an aggregate group indicated that citizen scientists should ideally be able to influence management decisions to a greater extent than they are able to currently, with a mean difference of 0.8 on a scale of 4 ($p<0.0001$, $n=313$).

When asked to indicate to what extent various stakeholder groups should be able to influence Chesapeake Bay environmental management decisions and public policy, respondents indicated that citizen scientists should have the least amount of influence (Figure 7). Perhaps unsurprisingly, stakeholders as an aggregate group again indicated that citizen scientists should have significantly less influence than professional scientists ($p<0.0001$), as well as less influence than members of respondents' own stakeholder groups ($p<0.0001$). Stakeholders also indicated that citizen scientists should be able to influence public policy and management decisions to a lesser extent than individuals who are not formally-trained environmental professionals ($p<0.0001$, $n=351$). It is especially noteworthy that the degree of influence deemed as appropriate for an unspecified, untrained stakeholder was significantly higher than the influence granted to citizen scientists, who are very often highly trained to participate in specific research activities. This particular discrepancy suggests a bias against citizen science, generally, or the volunteers who participate in these efforts.

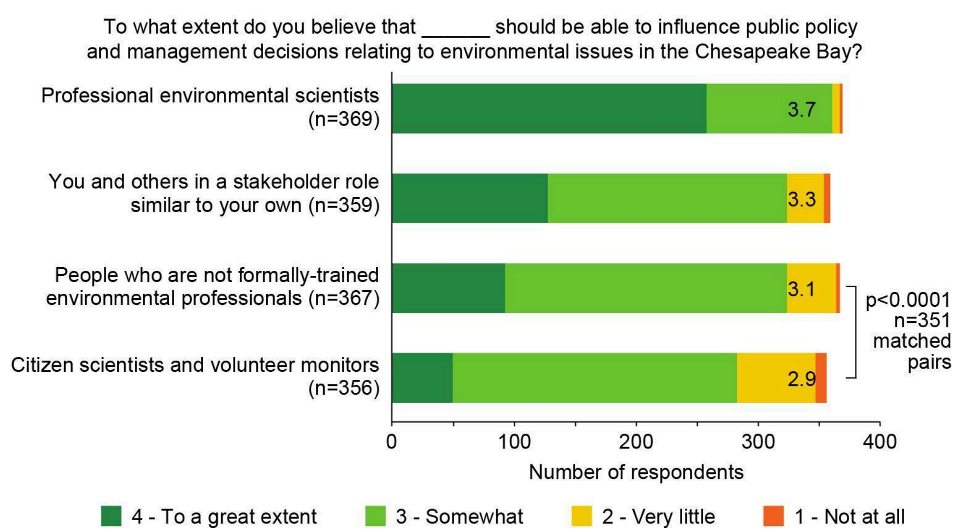


Fig. 7 The relative extent to which various stakeholder groups should be able to influence environmental policy and management decisions. Mean responses are reported on the graph, and corresponding standard deviations ranged from 0.5 to 0.7. Stakeholders as an aggregate group perceived that scientists should have the highest levels of interest, even compared to members of their own stakeholder group. Also notably, Stakeholders indicated that people who are not formally trained environmental professionals should be able to influence policy and management to a significantly greater extent than citizen scientists (t-test; $p<0.0001$).

Again, stakeholders' written survey responses further explored the nuances of environmental stakeholders' breadth of perspectives about the role of volunteers in environmental management. Several respondents argued that citizen scientists should be treated like any other stakeholder interest group, and should therefore have a role in contributing to management because "the Bay belongs to everyone, not just a few 'experts'." One respondent summarized this perspective, explaining that "everyone's needs, values, perspectives, and experiences matter and should be part of management decisions." Some respondents acknowledged that while citizen scientists might be able to contribute to management at a local level, they "lack a broad understanding of the entire Bay," and very rarely appreciate the complexity of the issues and trade-offs that must be factored into management decisions. Other respondents agreed that citizen scientists should not necessarily have a seat at the metaphorical table, but "the scientific data that volunteers collect should play a strong role" in management decisions.

Stakeholders also acknowledged that volunteers already contribute to Chesapeake Bay management in various ways, even beyond collecting environmental monitoring data. For example, citizen scientists often have deep knowledge of a particular geographic area and "can supplement scientific knowledge with stories that can truly help drive change and connect people through deeper engagement." Others elaborated on this concept, suggesting that while management decisions should be made by elected officials and panels of technical experts, citizen science is particularly valuable for management because of its ability to transform volunteers into environmental leaders who can "influence their neighbors to be better stewards and lean on elected officials to make Bay restoration a higher, better-funded priority." Respondents further explained that citizen science should not drive policy decisions, but volunteers can "be even more impactful as advocates than they can as scientists" because they can work with their volunteer organizations to identify priority issues, educate and engage others in their communities, and advocate for certain environmental decisions to be made.

Discussion

Our research determined that the Chesapeake Bay environmental community especially values science in the context of environmental decision-making. According to our survey responses, 100% of Chesapeake Bay environmental stakeholders believed that public policies should be based on the best available science, with 91% of respondents agreeing that science should influence policy "to a great extent" (n=372). When Research!America asked the same question as part of their 2018 national survey, they found that 67% of U.S adults agree that public policies should be based on the best available science (Research!America 2018). Both surveys suggest that a majority of stakeholders support science influencing policy decisions, but the differential in responses between the two surveys suggests that this is especially the case within the Chesapeake Bay environmental community. The discrepancy between the present study and the national survey are perhaps unsurprising, given the Chesapeake Bay's nearly 40-year history of science-based management that began with the formation of the Chesapeake Bay Program in 1983.

