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Water Resources Extension: Empowering Action Through Knowledge

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Water Resources Extension: Empowering Action Through Knowledge

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The topic of water resources is vast in its diversity and complexity as well as its integration with all components of the environment. In 2018, the editors of this special issue, as part of a National Sea Grant Water Resources Visioning Team, participated in an informal assessment of water resources-related efforts across the National Sea Grant College Program network. The Team received information from 25 individuals, representing 19 of the 34 state Sea Grant programs. No less than 56 discrete topics were identified within the context of water resources by this small sampling effort (Sea Grant 2018). The topics ranged from human health issues, such as access to safe drinking water; risks associated with flooding and drought; water infrastructure needs; land and water management; and social and economic issues associated with access to, and competing uses for, water. Clearly, water resources offer an abundance of challenges that demonstrate an ongoing need for reliable and trusted information.

Professional extension can provide this reliable and trusted information to communities in need, especially in critical times—for example, during natural disasters—when access to resources and knowledge may mean survival. At its most basic level, extension is the conveyance of information. However, there is no widely accepted definition for the term. For many years the focus of extension was often farming and farmers. However, the implementation of extension has expanded widely to encompass informational needs at the watershed scale as well as in marine, coastal, and Laurentian Great Lakes environments. Much of this work in the United States (U.S.) is underpinned by a national academic and legislative foundation (Figure 1).

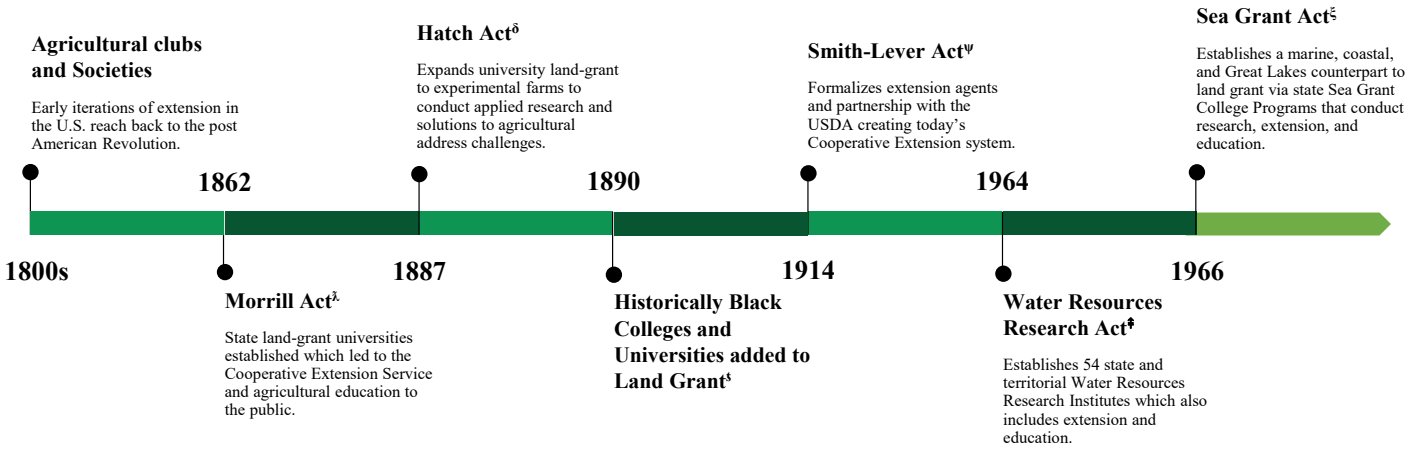
The U.S. System of Extension (extending science) is directly tied to, and reliant upon, the research capacities of the larger university enterprise. The extension system provides a critical connection between and among institutions and local communities, a mutualistic relationship with synergistic intent that is anchored in a grounded understanding of current needs, challenges, and opportunities to inform applied research. Extension is in turn necessarily responsive, offering needed information in accessible ways that local communities and individuals can and will use to make more informed decisions. The work of the extension agents and specialists that bridge these two worlds is often referred to as a "professional art." They must understand science and technical data as well as be able to translate it to be easily understood and utilized by their target audience(s). Extension professionals must be agile and able to adjust and adapt to new and changing needs, be problem-solvers, and above all able to communicate and collaborate within the expectations and identities of the local culture without advocation. This last is an absolutely critical component and the "superpower" of extension professionals; to convey knowledge and understanding without "pushing" any agenda to enrich the recipient's informed choice.

We have seen the expansion of extension needs and audiences over the last 50 years, and expect this trend to continue as our economy and social

needs change. Revolutionary technologies and the democratization of science learning has brought new ways to connect people with information, equipment, and each other. Accessibility is enhanced through online engagement and dialogue, though awareness and care are needed to not repeat injustices of the past and ensure access to everyone, e.g. bridging the digital divide. Like many systems built in the past, extension has not been without its own injustices toward people of color, Indigenous, and other disenfranchised individuals. We recognize that the extension of the future must necessarily face this past while seeking to develop and share information for the betterment of all persons residing in our country and across our globe. The activities described in this special issue demonstrate that extension remains a vital, critical service by which to improve the experience of individuals, communities, and our nation.

Many communities face acute and chronic water related challenges across the U.S. in both times of crises and everyday life. Access to clean water is vital, yet sometimes not given the critical attention it deserves, due to assumptions of a robust water treatment and delivery system in the U.S. This is especially demonstrated by those who themselves are not subject to questionable water quality or supply in their routine activities and homes. However, according to a recent analysis by Mueller and Gasteyer (2021), approximately 490,000 households in the U.S. lack complete plumbing and have poor overall water quality. Many of these households are associated with rural locations, Indigenous populations, and social dimensions surrounding poverty, education, and age (Mueller and Gasteyer 2021). Water related challenges are exacerbated by the global climate crisis and associated impacts such as more frequent natural disasters such as hurricanes and floods. Extension offers opportunities to link community, local, state, and national government agencies; non-profits; and industry with university capacity and resources to better understand and address water resources issues in the communities in which we live, work, and play.

Given the complex and interrelated nature of the water-related issues currently faced, including the resulting social and economic dilemmas and inequities, the need for water extension has never been more paramount. After all, water is needed for every aspect of life, directly or indirectly. Because the necessity is so great, and extension provides a pathway to broadly empower action and change, the editorial team sought to highlight a diverse set of water-related extension efforts at multiple scales and geographic locations. This work demonstrates the impact of extension work being done across our nation now, and highlights the importance and need for more integration of extension across



[λ]Morrill Act of 1862, 37 Cong. Ch. 130, 12 Stat. 503 (July 2, 1862) (codified at 7 U.S.C. § 301 et seq.)
[δ]Hatch Act of 1887, 49 Cong. Ch. 314, March 2, 1887, 24 Stat. 440 (Mar. 2, 1887) (codified at 7 U.S.C. § 361a et seq.)
[ϟ]Second Morrill Act of 1890, 51 Cong. Ch. 841, 26 Stat. 417 (Aug. 30, 1890) (codified at 7 U.S.C. §§ 321 to 326, 326a, 328)
Hatch Act Amendment extending to Alaska, Hawaii, and PR: [no short title], 84 Cong. Ch. 790, 69 Stat. 671 (Aug. 11, 1955) (same codification as original)
[ψ]Smith-Lever Act of 1914, 63 Cong. Ch. 79, 38 Stat. 372 (May 8, 1914) (codified at 7 U.S.C § 341 et seq.)
[ǂ]Water Resources Research Act of 1984, Pub. L. 98–242, 98 Stat. 97 (Mar. 22, 1984) (codified at 42 U.S.C. § 10301 et seq.)
[ς]National Sea Grant College and Program Act of 1966, Pub. L. No. 89-688, 80 Stat. 998 (1996) (codified at 33 U.S.C. Ch. 22, Subch. II).

Figure 1. Key national legislation underpinning professional extension in the United States.

all research, management, and policy endeavors. This issue provides specific research and outreach examples by which extension is addressing on-the-ground water resources challenges and supporting actionable community change.

If we are to meet the needs of our changing world and society, it will require the full extension enterprise (including Cooperative Extension, The National Oceanic and Atmospheric Administration (NOAA) National Sea Grant College Program, and the United States Geological Survey (USGS) Water Resources Research Institutes and Centers, among others). The Cooperative Extension System includes a network of education and extension agents in each state. This network of faculty and staff experts largely work within the Land Grant University System. The National Sea Grant College Program includes a network of more than 500 on-the-ground extension specialists and agents who are trusted experts and have earned a reputation as conveyors of science-based information within their communities. Sea Grant extension specialists and agents are part of a network of professionals, including communicators and educators, who connect university resources and expertise with local communities and user groups in 34 coastal and Laurentian Great Lakes states, as well as Puerto Rico, Guam, and the U.S. Affiliated Pacific Islands (USAPI). The USGS Water Resources Research Institutes and Centers provide outreach, technology transfer, and education services based on the research conducted in their respective states and communities to aid in the resolution of state and regional water problems. One Water Resources Institute or Center exists in each of the 50 states as well as the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and Guam. Here too, through programs in Hawai'i and Guam, programmatic content and activity spans the USAPI.

This issue presents five original research articles and five case studies. The original research spans the U.S. geographically and socioeconomically from Vermont, Ohio, and California to Texas and also includes one paper that focuses on a project in Columbia. The case studies include two examples with national scope, along with state-based studies from Wisconsin, Minnesota, and Mississippi and Alabama. Topics addressed include a breadth of critical water resources concerns from water quality (including harmful algal blooms, environmental plastic pollution, and drinking water contaminants) to implementation of best management practices, conservation agreements, a serious game that addresses nonpoint source pollution and resilience, a fellowship program, an urban stormwater research program, and oyster aquaculture. These manuscripts offer exceptional examples of extension, with contributions representing multiple extension enterprise organizations. They also demonstrate the diversity of water resources challenges and the myriad ways extension is being used to address those challenges. A short synopsis of each paper is provided below. We hope you find yourself informed and inspired by the work of these dedicated extension scholars.

Vaughan et al. describe how Lake Champlain has witnessed an increase in cyanobacteria blooms, impacting public health and recreation. A lake-wide cyanobacteria monitoring program has existed since 2000. However, advances in science and technology have brought programmatic changes to sampling efforts and the communication of risks. The article follows the evolution of the program and highlights the shift in focus to a qualitative approach, consisting of visual assessments, ground-truthed by water samples. Expanding monitoring, communication, and inclusion of a greater number of stakeholders has improved the monitoring program. Community volunteers generate timely data on bloom conditions, strengthening the geographic coverage of the program and the environmental literacy of lake users.

Talley et al. developed a community science program model to recruit, retain, and educate diverse populations in a study about trash in an urban watershed. The program was piloted, and found that recruitment strategies were successful, and that environmental stewardship was increased. In addition, the programs collected data about the trash found in the urban watershed, showing that the sources included homeless encampments, illegal dumping, and flow from stormwater drains. The study offers critical advancements in understanding how to empower diverse populations to contribute to, influence, use, and participate in science.

Berthold, Olsovsky, and Schramm describe research to understand if direct mailing educational materials to landowners in Lavaca County, Texas

could be used as an effective outreach approach to increase adoption of best management practices. They implemented a mass mailing campaign that included four mailings with the same messaging to more than 4900 landowners over approximately six months. Their findings showed that the mailings were effective in increasing the adoption of best management practices.

Bartolotta and Hardy utilize mixed methods to explore consumer support for, evaluate the ramifications of, and ascertain the effectiveness of a plastic bag ban in Cleveland, Ohio. The research showed that participants were supportive of limiting access to plastic bags, and that most individuals had access to reusable bags. However, they also found that voluntary reduction in plastic bag use by consumers was not effective, indicating that restrictive store policies or legislation would be required to reduce the use of plastic bags. This study contributes to the understanding of best management practices in implementing potential plastic bag bans.

Meza Prado et al. analyze the goals and motivations of upstream actors in a watershed investment program in Columbia to show the benefits for and contributions of those actors in addition to downstream participants. While upstream actors found value in the conservation benefits, they were also motivated by personal and community goals. As the program took time to build trust in this rural community, researchers learned how upstream participants' goals and motivations could be used to help downstream actors engage in more productive and equitable ways with upstream participants. This study offers useful lessons for watershed managers in recognizing the efforts of local landowners and connecting up and downstream actors.

Janasie, Deans, and Harris review efforts by the National Sea Grant Law Center to increase awareness and understanding of the legal framework for drinking water protection in regard to three contaminants: lead, nitrates, and PFAS. The team conducted comprehensive legal research, identified gaps and potential solutions, and finally developed outreach programing to inform stakeholders for each contaminant. The outreach approaches were specific to the audiences most in need of information to inform critical decisions related to that contaminant. The case study offers synergies between the legal analysis and extension by introducing readers to the legal analysis and solutions and by engaging stakeholders through an informed decision-making process.

Bareford et al. chronicle a case study where a multi-method needs assessment was conducted to identify water quality and management challenges in U.S. coastal regions and inform the expansion of a serious game to include coastal watersheds. Results showed high agreement among assessment methodologies regarding the most critical coastal challenges and important land uses to feature in the game. The results were used to produce a new model of an existing serious game that helps teach adults about how land use choices impact water quality and resilience to flooding across an entire watershed basin.

Voter et al. detail an adaptive fellowship model for early-career researchers in water resources. The fellowship allows post-masters and post-doctoral fellows to lead research projects focusing on high priority challenges identified by governmental agencies. The fellows receive mentorship from academic and agency personnel, and co-produce actionable knowledge. The model has proven to be a "win" for the fellows, the university, state agency partners, and the stakeholders that ultimately use the knowledge produced. The manuscript describes the model from the perspective of the fellows, agency mentors, and the university, and offers insights on how the model could be adapted for use in other states.

Bilotta and Peterson describe a collaborative process which developed a research program in urban stormwater management. The program obtains funding and engages diverse entities to build partnerships and identify strategic priorities for research. It then oversees a research competition and aids in the transfer of technology developed from the funded research. The program is a robust, comprehensive, and well-funded urban stormwater research program that advances science that embraces a collaboration of stormwater practitioners, policymakers, and professional researchers. The program has the potential to serve as a model of stormwater research collaboration, and could grow to address local, regional, and national needs.

Walton and Swann present the unique approach and investments by the Mississippi-Alabama Sea Grant Consortium to develop commercial off-bottom oyster aquaculture (COOA) in Alabama and Mississippi. The program utilized a network of partnerships, collaborations with other Sea Grant programs, Cooperative Extension, and stakeholders to establish COOA farms along the coast of the northern Gulf of Mexico. The core model can be used to leverage additional support from other funding agencies, helping to exponentially increase outcomes and impacts across the community. By combining applied research projects on farms, Extension projects, and outreach efforts, the approach demonstrates that COOA farms can yield measurable outcomes with significant impacts in coastal communities.

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Lake Champlain Community Scientist Volunteer Network Communicates Critical Cyanobacteria Information to Region-wide Stakeholders

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Abstract: Lake Champlain is a treasured resource for recreation, tourism, and drinking water situated in New York, Vermont (U.S.), and Québec (Canada). Because its shores span two states and two countries, management strategies for the lake require strong cross-boundary partnerships and cooperation. In recent decades, increased prevalence of harmful cyanobacteria blooms has impacted public health and recreation. A lake-wide cyanobacteria monitoring program was established in 2001 with an emphasis on water sample collection and analysis to inform management strategies. In 2012, this program transitioned from laboratory-based analyses at a limited number of locations to a visual assessment protocol validated by water samples. This transition opened the door to more effective and widespread monitoring, communication, and inclusion of a greater number of monitoring locations and stakeholders. Today, through a unique partnership of community scientist volunteers, public beach managers, nonprofit organizations, and state and federal agencies, a comprehensive network of trained cyanobacteria monitors generates timely data on water quality conditions to relay critical public health information. The majority of these reports are provided by trained community scientist volunteers, strengthening the geographic coverage of the program and the environmental literacy of lake users. This program now trains hundreds of community scientists, documents thousands of water quality condition reports annually, and communicates cyanobacteria conditions to the public via an online Cyanobacteria Tracker map. In this article, we describe the evolution of this successful program, discuss key findings from analysis of these volunteer-collected data, and suggest how similar programs could be effectively developed in other regions.

Keywords: *harmful cyanobacteria blooms, community science, education and outreach*

Cyanobacteria are microscopic, photosynthetic bacteria that can form large visible accumulations ("blooms") when chemical and physical conditions are favorable for growth (Paerl and Otten 2013). Cyanobacteria blooms are unsightly, are a nuisance to recreation, and can pose a risk to humans and pets when cyanotoxins are produced (Boyer 2007; Stone and Bress 2007). Land management activities have caused accelerated eutrophication in freshwater bodies around the world (Bennett et al. 2001) and led to increases in the prevalence of harmful cyanobacteria blooms. In addition, climate change has created more favorable conditions in which cyanobacteria are expected to dominate phytoplankton communities because of physiological (e.g., more rapid growth) and physical (e.g. increased stratification) factors (Paerl and Huisman 2008; O'Neil et al. 2012). Monitoring programs for cyanobacteria vary among U.S. states and there are multiple state agencies and local non-government groups with jurisdictional responsibilities that differ geographically for recreational and drinking water uses (Hardy et al.

