Community Science

COMMENTARY

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A Strategic Framework for Community Engagement in Oceans and Human Health

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Abstract Over the past two decades, scientific research on the connections between the health and resilience of marine ecosystems and human health, well-being, and community prosperity has expanded and evolved into a distinct "metadiscipline" known as Oceans and Human Health (OHH), recognized by the scientific community as well as policy makers. OHH goals are diverse and seek to improve public health outcomes, promote sustainable use of aquatic systems and resources, and strengthen community resilience. OHH research has historically included some level of community outreach and partner involvement; however, the increasing disruption of aquatic environments and urgency of public health impacts calls for a more systematic approach to effectively identify and engage with community partners to achieve project goals and outcomes. Herein, we present a strategic framework developed collaboratively by community engagement personnel from the four recently established U.S. Centers for Oceans and Human Health (COHH). This framework supports researchers in defining levels of community engagement and in aligning partners, purpose, activities, and approaches intentionally in their community engagement efforts. Specifically, we describe: (a) a framework for a range of outreach and engagement approaches; (b) the need for identifying partners, purpose, activities, and approaches; and (c) the importance of making intentional alignment among them. Misalignment across these dimensions may lead to wasting time or resources, eroding public trust, or failing to achieve intended outcomes. We illustrate the framework with examples from current COHH case studies and conclude with future directions for strategic community engagement in OHH and other environmental health contexts.

Plain Language Summary Over the past two decades, scientific research on the connections between ocean health and the well-being and prosperity of people has developed into a distinct field of study known as Oceans and Human Health (OHH). OHH goals seek to improve the health of people; promote the continued use of the world's oceans, lakes, and rivers; and strengthen the ability of communities to respond to public health concerns. OHH research has historically included some level of community outreach and involvement; however, the increasing deterioration of aquatic environments and urgency of public health impacts call for a more organized and deliberate approach to effectively work with community partners. Here, we outline a strategy developed collaboratively by community engagement personnel from the four recently established U.S. Centers for Oceans and Human Health (COHH). This strategy supports researchers in defining approaches to community engagement and in coordinating partners, purpose, activities, and approaches intentionally in their work with communities. We provide examples from current COHH case studies that show how to implement the strategy and describe future directions for community engagement in OHH and other research areas that focus on the interrelationships between people and their environment.

All authors contributed equally to this work.

Key Points:

- Effective engagement with communities is paramount to achieving goals and outcomes of Oceans and Human Health research
- Presented herein is a strategic framework to purposefully align partners, purpose, activities, and approaches for outreach and engagement
- Adopting a systematic approach to community engagement can help to improve the extent and quality of meaningful partner participation

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1. Introduction

Oceans and freshwater ecosystems provide a vast array of resources and services that directly and indirectly benefit human health and well-being, including regulating the world's climate, sustaining global food production, providing drinking water to local communities, and promoting physical and mental well-being through access to high quality "blue spaces" (e.g., Fleming et al., 2021; Halpern et al., 2012; Postel & Carpenter, 1997). These ecosystems are under increasing stress from human activities, which include chemical pollutants, climate-driven warming, population growth and development, resource utilization (e.g., aquaculture and fisheries) and overuse,

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acidification, and species introductions (Doney et al., 2009; IPCC, 2019; Landrigan et al., 2020; Rockström et al., 2009; Wells et al., 2015). Degradation and disruption of aquatic environments by these activities threaten global food security and an array of other resources that are critical for the well-being of humankind (Worm et al., 2006). These activities have also contributed to adverse impacts to human health from water-borne hazards such as harmful algal blooms (HABs) and their toxins (Anderson et al., 2021; Heisler et al., 2008), pathogenic microbes such as *Vibrio* spp. (Froelich & Daines, 2020), and chemical pollutants. These chronic stressors are in addition to (and can be compounded by) acute public health challenges caused by extreme weather events that impact coastal areas. Strategies to prevent and mitigate these hazards are urgently needed given global population growth and the need to ensure sustainable, long-term use of the world's oceans, lakes, and rivers for food and drinking water. Although coastal counties of the United States comprise less than 10% of the nation's land mass, almost 40% of the nation's total population live near the shoreline (National Oceanic and Atmospheric Administration [NOAA], 2013). The lives and livelihoods of many coastal residents are dependent on the economic resilience of communities to these multiple stressors.