The majority of Chesapeake Bay environmental stakeholders also believed that scientists themselves should have a substantial level of influence in environmental management decisions; however, the exact nature of scientists' role in management was debated throughout survey responses, and is also hotly contested in the academic literature. Many scholars have proposed frameworks describing specific roles that scientists can potentially play when navigating the science–policy interface (e.g., Lach et al. 2003; Pielke 2007; Milkoreit et al. 2015). These defined roles range on a spectrum. At one end are ‘pure scientists’ and ‘truth seekers’ who report value-neutral scientific facts but provide no additional insights that might influence how the science is interpreted or ultimately used. At the other end of the spectrum are ‘change makers’ and ‘issue advocates’ who share scientific results and also make the case for preferred management decisions based on their scientific expertise. Some scholars argue that ethical scientists must focus on providing scientific facts while remaining objective and apolitical. For example, Lackey (2007) says that scientists should avoid using value-laden words like “degradation” and “ecosystem health” because they imply a desired ecological state or preferred management decision. Indeed, several respondents in our study also appeared to prefer this prescribed role for scientists. However, considerably more studies (including the present study) reveal that people generally prefer scientists to be more active participants in management decisions (e.g., Lach et al. 2003; Nelson and Vucetich 2009; Pew Research Center 2020). Kotcher et al. (2017) maintain that by engaging in certain forms of advocacy, scientists do not negatively impact their own credibility or the trustworthiness of their science. The authors suggest that instead of debating whether or not scientists should or should not advocate, it would be more productive to work together to better understand what appropriate and ethical advocacy looks like (Kotcher et al. 2017).

Our results suggest that many Chesapeake Bay environmental stakeholders would like to see scientists take an active role in changing the way that environmental knowledge is communicated and used. Respondents emphasized the importance of effective science communication and generally agreed that scientists should be involved in interpreting their science and helping to integrate it into the context of potential management decisions. Lach et al. (2003) recommend that scientists who play more active roles in management decisions also have the responsibility to effectively communicate their research findings so that other stakeholders can adequately understand the scientific information and integrate it into decision making processes in more accurate and meaningful ways. Reed et al. (2014) impart a similar challenge on scientists, urging researchers to "go beyond simply producing and communicating new knowledge" and instead work together to co-produce and more effectively apply knowledge in order to solve environmental problems. By deliberately spanning the boundaries between science and decision making, scientists can facilitate a more inclusive knowledge exchange process in which relevant research is produced faster, accepted by more stakeholders, and swiftly integrated into decision-making processes (Bednarek et al. 2018).

The Chesapeake Bay environmental community must also welcome environmental anthropologists, economists, political ecologists, and other social scientists to the table to ensure that environmental decisions are indeed informed by the best available science. The present study focused on the roles that environmental science and environmental scientists play in environmental management, but we also recommend integrating social science research and researchers into environmental decision-making processes. As other scholars have already pointed out, many environmental challenges are, in fact, human problems; therefore, environmental management is as much about understanding people as it is about understanding ecology, physical geography, and other natural sciences (Mascia et al. 2003; Martin 2020). Furthermore, environmental management is a human-centric endeavor and environmental policies are social phenomena— stakeholders come together to share relevant information, consider competing values and priorities, and ultimately make decisions in hopes of achieving socially-desired outcomes as a result of human behavioral change (Mascia et al. 2003; Doremus and Tarlock 2005). Although social scientists have historically had fewer opportunities to meaningfully contribute to these types of decision-making processes than their natural science counterparts (Freudenburg 1989; Bennett et al. 2017), the value of social science in environmental management contexts is acknowledged with increasing frequency (Bennett et al. 2017). For example, studies on perceptions, similar to the present research, can give some indication of stakeholders' attitudes and level of support for management decisions and also provide insight into whether or not policies are likely to result in socially equitable outcomes (Bennett 2016; Bennet et al. 2017).

Our study provides evidence of widespread feelings of disempowerment throughout the Chesapeake Bay environmental community. Regardless of their individual stakeholder role, most respondents believed that they should ideally have a higher level of influence in environmental management than they perceived they had at the time of this study. Furthermore, members of the Chesapeake Bay environmental community agreed that stakeholder perspectives should be considered more during decision-making processes. This perspective is also common throughout the academic literature. Many researchers have found that engagement with diverse stakeholders is essential for addressing complex environmental challenges (e.g., Reed 2008). In order to increase the chances that stakeholder engagement in environmental management results in beneficial outcomes, Reed (2018) specifies that power dynamics must be understood and effectively managed so that all stakeholders feel empowered to contribute knowledge and influence decisions in an equitable way.

Our research clearly shows that Chesapeake Bay environmental stakeholders across the board would like to have a higher level of influence in management decisions, even if not quite as high as the level they would grant to scientists. In the Chesapeake Bay area, even though citizen committees and other stakeholders have been included in the management framework since the early years of the Chesapeake Bay Program (Hennessey et al. 1994), scientific knowledge (and therefore scientists' voices and research priorities) is still relatively privileged over other types of knowledge. As a result, management decisions and priorities are heavily influenced by scientific research and those who contribute science-based knowledge, while other sources of expertise, such as tacit knowledge and indigenous knowledge, are undervalued or overlooked (Boiral 2002). This disempowerment of other environmental stakeholders has been shown to contribute to environmental injustice (Johnson and Clisby

2009), and eventually puts scientists at risk of losing the trust and support of other environmental stakeholders (Berkes 2009). In contrast, when stakeholders are empowered to contribute to environmental management, there are increased levels of support and trust in environmental management practices (Goldman et al. 2011; Gray et al. 2012).

Strategic knowledge integration processes, such as participatory research, could help the Chesapeake Bay management community create additional space for other types of knowledge contributions and further empower other types of Chesapeake Bay environmental stakeholders. Fortunately, there is no shortage of knowledge integration products, processes, frameworks, and toolkits that can help facilitate stakeholder engagement, guide collaborative learning and decision-making, and integrate different forms of knowledge into environmental decision-making processes (e.g., Raymond et al. 2010; Alexander et al. 2019; Brouwer et al. 2019). Participatory research is a knowledge integration approach that challenges traditional power structures and abandons the expert-driven approach to solving complex problems (Kreuter et al. 2004) by empowering non-scientist stakeholders to contribute to the creation of new scientific knowledge. This approach involves incorporating local knowledge and local people into all stages of the scientific research process (Calheiros et al. 2000). Collaborators involved in a participatory research effort help to define research hypotheses and priorities, collect and interpret data, and disseminate research results.