Research Implications

- A novel visual assessment protocol was developed to indicate public health risk due to cyanobacteria on Lake Champlain.
- Community scientist volunteers collect critical public health information that is rapidly shared with stakeholders and lake users.
- Laboratory analyses show that the visual assessment protocol is a useful and effective indicator for public health risk.
- This article shares program findings and recommended practices so this approach can be successfully implemented in other regions.

2021). Cyanobacteria monitoring programs for relatively large lakes are each unique because they typically span multiple jurisdictions and are guided by local community needs and resource constraints.

Lake Champlain is a treasured natural resource located between the U.S. states of New York and Vermont, and the Canadian province of Québec (Figure 1). The lake is 19 km wide at its widest point, up to 122 m deep, and nearly 200 km long with a relatively large watershed (21,325 km^2) that has a population of approximately 571,000. Lake Champlain has more than 800 km of shoreline. The lake is used extensively for recreation, fishing, and as a drinking water source. The bordering U.S. states and Québec each have individual harmful cyanobacteria bloom response plans that differ in their history and scope. Their intersection, and the collaboration among several key groups, is a story of science and community coming together to address a challenge to water quality and public recreation.

Some areas of Lake Champlain have experienced cyanobacteria blooms since at least the late 1960s (Smeltzer 2003), but harmful cyanobacteria blooms were not widely reported in the lake until recent decades (Watzin et al. 2003). Two dog deaths in 1999 and 2000 were attributed to cyanotoxin poisoning and caused concerns about human and animal health risks. This led to increased documentation of bloom events and expanded monitoring. Because of the heterogeneous chemical and physiographic conditions in Lake Champlain, cyanobacteria blooms are not evenly distributed. Frequent and relatively intense annual cyanobacteria blooms tend to occur in the shallow, eutrophic regions and bays of the northeast section of the lake, including Missisquoi and St. Albans Bays (Smeltzer et al. 2012; Isles et al. 2015). Because cyanobacteria bloom formation and persistence are strongly influenced by local environmental conditions like wind and currents, water temperature, and nutrient availability, bloom conditions on Lake Champlain can change quickly.

In 2001, lake management partners developed a monitoring program aimed at detecting and identifying cyanobacteria blooms and associated toxins (microcystin and anatoxin-a) at sites that might impact drinking water and recreation at public beaches (Watzin et al. 2002; 2003; Boyer 2007). The program began with geographically-focused surveys and laboratory analyses of samples collected by professional staff. In the past two decades, it has grown to a network of hundreds of community scientist volunteers who primarily use a visual assessment protocol to identify and report on cyanobacteria growth conditions. Diverse stakeholders have worked together to form a unique partnership aimed at understanding and reporting on this resource management challenge. The partnership has been highly effective for data collection and for educating the community on the important issue of cyanobacteria blooms.

In this paper, we will 1) tell the story of collaborative efforts on Lake Champlain to address a challenging resource management issue, 2) explain how the Lake Champlain Cyanobacteria Monitoring Program works to serve as a useful model for other lakes, and 3) share program findings, best practices, and broader perspectives on community scientist volunteer-based cyanobacteria monitoring.

Cyanobacteria Monitoring on Lake Champlain

Development of the Lake Champlain Cyanobacteria Monitoring Program from Laboratory-based Analyses to Visual Assessment Protocol

Cyanobacteria monitoring on Lake Champlain began in 2001 with a laboratory-based approach

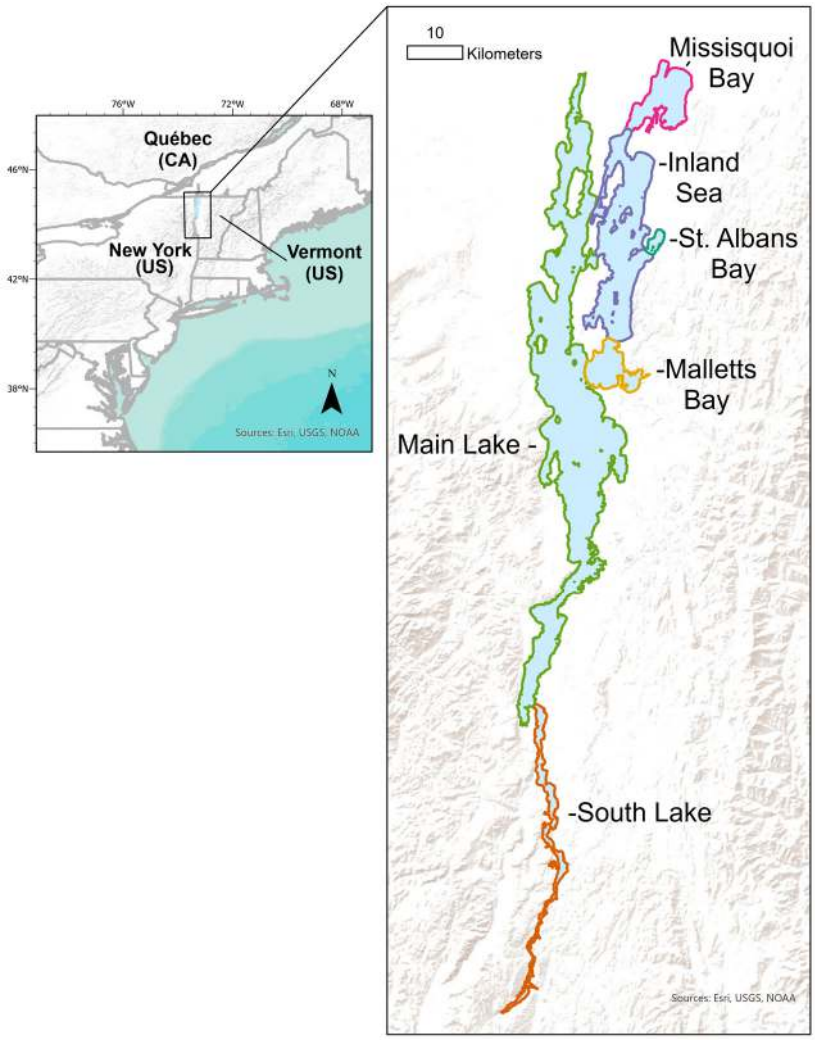

Figure 1. Map of Lake Champlain, with lake segments labeled and distinguished by color.

derived from the established World Health Organization (1999) alert framework (Watzin et al. 2006a). This initial monitoring was focused on off-shore locations that had a history of harmful cyanobacteria blooms (e.g., Missisquoi and St. Albans Bays), areas in the vicinity of public water intakes, and where recreational activities were concentrated (public beaches in Burlington, VT). Water samples were collected as grab samples or with a vertical plankton net tow and screened under a microscope for the presence of cyanobacteria. If present, the samples were evaluated for cyanobacteria cell density, and exceedance of a cyanobacteria cell density threshold triggered analysis for cyanotoxins. These analytical results were available within 24–48 hours of sample collection. Analysis for cell density and cyanotoxins would then continue at weekly intervals until cell density dropped below the threshold value (Watzin et al. 2002; 2003; 2004; 2005; 2006a; 2006b). Once this approach was established, the program collected samples from 30 - 50 routinely monitored stations each summer from 2004–2012 (Watzin et al. 2007; 2008; 2009; 2011a; 2011b).

As awareness of cyanobacteria-related public health and recreational impacts grew, there was an increase in inquiries about water quality conditions in unmonitored lake regions and near-shore recreational areas. Anecdotal accounts indicated that blooms in unmonitored locations may have impacted recreation, but data were not available to confirm these accounts for public health management. Funding availability limited the program's capacity to expand geographic coverage

of laboratory-based sampling and analyses, and cyanobacteria conditions could change on shorter timescales than the 24–48-hour timescale required for laboratory analysis.

To fill this information gap, program partners developed a novel visual assessment protocol to provide rapid assessments of visible water quality characteristics. The protocol was intended to provide actionable information on public health risk due to cyanobacteria in Lake Champlain more quickly than the typical 24-hour laboratory turnaround; provide a simple basis for beach managers to close beaches based on observed conditions; and increase geographic monitoring coverage by recruiting and training community scientist volunteers. This visual assessment protocol was officially adopted by the program in 2012, and data quality was evaluated by comparing visual assessment reports with laboratory-based results for cyanobacteria and cyanotoxins. Both approaches were used simultaneously for several summers to ensure usefulness. As the value of the visual assessment protocol became evident, the collection of water samples at every station was replaced by quality assurance samples collected at a subset of locations.

Overview of the Lake Champlain Cyanobacteria Monitoring Program Today

The Lake Champlain Cyanobacteria Monitoring Program is now a unique partnership that leverages existing monitoring programs around the lake and works with stakeholders from across the watershed. This partnership includes the Lake Champlain Basin Program (LCBP), an organization that coordinates management of Lake Champlain; Departments of Environmental Conservation (DEC) and Departments of Health (DOH) in New York and Vermont; and the Lake Champlain Committee, a watershed-based nonprofit. In addition to these coordinating partners, several other stakeholders actively participate, including: state and municipal park staff throughout the watershed; State University of New York at Plattsburgh; University of Vermont; and hundreds of community scientists that volunteer their time to monitor cyanobacteria in Lake Champlain.

Financial support for the Lake Champlain Cyanobacteria Monitoring Program is through a successful public-private funding partnership. The program is largely supported with U.S. Environmental Protection Agency funding to the LCBP, which then provides annual grants to the Lake Champlain Committee to implement the community scientist volunteer program. Additional monitoring, technical, and outreach support is provided by Vermont and New York DEC, Vermont and New York DOH, the New York Office of Parks, Recreation, and Historic Preservation, and Vermont State Parks. The Cyanobacteria Tracker and cyanotoxin analyses are currently supported by the Vermont DOH through funding received from the U.S. Centers for Disease Control and Prevention grants.

LCBP support began with $25,000 to supplement a U.S. Center for Disease Control grant for the initial 2000 field season; two decades later, the funding level planned for the 2022 field season is over $100,000. This includes one full-time-equivalent and supports efforts to recruit, train, and assist volunteers, review reports, and conduct outreach. Currently, Vermont state personnel support for the program totals approximately one full-time-equivalent, in addition to two summer interns and laboratory staff that assist with laboratory analyses. In New York, multiple state personnel, totaling two full-time-equivalents, coordinate efforts to monitor and report cyanobacteria blooms state-wide, including coordination with the Lake Champlain Cyanobacteria Monitoring Program.

Annual funding support from the LCBP has been critical to develop and maintain this volunteer-based monitoring program, and the LCBP continues to support the program as a high priority in their annual budget. Hundreds of community scientist volunteers, municipal and state recreational staff, and drinking water facility operators are trained each year to use the visual assessment protocol to identify and report on the presence or absence of cyanobacteria blooms. Although state and provincial jurisdictions maintain their own cyanobacteria bloom response protocols and management plans beyond the Lake Champlain Cyanobacteria Monitoring Program, this lake-wide, trans-boundary program provides consistent data that is useful to inform state and provincial response protocols and management programs.

The visual assessment protocol classifies water quality conditions into three categories and communicates these to the public as "generally safe," "low alert," or "high alert (Table 1). Community scientist volunteers are trained on protocol methodology and then given a toolkit with gloves, water sampling jars, photo cards for documenting blooms, thermometers to measure water temperature, written monitoring protocols with detailed guidance on how to assess conditions, and links to online resources. If cyanobacteria are observed (category 1d, category 2, or category 3), three photographs are requested: a close-up view of the water, a broad view to evaluate the extent of the bloom, and a water sample in a clear jar in front of a photo card. Photos are taken after 20 minutes to allow for settling and for cyanobacteria to float toward the water surface (Figure 2).

To submit a visual assessment report, program staff and community scientist volunteers upload observations through an online form that includes date, time, location, water quality condition, water temperature, water surface conditions, and a free-form field for additional information. Each report is vetted by program staff and then displayed on the online Cyanobacteria Tracker map (Figure 3; VTDOH 2021). This online map immediately publishes all cyanobacteria monitoring data to lake users, who can check the recent reports before traveling to recreate on the lake, and compiles data for lake managers. Reports on the map are color-coded based on whether the most recent assessment (up to two weeks old) was "generally safe," "low alert," or "high alert," and a table provides all approved reports for the year. Figure 4 summarizes the flow of information from the field collection to public dissemination.

Community scientist volunteers are asked to make weekly observations in at least one location for the duration of the monitoring period (mid-June through early fall), regardless of cyanobacteria conditions. These "routine" observations are made on the same day each week between the times of 10:00 and 15:00, when cyanobacteria blooms, if present, are typically most visible. Routine reports are critical to assessing the prevalence of cyanobacteria over time because they are conducted at a regular interval at consistent locations, and document seasonal patterns of both the presence and absence of cyanobacteria blooms.

Community scientists also are asked to submit "supplemental" reports immediately if they observe a cyanobacteria bloom outside of their routine reporting day or time, and to report daily during an active bloom until it is no longer present. Supplemental reports are critical for immediate public health response, recreation management (e.g., beach closures), and for determining changes in the persistence of blooms over time.

Table 1. Cyanobacteria condition categories of the visual assessment protocol.

Category	Cyanobacteria observed	Water description	Photo requested	Status
1a	No	Clear	No	Generally safe
1b	No	Brown or turbid	No	Generally safe
1c	No	Other material present	No	Generally safe
1d	Yes	Few cyanobacteria present—recreation not impaired	Yes	Generally safe
2	Yes	Cyanobacteria present—less than bloom levels	Yes	Low alert
3	Yes	Cyanobacteria bloom in progress	Yes	High alert

Figure 2. Close-up (left), broad view (middle), and water sample (right) photographs of water quality conditions. These photos show "high alert" conditions in North Hero, Vermont. Photos by community scientist volunteer Jeff van den Noort.

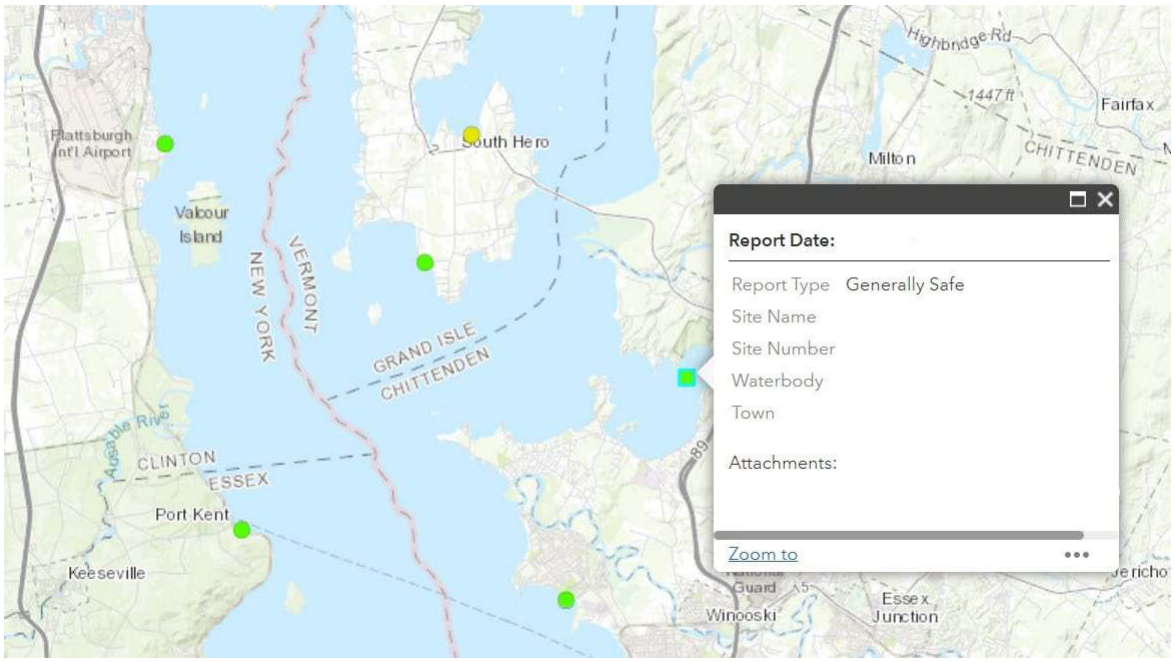

Figure 3. Screenshot of the Cyanobacteria Tracker map public interface. Sites with cyanobacteria monitoring reports are shown as colored circles on the map; green circles indicate "generally safe" conditions, yellow circles indicate "low alert" conditions, and red circles (not pictured) indicate "high alert" conditions. Selecting a site displays additional data, including photos taken to accompany the report. Visit the site here: https://www.healthvermont.gov/tracking/cyanobacteria-tracker.