Diverse and multidisciplinary research programs focused on promoting healthy oceans and freshwater bodies have provided new and fundamental insights into how people interact with and benefit from these ecosystems, and they have identified research areas where improved scientific understanding has the potential to reduce public health risks (National Research Council [NRC], 1999). Over the past two decades, scientific research on the connections between the health and resilience of marine ecosystems, and human health, well-being, and community prosperity has expanded and evolved into a distinct “metadiscipline” known as Oceans and Human Health (OHH), recognized by the scientific community as well as policy makers (Sandifer et al., 2013). OHH includes a multidisciplinary approach to addressing diverse challenges, including impacts of chemicals and pollutants on humans and wildlife, health threats from pathogens, HAB toxins, and plastics, and deteriorating water quality. OHH goals are similarly diverse, seeking to improve public health outcomes, ensure sustainable resource use, promote access to marine systems for tourism and community well-being, and strengthen community resilience to natural hazards (e.g., HABs).

In the United States, OHH themes and research priorities have been integrated into national competitive funding programs developed by several federal agencies (e.g., the National Institute of Environmental Health Sciences [NIEHS], the National Science Foundation [NSF], the National Oceanic and Atmospheric Administration [NOAA], and the Environmental Protection Agency [EPA]) and have informed strategies at the state, regional, and national levels. Sustained support for these programs has resulted in a number of significant scientific findings and achievements that have led to deeper understanding of the physiology and dynamics of HABs and bacteria, development of forecast products, tools, and models to provide early warning of health threats, and construction of infrastructure for detection and monitoring (e.g., autonomous sensors and instrumentation). These efforts have also supported the establishment of long-term interagency collaboration and cooperation as well as international coordination to identify global priorities. In addition, these efforts are providing a better understanding of the economic impacts and social disruptions caused by OHH-related hazards such as HABs (C. M. Adams et al., 2018; Hoagland et al., 2002; Moore, 2019), which disproportionately impact underserved and vulnerable communities. Through these programs, a number of OHH researchers have built strong relationships and mutually beneficial collaborations with natural resource and public health managers, which has served to improve scientific information and tools for decision-making, and also provided a better understanding of management concerns within the U.S. OHH community. OHH programs have also been developed internationally, and OHH scientists in the European Union and the United Kingdom have conducted extensive research on health-promoting effects of coastal environments through programs such as the “Blue Gym” initiative (Borja et al., 2020; White et al., 2016).

As the OHH field continues to expand and mature as a scientific metadiscipline, there is growing recognition of the importance of proactively and effectively engaging partners and communities. Principles of research translation and public engagement, in particular community-based participatory research, were established in biomedical research, and further expanded and refined through EPA and NIEHS-sponsored environmental health programs that recognized the importance and positive impacts of promoting community involvement (Minkler & Wallerstein, 2008; O'Fallon & Dearry, 2002). The NIEHS currently recommends and supports a variety of strategies to develop a national environmental health research agenda that is responsive to community concerns, including workshops, retreats, community advisory groups, and Town Meetings. Notably, input from Town Hall

meetings helped to shape the initial establishment of the Centers for Oceans and Human Health (COHH) program jointly funded by the NIEHS and NSF (O'Fallon et al., 2003).

OHH research has historically included some level of community outreach and community partner involvement, commonly guided by broader impact requirements stipulated by funding agencies. Consequently, "low-engagement" activities such as research dissemination and outreach were common initially as compared with "high-engagement" activities promoting active community involvement and participation (Cruz, 2019). However, through collaborations and partnerships, OHH programs have recognized the benefits of integrating higher engagement activities into project objectives and activities. For example, over the decade during which the NIEHS-funded Florida Red Tide Research Group operated, communication strategies evolved from the dissemination of basic print materials and logos into more information-rich products, such as an interactive website allowing users to access and interact with project data on beach conditions, and informational videos or artist products tailored to particular audiences (Hall et al., 2012). Based on these experiences, the most productive messaging resulted when partners were engaged as early as possible in the project and the communication channels and information were customized to the audience. In New England, OHH investigators involved in ongoing HAB research have established close working relationships with managers and groups involved in shellfish management and biotoxin monitoring, some extending back for a decade or more. These collaborations led to a more complete understanding of HAB dynamics in that region and facilitated the coordination of field sampling and responses to unexpected HAB events. As the OHH community has continued to grow and evolve, the value of establishing community engagement as a core programmatic activity has been illustrated by these and other successes.