Participatory research could be especially productive and appropriate for engaging Chesapeake Bay environmental stakeholders and other groups of people who value the role of science in management decisions but simultaneously want to have more influence in management themselves. In the context of Chesapeake Bay management, this approach of bringing people together in a research-focused context could be a way of capitalizing on a point of convergence within the Chesapeake Bay environmental community. Participatory research is beneficial because it can increase the rigor, relevance, and reach of science (Balazs and Morello-Frosch 2013), and often results in research that is more widely accepted by broader communities (Calheiros et al. 2000). Participatory research also offers stakeholders the opportunity to co-develop a more comprehensive understanding of their environment and the management of socio-environmental systems (Calheiros et al. 2000). Participatory research is not a substitute for other opportunities that invite stakeholders to meaningfully contribute their own diverse forms of knowledge, experiences, and perspectives to environmental management in non-research contexts, but it could offer a supplemental avenue for empowering non-scientists.

Transdisciplinary research is a participatory approach that aims to produce solution-oriented science that responds to societal needs (Roux et al. 2010; Lang et al. 2012). To accomplish this goal, the transdisciplinary research approach not only recognizes the importance of integrating social and natural sciences (Heberlein 1988; Bennett et al. 2017), but also extends the deliberative peer community beyond academia to include other individuals with interest in the outcome of the research (Bidwell 2009; Lang et al. 2012; Reed et al. 2018). Members of transdisciplinary research teams work together to synthesize their diverse expertise and co-produce new knowledge that more holistically characterizes socio-environmental systems and solves “wicked” problems of common interest (Milkoreit et al. 2015). The transdisciplinary approach broadens the scope of which sources of knowledge are considered legitimate and valuable in the context of scientific research. In doing so, transdisciplinary research empowers environmental stakeholders whose expertise has been historically undervalued by incorporating often-overlooked information such as community values, historical context, and personal experiences (Bidwell 2009). In this sense, transdisciplinary research creates a space for an inclusive discourse and continuous blending of knowledges (Milton 1993). The process of blending diverse stakeholder knowledge, including traditional scientific knowledge, can support the creation of a new, more holistic approach to knowing, valuing, and managing the environment (Milton 1993). Because the new co-created approach is more reflective of diverse environmental values and realities, it is often more practically useful for decision making and management purposes (Goldman et al. 2011).

Citizen science is another form of participatory research that offers non-scientists the opportunity to contribute to scientific research and knowledge production, to varying degrees. In contrast to transdisciplinary research projects, wherein participants are most often selected by the project coordinators, citizen science efforts are usually open to all interested individuals (Pettibone et al. 2018). Citizen science therefore allows for broader societal involvement in scientific knowledge production, and is less dependent on participant selection processes and biases that determine which stakeholders are included or excluded (Pettibone et al. 2018). Citizen science projects vary on a continuum in the degree to which participants are involved throughout various phases of the research effort (e.g. Danielsen et al. 2009; Shirk et al. 2012). For example, some citizen science research limits volunteer contributions to data collection, while other research is more community-driven and transdisciplinary, and includes volunteers in other phases of research, such as problem definition, data analysis, and communication of results. The ideal scope of volunteer inclusion depends on the specific goals of a particular research project and its participants (Pettibone et al. 2018). Regardless of the exact nature of volunteers' roles in particular projects, citizen science contributes to a better understanding of environmental systems and benefits environmental science, management, and stakeholder communities (Dickinson et al. 2010; Conrad and Hilchey 2011; McKinley et al. 2017).

In certain circumstances, the benefits of citizen science increase when volunteer participation expands beyond environmental data collection (Freitag and Pfeffer 2013; Buytaert et al. 2014; Jollymore et al. 2017). In these situations, citizen science functions as a platform for different stakeholders to synthesize local-scale data and bridge together multiple knowledge streams (Irwin 1995). Citizen science programs serve as boundary-spanning organizations by facilitating knowledge integration and helping to establish and maintain collaborative partnerships between various stakeholders (Berkes 2009; Webster et al. 2021). Beyond empowering non-scientists to participate in scientific knowledge creation, this more iteratively collaborative, transdisciplinary citizen science can also create opportunities for non-scientists to actively contribute to environmental discourse and work together to translate their integrative research into management recommendations. When the production of scientific knowledge is collaborative and democratized, the resulting science-based management recommendations are more reflective of the needs and knowledge of a diverse public and more representative of the environment as a complex socioecological system (Buytaert et al. 2014; McKinley et al. 2017). Citizen scientists' contributions can, therefore, give them more influence as actors at the science-policy interface, rather than passive recipients of environmental policy (Bäckstrand 2003). This is especially true in the Chesapeake Bay context, where stakeholders share the perception that science should play a large role in environmental decision-making. Thus, citizen science can shift authority structures, decentralize political power, and enable more democratized management of resources (Freitag and Pfeffer 2013).

Chesapeake Bay environmental stakeholders have mixed perspectives on the utility of citizen science for Chesapeake Bay environmental research and management, despite the clear potential that citizen science has in the Chesapeake Bay area, as well as its proven benefits elsewhere. In order to fully take advantage of citizen science as a tool to empower more stakeholders and improve Bay management, members of the Chesapeake Bay environmental community must first acknowledge and overcome their biases against citizen science and their distrust or misunderstanding of the volunteers who participate in these efforts. Specifically, stakeholders in aggregate believed that citizen scientists should possess lower levels of influence than other stakeholder groups, including generic "people who are not formally-trained professionals." Even so, respondents also specified that citizen scientists should ideally be able to influence management decisions to a greater extent than they are able to currently. This perspective indicates that Chesapeake Bay environmental stakeholders are indeed open to expanding the role of citizen science and its participants in environmental management.