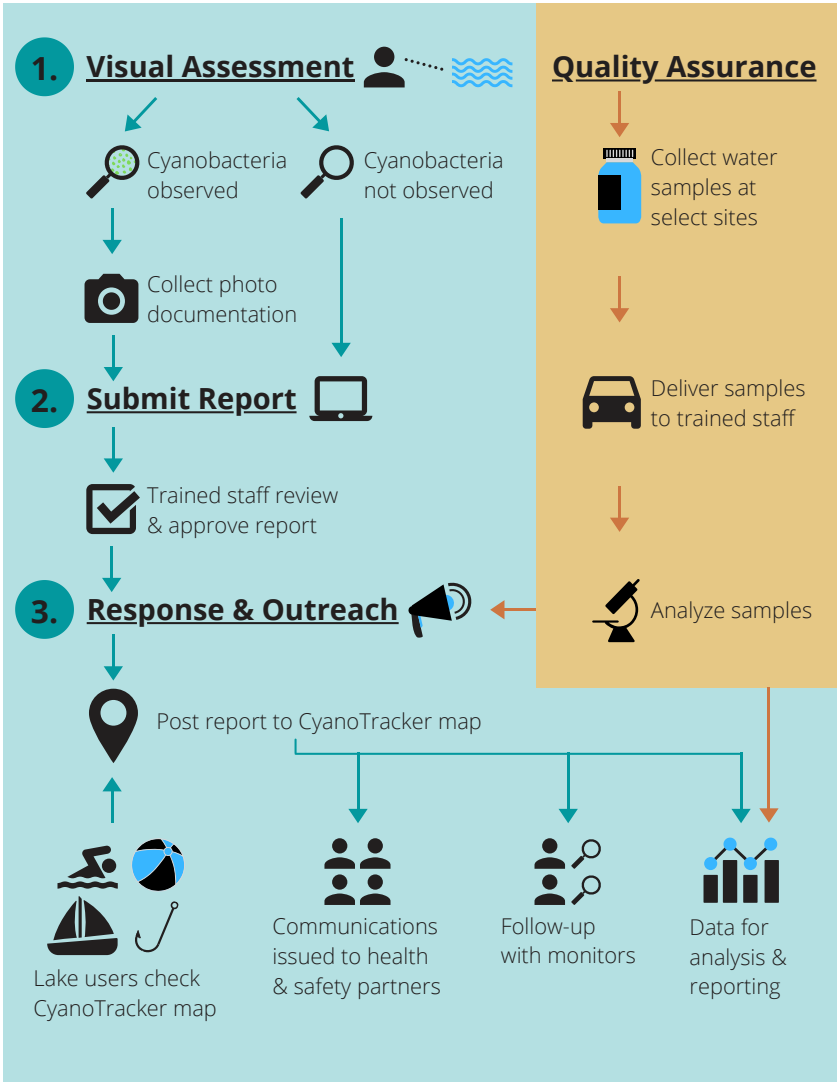

Figure 4. Summary of the flow of information in the Lake Champlain Cyanobacteria Monitoring Program.

Program Efficacy and Key Findings

The visual assessment protocol has greatly enhanced cyanobacteria monitoring on Lake Champlain by leveraging available funds to increase geographic coverage, and by focusing on the most important information for public health and recreation management. Before 2012, the annual average number of cyanobacteria monitoring reports ranged from 180 to 460; following the adoption of the visual protocol in the 2012–2020 time period, an annual average of 1,404 reports were received (Figure 5a). Lake-wide geographic coverage also grew from an annual average of 47 locations prior to 2012, to an annual average of 138 locations in 2012–2020 (Figure 5b). Interest in the program continues to grow; in 2019 and 2020, approximately 2,000 reports were received each year from over 170 unique locations on Lake Champlain.

Results from nine years of using the visual assessment protocol are consistent with historical monitoring trends (Smeltzer et al. 2012). Over 95% of the 9,555 routine visual assessments submitted since 2013 (when routine and supplemental reports began to be distinguished) reported "generally safe" conditions, indicating no visual accumulations of cyanobacteria (Figure 6). In contrast, 41% of supplemental reports, which are often collected in response to active cyanobacteria bloom conditions, were of low or high alert level during this time period. This contrast highlights the importance of collecting both routine and supplemental reports;

while supplemental reports are critical for short-term public health response and information on bloom persistence, routine reports document the presence or absence of cyanobacteria blooms with regular frequency in order to capture both types of information and assess longer-term trends.

Grouping report data by lake region shows that cyanobacteria growth greatly varies geographically, and that some areas of the lake are more susceptible to cyanobacteria blooms during the monitoring season than others (Figure 7). For example, 98% of reports from Main Lake locations since 2013 indicated "generally safe" conditions, while that figure is 77% and 79% for St. Albans and Missisquoi Bays, respectively. These differences are due to distinct physiographic and biogeochemical characteristics and heterogeneous nutrient availability (Isles et al. 2015) and have important implications for lake management.

To ensure that the visual assessment protocol effectively indicates public health risk, a subset of visual assessment reports is compared to laboratory-based analyses of cyanobacteria taxonomy, cyanobacteria cell density, and cyanotoxin concentrations for concurrent and co-located water samples at Vermont monitoring locations (Shambaugh et al. 2018; 2019; 2020). Favorable comparisons should show that reports in different visual assessment protocol categories generally differentiate between low and high cyanobacteria cell densities, and that conditions described as category 1 are indeed "generally safe," with no cyanotoxin concentrations measured above a public safety threshold value for recreation.

Results of 371 quality assurance comparisons during the 2017–2019 time period show that the visual assessment protocol is a useful and effective indicator of public health risk (Figure 8). Median cyanobacteria cell densities for samples associated with visual assessment report categories 1a–c, 1d, 2, and 3 each differed by at least one order of magnitude and were each significantly different from the others by the non-parametric Kruskal-Wallis test ($p < 0.0001$). During this time period, no laboratory analyses for microcystin or anatoxin exceeded the lowest public safety threshold concentration values for recreation within Lake

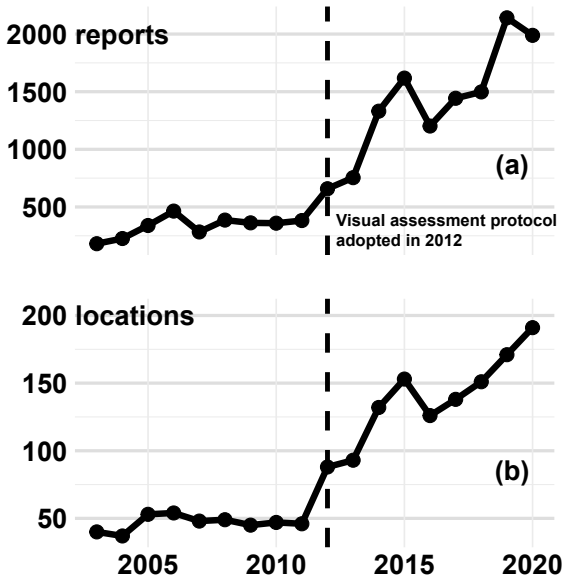

Figure 5. The number of (a) cyanobacteria monitoring reports received and (b) the number of locations monitored on Lake Champlain from 2003–2020. The dashed vertical line indicated the adoption of the visual assessment protocol in 2012, which facilitated an increase in the number of sites monitored and reports received. These plots include routine and supplemental reports.

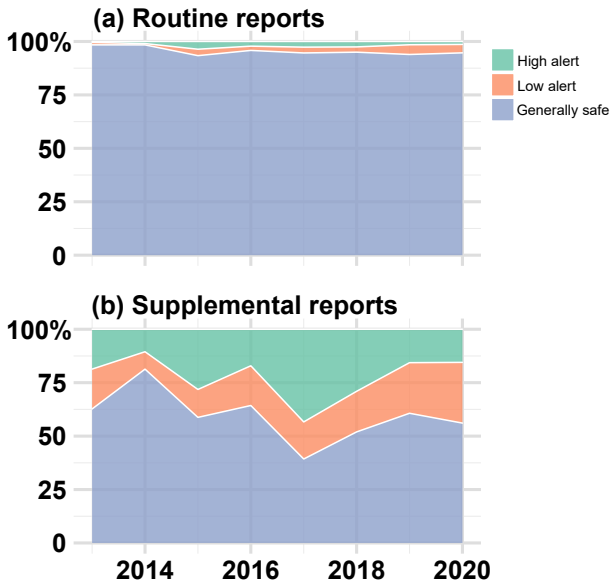

Figure 6. Percentages of (a) routine and (b) supplemental cyanobacteria monitoring reports received and vetted from 2013–2020, colored by status ("generally safe," "low alert," or "high alert"). Supplemental reports are biased toward alert statuses because they often are submitted specifically in response to an active cyanobacteria bloom.

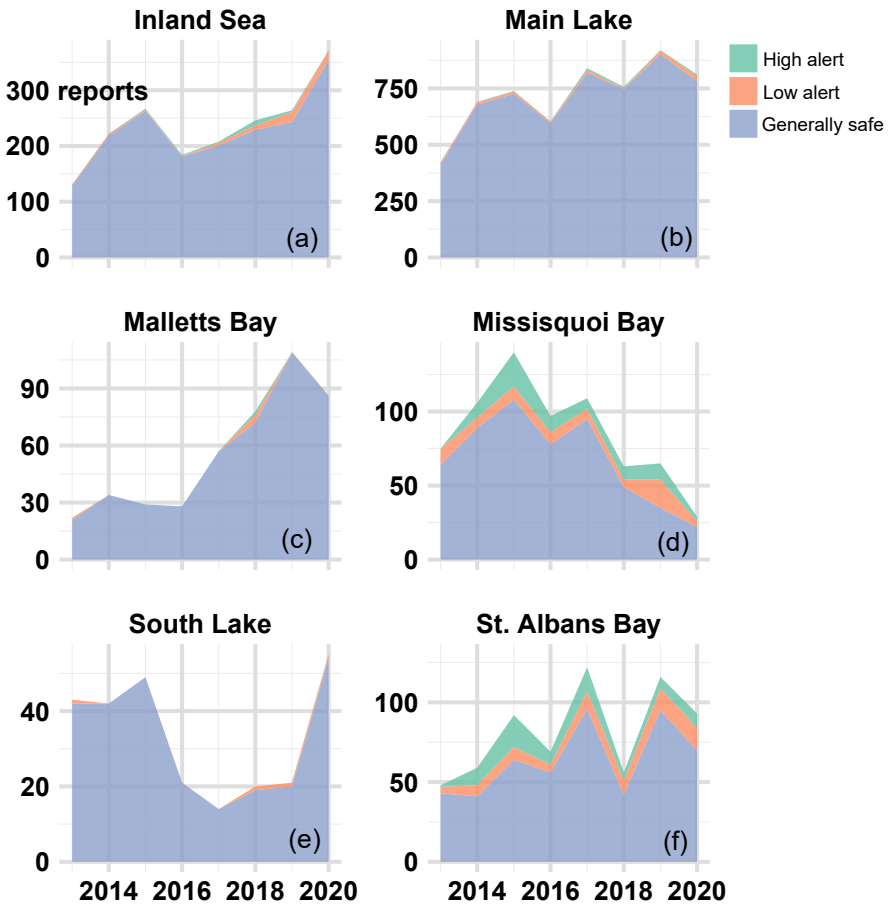

Figure 7. Number of routine cyanobacteria monitoring reports received by lake segment from 2013–2020, colored by status ("generally safe," "low alert," or "high alert"). Figure 1 shows a map of region locations.

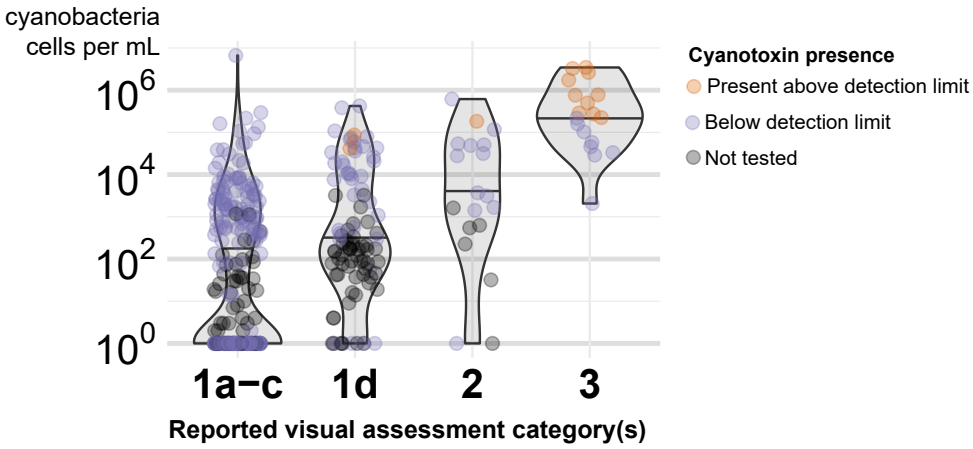

Figure 8. Laboratory-based quality assurance checks of cyanobacteria cell densities and cyanotoxin concentrations compared to categories reported using the visual assessment protocol during from 2017-2019. Violin plots are shaped by cyanobacteria cell density distribution, and medians are indicated with horizontal lines. Points are colored by analytical results for microcystin and anatoxin cyanotoxins: at least one cyanotoxin present above the detection limit (orange), neither cyanotoxin present above detection limits (purple), or not tested for cyanotoxins (black). Analytical detection limits are 0.16 µg L^{-1} and 0.5 µg L^{-1} for microcystin and anatoxin, respectively. Of these 371 quality checks, 103 had zero cyanobacteria cells per mL and were category 1a, b, or c. To plot on a log scale, cyanobacteria cell densities were transformed by adding 1 to each value.

Champlain management jurisdictions (6 µg L^{-1} and 10 µg L^{-1}, respectively). Importantly, all cyanotoxin detections for samples associated with visual assessment categories 1a-d ("generally safe") were well below these threshold values. Further, different visual conditions generally indicated a different likelihood of cyanotoxin detection. For example, samples associated with 99.1% of visual assessment reports described as category 1 ("generally safe") had no detectable cyanotoxins present. Although sample sizes differ, 47.4% of samples associated with category 3 reports ("high alert") had no detectable cyanotoxins present (n = 19).

Best Practices and Broader Perspectives

Practice Recommendations for Developing a Community Scientist-based Program

Our long experience running a community scientist-based monitoring program has allowed us to identify and share these essential best practices for others who may consider developing a similar program:

1) Communicate regularly to provide ongoing training and support. Weekly communications during the monitoring season and at several times throughout the year help keep trained community scientists engaged and informed, and contribute toward maintaining the target frequency and quality of reports. Weekly emails include reminders on protocols, links to report instructions, a compilation of weekly reporting results, photographs and descriptions of cyanobacteria, and contact information (view an example of a weekly email at https://mailchi.mp/lakechamplaincommittee.org/week-20-cyanobacteria-monitoring-report-community?e=abafd0bc76). These emails also profile exemplary community scientists, feature different lake phenomena each week, and reinforce participants' valuable contributions to the program.

2) Budget time and resources for frequent volunteer support. It is helpful for program staff to frequently follow up with monitors, whether it is to answer questions about water conditions they observe, clarify an element of their online report form submittal, or troubleshoot technical issues. Community scientists have a wide range of experience with technology and some need additional assistance to submit reports. We recommend giving community scientists step-by-step guidance on how to fill out online report forms, label photos on a smartphone, and fulfill other program reporting requirements. We also suggest creating a range of education and outreach materials that target different learning styles, including visual, auditory, and verbal.

3) Strike a balance between public and private monitoring sites. Although data from high-traffic public areas (e.g., beaches, boat launches, and parks) are most useful for the general public, backyard monitoring also provides valuable information and the opportunity for more volunteers to engage in water quality issues.

4) Provide training to improve the quality of photographic documentation. Submitted photos are valuable and effective at confirming reported water conditions and complementing education and outreach efforts (Figure 2). In addition, posting report photos on an online map (e.g., as with the Lake Champlain Cyanobacteria Tracker) provides a learning opportunity for anyone who checks on water quality conditions. Photos of water quality conditions can be challenging to capture, especially when cyanobacteria are visible at low densities (e.g., category 1d). Factors that influence the quality of photos include sun glare, low light, camera focus, and image resolution. Specific training at the onset of the program on how to take high quality photographs can prevent data quality issues later in the season. Community scientist volunteers should be encouraged to provide narrative descriptions of their photos, such as approximate bloom extent along the shore and into the water; this approach creates a more efficient report review process for trained staff.

5) Let community scientist volunteers know they are valued. Because the community scientist volunteers are key to the success of the monitoring program, we recommend thanking volunteers early and often in all communications. Constant feedback is incredibly valuable, and sharing volunteers' monitoring results weekly by personalized email communication affirms

the value of their contributions. Our experience suggests that maintaining personal contact and emphasizing the importance of volunteers in trainings, direct communications, and social media throughout the year improves participation and increases volunteer retention.

6) Encourage communication on all water-related phenomena and unusual conditions. It is helpful to encourage monitors to share unusual observations with program staff and submit a water sample if they see something unfamiliar. This approach assists community scientists with cyanobacteria identification and fosters environmental literacy, especially when these findings are shared with all program participants. In recent years, community scientists have encountered cyanobacteria in Lake Champlain that are challenging to evaluate solely by visual observation. For example, the benthic cyanobacterium *Scytonema* sp. has been observed several times in parts of Lake Champlain, where it can form surface accumulations that may appear more similar to filamentous green algae than other cyanobacteria. In addition, the colonial cyanobacterium *Gloeotrichia* sp. appeared at several Lake Champlain locations in 2017 as small surface scums that appear more similar to pollen than other cyanobacteria.

7) Encourage reporting beyond the peak recreation season. We recommend targeting personnel time and resources to maintain report frequency and quality after the close of the peak recreational season. This is a time when cyanobacteria blooms and associated public health risks may still occur even though many seasonal community scientist volunteers have left summer residences, volunteer interest and dedication can wane, and seasonal parks may be unstaffed but still accessible to the public.