Recognizing the growing importance of public and partner participation in OHH research, the NIEHS and NSF directed the four recently established U.S. COHH to include a Community Engagement Core (CEC) in addition to the research projects and the Administrative Core required of each Center. The centers are the:

1. Center for Oceans and Human Health and Climate Change Interactions (OHHC2I) led by the University of South Carolina;
2. Woods Hole Center for Oceans and Human Health at the Woods Hole Oceanographic Institution;
3. Great Lakes Center for Fresh Waters and Human Health at Bowling Green State University; and
4. Greater Caribbean Center for Ciguatera Research at the Florida Gulf Coast University.

Research programs underway by these Centers are investigating the effects of HABs on our oceans, Great Lakes, and other freshwater aquatic ecosystems; assessing developmental and other health effects of exposure to HAB toxins using experimental animals; investigating the potential impacts of climate change on the occurrence and virulence of pathogenic aquatic microbes such as *Vibrio* bacteria; identifying and quantifying occurrence of microplastics in coastal waters and evaluating health risks associated with them; and supporting environmental justice and other underserved communities in understanding and mitigating OHH health risks that they may disproportionately bear.

The first joint annual meeting of these four OHH centers funded by the NIEHS and the NSF was convened in 2019. The goals of this meeting were to review and discuss community engagement activities among Centers and identify opportunities for collaboration and focus. The conference resulted in a joint Centers' CEC collaborative working group that refined the concepts discussed in 2019. Herein, we present a strategic framework developed collaboratively by our working group to support researchers in defining levels of community engagement and in aligning partners, purpose, activities, and approaches intentionally in their community engagement efforts. Case studies from the four OHH centers are used to illustrate the strategic framework.

2. Discussion

The strategic framework for community engagement in OHH is presented in Figure 1 and comprises a continuum of approaches with varying degrees of community involvement, communication, decision-making power, leadership, and control (Centers for Disease Control and Prevention, 2011; International Association for Public Participation, 2018; Morgan & Lifshay, 2006; NOAA, 2016). The original IAP2 spectrum includes *inform*, *consult*, *involve*, *collaborate*, and *empower.* The OHH strategic framework includes two modifications of the IAP2 spectrum of public participation: an alignment of partner, purpose, activity, and approach and revisions to continuum or participation language. First, the strategic framework begins with centering community partners

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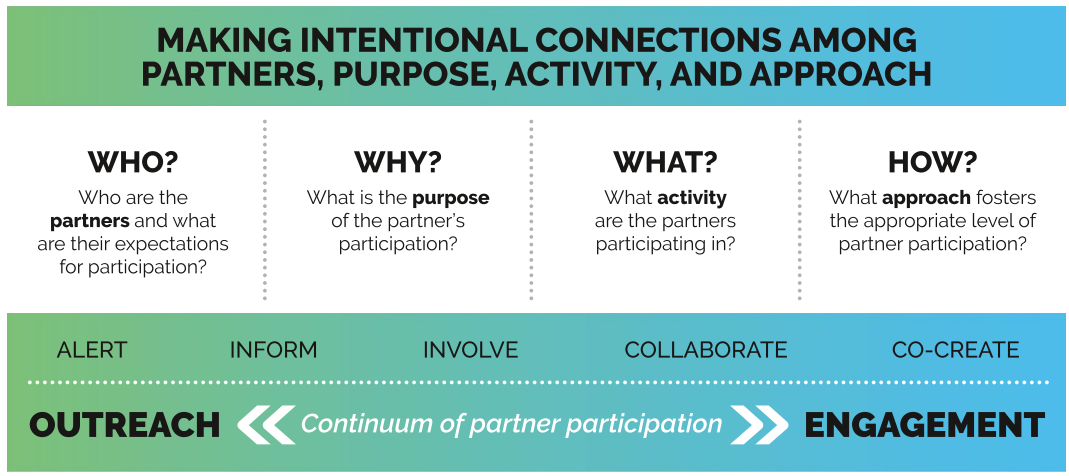