We offer four recommendations that could help the Chesapeake Bay environmental community make citizen science participatory research more impactful and empowering in the Chesapeake Bay region. First, stakeholders should work together to increase the degree of coordination and data comparability between various citizen science efforts in the watershed. Greater comparability between individual monitoring efforts will help stakeholders meet multiscalar data needs and make the best use of data collected through various citizen science efforts (Conrad and Daoust 2008; Webster et al. 2021). Second, stakeholders should encourage additional support of volunteer efforts (financial or otherwise) from influential science and management authorities, such as the Chesapeake Bay Program and other regional partnerships. Effective capacity building of citizen science requires the engagement of stakeholders who represent science, policy, and different cultures and socio-economic communities within society (Richter et al. 2018). Third, Chesapeake Bay environmental stakeholders should reach out to underserved communities to include these stakeholders in participatory research efforts. Improving the accessibility of citizen science will increase inclusion and environmental justice within the Chesapeake Bay environmental community, while also increasing scientific data representation and knowledge integration across the watershed (Blake et al. 2020; Hermoso et al. 2021). Finally, particularly if transdisciplinary citizen science efforts become more common within the Chesapeake Bay environmental community, stakeholders must bear in mind that the process of integrating different forms of knowledge is a difficult undertaking (Buytaert et al. 2014). Multi-stakeholder knowledge integration, when done ineffectively, can result in surface-level public “participation” that does not truly incorporate multiple voices, but instead perpetuates the dominant discourse, and further disempowers participants (Brosius et al. 1998; Bäckstrand 2003; Pettibone et al. 2018).

Conclusion

Chesapeake Bay scientific research has become increasingly interdisciplinary over time in order to inform adaptive management of the Bay as a complex socio-ecological system. In recent years, the Chesapeake Bay environmental management community has identified a need for more fine-scale environmental data and multi-stakeholder engagement, and has turned to citizen science as a tool for meeting these needs. Though studies have demonstrated numerous positive outcomes of participatory research in other systems, citizen science is not yet fully leveraged as a source of data and knowledge production within the context of Chesapeake Bay management. Furthermore, despite a long history of efforts to engage stakeholders in Chesapeake Bay management, stakeholders continue to feel disempowered.

This study presents a more complete understanding of Chesapeake Bay environmental stakeholders' perspectives of the roles that science and citizen science currently and ideally should play in Bay decision-making processes. This research is a productive step in helping the Chesapeake Bay environmental community identify and address existing barriers to engaging stakeholders and expanding public engagement in scientific research. Still, additional research is needed to more fully understand how Bay managers can strategically use citizen science to address existing data gaps, empower stakeholders to play a more influential part in scientific knowledge production and environmental discomately improve Chesapeake Bay science and management. Citizen science appears to be a promising new frontier that could help Chesapeake Bay science and management continue to progress along its present trajectory towards more inclusive and holistic transdisciplinary decision-making processes.

Acknowledgements

We would like to thank all of the Chesapeake environmental stakeholders who participated in this study. We are also grateful to Natalie Spitzer for her statistical assistance and Drew Webster for his thoughtful comments on earlier versions of the manuscript. We also thank Michael Paolisso, Astrid Caldas, Andrea Grover, and Judy O'Neil for their comments and suggestions on the study and survey design, as well as their mentorship and support.

Author contributions

Suzanne E. Webster: Conceptualization, Methodology, Investigation, Formal analysis, Visualization (lead), Writing - Original draft (lead), Writing- Reviewing and Editing (equal).

William C. Dennison: Visualization (supporting), Writing - Original draft (supporting), Reviewing and Editing (equal), Funding acquisition.

References

Aceves-Bueno, E., A. S. Adeleye, D. Bradley, W. T. Brandt, P. Callery, M. Feraud, K. L. Garner, R. Gentry, Y. Huang, I. McCullough, I. Pearlman, S. A. Sutherland, W. Wilkinson, Y. Yang, T. Zink, S. E. Anderson, and C. Tague. 2015. Citizen science as an approach for overcoming insufficient monitoring and inadequate stakeholder buy-in in adaptive management: criteria and evidence. *Ecosystems*. doi: 10.1007/s10021-015-9842-4

Alexander, S. M., J. F. Provencher, D. A. Henri, J. J. Taylor, J. I. Lloren, L. Nanayakkara, J. T. Johnson, and S. J. Cooke. 2019. Bridging Indigenous and science-based knowledge in coastal and marine research, monitoring, and management in Canada. *Environmental Evidence*. doi: 10.1186/s13750-019-0181-3

Ator, S. W., J. D. Blomquist, J. S. Webber, and J. G. Chanat. 2020. Factors driving nutrient trends in streams of the Chesapeake Bay watershed. *Journal of Environmental Quality*. doi: 10.1002/jeq2.20101

Bäckstrand, K. 2003. Civic science for sustainability: Reframing the role of experts, policymakers and citizens in environmental governance. *Global Environmental Politics*. doi: 10.1162/152638003322757916

Balazs, C. L., and R. Morello-Frosch. 2013. The three Rs: How community-based participatory research strengthens the rigor, relevance, and reach of science. *Environmental Justice*. doi: 10.1089/env.2012.0017

Bednarek, A. T., C. Wyborn, C. Cvitanovic, R. Meyer, R. M. Colvin, P. F. E. Addison, S. L. Close, K. Curran, M. Farooque, E. Goldman, D. Hart, H. Mannix, B. McGreavy, A. Parris, S. Posner, C. Robinson, M. Ryan, and P. Leith. 2018. Boundary spanning at the science–policy interface: the practitioners' perspectives. *Sustainability Science*. doi: 10.1007/s11625-018-0550-9

Bennett, N. J., R. Roth, S. C. Klain, K. Chan, P. Christie, D. A. Clark, G. Cullman, D. Curran, T. J. Durbin, G. Epstein, A. Greenberg, M. P. Nelson, J Sandlos, R. Stedman, T. L. Teel, R. Thomas, D. Veríssimo, and C. Wyborn. 2017. Conservation social science: Understanding and integrating human dimensions to improve conservation. *Biological Conservation*. doi: 10.1016/j.biocon.2016.10.006

Bennett, N. J. 2016. Using perceptions as evidence to improve conservation and environmental management. *Conservation Biology*. doi: 10.1111/cobi.12681

Berkes, F. 2009. Evolution of co-management: role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management*. doi: 10.1016/j.jenvman.2008.12.001

Bidwell D. 2009. Is community-based research postnormal science. *Science, Technology & Human Values*. doi: 10.1177/0162243909340262

Blake, C., A. Rhanor, and C. Pajic. 2020. The demographics of citizen science participation and its implications for data quality and environmental justice. *Citizen Science: Theory and Practice*. doi: 10.5334/cstp.320

Boesch, D. F. and E. B. Goldman. 2009. Chesapeake Bay. In: *Ecosystem-based management for the oceans,* eds. K. McLeod and H. Leslie, 268-293. Island Press.