The season when cyanobacteria are active on Lake Champlain is starting earlier and ending later than in the past. Based on projected impacts of climate change in the Lake Champlain watershed, including increased temperatures (up to 0.49°C decade^{-1}) and days over 32.2°C (90°F) (Guilbert et al. 2014), cyanobacteria blooms may increase in intensity and persistence in the future. Climate change has already altered ecological conditions in the northeastern U.S. and southern Canada, and different aspects of climate change favor cyanobacteria growth (Paerl and Huisman 2008; Harke et al. 2016) and make mitigation and control efforts more challenging to implement (Paerl et al. 2020). Cyanobacteria monitoring programs in regions with a similar outlook will need to dedicate adequate resources throughout a longer growing season in order to protect public health and inform effective lake management.

Conclusion

The success of this program demonstrates that visual assessments conducted by trained community scientist volunteers are a viable way to document and disseminate critical public health information. Our initial laboratory-based approach was a valuable first step in understanding cyanobacteria blooms in Lake Champlain, and the development of the visual assessment protocol has allowed the program to greatly expand geographic coverage and rapidly deliver the most important information to stakeholders. This simple method creates opportunities to share water quality conditions in a way that resonates with the public and generates actionable information to immediately protect public health. The combination of our visual tool with quality assurance sampling for cyanobacteria densities and cyanotoxin concentrations has allowed our collaborative team to monitor a very large geographic area with credibility and public engagement.

We are currently developing methods to compare cyanobacteria seasons to historic data and incorporate satellite-based measurements and model outputs (Schaeffer et al. 2018). However, because monitoring locations and times are dependent on volunteer locations and schedules, they can vary from year to year, which confounds statistical analyses on a lake-wide or even site-by-site basis. This is one limitation of the community-scientist based program, compared to a traditional research program that may have limited geographic coverage but a more consistent sampling regime.

Lake Champlain cyanobacteria monitoring partners continue to seek out opportunities that will enhance and improve the monitoring program. For example, the visual assessment protocol guidance for the Lake Champlain program is heavily

focused on the planktonic (floating) cyanobacteria. We are working to improve guidance materials to better incorporate information on benthic (bottom dwelling) cyanobacteria as well. In addition, collaborations are underway to evaluate the combination of visual assessments with dipstick cyanotoxin testing as a way to quickly reopen a beach with confidence that cyanotoxin concentrations are below the public safety threshold values for recreation.

The visual assessment protocol is now used to evaluate smaller lakes throughout Vermont. Since 2012, New York DEC has evaluated cyanobacteria bloom reports from lakes in other parts of the state using a combination of visual evaluation and analytical results to determine a bloom status designation. In 2019, New York DEC initiated the New York Harmful Algal Bloom System (NYHABS), which is similar to the Cyanobacteria Tracker map. Most states around the U.S. accept photos as documentation of potential cyanobacteria blooms and, with training for community scientist volunteers and a reasonable level of sustained funding, could build similar cyanobacteria data collection and outreach tools.

The Lake Champlain Cyanobacteria Monitoring Program has built a common understanding of cyanobacteria blooms around Lake Champlain that can be understood by all lake users and used by all jurisdictions following their respective response plans. As pressures on water quality continue and climate change exacerbates potential cyanobacteria bloom conditions, we expect that the future of cyanobacteria monitoring will be driven by lake users' enthusiasm to adapt and steward their resource.

Our community scientist-based monitoring program has had a positive impact well beyond expanding the number of people who are collecting water quality data. Each person who attends a training becomes familiar with cyanobacteria, associated potential health risks, the water quality conditions that increase the likelihood of blooms, and individual actions they can take to improve water quality. Community scientist volunteer training gives each participant a way to be actively involved with their watershed or lake. By assessing water conditions at a local site on a routine basis week after week, community scientist volunteers deepen their connection to nature, and actively participate in stewardship of their natural resources.

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Using Community Science to Address Pollution in an Urban Watershed: Lessons about Trash, Diverse Engagement, and the Need for Science Mindsets

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Abstract: Community science projects offered in urban areas may be particularly effective at addressing environmental problems and engaging people in science, especially individuals whose identities have historically been underrepresented in the field. In this project, we worked with individuals from a racially diverse, low-income community in San Diego, California to conduct community science to: 1) test a conceptual program model aimed at engaging diverse communities in science, and 2) contribute to scientific knowledge about the inputs and accumulations of trash in an urban watershed. While the program model did well at bolstering environmental stewardship, recruitment, and short-term retention of community members as project participants, it was not as effective at building science understanding, interest in science, and awareness of doing science, indicating a need for a mindset approach. Despite this, the data collected by the community between 2014-2018 revealed in-depth information about the spatial and temporal distributions of trash, including the identification of three main debris inputs: encampments, illegal dumping, and storm drain flows, as well as the validation of global trends of a predominance of plastics across waterways and through time. In a few instances, community stewards became community scientists—the quantity and quality of data collected improved, and community members presented results to authorities who responded with concordant management actions (e.g., help with cleanups, outreach to unhoused communities). Based on project outcomes, our revised community science program model includes a focus on strengthening a science mindset, in which even short-term science interventions that improve the recognition of science, a sense of belonging, and access to mentorship may have meaningful long-lasting effects on increased participation in science.

Keywords: *citizen science, community engaged science, DEI, illegal dumping, marine debris, plastics pollution, STEM, stormwater flows*

Trash pollution is a ubiquitous, global problem with well-documented effects on coastal communities and marine ecosystems (UNEP 2014; Rochman et al. 2016). Most trash found throughout watersheds and in lakes and oceans around the world originates from land (Rochman 2013). California is no exception, with trash collected during coastal cleanups dominated by single-use and plastic food containers and wrappers, tableware, bottles, bags, straws, and cigarette butts (CCC 2019), reflecting global trends (Ocean Conservancy 2020; Reddy and Lau 2020). Trash, in particular plastic trash, is concerning because of its persistence in the environment and its potential to harm wildlife through entanglement, suffocation, malnutrition (when ingested), internal blockages, and increased exposure to environmental toxins (e.g., Teuten et al. 2009; Rochman et al. 2013a; 2013b; Kühn et al. 2015). With rapidly growing awareness of the ubiquity of trash and its detrimental effects on wildlife and humans, trash is increasingly being treated as a water pollutant (Moore 2008; Koch and Calafat 2009; Hollein et al. 2014;

Research Implications

- Community science practices that maximize accessibility and relevance to community members by tackling problems that are ubiquitous and important to the community (e.g., trash pollution, in the case of this project) will increase diverse participation in the activities and facilitate entry into science.
- Community science practices that provide impactful experiences, such as guided, hands-on, authentic science activities led by people from the community, will increase environmental awareness, enthusiasm, and stewardship; strengthening diversity in science will require the addition of practices that build science mindsets.
- Community science practices that build science mindsets, in particular activities that are impactful even with brief exposure such as inclusion of STEM role models, may heighten participants' recognition of doing science, valuing of science, and sense of belonging, which may in turn increase engagement and perseverance of a greater diversity of people in science.
- Guided research experiences with the community, in particular collaboration between scientists and key community members within and between project sessions, contributes to the generation of appropriate, high-quality data and community empowerment—both needed for effective communication with officials and crafting of locally-relevant solutions.
- Recording even basic data about trash during cleanups, such as location, counts, volumes, and/or weights, can reveal much about sources of inputs and serves as a powerful public education and action tool.

USEPA 2020). In California, a 2015 state permit amendment mandated that all municipalities eliminate trash from flows into receiving waters by 2030 through the installation of trash capture devices or alternative trash reduction innovations (CSWRCB 2015; USEPA 2020). In order to develop appropriate and effective trash solutions, better understanding is needed of both the trash dynamics within individual coastal watersheds, including sources of inputs, types of debris, and spatial and temporal distributions of trash, and how to engage people throughout the watershed in trash reduction practices.

Community science can strengthen the environmental awareness, stewardship, and literacy of non-scientist community members (Trumbull et al. 2000; Brossard et al. 2005; Evans et al. 2005; Ballard and Belsky 2010; Jordan et al. 2011; Bonney et. al 2009; 2016) and facilitate the inexpensive collection of data over large geographic areas, which can then advance scientific knowledge, practice, and policy (Cooper et al. 2007; Ballard and Belsky 2010; Conrad and Hilchey 2011; Miller-Rushing et al. 2012; Sauermann and Franzoni 2015; Theobald et al. 2015). Community science projects offered in urban regions may be particularly productive and important given the high densities of potential participants, and the need for studies of urban ecosystems which provide crucial services for many communities, in spite of their often-degraded states (Elmqvist et al. 2015). Further, urban populations tend to be diverse, with relatively high proportions of people from the very minority groups that are underrepresented in science, giving urban community science projects great potential for engaging and increasing representation of these groups in science (Evans et al. 2005; Pandya 2012; NSF 2015).

Effectively engaging people from diverse groups in science remains a challenge (Miller-Rushing 2013), so increasing participation in community science efforts may be an effective way to increase representation in science more generally. We developed and tested the effectiveness of a conceptual community science program model (Figure 1; Ruzic et al. 2016) aimed at engaging a diverse urban community in community science, specifically in the investigation of trash pollution in their neighborhood's waterways. The model was based on emerging best practices which we categorized as improving ***science entry*** (access to experiences and encouraging initial participation; Figure 1) and ***science intervention*** (impact, meaning, value, and/or inspirational power of initial and early experiences; Figure 1). We chose seven best practices, two practices aimed at facilitating science entry and five aimed at providing impactful science interventions

(Figure 1), that have been linked with increases in participants' ***understanding*** of (e.g., knowledge, skills, interest; Figure 1) and ***persistence*** in science (i.e., long-term, repeated participation including interest in science careers; Figure 1) (Bell et al. 2003; Dee 2004; Lauver et al. 2004; Bang and Medin 2010; Sadler et al. 2010; Wu and Van Egeren 2010; Harrison et al. 2011; Pandya 2012; Graham et al. 2013).

The causes and effects of trash pollution are issues that most people understand, and trash reduction is a priority for many communities, making trash a logical focus of community science projects (i.e., science relevant to participants' daily lives; Figure 1). As in many urban neighborhoods, the residents, community-based organizations, and civic leaders in City Heights, a neighborhood located in the middle of San Diego, California, USA (Figure 2), often work together to conduct trash cleanups and move toward sustainable solutions to improve and steward their urban waterways. We worked with members of City Heights because our project team had existing ties with community groups in City Heights. We chose trash as this project's subject matter because community members had been working together to reduce trash pollution in local waterways for more than five years before this project began (Ruzic et al. 2016), indicating that trash control was a priority for many in the community. No group had previously engaged the community in an organized, hands-on, authentic (not classroom science; Crawford 2015) science project (Figure 1) built around the community's trash reduction goals.

City Heights was also an ideal focus for this project because it is a highly urbanized, high-poverty, "disadvantaged" community (DWR 2015; Ruzic et al. 2016). It is highly diverse, with at least 40 languages and 80 dialects spoken by neighborhood residents (EHC 2011; Mento 2018). The community has been identified as having low engagement and performance in STEM and being "vulnerable to climate change impacts" (Cooley et al. 2012; CDE 2013; SANDAG 2015; Ruzic et al. 2016). All community science project activities took place in four canyons in City Heights (Figure 2). These canyons are seasonal waterways that serve as green spaces, wildlife and sensitive species habitat, and the city's stormwater system, and are part of the Chollas Creek sub-watershed, labeled one of the most impaired waterbodies in San Diego County (Anderson et al. 2012; San Diego Coastkeeper 2014). These facts combined indicate a need for strengthened stewardship and bolstered resilience of both the urban community and ecosystem.

Project Goal and Objectives

The goal of our project was, therefore, to address the issue of trash pollution in a coastal urban watershed through community science, and engagement in science more generally, to lead to longer-term, sustainable solutions. We addressed this goal by using social science approaches to study the community as they participated in a community science project called the "Discoverers Program," which employed applied natural science approaches to study trash pollution. Specifically,

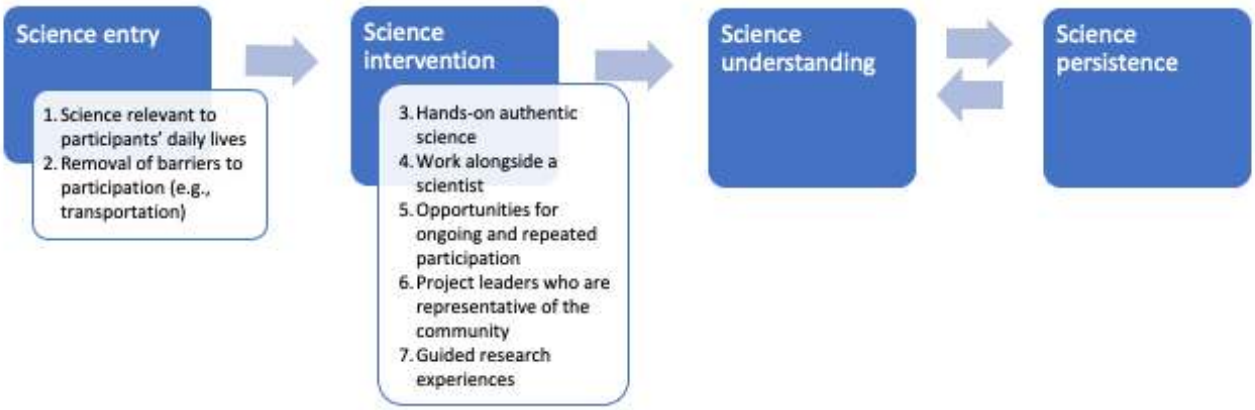

Figure 1. An initial conceptual community science program model used to recruit (entry) and engage (intervention) members of a diverse community in community science with hopes of ultimately increasing science understanding and persistence. Modifications were made based on project outcomes resulting in a more effective model.

we fulfilled the following two objectives by answering the associated research questions:

1. Assess our newly developed conceptual program model (Figure 1) aimed at engaging diverse communities in community science and, ultimately, increasing science understanding and participation in science, by piloting, evaluating, and subsequently modifying the initial model which was based on known best practices.
   a. To what extent did our science entry practices (Figure 1, Practices 1-2) contribute to the participation of people from all demographic variables?
   b. To what extent did our science intervention practices (Figure 1, Practices 3-7) influence science understanding and persistence in participants from all demographic variables?
2. Improve our understanding of trash pollution, specifically the types and abundances of trash inputs through space and time in an urban waterway.
   a. How do the types and abundances of trash inputs differ across canyons and with time (year and season)?

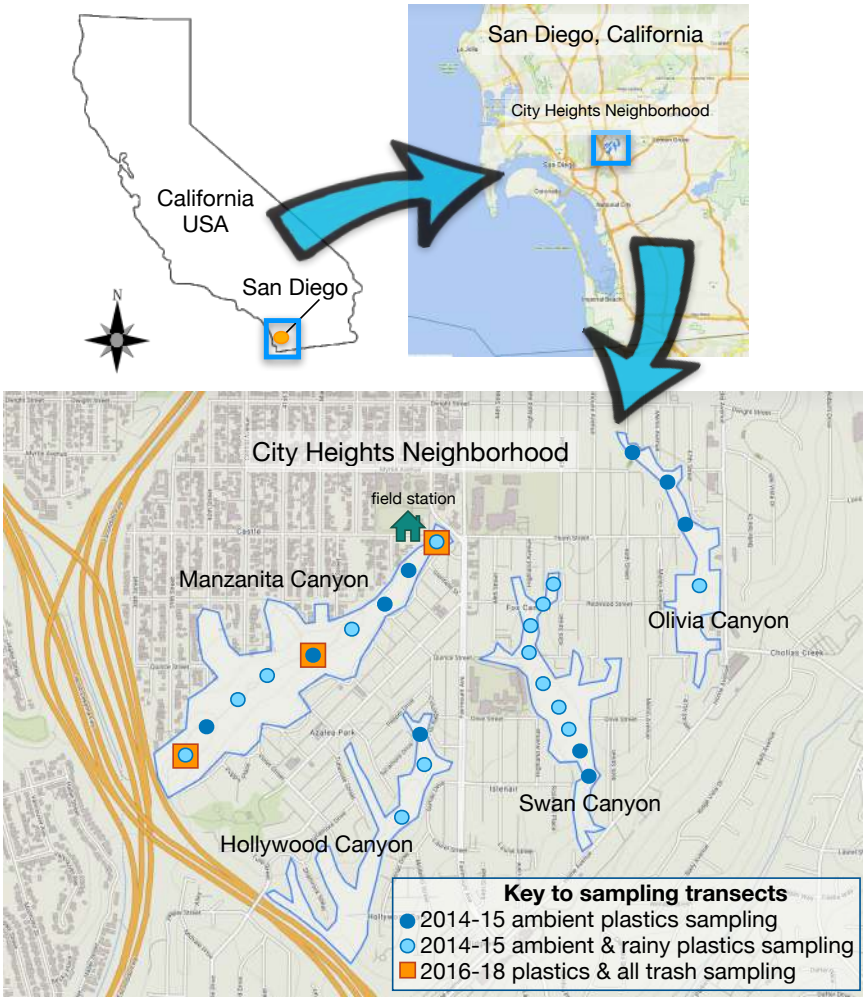

Figure 2. Location of canyons where community science efforts were conducted between 2014-2018 in the City Heights neighborhood of San Diego, California. In 2014-2015, all four canyons were used for both the Discoverers Program (the community science project) and the community science program model assessment. In 2016-2018, only the Discoverers Program was conducted and only in Manzanita Canyon; besides the transects (orange squares), the whole canyon was also studied for trash.

b. What is the total magnitude of inputs of all types of trash into these canyons, using Manzanita Canyon as an example?