Figure 1. Strategic Framework for Oceans and Human Health Community Outreach and Engagement modified from the International Association for Public Participation (IAP2) spectrum of public participation (International Association for Public Participation, 2018). See www.iap2.org and https://cdn.ymaws.com/www.iap2.org/resource/resmgr/pillars/Spectrum_8.5x11_Print.pdf.

in the beginning of the participation process by intentionally aligning these four important dimensions: *partners* (Who?), *purposes* (Why?), *activities* (What?), and *approaches* (How?). In the framework, *Partners* reminds us of the importance of identifying the appropriate individuals or organizations for our work and intentionally including nontraditional groups, tribal partners, public health officials, those with underlying health conditions, and those who have been traditionally underrepresented in sciences. *Partners* also entail understanding our partners' expectations for their involvement and clearly articulating their role in the process. Essential to identifying partners is dispelling the notion of a "general public" and identifying specifically stratified audiences and partners, which allows researchers to characterize each group's needs, understand their communication preferences, and tailor collaboration and participation in ways that address those needs and preferences. *Purpose* refers to the reason for involving specific partners and the goal of their participation. *Purposes* range from passive delivery of information to recipients, to more active roles in the co-creation of knowledge. *Activities* typically conducted by the COHH include research, K-12 education, informal education, policy, management, communications, public health, and clinical practice. Clarifying the nature of the activity helps to locate theories, conceptual frameworks, and best practices to guide and inform that activity. Finally, *Approach* refers to the myriad of facilitation, collaboration, and engagement techniques that may be implemented as part of community engagement efforts.

Second, this framework expands upon and refines IAP2's language to better reflect OHH's public partnerships. This strategic framework includes *alert* on the spectrum's left side, drops *consult*, changes the word *empower* to *cocreate* on the right side, and labels the IAP2 continuum with a parallel outreach to engagement continuum. On the outreach end of the continuum are *alert* and *inform*. *Alert* refers to multilayered messaging of time-sensitive health risk information on emerging, potentially hazardous situations, as well as general health risk messaging. *Alert* is a one-way flow of information from scientists or public health officials to members of the public and differs from inform due to its urgent nature. *Inform* refers to the conveyance of scientific knowledge to nonscientists and may address a wide range of issues and topics. Similar to alert, inform represents a one-way flow of knowledge but without a sense of urgency. At the midpoint of the continuum, *Involve* means researchers invite ideas, input, and reactions from non-researchers in an advisory or consultative capacity. With *involve*, researchers work to understand the perspectives of partners but retain ultimate authority and control of final decisions. At the engagement end of the continuum are *collaborate* and *cocreate*. *Collaborate* refers to situations where researchers and partners participate in two-way exchanges of information. Partners have influence on decisions made, with researchers sharing some authority and control. *Cocreate* continues the two-way nature of the interactions, with researchers and partners sharing equally in goal-setting, information-sharing, decision-making power, leadership, and various aspects of project execution such as data collection, analysis, interpretation, and dissemination of results.

Making clear distinctions about the level of participation and partners' roles at the outset of partner collaboration is an important way to prevent misunderstandings and miscommunications and avoids introducing delays to the process, both of which can undermine trust and challenge project success. It is important to note that activities on both ends of the continuum are legitimate and that any one continuum position is not inherently preferable to another. Ultimately, where a project falls on the continuum should be dictated by the desired outcomes and by responses to fundamental process questions posed in the strategic framework. We also recognize that researchers, especially those from outside of the United States, may use terminology in this strategic framework a bit differently.

It is essential for OHH leaders and partners to purposefully choose effective approaches that achieve specified goals. Misalignment across these four elements leads to failures in achieving intended outcomes, wasted time and resources, eroded public trust, and makes future engagement more difficult. Multiphased outreach and engagement efforts often include different activities, purposes, partners, and approaches at different stages of the project, and these may change over time as needed. The following studies illustrate the strategic framework's levels of participation with partners and how alignment across the four community engagement aspects was achieved.

3. Case Studies

3.1. Case Study 1—Informal Education Via Documentary About Use and Fate of Plastics in South Carolina

Plastic pollution is a growing problem for coastal and ocean waters, posing threats to both environmental and human health. The public, however, is generally unaware of the extent of this problem, and recent research suggests that people do not commonly make associations between their personal use of plastics and ocean pollution (Henderson & Green, 2020). To address this issue, a University of South Carolina graduate student produced a documentary entitled “Macroplastics in South Carolina Waters: Connecting the Midlands to the Coast” (https://macroplasticsinsouthcarolinawaters.com/).