Boiral, O. 2002. Tacit knowledge and environmental management. *Long Range Planning*. doi: 10.1016/S0024-6301(02)00047-X

Brosius, J. P., A. Lowehaupt Tsing, and C. Zerner. 1998. Representing communities: Histories and politics of community-based natural resource management. *Society and Natural Resources*. doi: 10.1080/08941929809381069

Brouwer, H., J. Woodhill, M. Hemmati, K. Verhoosel, and S. van Vugt. 2019. *The MSP guide: How to design and facilitate multi-stakeholder partnerships*, 3rd edn. Wageningen: Wageningen Centre for Development Innovation and Rugby: Practical Action Publishing. doi: 10.3362/9781780446691

Buytaert, W., Z. Zulkafli, S. Grainger, L. Acosta, T. C. Alemie, J. Bastiaensen, B. De Bièvre, J. Bhusal, J. Clark, A. Dewulf, M. Foggin, D. M. Hannah, C. Hergarten, A. Isaeva, T. Karpouzoglou, B. Pandeya, D. Paudel, K. Sharma, T. Steenhuis, S. Tilahun, G. Van Hecken, and M. Zhumanova. 2014. Citizen science in hydrology and water resources: opportunities for knowledge generation, ecosystem service management, and sustainable development. *Frontiers in Earth Science*. doi: 10.3389/feart.2014.00026

Calheiros, D. F., A. F. Seidl, and C. J. Ferreira. 2000. Participatory research methods in environmental science: local and scientific knowledge of a limnological phenomenon in the Pantanal wetland of Brazil. *Journal of Applied Ecology*. doi:10.1046/j.1365-2664.2000.00524.x

Chesapeake Bay Program. 2018. Memorandum of understanding regarding using citizen and non-traditional partner monitoring data to assess water quality and living resource status and our progress toward restoration of a healthy Chesapeake Bay and watershed. https://www.chesapeakemonitoringcoop.org/wp-content/uploads/2019/07/2018-Citizen-Science-MOU-signed.pdf. Accessed 1 June 2021.

Conrad, C. C., and K. G. Hilchey. 2011. A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental Monitoring and Assessment*. doi: 10.1007/s10661-010-1582-5

Conrad, C. T. and T. Daoust. 2008. Community-based monitoring frameworks: Increasing the effectiveness of environmental stewardship. *Environmental Management*. doi: 10.1007/s00267-007-9042-x
Costanza, R., and J. Greer. 1995. The Chesapeake Bay and its watershed: a model for sustainable ecosystem management?. In: *Barriers and Bridges for the Renewal of Regional Ecosystems,* eds. L. H. Gunderson, C. S. Holling and S. Light, 169-213. Columbia University Press.
Danielsen, F., N. D. Burgess, A. Balmford, P. F. Donald, M. Funder,J. P. Jones, P. Alviola, D. S. Balete, T. Blomley, J. Brashares, B. Child, E. Enghoff, J. Fields, S. Holt, H. Hübertz, A. E. Jensen, P. M. Jensen, J. Massao, M. M. Mendoza, Y. Ngaga, M. K. Poulsen, R. Rueda, M. Sam, T. Skielboe, G. Stuart-Hill, E. Top-Jørgensen, and D. Yonten. 2009. Local participation in natural resource monitoring: a characterization of approaches. *Conservation Biology*. doi: 10.1111/j.1523-1739.2008.01063.x
Davis, J. 1977. *The effects of tropical storm Agnes on the Chesapeake Bay estuarine system*. Chesapeake Research Consortium Publication no. 54.
Dickinson, J. L., B. Zuckerberg, and D. N. Bonter. 2010. Citizen science as an ecological research tool: challenges and benefits. *Annual Review of Ecology, Evolution, and Systematics*. doi: 10.1890/110236
Dickinson, J. L., J. Shirk, D. Bonter, R. Bonney, R. L. Crain, J. Martin, T. Phillips, and K. Purcell. 2012. The current state of citizen science as a tool for ecological research and public engagement. *Frontiers in Ecology and the Environment*. doi: 10.1890/110236
Doremus, H., and A. D. Tarlock. 2005. Science, judgment, and controversy in natural resource regulation. *Public Land and Resources Law Review*., 26, 1.
Freitag, A., and M. J. Pfeffer. 2013. Process, not product: investigating recommendations for improving citizen science “success”. *PLoS One*. doi: 10.1371/journal.pone.0064079
Freudenburg, W. R. 1989. Social scientists' contributions to environmental management. *Journal of Social Issues*. doi: 10.1111/j.1540-4560.1989.tb01536.x
Gillelan, M. E., D. Haberman, G. B. Mackiernan, J. Macknis, and H. W. Wells Jr. 1983. Chesapeake Bay, a framework for action. U.S. Environmental Protection Agency. https://www.chesapeakebay.net/content/publications/cbp_12405.pdf. Accessed 1 June 2021.
Goldman, M. J., P. Nadasdy and M. D. Turner, M. D. (Eds.) 2011. *Knowing nature: Conversations at the intersection of political ecology and science studies*. University of Chicago Press.
Gray, S., R. Shwom, and R. Jordan. 2012. Understanding factors that influence stakeholder trust of natural resource science and institutions. *Environmental Management*. doi: 10.1007/s00267-011-9800-7
Heberlein, T. A. 1988. Improving interdisciplinary research: integrating the social and natural sciences. *Society & Natural Resources*. doi: 10.1080/08941928809380634
Hennessey, T. M. 1994. Governance and adaptive management for estuarine ecosystems: The case of Chesapeake Bay. *Coastal Management*. doi: 10.1080/08920759409362225
Hermoso, M. I., V. Y. Martin, S. Gelcich, W. Stotz, and M. Thiel. 2021. Exploring diversity and engagement of divers in citizen science: insights for marine management and conservation. *Marine Policy*. doi: 10.1016/j.marpol.2020.104316
Hood, R. R., G. W. Shenk, R. L. Dixon, S. M. Smith, W. P. Ball, J. O. Bash, R. Batiuk, K. Boomer, D. C. Brady, C. Cerco, P. Claggett, K. de Mutsert, Z. M. Easton, A. J. Elmore, M. A. M. Friedrichs, L. A. Harris, T. F. Ihde, L. Lacher, L. Li, L. C. Linker, A. Miller, J. Moriarty, G. B. Noe, G. Onyullo, K. Pose, K. Skalak, R. Tian, T. L. Veith, L. Wainger, D. Weller, and Y. J. Zhang. 2021. The Chesapeake Bay program modeling system: Overview and recommendations for future development. *Ecological Modelling*. doi: 10.1016/j.ecolmodel.2021.109635