Methods

Assessing Our New Community Science Program Model

The influence of our initial community science program model on levels of participation and persistence, indicated by retention, learning, and interest in science (Table 1) of participants eight years and older was tested between January and July 2015, in conjunction with the Discoverers Program (the community science project). Of the 215 individuals who participated in the project throughout this period, 208 met the minimum age requirements and 95% (198) chose to participate in the assessment. Up to five types of data were collected from each participant to answer research questions (Table 1):

1. Tracking data – the number of individuals who attended each session and attendance over time using a participant ID number assigned during each person's first visit.
2. Written surveys – administered at the beginning of each participant's first session. Surveys collected demographic information (zip code, age range, gender, race/ethnicity) and data about how the person heard about the initiative (n=198 individuals).
3. Written assessments – administered at the beginning and end of each participant's first session. Assessments asked a basic science question (specifically, an illustrated question about the direction that water (and, in turn, trash) flows in a watershed) and a question about the participant's interest in particular conservation and science topics (n=125 individuals who completed both the pre- and post-session written assessments).
4. Individual interviews – administered at the end of one session, in either English or Spanish. Interviews were composed of questions about the day's activity, the participant's experience and learning during the activity, and reasons for attending (n=32 individual (or family) interviews).
5. Field recordings – one- to two-hour long audio recordings from recorders voluntarily worn around the necks of 64 unique individuals over 10 sessions that captured all audible sounds, including conversations with consenting participants without recorders, to determine the type and frequency of science talk during the sessions. Of these, the recordings from the final three project sessions were selected for analysis because they were best suited (see Ruzic et al. 2016 for details) for comparisons of discussions with and without a scientist present (n=1 session with a scientist and n=2 sessions without a scientist present for a total of 16 recordings from 12 unique individuals).

During the 2016–2018 Manzanita Canyon project, the number of community participants, as well as participants' zip codes and age ranges (adult, minor) were recorded for all sessions. The names, contact information, and demographic information of high-frequency participants were voluntarily provided.

Model Assessment Data Analysis. For each type of data collected, analyses were performed to test for overall trends and differences by demographic variables such as race/ethnicity, age range, and gender. Paired t-tests were used to identify changes in science understanding and interests before and after participation in the project. The individual interviews and field recordings, which consisted of multiple, different recording perspectives of each conversation and session, were transcribed verbatim. Transcripts were imported into HyperRESEARCH™ qualitative analysis software. Both the transcripts and original audio recordings were used concurrently during coding to distinguish near, far, and inaudible conversations from each participant's vantage point during the field session. Data were analyzed using a modified grounded theory approach. We applied a set of *a-priori* coding categories while also allowing codes and themes to emerge from the data, all with consideration of each recorded participant's unique experience within the larger context of the field session. Transcripts were coded for participants' reasons for attending the project session, what they got out of or learned through the project, their understanding of the community

Table 1. The variables measured or assessed, and the methods used to fulfill this interdisciplinary project's two research objectives by answering corresponding research questions. The testing of science intervention practices (3-7) additionally assessed the effect of the presence/absence of a scientist on the variables listed.

Research Questions	Variables Measured	Data Collection Methods
Objective 1. Assess our new community science program model		
To what extent did our science entry practices (1-2) contribute to the participation of people from all demographic variables?		
Relevance of project to participants	participant motivations for participating	individual interviews
Removal of barriers (accessibility to the community)	participant zip code and demographics (vs. community demographics)	written surveys
	how participants heard about the event	written surveys
	participant return rates	tracking data
To what extent did our science intervention practices (3-7) influence science understanding and persistence in participants from all demographic variables?		
Changes in understanding: level, type, and drivers of	pre- and post-session ability to answer a basic science question	written assessment
	type and frequency of talk about science and related topics during the field session	field recordings
	understanding of the trash study during field sessions	field recordings
	understanding of science and/or the trash study after field sessions	individual interviews
Persistence in science: return rates, expressed interests, and drivers of	participant return rates (overall), participant return rates with and without a scientist present on first visit	tracking data
	repeat participant vs. leader demographics	tracking data and written assessment
	pre- vs. post-proportions of participants interested in various science and conservation topics	written assessment
	type and frequency of talk about science and related topics during the field session	field recordings and individual interviews
Objective 2. Improve our understanding of trash pollution (specifically the types and abundance of trash inputs through space and time)		
How do the types and abundance of trash input differ across canyons and with time (year and season)?		
Spatial and annual dynamics of plastics trash	annual proportional numeric abundances of each type of meso-plastic trash from each of the four canyons in 2014 and from 2015-2018 in Manzanita Canyon	2014 ambient plastics sampling, 2014-15 rainy plastics sampling, 2016-18 all trash sampling
Rainy season plastics trash inputs	average volume of the different types of meso-plastics trash collected from each canyon in the rainy season vs. pre-rainy season (ambient)	2014 ambient plastics sampling, 2014-15 rainy plastics sampling
What is the total magnitude of inputs of all types of trash into these canyons using Manzanita Canyon as an example?		
Magnitude of inputs of all trash	volume and weight of each type of meso-trash and large items totaled by location within Manzanita Canyon by year	2016-18 all trash sampling

science study, and their conceptions of science (Ruzic et al. 2016).

Community Science Project: The Discoverers Program

Session Access and Leadership. The Discoverers Program was conducted between January and July 2015 in four neighborhood canyons and between April 2016 and May 2018 in Manzanita Canyon only (i.e., Figure 1, Practices 1, 5: Relevant science, repeated opportunities; Figure 2). All canyons were within walking distance of multiple schools and residential areas within the community (i.e., Figure 1, Practice 2: Removal of barriers; Figure 2).

Each session of the Discoverers Program was advertised through multiple channels, including neighborhood and school newsletters, phone calls to local groups and partners, presentations at community events, and community group mailing lists and social media (i.e., Figure 1, Practice 2: Removal of barriers; Ruzic et al. 2016). Each 2015 session was led by a staff educator from a community-based science education organization and two members of a trained team of four project leaders. The project leaders were high school students from the community who were representative of the cultural/ethnic diversity in the community and spoke the three most common languages in the community (English, Spanish, and Vietnamese) (Figure 1, Practice 6: Leaders from the community). The project leaders, guided by the staff educator, provided participants with an introduction at the start of the day consisting of an overview of the science research project (methods, results to date) and basic underlying science concepts, including what a watershed is and the impact of trash locally and downstream (Figure 1, Practices 1, 3, 7: Relevant, hands-on and authentic, guided research). The project leaders and staff educator also oversaw the field activities, ensuring protocols were followed and providing participants with assistance and information about the activity and the underlying science as needed or as opportunities arose to share information (Figure 1, Practice 7: Guided research). The project scientist actively participated in half of all the sessions including the field activities because the study tested the influence of scientist presence (and absence) on participant engagement (Figure 1, Practice 4: Work alongside a scientist; Ruzic et al. 2016). While the project scientist—a white, middle-aged female PhD-level ecologist—was not representative of any of the underrepresented groups from the community (i.e., did not fulfill Figure 1, Practice 6: Leaders from the community), she had over a decade of experience working with diverse students in this community on science research projects.

The 2016-2018 Discoverers Program sessions were held in conjunction with semi-weekly stewardship events led by staff of a local environmental non-profit group, and five biannual (spring and fall) regionally organized stewardship events (e.g., California Coastal Cleanup Day; Figure 1, Practices 1, 2, 5, 6, 7). Key volunteers also frequently engaged in community science activities on their own, independent from organized events. The project scientist, the same scientist as in the 2015 program, and a mid-20s white, female scientist participated in all five of the biannual sessions from 2016-2018, with occasional participation in the semi-weekly events (Figure 1, Practice 4: Work alongside a scientist).

Plastics in Time and Space. Within each of the four canyons, three to nine 30-m long transects were established longitudinally and equidistantly along the canyon floor from the upstream head to the downstream drainage point (total number of transects across all canyons = 25). Each 30-m long transect included the adjacent reach of flood plain, or bank-full width. The average width of each transect ranged from 7.2±0.26 to 8.6±0.5 m, for a range of 216-258 m^2 of surveyed area.

Three types of surveys were conducted to address research questions (Table 1). "Ambient plastics sampling" consisted of surveys of meso-plastic trash (2-50 cm) that were performed in all four canyons during an initial 2014 dry season (n=25 transects; Figure 2). "Rainy plastics sampling" consisted of meso-plastic trash surveys conducted in Swan Canyon throughout the 2014-2015 rainy season (n=7 transects), and again in all canyons after the end of the 2014-2015 rainy season (n=15 transects; Figure 2). Rainy season data from Swan Canyon were summed for a cumulative rainy season total that was comparable to the end of rainy season surveys conducted in the other canyons.

During the 2014-2015 meso-plastics surveys in the four canyons, plastics were collected, sorted, and counted within general use categories (bags and packaging, construction and auto, food and kitchen, home and office, other unidentifiable pieces, outdoor and sports, personal care and health) following rapid trash assessment protocols (SWAMP 2007; Miller-Cassman et al. 2016). The total volume of each general use category was measured at the end of the survey. In the spring and fall of 2016-2018 in Manzanita Canyon, all other types of meso-trash were also collected and sorted by material type (e.g., plastic, metal, wood, natural fiber cloth, paper). Total weight and volume of each material type were measured.

Magnitude of Inputs of All Trash: Manzanita Canyon. "All trash sampling" consisted of surveys conducted in Manzanita Canyon throughout 2016 and 2018 to assess the abundances of all types of meso-trash (e.g., plastic, metal, wood, natural fiber cloth, paper) along three transects (Figure 2) and both meso-trash and large items (>50 cm long) from throughout the whole canyon. Large trash items (e.g., discarded furniture, whole bags of trash) and meso-trash litter were documented and removed from across the whole canyon area throughout 2016-2018 by the project team and community volunteers. Team members and neighbors reported the location, volume, and weight of all material removed, and often provided a general description or qualitative assessment of the types of trash removed during each visit to the canyon. These data were totaled to create assessments of the total amounts of trash removed from within regions of Manzanita Canyon and across the whole canyon over the course of two years.

Trash Data Analyses. Abundances and compositions of all the recorded sizes and categories of trash were summarized using descriptive statistics. All meso-trash abundances (density, volume) were standardized to 200 m^2. Abundance data were $\log_{10}(x+1)$ transformed before analysis, unless otherwise noted, to normalize data and homogenize variances.

Comparisons of plastics abundance before and at the end of rainy season were made using paired t-tests in JMP Pro 12. Comparisons of plastics trash composition before and at the end of rainy season were carried out with multivariate analyses using Primer 7 (Clarke and Gorley 2015), specifically analysis of similarity (ANOSIM) on Bray Curtis similarity indices of standardized, 4th root transformed data to reduce the dominant contributions of abundant items. Analyses of dissimilarities in trash composition found before and at the end of rainy season, and the particular items contributing to those dissimilarities, were carried out using SIMPER.

Results

Participant Zip Codes and Demographics

Of the 190 participants who provided their home zip codes for the 2015 community science program model assessment, most (71%) were from the local community, 10% were from the surrounding city, and 17% were from the surrounding county. Nearly 64% of the 2,589 participants in the 2016-2018 Discoverers Program were from the local community.

Self-identified females made up 67% (133 of 198) of participants in the 2015 community science program model assessment and the rest identified as male. While gender information was not collected from all participants in 2016-2018, 40% of the high-frequency participants identified as female and the rest as male. Adults over the age of 18 made up 28% of participants in 2015 and 42% of participants in 2016-2018.

The self-identified races and ethnicities of individuals who participated in the 2015 community science program model assessment were similar to those in the local community as a whole (Chi square=2.4, df=5, p=0.79; Figure 3). However, a slightly larger percentage of individuals who self-identified as Hispanic/Latino or white, and a smaller percentage of individuals who self-identified as African/African American and Asian/Pacific Islander, as compared with participants overall, attended more than one session (Chi square=14.7, df=5, p=0.01; Figure 3). The racial/ethnic composition of returning participants began to converge with that of the individuals who led the Discoverers Program, who were majority Hispanic/Latino and white (Figure 3). Information on race and ethnicity was only collected from the

five 2016-2018 high-frequency participants, who self-identified as white (60%), Hispanic/Latino (20%) and Native American (20%).

Participant Return Rates

The majority of people who participated in the Discoverers Program attended only once (2015: 83%; 2016-2018: 83%). Over half of returning participants were from the local community (2015: 64%; 2016-2018: 58%). Only about 8% of 2015 participants and 4% of 2016-2018 participants attended more than two sessions of the Discoverers Program. In 2016-2018, 3.8% returned 3-5 times and <1% (5 people, all from the neighborhood) participated anywhere between 12-53 times. A total of 33 groups helped to organize volunteers to work in Manzanita Canyon in 2016-2018, including non-profits, community groups, faith-based groups, businesses, K-16 schools and clubs, and the Navy.

The chance to interact with a scientist on the first visit was not associated with increased rates of participation in future sessions. The proportion of returning participants who had the opportunity to interact with the project scientist on their first visit (27%) was similar to the proportion of individuals who returned and had not interacted with the scientist on their first visit (29%) (Chi Square=0.15, p=0.70, n=149).

Motivations for Participating

In response to the question "Why did you choose to come to the session today?" about one-third of participants (n=29) said that they came with a community service, faith-based, or school group, and 10% said they attended as part of a school or club project. Just over one-third of participants cited altruistic reasons for participating in the project, including wanting to help the community or the environment. Nearly half of the participants cited reasons related to personal growth and recreation, including to have fun, be outside or in nature, meet new people, learn about the environment, and get exercise (participants gave one or more responses so responses total >100%). No participant mentioned science or doing science as a reason they came to the initiative.

Motivations underlying participation were not explored in 2016-2018, but the highest volunteer turnout occurred when sessions coincided with organized regional cleanup efforts, such as the annual spring "Creek to Bay Cleanup" and fall "Coastal Cleanup Day," which stress the stewardship aspects of events. Similar to the 2015

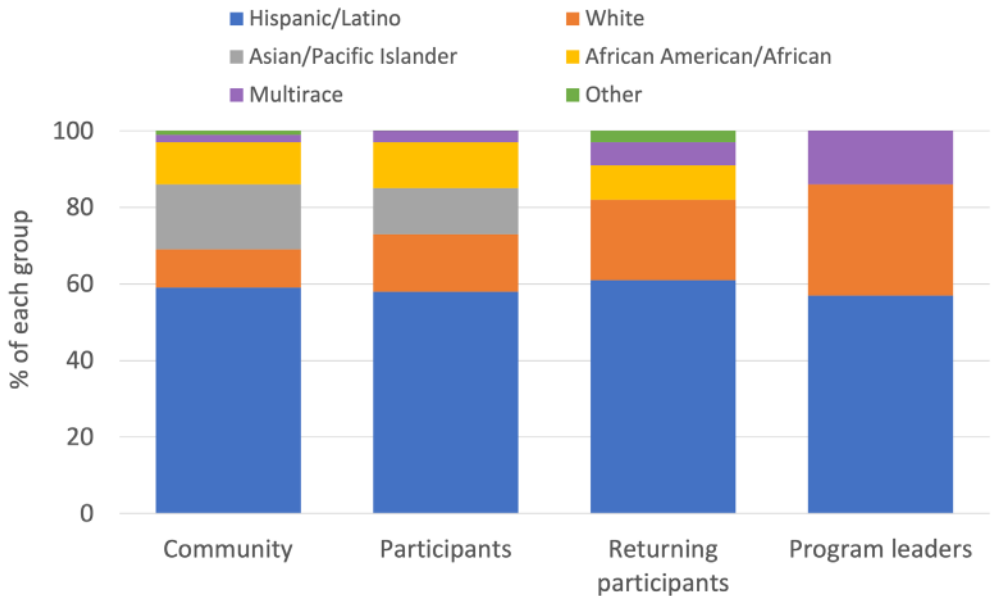

Figure 3. The percent of each self-identified racial and ethnic group comprising the whole community in which the Discoverers Program (the community science project) was conducted, the people who participated at least once, the people who participated two or more times, and the program leaders. N=77,697 people in the community (SANDAG 2015), 198 participants, 33 returning participants, and 7 leaders, respectively. Data are from 2015.

sessions, many attended as members of groups that have educational or philanthropic missions (e.g., K-16 schools, community service or faith-based groups, local businesses). These organizations tended to participate repeatedly even if many of the individual members came only once or twice. Local community activists (the five high-frequency participants and several other neighbors), although few, were effective at motivating and leading many other community volunteers throughout the year at informal events. The community activists participated repeatedly while the volunteers they recruited came once to a few times per year.

Changes in Scientific Understanding and Interest after Participation

There was no change observed in the performance of any age group, or the group as a whole, in correctly indicating on a watershed diagram the direction that water (and therefore trash) flows following participation in a community science session (four answer options with one being the mouth of a watershed; $P \geq 0.10$, paired t-test, n=125). When model assessment interviewees (n=30) were asked "What question were you investigating today?" just under half (46%) were not able to identify a purpose for the study.