The *purpose* of the project was to inform South Carolina plastic users about the sources of plastic pollution and the ways that these pollutants, even those that originate in inland areas, ultimately make their way to the ocean. Production of the documentary involved filmed interviews with project *partners*, who were subject matter experts ranging from chemists who specialize in plastics to “riverkeepers” who lead monitoring of waterways at various locations in the state. The student-led team adopted an informal education *approach,* with development and release of the documentary film as the primary *activity* of the project. The team offered several public screenings of the film at science-oriented community venues and later made the film viewable online at no charge. The documentary was first screened in Columbia, SC in March 2021 at the Arnold School of Public Health; a second screening was hosted at EdVenture Children's Museum in Columbia; and a series of screenings took place at the SC Aquarium in Charleston, SC. In addition to attendance and participation by the public, among those in attendance at the various venues included staff from federal, state, county, and local public health and environmental agencies; state and local elected officials; and local celebrities. This project conveyed scientific knowledge to nonscientists through the use of an informational documentary and therefore falls under *inform* on the OHH strategic framework's continuum of partner participation.

3.2. Case Study 2—Educational Enrichment for K-12 Students

Integrating OHH science into educational curricula helps to address the need for improved ocean literacy in K-12 classrooms, encompassing key concepts regarding ocean ecosystems and processes, as well as the importance of coastal ecosystems to human health and the well-being of communities (Santoro et al., 2017). In particular, activities focused on HABs can provide students with the opportunity to investigate a topic that spans multiple scientific disciplines and that may have relevance to their own community. Multiple OHH classroom activities have been developed by COHH researchers and collaborators that focus on the dynamics and chemistry of HABs (Curran & Richlen, 2019; Curran & Robertson, 2020; Richlen et al., submitted). Classroom exercises include the analysis and interpretation of data sets generated by project investigators, thus providing students with a data-rich experience, while fulfilling multiple science education standards (Next Generation Science Standards, Common Core State Standards) as well as several Ocean Literacy principles (Schoedinger et al., 2006). This approach further engages students by providing authenticity as well as opportunities for students to interact with

technology and information in the same manner as researchers (L. G. Adams & Matsumoto, 2006). Materials adapted for visually impaired students are described in all activities to facilitate full participation of a community of students often overlooked in ocean science. Specifications for tactile teaching aids include 3D printed models of several dinoflagellate and diatom species associated with HABs, raised-line or embossed drawings and graphs for data interpretation, molecular models and braille captioning.

Educational activities were created in close collaboration with a specialist science educator with expertise in designing and implementing classroom activities focused on the marine sciences. Partner participation in activity development falls under *inform* and *involve* on the OHH strategic framework's continuum of partner participation. *Partners* include the K-12 teachers and students, including classrooms in schools that serve the visually impaired. The *purpose* of their participation was to provide feedback on the activities and exercises through classroom testing. The primary *activity* comprised classroom evaluations of draft educational materials and tactic teaching aids during the development process. This approach ensured subsequent revision and refinement of each educational activity based on participation and feedback from students and teachers in multiple classrooms prior to publication and broader dissemination.

3.3. Case Study 3—Citizen Science Research With Lake Erie Charter Boat Captains

Research conducted with nonscientists is called *citizen* or *community* science, and it can be an effective means of developing projects, gathering important data, interpreting conclusions, and educating others about important place-based issues (Sea Grant, 2021). Citizen science has been largely replaced by community science since citizenship is not required for participation. Community science programs developed or implemented with anglers, boat captains, and others using water bodies can provide important contextual, spatial, and temporal perspectives to developing efforts as well as involve people who are in the right place at the right time to collect needed data to complement professional scientific initiatives.