Houde, E. D. 2011. *Chesapeake Perspectives: Managing the Chesapeake's Fisheries*. College Park: Maryland Sea Grant College.

Irwin, A. 1995. *Citizen science: A study of people, expertise and sustainable development*. Psychology Press.

Johnson, M., and S. Clisby. 2009. Naturalising distinctions: the contested field of environmental relations in Costa Rica. *Landscape Research*. doi: 10.1080/01426390802390517

Jollymore, A., M. J. Haines, T. Satterfield, and M. S. Johnson. 2017. Citizen science for water quality monitoring: Data implications of citizen perspectives. *Journal of Environmental Management*. doi: 10.1016/j.jenvman.2017.05.083

Kotcher, J. E., T. A. Myers, E. K. Vraga, N. Stenhouse, and E. W. Maibach. 2017. Does engagement in advocacy hurt the credibility of scientists? Results from a randomized national survey experiment. *Environmental Communication*. doi: 10.1080/17524032.2016.1275736

Kreuter, M. W., C. De Rosa, E. H. Howze, and G. T. Baldwin. 2004. Understanding wicked problems: a key to advancing environmental health promotion. *Health Education & Behavior*. doi: 10.1177/1090198104265597

Lach, D., P. List, B. Steel, and B. Shindler. 2003. Advocacy and credibility of ecological scientists in resource decisionmaking: a regional study. *BioScience*, *53*(2), 170-178. doi: 10.1641/0006-3568(2003)053[0170:AACOES]2.0.CO;2

Lackey, R. T. 2007. Science, scientists, and policy advocacy. *Conservation Biology.* doi: 10.1111/j.1523-1739.2006.00639.x

Lang, D. J., A. Wiek, M. Bergmann, M. Stauffacher, P. Martens, P. Moll, M. Swilling, and C. J. Thomas. 2012. Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science*. doi: 10.1007/s11625-011-0149-x

Martin, V. Y. 2020. Four common problems in environmental social research undertaken by natural scientists. *BioScience*. doi: 10.1093/biosci/biz128

Mascia, M. B., J. P. Brosius, T. A. Dobson, B. C. Forbes, L. Horowitz, M. A. McKean, and N. J. Turner. 2003. Conservation and the social sciences. *Conservation Biology*. doi: 10.1046/j.1523-1739.2003.01738.x

McKinley, D. C., A. J. Miller-Rushing, H. L. Ballard, R. Bonney, H. Brown, S. C. Cook-Patton, D. M. Evans, R. A. French, J. K. Parrish, T. B. Phillips, S. F. Ryan, L. A. Shanley, J. L. Shirk, K. F. Stepenuck, J. F. Weltzin, A. Wiggins, O. D. Boyle, R. D. Briggs, S. F. Chapin, D. A. Hewitt, P. W. Preuss, and M. A. Soukup. 2017. Citizen science can improve conservation science, natural resource management, and environmental protection. *Biological Conservation*, *208*, 15-28.

Milkoreit, M., M. L. Moore, M. Schoon, and C. L. Meek. 2015. Resilience scientists as change-makers—Growing the middle ground between science and advocacy?. *Environmental Science & Policy*. doi: 10.1016/j.envsci.2014.08.003

Milton K. 1993. Environmentalism and anthropology. In: *Environmentalism,* ed. K. Milton, 1-17. London and New York: Routledge.

Moyer, D. L., and M. J. Langland. 2020. *Nitrogen, phosphorus, and suspended-sediment loads and trends measured at the Chesapeake Bay Nontidal Network stations: Water years 1985-2018*. U.S. Geological Survey. doi: 10.5066/P931M7FT

Nelson, M. P., and J. A. Vucetich. 2009. On advocacy by environmental scientists: what, whether, why, and how. *Conservation Biology*. doi: 10.1111/j.1523-1739.2009.01250.x

Orth, R. J., and K. A. Moore. 1983. Chesapeake Bay: an unprecedented decline in submerged aquatic vegetation. *Science*. doi: 10.1126/science.222.4619.51

Oxnam, G., and J. P. Williams. 2001. Saving the Chesapeake. *Forum for Applied Research and Public Policy* 16(1): 96.

Pew Research Center. 2020. *Key findings about Americans' confidence in science and their views on scientists' role in society.*

https://www.pewresearch.org/fact-tank/2020/02/12/key-findings-about-americans-confidence-in-science-and-their-views-on-scientists-role-in-society/. Accessed July 12 2021.

Pettibone, L., B. Blättel-Mink, B. Balázs, A. D. Giulio, C. Göbel, K. Heubach, D. Hummel, J. Lundershausen, A. Lux, T. Potthast, K. Vohland, and C. Wyborn. 2018. Transdisciplinary Sustainability Research and Citizen Science: Options for Mutual Learning. *GAIA-Ecological Perspectives for Science and Society*. doi: 10.14512/gaia.27.2.9.

Pielke Jr, R. A. (2007). *The honest broker: making sense of science in policy and politics*. New York: Cambridge University Press.