When asked "Do you feel like you learned anything today? If so, what?" the majority (83%) of interviewees (n=28) reported that they learned while participating in the Discoverers Program. Over half said they learned about the sources or amounts of trash, water flows, and trash effects on wildlife, the canyon, and/or the ocean. A quarter said that they learned about actions that a person can take to prevent trash from flowing into the watershed and subsequently hurting the environment or animals (e.g., not littering). Just over a third of people reported learning about the impacts that they personally or humans generally have on the environment (participants could give more than one answer, so percentages add up to >100%). No individual reported learning about scientific processes or methods.

On written surveys, participants reported increased interest in conservation or stewardship topics related to the community science experience rather than increased interest in science or the scientific process (Table 2). These changes in interest were reported by individuals across all zip codes, race/ethnicities, genders, and ages.

Drivers of Science Understanding and Interests

Despite explicit and consistent marketing of the initiative as a community science opportunity, over a quarter of the 19 interviewees who were asked whether they felt like they were doing science said they were unsure (11%) or did not think so (16%). Of those who said they felt like they were or might be doing science and who gave a reason, 42% said it was because they were collecting data, one-third said it was because they learned, heard, or were told facts or information, and a quarter said they were or may have been doing science because they were collaborating, measuring, or using science tools (Figure 4).

Of the four individuals who said they were not or might not be doing science and gave a reason, two (50%) said they were picking up trash and/or doing community service, not science; one said that "bringing in the information" [collecting data] was helping science but not necessarily science itself; and one said, "*Because it's different than science. Usually in science I learn different things, like I usually do physical science like with chemicals*" (i.e., the day's activities did not match what the participant usually did in science in school).

Data from the field recordings revealed inconsistency in participants' access to science mentoring during any one session. The project scientist consistently engaged with participants as an equal in the task of collecting trash while simultaneously discussing the logistics of the scientific activity, modeling comfort with the natural environment, and sharing context-related scientific concepts in response to others' experiences or questions. However, the participants in the "scientist groups" had varying exposure to the scientist depending upon physical proximity and levels of sociability, and thus, science mentorship was not consistent across all participants. Further, others outside the scientist group were sometimes exposed to the scientist's knowledge before the day began, during breaks, or while moving around the canyon. Field recordings also revealed that, while the high school-aged project leaders clearly explained the logistical tasks associated with the project to the participants, they tended not to put

Table 2. Changes in individual interest in science and stewardship topics before and after participating in the community science project. Data are number of responses (and percent of all participants who answered that question) from 2015, n=84 surveys/participants. * = P≤0.05, paired t-test. Participants completed the sentence "I am interested in learning more about (please check all that apply):"

Topic	Pre	Post	Change
How the local watershed affects my community	26 (31%)	37 (44%)	+11*
How my community affects the local canyons	30 (36%)	39 (46%)	+9*
How I can help take care of our local canyons	24 (29%)	33 (39%)	+9*
How I can help take better care of the Earth	41 (49%)	49 (58%)	+8
How a watershed works	20 (24%)	28 (33%)	+8
Plants and animals	58 (69%)	64 (76%)	+6
What scientists do in their jobs	23 (27%)	29 (35%)	+6
How science works	29 (35%)	34 (40%)	+5
Science facts	42 (50%)	44 (52%)	+2
Nature	60 (71%)	60 (71%)	---
How I can get involved in community science projects	28 (33%)	28 (33%)	---
How to become a scientist	25 (30%)	20 (24%)	-5
What a watershed is	20 (24%)	14 (17%)	-6

the tasks in the context of the study or science more generally. The project leaders also tended to focus on the project task of collecting and sorting trash and work silently, only occasionally sharing a science fact with participants. This excerpt from a field recording between one of the high school-aged project leaders and a Discoverers Program participant illustrates a general lack of both scientific context and interactive approach in communications that took place during field logistical tasks and, therefore, a lack of an engaged response from the participant.

> Project leader: *Would someone like to help me take the picture? [long pause] Come on over here. [long pause] ... Okay, could you hold this and stand right here. [pause] Hold on. Yeah, that's good. All right, so now we head back. Thank you.*
>
> Participant: *Mm-hmm.*

Recordings further revealed that participants, in general, tended to stay with the groups with which they came, rather than integrating into one single "fieldwork" group. Many individuals, both youth and adults, spoke almost exclusively to members of their own group throughout the day, even when the scientist or educator staff member tried to engage members of the group. The talk among members of these groups was usually non-science related. All of these factors served to limit the numbers of participants who had consistent access to science mentoring during any one session.

Urban Watershed Trash Pollution Dynamics

While the Discoverers Program more strongly fostered environmental stewardship than science understanding and interest in participants, the scientific data collected by participants from 2014-2018 constituted an in-depth look at the inputs and the spatial and temporal distributions of trash pollution in these urban waterways.

Spatial and Annual Dynamics of Plastics Trash in Urban Waterways. Combining the plastic meso-trash data from community science sessions

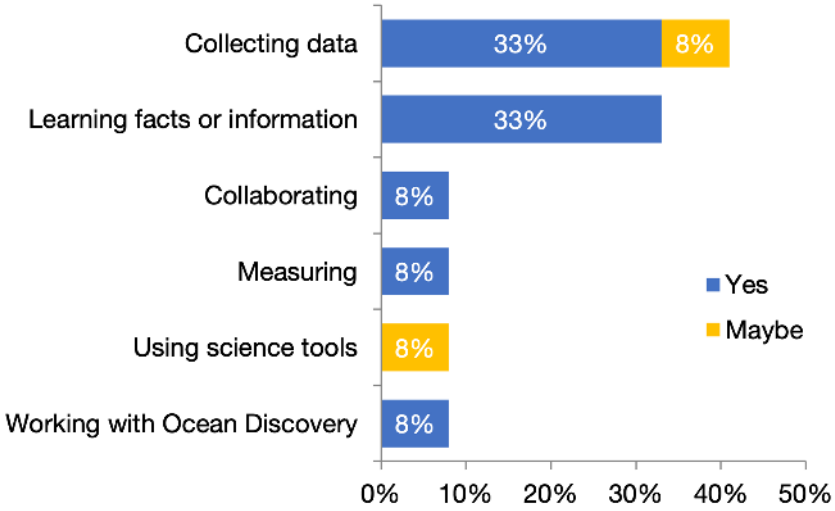

Figure 4. Reasons given by participants who answered "yes" or "maybe" to the question "Did you feel like you were doing science today?" for why they felt that way. Data are from 2015, n=12 interviewees; each person could give more than one reason, so the total is greater than 100%. Ocean Discovery = the community-based science education organization that partnered on this project.

between 2014-2018 revealed that plastic bags, packaging, and wrappers consistently dominated plastics trash across all four neighborhood canyons (Figure 2) and through time, with additional consistent proportions of plastics from food and kitchen items (e.g., single-use cups, plates), and home and office items (e.g., pieces of duct tape, small toys, pens/markers) (Figure 5). Small pieces and fragments also consistently made up 10-25% of all plastic items found across the four canyons (Figure 5).

Rainy Season Plastic Trash Inputs. Ambient plastic meso-trash collected at the start of the study, before rainy season began, represented amounts influenced by dry season inputs (e.g., wind, flows from irrigation runoff), directly deposited litter, and items left behind after previous community trash cleanups. The greatest volumes (and densities) of plastic meso-trash collected pre-rainy season were found at the head region of each of the four canyons. Amounts of trash per 200 m^2 ranged from 95±56 pieces (or 2.4±0.5 L) in Hollywood Canyon to 267±97 pieces (or 31±23 L) in Olivia Canyon (Figure 2).

Roughly 9-10 times greater densities and volumes of plastics flowed into all canyons during the rainy season than were found at ambient levels before the rainy season (Average±1SE across four canyons: 1607±713 vs. 187±36 pieces per 200 m^2 and 106±49 vs. 10±2 L per 200 m^2; paired t-tests $p \leq 0.001$, $t_{14} \geq 6.11$; Figure 6). Total amounts (volume and density) of every category of plastics trash were greater at the end of the rainy season than they were at ambient levels (paired t-tests, $p \leq 0.005$, $t_{14} \geq 3.35$; Figure 6) except for amounts of unidentifiable plastic pieces, which remained similar across time (paired t-test for density and volume both: $p=0.075$, $t_{14}=1.5$).

Composition of plastics in the ambient surveys and at the end of the rainy season remained broadly dominated by bags and packaging across all four canyons (Figure 6), but the individual items differed (ANOSIM Global P=0.001). Trash that flowed in with the rainy season, as compared to ambient trash, contained higher abundances of many items from across the trash categories, including bags and packaging (e.g., single-use grocery bags, trash bags), food and kitchen items (e.g., polystyrene foam pieces and take-out containers, single-use cups and plates, drinking straws and lids, utensils, bottles, caps), household items (e.g., pieces of electrical and duct tape, small plastic toys, ribbons, CDs/DVDs, pens/pencils/markers), personal care items (e.g., cotton swabs, bandages), electronic parts (e.g., cords, phones), synthetic cloth, cigarette butts, and soft and hard plastic pieces. The ambient trash contained higher abundances of take-out and retail bags (whole and pieces),

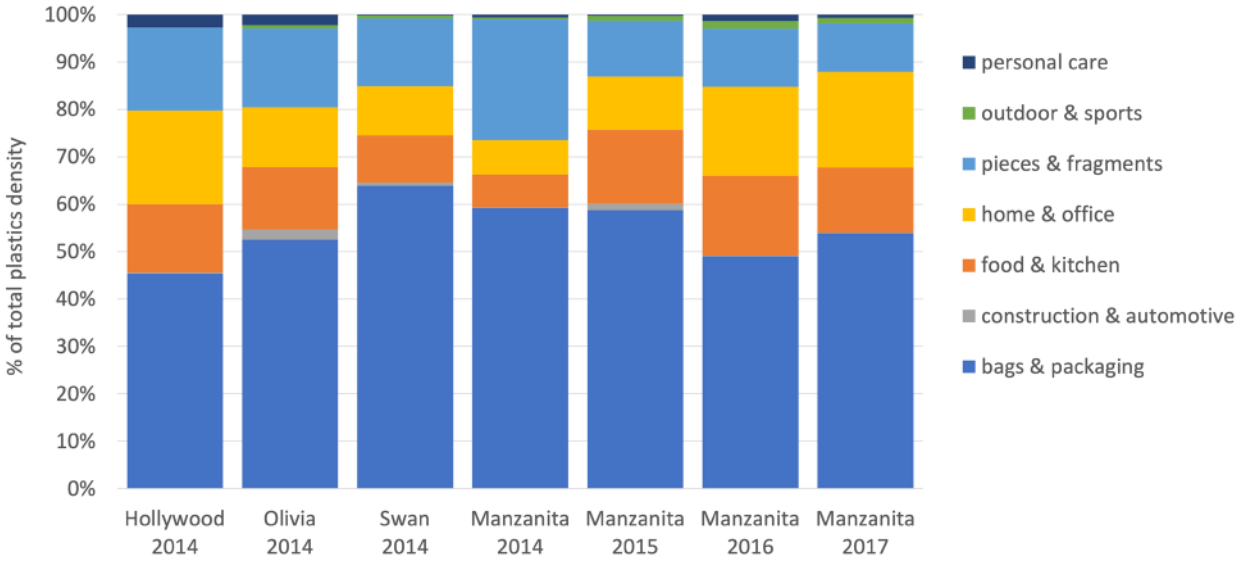

Figure 5. Composition of plastics found in each of the four City Heights canyons in 2014 and through time in Manzanita Canyon, San Diego, California. Data are calculated from total density (# per 200 m^2) of meso-plastics found in each canyon for each year shown.

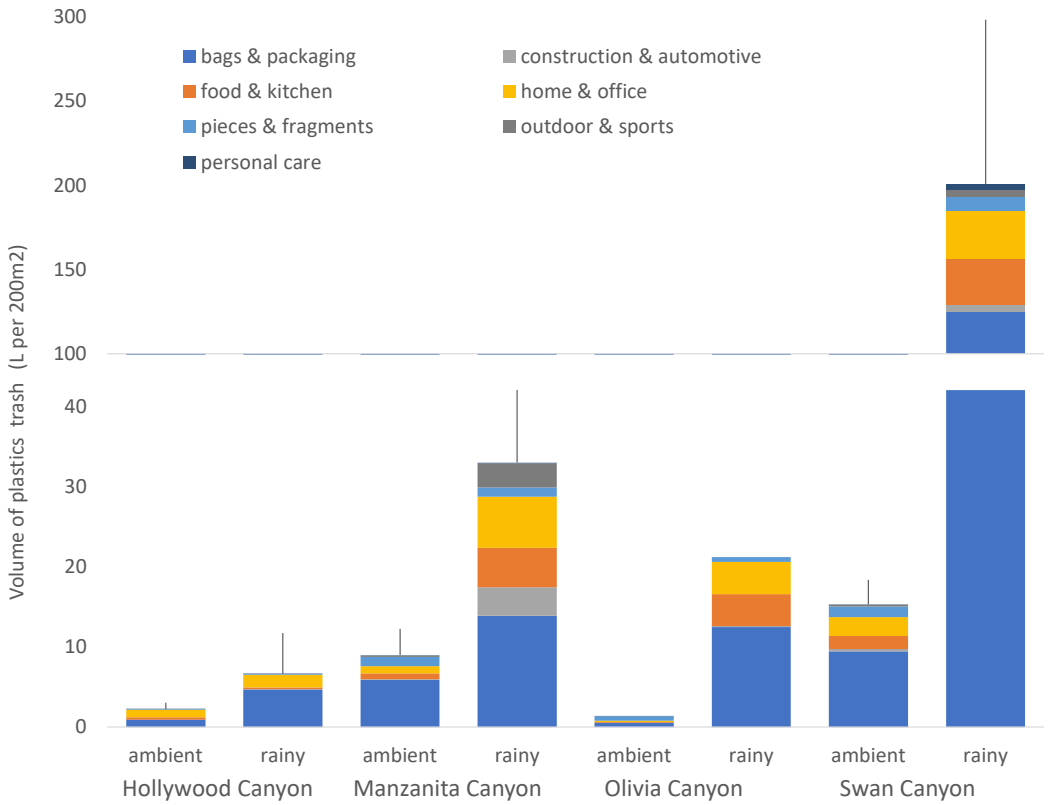

Figure 6. Average volume of plastics trash collected before the start of the 2014-2015 rainy season (ambient) and at the end of rainy season from the four City Heights canyons, San Diego, California, USA. Patterns were similar for trash density so only volume is shown. N=2 transects (200m^2) in Hollywood, 5 in Manzanita, and 1 in Olivia that were sampled before and at the end of rainy season, as well as 7 transects in Swan Canyon that were sampled before and throughout rainy season (average cumulative rainy season totals shown). Error bars are 1 standard error.

six-pack rings, and straw and utensil wrappers (SIMPER, items contributing to 65% of variation between seasons) indicating greater dry season inputs of these items, or lack of removal during cleanup efforts. Abundances of snack wrappers remained similarly high in the ambient and end of rainy season surveys, indicating consistent inputs throughout the year and/or lack of removal during cleanup efforts.

The Magnitude of Inputs of All Trash. Between April 2016 and May 2018, the community recorded and removed a total of 138 m^3 of trash from Manzanita Canyon. This trash weighed a total of 13 mt and included meso-trash items, furniture, engines, tires, camping gear, and whole bags of trash. The community data revealed that the head of Manzanita Canyon and major access trails that run through small side canyons were areas of most frequent and/or highest trash inputs. Data received from the community on the locations, amounts, and types of trash collected from around Manzanita Canyon throughout this time indicated three main inputs of trash to the canyon—encampments of unhoused individuals (e.g., abandoned camping and cooking gear in obscured areas off the canyon floor and in side canyons), illegal dumping (e.g., broken furniture at the canyon ridge and in side canyons where roads and alleys abut the canyon), and storm drain flows (e.g., assortments of meso-trash along the canyon floor downstream of storm pipes).

Despite the variety of items found in Manzanita Canyon, plastics generally dominated the meso-trash and large items that were removed (Figure 7). Fragments of illegally dumped wood and wood-composite furniture and construction materials, as well as metal construction and automotive materials, were also common, especially in the upper reach of Manzanita Canyon (Figure 7). Cloth (e.g., clothing, blankets) was common in spring 2016 in association with recently abandoned camps (Figure 7).

Discussion

Participation in Community Science Does Not Mean Science Understanding or Persistence

The seven practices that made up the initial community science program model (Figure 1) were successful at bolstering environmental stewardship and were somewhat successful at increasing participation and short-term retention of members of the targeted community in the science project, but did not lead to increased learning of science concepts or interest in science.