Lake Erie Charter Boat Association captains went to the Ohio EPA in 2011 asking how to help with data collection needs for HAB monitoring. In 2012, the charter boat captains began Lake Erie water quality sampling for the Ohio EPA. In 2013, The Ohio State University and Ohio Sea Grant's Stone Laboratory began managing this community science research program with funding from the Ohio EPA. In 2018, the program began receiving funding from the Great Lakes Center for Fresh Waters and Human Health further enhancing the program, such as exploring the reliability of community science data with professionally collected data. The purpose of this community science project was to train and mobilize captains from the Lake Erie Charter Boat Association for community science research to determine the presence, extent, and potential toxins related to Western Lake Erie algal blooms. Additionally, the captains provided education, materials, and information about Lake Erie algal blooms to charter fishing clients. The charter captains collected water quality samples and other critical data at the right place and time during the summer months, when HAB risk was highest. This project thus utilized a *collaborative* approach. Since 2012, this community science effort has collected more than 800 samples from 22 captains with >2,458 anglers onboard. The researchers provided weekly data summary fact sheets to charter fishing captains, resulting in anecdotal stories of captains' increased understanding of science and trends and ability to educate fishing clients about algal blooms in Western Lake Erie. For more information, see https://ohioseagrant.osu.edu/products/4c0k6/charter-boat-captains-help-monitor-lake-erie-water-quality.

3.4. Case Study 4—Seafood Consumption Communication for Ciguatera Poisoning

Ciguatera poisoning (CP) is the most common form of HAB-related seafood poisoning, affecting ∼16,000 cases per year in the United States (UpToDate, 2021). Symptoms lasting for days and even years include gastrointestinal illness as well as neurological symptoms such as paresthesias (numbness and tingling), pruritis (itching), and temperature sensation reversal (i.e., hot surfaces feel cold and vice versa) among others. As CP is endemic to tropical and subtropical regions, people who consume reef fishes (e.g., barracuda, snapper, or grouper) that have accumulated toxins through the food web are potentially at risk (reviewed by Soliño and Costa (2020)). Although CP is endemic to tropical and subtropical regions, an ever-expanding international seafood trade has brought reef fishes to the kitchens of restaurants and homes in temperate and/or landlocked regions (e.g., Europe and Canada; Mattei et al., 2014). Documented CP caused by fishes caught in the Gulf of Mexico and the Canary Islands suggest that climate change and warming sea surface temperatures are expanding the geographical range of

Gambierdiscus, the primary source of the toxin (ciguatoxin) thought to be responsible for CP (Gingold et al., 2014; Kibler et al., 2015; Rodríguez et al., 2017; Tester et al., 2010). Effective communication with consumers about the risks of CP in the Gulf of Mexico and elsewhere is an important component of safe seafood consumption.

The project partners included members of the communities directly and indirectly impacted by a possible rise in CP cases: fishing industry, tourism, restaurant/food industry, government/public health sector, education, and health care. These partners were selected to be representative across the six domains as well as representative by region and various demographics. The *purpose* was to ascertain their knowledge of CP risks as well as the information they would like to have access to regarding CP so that scientists could determine how to better communicate research findings and education partners about the potentially increasing risk of CP in the Gulf of Mexico and elsewhere. Sixty partners participated in interviews as their *involvement* in this effort. As a result of the information learned through the involvement activity, a Frequently Asked Questions was developed and posted on a website (https://ciguacohh.org/), and ongoing communication through the website and Facebook pages occurs. Future activities include plans for collaboration or cocreating community-facing educational materials.

4. Future Directions

The challenges being investigated and addressed by organizations within the OHH "metadiscipline" are inherently complex. Making progress at any scale on OHH issues that represent significant and far-reaching threats to human health requires a multidisciplinary approach and creative problem-solving. Further, the fact that many OHH issues and potential solutions are rooted in human behavior and public policy points to the importance of partner participation. The need for partner participation in the OHH realm has been affirmed and formalized with all US COHH establishing "CECs" focused on translating science for audiences, developing educational materials and programming, and involving various partners in the research itself, as illustrated by the case studies within this commentary.