Raymond, C. M., I. Fazey, M. S. Reed, L. C. Stringer, G. M. Robinson, and A. C. Evely. 2010. Integrating local and scientific knowledge for environmental management. *Journal of Environmental Management*. doi: 10.1016/j.jenvman.2010.03.023

Reed, M. S. 2008. Stakeholder participation for environmental management: a literature review. *Biological Conservation*. doi: 10.1016/j.biocon.2008.07.014

Reed, M. S., L. C. Stringer, I. Fazey, A. C. Evely, and J. H. Kruijsen. 2014. Five principles for the practice of knowledge exchange in environmental management. *Journal of Environmental Management*. doi: 10.1016/j.jenvman.2014.07.021

Reed, M. S., S. Vella, E. Challies, J. De Vente, L. Frewer, D. Hohenwallner‐Ries, T. Huber, R. K. Neumann, E. A. Oughton, J. S. del Ceno, and H. van Delden. 2018. A theory of participation: what makes stakeholder and public engagement in environmental management work?. *Restoration Ecology*. doi: 10.1111/rec.12541

Research!America. 2018. *Advocating for science: Your role in changing hearts and minds.* https://www.researchamerica.org/sites/default/files/newsletter/Images/ASM%20Policy%20Board_FINAL.pdf. Accessed 11 July 2021.

Richter, A., D. Dörler, S. Hecker, F. Heigl, L. Pettibone, F. Serrano Sanz, K. Vohland, and A. Bonn. 2018. Capacity building in citizen science. In C*itizen science: Innovation in open science, society and policy,* eds. S. Hecker, M. Haklay, A. Bowser, Z. Makuch, J. Vogel, and A. Bonn. London: UCL Press.

Roman, M., X. Zhang, C. McGilliard, and W. Boicourt. 2005. Seasonal and annual variability in the spatial patterns of plankton biomass in Chesapeake Bay. *Limnology and Oceanography*. doi: 10.4319/lo.2005.50.2.0480

Roux, D. J., R. J. Stirzaker, C. M. Breen, E. C. Lefroy, and H. P. Cresswell. 2010. Framework for participative reflection on the accomplishment of transdisciplinary research programs. *Environmental Science & Policy*. doi: 10.1016/j.envsci.2010.08.002

Rubin, L., C. Donovan, A. Fries, J. Vastine, J. Monismith, S. Spitzer, D. Donkersloot, and N. Dean. 2017. Chesapeake Monitoring Cooperative prioritization report: How volunteer and nontraditional monitoring can help fill data gaps in the Chesapeake Bay watershed. Chesapeake Monitoring Cooperative. https://www.allianceforthebay.org/wp-content/uploads/2017/05/Prioritization-Report_Final.pdf. Accessed 13 June 2021.

Shirk, J., H. Ballard, C. Wilderman, T. Phillips, A. Wiggins, R. Jordan, E. McCallie, M. Minarchek, B. V. Lewenstein, M. E. Krasny, and R. Bonney. 2012. Public participation in scientific research: a framework for deliberate design. *Ecology and Society,* 17(2).

Shenk, G. W., and L. C. Linker. 2013. Development and application of the 2010 Chesapeake Bay watershed total maximum daily load model. *Journal of the American Water Resources Association*. doi: 10.1111/jawr.12109

Tillman, N. 2009. *The Chesapeake Watershed: a sense of place and a call to action*. Chesapeake Book Company.

Trombley, J. M. 2017. *An Environmental Anthropology of Modeling and Management on the Chesapeake Bay Watershed.* (Doctoral dissertation, University of Maryland, College Park). doi: 10.13016/M2CV4BS14

Webster, S. E., E. C. Donovan, E. Chudoba, C. D. Miller-Hesed, M. Paolisso, W. C. Dennison. 2021. Identifying and harmonizing the priorities of stakeholders in the Chesapeake Bay environmental monitoring community. Manuscript submitted for publication.

Whitelaw, G., H. Vaughan, B. Craig, and D. Atkinson. 2003. Establishing the Canadian community monitoring network. *Environmental Monitoring and Assessment*. doi: 10.1023/A:1025545813057

Zhang, Q., R. R. Murphy, R. Tian, M. K. Forsyth, E. M. Trentacoste, J. Keisman, and P. J. Tango 2018. Chesapeake Bay's water quality condition has been recovering: Insights from a multimetric indicator assessment of thirty years of tidal monitoring data. *Science of the Total Environment*. doi: 10.1016/j.scitotenv.2018.05.025

Appendices

Appendix 1. List of the organizations represented among the survey respondents. Respondents were asked to provide the name of the organization that they were primarily affiliated with in their role as an environmental stakeholder.