Effectiveness of Practices for Facilitating Science Entry and Intervention. Well over half of the participants (64-71%) in the Discoverers Program were from the local community, and the races and ethnicities of participants involved in the 2015 sessions were similar to those in the local community as a whole, indicating that the

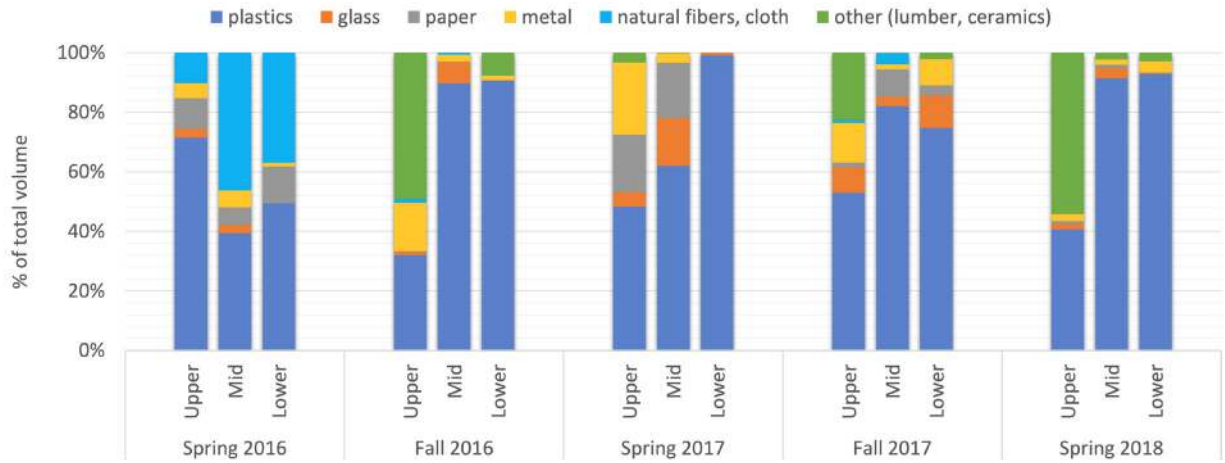

Figure 7. Composition of all meso-trash (by volume) collected biannually along three transects located at the head (upper), mid-reach (mid), and downstream end (lower) of Manzanita Canyon in San Diego, California between April 2016-May 2018. N=1 200 m^2 transect per season and location.

neighborhood-based project likely had equitable accessibility (e.g., the advertising was widespread, the meeting location was walkable; Practice 2). Repeated and ongoing guided opportunities (i.e., staff-guided sessions) helped to engage people (Practices 5 and 7), with nearly one-fifth of people participating two or more times and a few people in 2016-2018 continuing to work on their own between 12-53 times.

The integration of a trash cleanup activity (i.e., a hands-on stewardship activity) with scientific data collection (Practices 1 and 3) may have made the project more meaningful to community members and may have increased community participation and retention as a result. Many project participants surveyed in 2015 reported that they had attended sessions to help the community and/or the environment. Participants' explicit acknowledgment of and interest in affecting positive change in their community and environment indicate that connections to 'bigger picture' science may be more meaningful to potential community scientists (National Research Council 2015) and may be a way to increase participation and investment in STEM activities. Trash pollution may serve as especially poignant subject matter for community science, as it is ubiquitous, generally well understood by the public, and mitigated via relatively accessible actions like cleanups and waste reduction (Sheavly and Register 2007).

Contrary to what was expected based on community science literature (Bell et al. 2003; Sadler et al. 2010), working alongside a scientist (Practice 4) did not influence retention in our project. While the project scientist consistently engaged with participants throughout community science activities, only those nearby or willing to engage were reached and, even then, the sharing of knowledge typically ran unidirectionally from scientist to participant, rather than between the two parties. Further, the high school-aged project leaders from the community (Practice 6) tended to interact with participants infrequently; when leaders did interact with participants, they spent time explaining project logistics, rather than the scientific context and objectives of the project. Because of these dynamics, even participants who worked alongside each other may have had very different science experiences, from no science talk to short amounts of science talk to frequent and rich science-related conversations. This may have limited both the exposure to science concepts and the opportunity to integrate and feel culturally like a part of a science team.

The lack of effect of scientist presence on participant retention may also be partially explained by the fact that the project scientist was not reflective of any underrepresented minority group (Practice 6), which may have limited the meaningfulness and value of the experience of interacting with a scientist for participants (e.g., Bang and Medin 2010; Pandya 2012). The 2015 project leaders reflected the diversity of the community (Practice 6) and may have influenced repeated visits, though this was not directly tested. Integrating project scientists and other STEM professionals who also reflect the diversity of the community into projects as mentors has been shown to improve participation and retention (Pandya 2012). Mentoring by individuals who have received mentorship training, are at varying science career levels, and/or are from within the community have been associated with higher performance, higher grades, and persistence in college and STEM fields, particularly for members of high-need groups (Myers et al. 2010; Stolle-McAllister et al. 2011; Wilson et al. 2012; National Research Council 2015; Pfund et al. 2015).

Strengthening the Science in Community Science. Despite the project's relative success in the engagement and short-term retention of individuals from diverse backgrounds in project activities, it was not as effective at increasing participants' awareness of doing science or science understanding. Participants' understanding of how water (and trash) flows through a watershed did not improve after they had participated in the 2015 sessions, and only about half of those same participants were able to correctly identify an aspect of the project's purpose when they were surveyed following the day's activities. Furthermore, none of the participants who were interviewed in 2015 mentioned science as a motivation for participating in the trash study, and no interviewees reported learning about scientific processes or methods during the project. Some participants did not

conceive of the day's activities as participation in a scientific study, despite recruitment materials clearly stating that fact. The largest increases in reported interests after participation in the project related to the focus of the community science experience, but through a conservation or stewardship lens rather than a science lens.

This disconnect between the Discoverers Program and science itself may be related to the participants' ideas about what activities constitute science, and participants' interactions (or lack thereof) with the science team throughout the project. Many of the participants who were interviewed in 2015 defined science as learning, hearing, or being told facts or information, and only a quarter of participants defined science using an aspect of the hands-on, authentic community science activity they had participated in (measuring, collecting data, and/or collaborating with others). Science other than "classroom" science—narrowly defined as learning facts, being told information, or doing experiments—is not a common or core experience in the local schools or community of City Heights, as has long been the case in urban centers (Day and George 1970; Lippman et al. 1996; Barton 2001). Exposure to different types of science, other STEM fields, and the careers and opportunities that are associated with those fields may increase enthusiasm, self-efficacy, and persistence of underrepresented individuals in science (Blotnicky et al. 2018).

The Need for a Science Mindset

Project outcomes revealed that our initial community science program model was lacking elements that made participants want to do science, aware that they were doing science, and/or aware that they were able to do science. Based on these findings, we modified our initial community science program model by creating and adding a new "science mindset" component to the model. The "science mindset" adopts the tenets of the "academic mindset" concept from the fields of psychology and education that emphasizes valuing, recognizing, belonging, and self-efficacy, and has been shown to support and retain underrepresented youth in academia (Farrington et al. 2012). This new science mindset component consists of five elements aimed at strengthening the understanding, participation, and persistence of people from underrepresented groups in science: 1) **recognizing** scientific activity as science, 2) **valuing** scientific activity, 3) feeling a sense of **belonging** within the science community, 4) believing in one's capacity to do science (**self-efficacy**), and 5) **growth mentality** (Figure 8).

Even brief, one-time interventions that emphasize social belonging and both the valuing and recognition of science can have persistent, long-lasting effects on individuals' engagement and perseverance in education (Aronson et al. 2002; Cohen et al. 2006; Hulleman and Harackiewicz 2009; Walton and Cohen 2011; Yeager and Walton 2011). Such interventions or experiences that cultivate a science mindset may similarly lead to increased participation in scientific activities, increased understanding of science, and increased persistence in science which, in turn, may further bolster all five elements of the science mindset through a positive, reinforcing cycle (e.g., Cohen et al. 2006; Oyserman et al. 2006; Yeager and Walton 2011). This project's updated community science program model (Figure 8) incorporates four additional practices shown to contribute to academic mindset growth (explained below). The updated model is meant to serve as a framework for increasing participation and retention of individuals, especially youth, from diverse communities with low levels of science exposure and engagement, in informal STEM activities.

The four specific practices added to the model to bolster science mindsets (Figure 8, Practices 8-11) include designing community science projects that are not only locally based but that have larger-scale or bigger-picture connections ("globally-connected"; Practice 8) to motivate and strengthen participants' sense of belonging and valuing of the activity (Figure 8; National Research Council 2015; Briggs 2016). Being able to use science to make a difference, such as contributing to a discovery or a solution to a problem as occurred in this project, may strengthen people's understanding, self-efficacy, growth mentality, and value of science (e.g., National Research Council 2015; Briggs 2016). For example, throughout 2016-2018, high-frequency participants exhibited growing enthusiasm for and depth of understanding of the science they were contributing to, as evidenced

by vast increases in the quantity and quality of data they provided to the project scientists. Although these improvements in data quality and quantity may have been due in part to longer-term communication and relationship building with the project scientists, they were often accompanied by enthusiastic communications about the project results, which pointed to the community's pride and investment in the project. Participants frequently released results about trash abundances and inputs via neighborhood newsletters and Nextdoor.com and gave a presentation to City Council. These actions led to acknowledgments and further action by neighbors, and responses by City officials, including assistance with canyon trash removal and contributing to the creation of the San Diego Homeless Outreach Team.

Adding structured reflections about both personal and scientific experiences in community science activities (Practice 11) may improve participants' recognition that they are doing science while building a growth mentality and sense of self-efficacy through self-reinforcing cycles of belief and behavior (Figure 8; Lew and Schmidt 2011; Yeager and Walton 2011; Wilson et al. 2012; Briggs 2016). More structured interactions over the short- and long-term, among participants and science role models (Practice 10) who are reflective of the diversity of the community, may help to strengthen a sense of belonging, recognition that one is doing science, and self-efficacy (Figure 8). In any one community science session, this may be as simple as integrating all individuals into a single group that works closely with scientists and/or science role models (Practices 9 and 10) to accomplish tasks that require the sharing of expertise among all participants.

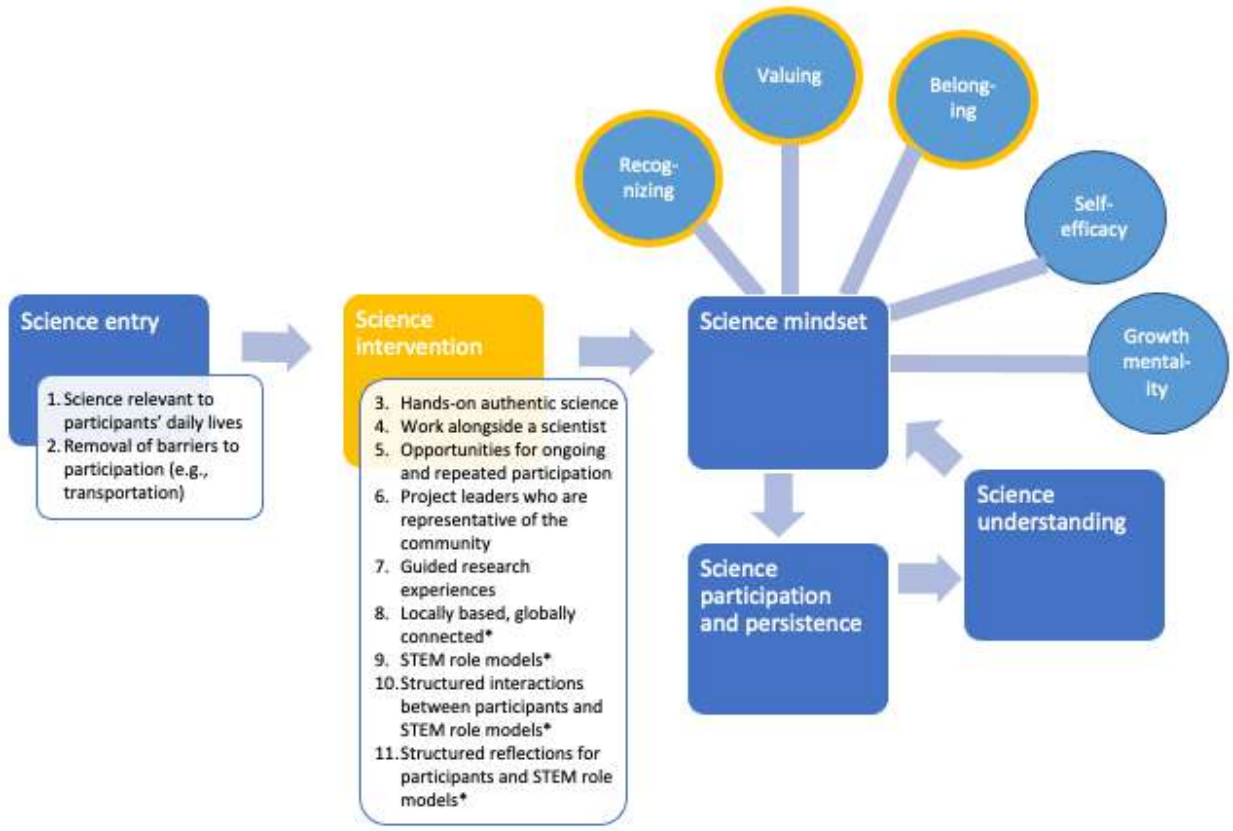

Figure 8. The new community science program model, which maintains all elements of the initial community science program model and adds practices aimed at building a science mindset. *= Practices added to the original conceptual model based on the lessons learned from this study to create this new model. The first three elements of the new science mindset component, which could potentially be achieved in as little as one community science session or intervention, are outlined in yellow.

Limitations of the Community Science Program Model Assessment

While the rate of participation in the model assessment study was very high (95%), not all data were collected from all participants—not all participants completed both the pre- and post-activity written assessments, answered all questions on surveys and assessments, or were selected for interviews. While the data collected across instruments and individuals tell a coherent story, it is possible that the experiences of individuals who were less engaged in the project activity or who were less comfortable speaking or writing in English or Spanish were underrepresented in the data and findings. Further, this study took place in a single community. While the community was selected because of its high levels of cultural, ethnic, and racial diversity, the implementation of the model and its effects may be different in other communities.

Conclusions: From Community Discovery to Environmental Solutions

A diverse STEM workforce holds our best hope of developing innovative, sustainable, scientific, social, and technological solutions to trash pollution and other environmental challenges (Østergaard et al. 2011; Hofstra et al. 2020). Achieving diverse participation in science relies on the widespread use of practices that provide entry points (access) to science and impactful interventions that set into motion the positive feedback loop of scientific learning, engagement, and belonging (i.e., science mindsets) (This study; Yeager and Walton 2011). Community science projects provide both science entry points and meaningful interventions to engage people of all ages in science while addressing environmental challenges. Through the Discoverers Program (the community science project), we were able to gain a better understanding of the trash pollution problem in San Diego's urban canyons that not only serve as green space for the community, but also as the city's stormwater system, channeling street runoff and other trash inputs from mid-city to San Diego Bay. Community members had long been engaged in stewardship activities in City Heights and, before this study, their frequent stewardship and cleanup efforts had kept the canyons clean to some degree, but had not contributed the quantitative information surrounding the magnitude and sources of the problem that often forms the foundation of solutions (e.g., CAW 2017; Reddy and Lau 2020). Through cooperation and collaboration, the community revealed that 138 m^3 of trash weighing 13 mt entered the 1-km long Manzanita Canyon over two years. This volume is equivalent to nearly 50 trash cans (32 gal or 121 L) of trash being removed from the canyon every month for two years. Further, the community data revealed the three main inputs of trash to the canyon—encampments of unhoused individuals, including trash generated from active camps and gear from abandoned camps, illegal dumping of large items and whole bags of trash, and storm drain flows, with the highest abundances of all sorts of items from around the house pulsing into waterways with rains. The community also revealed that plastics, especially small plastic fragments (which are often overlooked during cleanups), and single-use wrappers, bags, and packaging, dominated the trash pollution across locations and through time, a trend mirrored in many ecosystems throughout the region and around the world (Miller-Cassman et al. 2016; SCCWRP 2016; Lebreton et al. 2018; CCC 2019; Ocean Conservancy 2020; Parker 2020; Reddy and Lau 2020; Tiseo 2020).

Despite ongoing trash management efforts (e.g., street sweeping; CSD 2021), the community's data on trash inputs revealed that the amounts of trash entering these canyons still far exceeded the State's goal of eliminating trash flows into state surface waters (CSWRCB 2015). Further, the data provided insights into solutions to trash pollution, including the need to address the sources of trash flows into stormwater (e.g., reduce leakage from waste receptacles, educate the public on use reduction, and better control of wrappers), and reduce illegal dumping (e.g., through improved enforcement, more frequent and better-advertised free furniture and mattress pick-ups, education on the hazards of dumping/benefits of recycling). The prevalence of large trash items revealed by community data, coupled with an emerging awareness of the threats of small plastics that result from the break-down

of large items (nanoplastics, microplastics; Moore 2008; Barnes et al. 2009; Rochman et al. 2015) highlight the ultimate solution—keeping trash out of waterways in the first place. By pairing science projects with a social science-based strategy for facilitating diverse participation, such as the model developed in this project, we can empower diverse community members to contribute to, affect, use, and become a part of science, and drive solutions.

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Rochelle Mothokakobo has 20 years of experience as a science educator, using her background in science research as a starting point to excite students to be curious about how the world works. Her work has centered on creating science experiences for diverse learners that allow them to see themselves as a scientist in their future. Currently, as a Kinder through 5th grade science teacher, she builds science belonging, interest, and knowledge to students of diverse backgrounds. She has a B.S. from Hawaii Pacific University and a M.S. from San Diego State University. She may be contacted at Phillips Brooks School, 2245 Avy Ave, Menlo Park, CA 94025.