Considering the vast number of people who rely on ocean resources for subsistence or recreation as well as those who are affected by changing ocean conditions such as sea level rise, partner participation in the OHH realm also offers important avenues specifically for engaging underserved audiences including environmental justice communities. US COHH are embracing these opportunities as they present themselves. For example, the OHHC2I led by the University of South Carolina laid the groundwork for engaging underserved audiences by involving the Lowcountry Alliance for Model Communities (LAMC) as one of its initial, funded partners. LAMC is a nonprofit organization founded to advocate for environmental justice and promoting community development, education, employment, quality housing, and community involvement for the four neighborhoods in its Charleston, SC study area. Engaging LAMC so early, during the inception of the OHHC2I, has fostered the Center's involvement in several important following projects such as the EJSTRONG initiative. This initiative delivers training to environmental justice communities, designed to help community members prepare to respond to disasters such as hurricanes, flooding, chemical releases, and pandemics. This early partnership has also opened the door to the OHHC2I, LAMC, and the Southeast Coastal Ocean Observing Regional Association establishing a citizen science monitoring program in the Rosemont community of Charleston County, to monitor and document flooding exacerbated by a changing climate and modifications to nearby port-related transportation infrastructure.

The sheer scale and the growing urgency of OHH issues call for a more systematic view of partner participation in which the partners, purpose, activity, and approach are considered in tandem when designing a project. A more intentional view such as this, calling for connections among all four aspects of community engagement, could support US COHH and others' efforts to more clearly and more consistently describe their current and prior partner participation, as was done in the Case Studies section of this commentary. Adopting this multifaceted view of partner participation in OHH, and even more broadly in other environmental health contexts, such as environmental health research, transdisciplinary research, and complex societal problem solving, could identify opportunities for new partners, approaches, and activities and improve the design of participatory strategies to better align with desired outcomes of the process. In the longer term, a strategic framework for community engagement in OHH could spur not only *more* (i.e., quantity) partner participation, but also *more meaningful* (i.e., quality) participation, moving beyond traditional outreach and information campaigns as OHH practitioners gain a stronger understanding of the many possible models for engaging partners. Finally, a strategic framework

for community engagement in the US OHH work could foster comparisons between the US and other countries, highlighting important differences in terminology and methods from one country to another and helping to identify best practices that cut across both institutional and international boundaries.

Using the proposed strategic framework to characterize a selection of OHH partner participation case studies and to perform a cursory inventory of the work of the four US COHH thus far points to an important gap in partner participation in OHH. This gap is the lack of project examples lying on the highest-engagement end of the continuum of partner participation—the type of engagement labeled "*co-creating*." As defined earlier, *cocreate* expands upon the two-way interactions entailed in collaboration, with researchers and partners sharing equally in goal-setting, information-sharing, decision-making power, leadership, and various aspects of project execution such as data collection, analysis, interpretation, and dissemination of results.

US COHH are actively pursuing efforts to support *co-creation* with specific community partners that thus far have not participated extensively in OHH in the US—public health and medical professionals. Participation of healthcare personnel has been hindered by continued acute public health crises; most recently the COVID-19 pandemic emergency. The global COVID-19 pandemic shifted the focus of not just every health system but every person involved in any sort of work in public health to focus solely on this global threat. Even some of our epidemiology partners' work shifted from environmental to infectious outbreaks. We remain hopeful that the lessons learned from COVID-19 and the new alliances formed in this work will build resilience for future "outbreaks" of HABs or other environmental emergencies such as flooding or storms. This will be necessary as we see increasing events across the globe related to climate change.

Garnering participation from health care communities was identified as an OHH priority during the 2019 joint meeting of CECs in South Carolina, and it continued to be a focal point of partner participation discussion during the 2020 and 2021 joint meetings of OHH Centers conducted virtually. As the "first line of defense" in detecting, diagnosing, and treating human (and animal) illness stemming from OHH threats such as HAB toxins as well as foodborne and waterborne marine pathogens, clinicians' understanding of these illnesses and their accurate diagnoses is a critical step in developing baseline data on their occurrence and distribution. The notion of co-creating with public health and healthcare partners in the OHH realm is one that has gained traction internationally, for example, the recent launch of Natural Healthcare Systems Ocean, a United Kingdom-based initiative with the vision to "conserve and protect coastal and marine ecosystems through minimizing harm resulting from the procurement and delivery of healthcare while increasing awareness of the benefits to human health and well-being from healthy seas, coasts, and waterways." Moving forward, US COHH will be developing and implementing specific strategies and pursuing new partnerships to engage with domestic healthcare and public health audiences.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

The resources and products described herein are available through the URLs provided in the text, as well as via the cited references (DOIs or URLs provided throughout the reference section).

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