1. Alan J. Anderson Foundation
2. Alexandria Renew Enterprises
3. Allegheny Mountain Chapter of Trout Unlimited
4. Alliance for the Chesapeake Bay
5. Anacostia Riverkeeper
6. Anne Arundel Community College Environmental Center
7. Anne Arundel County Public Schools
8. Anne Arundel Watershed Stewards Academy
9. Antietam-Conococheague Watershed Alliance
10. Arundel Rivers Federation
11. Audubon Naturalist Society
12. Baltimore County Department of Environmental Protection & Sustainability
13. BayLand Consultants & Designers, Inc.
14. Berkeley County Farmland Protection Board
15. Blue Water Baltimore
16. Bradford County Conservation District
17. Cambridge South Dorchester High School
18. Capital Stand up Paddleboarding
19. Charles County Government
20. Chesapeake Bay Commission
21. Chesapeake Bay Environmental Center
22. Chesapeake Bay Foundation
23. Chesapeake Bay Magazine
24. Chesapeake Bay National Estuarine Research Reserve, Maryland
25. Chesapeake Bay National Estuarine Research Reserve, Virginia
26. Chesapeake Bay Program
27. Chesapeake Bay Trust
28. Chesapeake Conservancy
29. Chesapeake Conservation Landscaping Council
30. Chesapeake Legal Alliance
31. Chesapeake Research Consortium
32. Citizens Advisory Committee
33. City of Annapolis, Maryland
34. City of Gaithersburg, Maryland
35. City of York, Pennsylvania
36. Colonial Soil and Water Conservation District
37. Columbia County Conservation District
38. Delaware Division of Parks and Recreation
39. Dewberry Engineers
40. District of Columbia Department of Energy and Environment
41. District of Columbia Government
42. Eastern Shore Land Conservancy
43. Eastern Shore Maryland local government
44. EcoLatinos, Inc.
45. EcoLogix Group, Inc.
46. Environmental Finance Center
47. Fairfax County Government
48. Four Mile Run Conservatory Foundation
49. Friends of Herring Run Parks
50. Friends of the Rappahannock
51. Geosyntec Consultants, Inc.
52. Glen Echo Park Aquarium
53. Great Bay Work
54. Gunpowder Valley Conservancy
55. Hampton Roads Planning District Commission
56. Harford County Watershed Stewards Academy
57. Havre de Grace Maritime Museum, Inc. & Environmental Center
58. Headwaters, LLC
59. Howard County Office of Sustainability
60. Interfaith Partners for the Chesapeake
61. Interstate Commission on the Potomac River Basin
62. Izaak Walton League of America
63. James River Association
64. Johns Hopkins University
65. Lancaster Clean Water Partners
66. Lancaster County Conservation District
67. Lancaster Farmland Trust
68. Little Falls Watershed Alliance
69. Local Government Advisory Committee to the Chesapeake Executive Council
70. Lord Fairfax Soil and Water Conservation District
71. Magothy River Association
72. Maryland Agricultural Education Foundation
73. Maryland Association for Environmental and Outdoor Education
74. Maryland Campaign for Environmental Human Rights
75. Maryland Department of Agriculture
76. Maryland Department of Natural Resources
77. Maryland Department of Planning
78. Maryland Department of the Environment
79. Maryland Department of Transportation
80. Maryland Environmental Service
81. Maryland Environmental Trust
82. Maryland Farm Bureau
83. Maryland Forest Service
84. Maryland General Assembly
85. Maryland House of Delegates
86. Maryland League of Conservation Voters
87. Maryland Master Naturalists
88. Maryland Park Service
89. Maryland Sea Grant
90. Mathews County Land Conservancy
91. Mid-Atlantic 4R Nutrient Stewardship Association
92. Mitchell Enterprises, Inc.
93. Montgomery College
94. Montgomery County Department of Environmental Protection
95. Morgan State University
96. National Aquarium
97. National Fish and Wildlife Foundation

98. National Marine Fisheries Service
99. National Oceanic and Atmospheric Administration
100. National Park Service Chesapeake Bay Office
101. Natural Resources Conservation Service
102. OpinionWorks, LLC
103. Oyster Recovery Partnership
104. Patapsco Heritage Greenway
105. Patuxent Riverkeeper
106. Paxton Creek Watershed & Education Association
107. Peninsula Master Naturalist
108. Penn State Communication, Science, and Society Initiative
109. Penn State Master Watershed Stewards
110. Penn State University
111. Pennsylvania Association of Conservation Districts
112. Pennsylvania Department of Conservation and Natural Resources
113. Pennsylvania Department of Environmental Protection
114. Pennsylvania Forest Stewards
115. Pennsylvania House of Representatives
116. Pennsylvania No Till Alliance
117. Pennsylvania Organization for Watersheds and Rivers
118. Pennsylvania Townships Association
119. Petro Design Build
120. Pickering Creek Audubon Center
121. Piedmont Environmental Council
122. Plisko Sustainable Solutions, LLC
123. Potomac River Fisheries Commission
124. Potomac Riverkeeper Network
125. Prince William Soil and Water Conservation District
126. Red Lion Municipal Authority
127. Reed Smith, LLP
128. Renfrew Institute for Cultural & Environmental Studies
129. Rivanna Conservation Alliance
130. River Network
131. Robinson Nature Center
132. Safe Skies Maryland
133. Sassafras Environmental Education Center
134. Scientific and Technical Advisory Committee
135. Severn River Association
136. Severn Riverkeeper Program
137. Shore Rivers
138. Smithfield Foods
139. Smithsonian Environmental Research Center
140. Smithsonian Institution
141. Spa Creek Conservancy
142. St. Mary's College of Maryland
143. St. Mary's County Commission on the Environment
144. St. Mary’s County Government
145. Stroud Water Resource Center
146. Susquehanna River Basin Commission
147. Tetra Tech, Inc.
148. The Conservation Fund's Freshwater Institute
149. The Downstream Project
150. The Foundation for Pennsylvania Watersheds
151. The Minimalist Garden
152. The Nature Conservancy
153. Trout Unlimited
154. U.S. Department of Agriculture Natural Resources Conservation Service
155. U.S. Department of Defense
156. U.S. Environmental Protection Agency
157. U.S. Fish and Wildlife Service
158. U.S. Geological Survey
159. University of Baltimore
160. University of Maryland Center for Environmental Science
161. University of Maryland College Park
162. University of Maryland Environmental Finance Center
163. University of Maryland Extension
164. University of Maryland Sea Grant Extension
165. University of Virginia Institute for Engagement & Negotiation
166. University System of Maryland
167. Upper Susquehanna Coalition
168. Verna Harrison Associates, LLC
169. Versar Natural Resources Team Columbia
170. Virginia Coastal Zone Management Program
171. Virginia Conservation Network
172. Virginia Department of Conservation and Recreation
173. Virginia Department of Environmental Quality
174. Virginia Department of Wildlife Resources
175. Virginia Institute for Marine Science
176. Virginia Master Naturalist program
177. Virginia Sea Grant
178. Virginia Wildlife Magazine
179. Washington College
180. Waterford, Inc.
181. Watershed Alliance of Adams County
182. Watershed Alliance of York, Inc.
183. Watershed Stewards Academy
184. West Virginia Conservation Agency
185. West Virginia Department of Agriculture
186. West Virginia Department of Environmental Protection
187. West Virginia Rivers Coalition
188. Wildlife Leadership Academy
189. York County Conservation District
190. York County Extension