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Direct Mailing Education Campaign Impacts on the Adoption of Grazing Management Practices

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Abstract: The Texas Commission on Environmental Quality facilitates the Clean Rivers Program where many of Texas' waters are monitored for various parameters. A common approach to address water quality impairments is to develop and implement Watershed Protection Plans, where a key management measure is to increase the adoption of best management practices through existing government programs that provide technical and financial assistance. A key role for watershed managers during implementation is to raise awareness that technical and financial resources are available to assist producers with adoption. Outreach approaches thus far have included in-person education programs, attendance at local Soil and Water Conservation District (SWCD) meetings, newsletters, and other efforts that have only had minimal reach. As a result, we initiated a mass mailing campaign where 4,921 landowners within Lavaca County, Texas were reached four times in approximately six months with the same message. Partnering with the local SWCD and United States Department of Agriculture Natural Resources Conservation Service offices, the number of individual best management practices were acquired for the current and previous five federal fiscal years to measure changes. Results suggest directly mailing educational materials to landowners is an effective outreach approach to increase the adoption of best management practices. Model results indicate a significant 300% increase in adoption of practices compared to historic levels.

Keywords: *nonpoint source pollution, adoption, best management practices, education, direct mailing*

Nonpoint source pollution is the leading cause of water quality impairments in the United States, and Texas waters are monitored for and impacted by point and nonpoint source pollution (U.S. EPA 2017). In Texas, the Texas State Soil and Water Conservation Board (TSSWCB) and Texas Commission on Environmental Quality (TCEQ) are responsible for maintaining and improving water quality through many programs including the Clean Rivers Program, the Total Maximum Daily Load (TMDL) program, and the Texas Nonpoint Source Management Program (TCEQ 2020). The Texas Integrated Report, delivered in compliance with the federal Clean Water Act Sections 305(b) and 303(d), evaluates the state's natural surface waters' quality based on historical records and criteria aligning with the Texas surface water quality standards (TCEQ 2019b). Water bodies not meeting the established water quality standards are considered impaired for their designated uses and included on the 303(d) list as not meeting standards. This report is created every two years yet can take three years to be approved. The 2016 report approved by the U.S. Environmental Protection Agency (EPA) in August 2019 found the Lavaca River Above Tidal contained a geometric mean of 260.84 *Escherichia coli* cfu/100mL and that Rocky Creek had 311.13 cfu/100mL (TCEQ 2019a). Under the current assessment approach, water bodies are considered impaired if the geometric mean and 80% confidence interval of all water body samples over seven years exceed 126 cfu/100mL *E. coli* bacteria (TCEQ 2019a). These numbers show a significant need for action and change to decrease the *E. coli* concentrations.

To address water quality impairments identified in the Texas Integrated Report, TMDLs and Watershed Protection Plans (WPPs) are created and implemented. A major component of these

Research Implications

- Direct mailing educational materials is an effective method to reach landowners unable to attend in-person education programs.
- Direct mailing campaign increases adoption of best management practices.
- Water quality improvement is an anticipated effect of increasing adoption of best management practices through direct mailing outreach.

response strategies is encouraging the adoption of agricultural best management practices (BMPs). The United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS) and TSSWCB provide technical and financial assistance to landowners and agricultural producers for the adoption of practices that both improve operations and have water quality benefits. While TMDLs have regulatory aspects, WPPs are entirely voluntary and have been developed in watersheds following the EPA nine element guide (U.S. EPA 2008). To develop these plans, stakeholders meet to identify causes and sources of nonpoint source pollution, loading reductions needed to meet water quality standards, management measures that should be taken to reduce the pollutant, sources of technical and financial assistance, interim measurable milestones, and other elements outlined in the above-mentioned EPA guidance. These comprehensive plans are also adaptive to accommodate changes that occur in the watershed (such as population growth and land use changes) as well as the approaches taken to implement the plan.

The Lavaca River Watershed is located in southeast Texas and consists mainly of two counties, Lavaca and Jackson (Schramm et al. 2018). Most land in Lavaca County is used for livestock production and, according to the USDA, Lavaca County is one of the most concentrated beef cattle producing counties in Texas (National Agriculture Statistics by State 2019). An inventory report from 2018 indicated 105,000 head of cattle in Lavaca County, including calves (National Agriculture Statistics by State 2019). Landowners using improper stocking rates can damage the land quality and diminish forage availability by overgrazing, which leaves little soil protection or vegetation to filter runoff from rainfall events. Therefore, livestock production was identified by stakeholders as a potential contributor to the bacteria impairments within the Lavaca River Watershed, and BMPs which can help support proper stocking rates and have a positive impact on water quality were included in the Lavaca River WPP. BMPs included were cross fencing, alternative water sources, alternative feed/salt/mineral locations, alternative shade structures, and calculating stocking rates using grazeable acres. Cross fencing can be used to keep cattle from entering riparian areas while also supporting rotational grazing (Beef Cattle Research Council 2020). Rotational grazing allows landowners to move cattle to different pastures on the property and gives the forage a recovery period. This also ensures the cattle are grazing the properties evenly. Alternative water sources, alternative shade structures, and alternative feed/salt/mineral locations also encourage cattle to keep away from riparian areas and graze the forage evenly (Clary et al. 2016).

Calculating stocking rates using grazeable acres requires the landowner to consider how many acres are grazeable by subtracting the acreage that includes rocky areas, ponds, and other areas cattle cannot graze (Beef Cattle Research Council 2020). Excluding these areas gives an accurate measure for stocking rate and ensures landowners are not overstocking. Additionally, this calls attention to stocking rates for landowners who might have previously overlooked that aspect of their operation.

Watershed managers have provided outreach through in-person workshops, meetings, newsletters, and other communication channels; however, these approaches are limited in the number of landowners that can be reached. According to watershed managers and sign-in sheet records, outreach efforts within the watershed, including in-person education programs (30 people per event on average), Soil and Water Conservation District Meetings (6 people on average), and newsletters (84 subscribers), have had minimal impact at reaching intended audiences (E. Monroe, personal communication, August 24, 2021). Often, the workshops are during the day and a limited number

of the target audience is able to attend. Additionally, it is not uncommon for the same people to attend various events, creating a need for Extension personnel to explore strategies to diversify their audience. There is a continuous need to utilize better communication approaches that can reach more stakeholders. A study conducted in a rural Central Texas watershed by Dewald et al. (2018) showed that landowners, especially those whose age range falls in the 50's and up, preferred to be contacted quarterly through direct mailings from a trusted source (such as Texas A&M AgriLife Extension Service) about conservation practices to improve water quality.

Political campaigns use a variety of communication channels to reach the public. While television commercials and social media are a popular and productive means of advertising, direct mailing is still largely used (Van Diepen et al. 2009). In 2019, 142.57 billion items were directly mailed to U.S. households (Mazareanu 2021). Promotional mailings are used as a "call to action" piece to relay information and appear to have a positive short-term response versus a long-term response. Gázaquez-Abad et al. (2011) conducted a study relating to the role of direct mailing in apparel retail and found the marketing strategy to have an influence on their sample. The direct mailings influenced purchase decisions, with dependence on the timing and nature of the mailing (Gázaquez-Abad et al. 2011).

Additionally, Benoit and Stein (2006) list several other advantages of direct mailing over other forms of media, including amount of information relayed and ability to target a particular audience. Brochures, for example, allow for more information to be dispersed than spot advertising (Trent and Friedenberg 2004). Benoit and Stein (2006) compared a sample of Benoit's (1999) study on television ads to the direct mail from the current study and found the television ads contained 5.2-5.5 themes while the direct mail allowed for 25.8-33.9 themes. This suggests direct mail postcards can provide an adequate and successful platform for disseminating information. Trent and Friedenberg (2004) also noted the advantage in direct mailing relating to targeting audiences. In Benoit and Stein's (2006) study, reports indicated 53% of the general campaign direct mailings and 8% of the primary campaign direct mailings targeted a particular audience.

Direct mail can have a larger impact on consumers than other mediums. One study conducted by Gerber et al. (2011) analyzed the effect of direct mail on election turnout and voter share. While turnout did not increase because of direct mailing, voter share for one party increased by 1.5 to 3.5 percentage points. The direct mailing changed already decided votes to the opposing party on the ballot. Other similar political studies which used direct mailing flyers, conducted by Green and Gerber (2008) as well as Gerber et al. (2008), also found an increase in percentage points for the targeted party as a result of the intervention.

Virtual communication is a common outreach method for marketing, education, and many other industries. Advancing technology in the last twenty years has led to email replacing various tasks like sending memos via fax (Turville 2019) or mail. Many people both professionally and otherwise now use email to send meeting invitations, share calendar events, receive digital purchases such as tickets, and more (Turville 2019). However, with email used for both personal and work purposes, there is the potential for email overload.

Thousands of emails are sent weekly and can be simply deleted or remain unopened. Turville (2019) pointed out that some people are diligent in managing emails while others are not. Langer (2015) tweeted "[t]here are 2 kinds of people in this world" with a photo of two apple email icons – one with no email notifications and the other indicating there were 13,678 emails unread. This tweet went viral and received thousands of retweets from people who could relate (Langer 2015).

Aside from emails, social media and other apps have also become a major source of information, as well as communication. One example includes the Texas A&M AgriLife Extension Nutrition Department's Instagram page which provides nutritional information to anyone who follows the account. Several accounts and pages such as this one are free to the public to view, which can contribute to information overload. Benselin and Ragsdell (2016) conducted a study relating to information overload as it relates to age. Similar to many past literature articles, Benselin and

Ragsdell (2016) had asked participants to identify information overload and results concluded that no single definition or single source could be provided. However, technology was a common theme in responses from older aged groups when asked for a source of information overload (Benselin and Ragsdell 2016). Even so, all age groups reported to have likely experienced information overload (Benselin and Ragsdell 2016).

Given the crowded digital space and the positive outcome that political campaigns have had through direct mailing, there is potential to use this as an educational approach to influence behavioral change. By directly mailing educational flyers to landowners to raise awareness on the impacts of stocking rates and available sources of technical and financial assistance, an increase in the adoption of BMPs may be realized. Additionally, this outreach approach may also be a more cost-effective method to connect with landowners than previous efforts.

Purpose and Objectives

This study sought to evaluate the efficacy of direct mailing educational flyers as a method that increases the adoption of BMPs through USDA NRCS and SWCDs. To evaluate the approach, the following were key study objectives during the course of the project:

1. Collect pre-intervention survey data, including knowledge of stocking rates, awareness of USDA NRCS and local SWCDs and intention to adopt, and assessment of potential differences in both the treatment and control Texas counties of Lavaca and Goliad, respectively.
2. Conduct an intervention by developing a single educational flyer regarding stocking rates, and distribute via mail four times in one year to all Lavaca County landowners who own 10 or more acres.
3. Evaluate changes in the adoption of BMPs through Conservation Plans/WQMPs over the previous five years within each respective county (before and after intervention), as well as adoption change trends between treatment and control counties.

Methods

Lavaca and Goliad Counties are Texas counties similar in percent of land use types and percent of total farms by farm size (see Table 1), and agricultural production is dominated by beef cattle production, specifically cow-calf, in both counties. Because of these similarities, researchers hypothesized that populations would also be similar regarding methods of determining beef cattle stocking rates, awareness of sources for technical and financial assistance, and intentions to adopt grazing BMPs.

A survey instrument was administrated prior to the educational intervention to help explain potential differences in adoption between the two counties. The instrument consisted of 19 questions, and each survey was labeled with an identification number to ensure easy tracking of responses and removal of respondents from the mailing list to reduce survey fatigue. The survey questions were divided into sections. The first section consisted of questions about landowners' knowledge of stocking rates and contained four constructs: strategies to determine stocking rates, indicators of overstocking, results of overstocking, and advantages of properly stocking. The second section assessed intention to adopt, and the third, awareness of USDA NRCS and TSSWCB. The final two sections recorded farm and personal characteristics.

Landowner contact lists were acquired through the local county appraisal districts and were further developed by eliminating parcels under 10 acres and duplicate listings. The final Lavaca County contact list included 4,921 landowners, while Goliad's final list had 1,959 landowners. For the survey mailing, a simple random sample was drawn from both populations. As a result, 1,200 surveys were mailed to Lavaca County and 500 to Goliad County through a modified Dillman et al. (2014) Tailored Design Method.

The survey mailing schedule consisted of four stages. First, a pre-notice postcard was mailed in early June 2020, followed by a survey package one week later, a thank you and reminder postcard one week after that, and a final survey package two weeks later. Data collection ended in the final week of July 2020, having been extended due to COVID-19 delays in return mail. The final

combined response rate was 37%, with a total of 271 usable responses and 64 undeliverable.

To analyze data collected through surveying landowners, a quantitative research design was used. Nonresponse error was tested by comparing early and late responders and no significant differences were found, meaning that it can be assumed that respondents were representative of the population (Lindner et al. 2001). All scale constructs were found reliable ($\alpha \geq 0.70$) and data were analyzed using t-tests.

The educational intervention was the mailing out of an identical information flyer containing overstocking indicators, implications of overstocking, advantages of properly stocking, practices to assist in proper stocking, a call to action, and local contact information for technical and financial assistance. The educational flyer was mailed through the U.S. Postal Service to the entire population of 4,921 in Lavaca County every other month, starting in July 2020 and ending in January 2021. No mailing of the educational flyer occurred in Goliad County. Two months after the final mailing, researchers worked with USDA NRCS to gather data on the number of BMPs and plans (both Conservation Plans and WQMPs) adopted in both Lavaca County (the intervention county) and Goliad County (the control county). On March 24, 2021, USDA NRCS provided summary data via email message regarding the number of BMPs and plans adopted using financial assistance for both Lavaca and Goliad Counties.

To infer potential effects of mailings on the number of practices adopted, we modelled the effect of year, presence or absence of mailing (binary variable), and county on the count of practices adopted, using a generalized linear model (GLM). The GLM was fit with a poisson error structure and log link. GLMs were fit using the R statistical software version 4.0.5 (R Core Team 2021). Under the assumption that within county measurements are not independent, we considered a random effect model that included county as a random intercept. However, the estimates of random effects with only two groups are not reliable and in practice showed little improvement in model performance, with harder-to-interpret results. Given the small sample size, the model is not intended to be predictive of results but to provide reasonable insight into the effect that mailing might have on practice counts.

Results

Demographics for both Lavaca and Goliad County are given in Table 2. Lavaca and Goliad County samples consisted of primarily white males, 51+ years-old, who receive 0-20% of their household income from the beef operations.

The following results from the pre-intervention evaluation are broken down by variable. Independent t-tests were used to compare Lavaca and Goliad County landowners. Table 3 presents a comparison of landowners' knowledge of strategies to determine stocking rates, indicators

Table 1. Lavaca and Goliad County 2017 land use type and percent of total farms by farm size.

	Lavaca County (%)	Goliad County (%)
Land Use Type		
Cropland	15	10
Pastureland	67	72
Woodland	15	13
Other	3	5
Farm Size		
1 to 9 acres	7	6
10 to 49 acres	28	26
50 to 179 acres	41	31
180 to 499 acres	18	25
500 to 999 acres	4	6
1,000+ acres	2	5

Note. Data acquired from National Agriculture Statistics by State 2017 Census of Agriculture Report.

Table 2. Descriptive statistics for respondents' personal characteristics.

	Lavaca		*Goliad*	
	f	*%*	*f*	*%*
Gender				
Male	135	75	59	79
Female	44	25	16	21
Age				
51-70	88	48	41	54
71 and over	69	38	25	33
31-50	26	14	8	10
18-30	1	1	2	3
Ethnicity				
White	167	94	69	96
Spanish, Hispanic, or Latino	6	3	3	4
American Indian or Alaskan Native	3	2	0	0
Black or African American	1	1	0	0
Education Level				
Bachelor's Degree	55	29	23	31
Graduate Degree	39	21	16	21
High School Graduate	38	20	11	15
Some College	31	16	18	24
Associate degree	21	11	6	8
Less than High School	6	3	1	1
Percentage of Income from Beef Production				
1-20%	119	68	43	57
0%	26	15	22	29
21-40%	20	11	2	3
41-60%	8	5	3	4
61-80%	1	1	4	5
81-100%	2	1	1	1
Operation Type				
Commercial Cow/Calf	145	83	57	81
Other	15	9	9	13
Backgrounder/Stocker	6	3	1	1
Feedlot/Finishing Operation	5	3	1	1
Seedstock	3	2	2	3
Years in Production				
11-25 years	52	29	16	21
26-40 years	45	25	19	25
41-60 years	37	21	18	24
0-10 years	23	13	13	17
None – I lease my property for ag production.	15	8	5	7
61+ years	8	4	5	7

of overstocking, results of overstocking, and advantages of using appropriate stocking rates from each county prior to mailing the flyer. There was no significant difference between Lavaca and Goliad County landowners in terms of knowledge of strategies to determine stocking rates based on county appraisal district recommendations, forage availability, calculated grazeable acres, and preparation for change in season. However, there was a significant difference between the two counties as it relates to methods used to determine stocking rates based on current or anticipated market prices. Lavaca County landowners somewhat disagreed with using current or anticipated market prices to determine stocking rates while Goliad County landowners somewhat agreed with the strategy. There was no significant difference between Lavaca and Goliad landowners regarding indicators of overstocking, results of overstocking, and advantages of properly stocking. Both counties presented knowledge in each construct.

Table 4 details the intention of Lavaca and Goliad County landowners to adopt BMPs prior to receiving the educational flyer. There were no significant differences between Lavaca and Goliad County landowners related to their intentions to adopt calculating grazeable acres for stocking rates, grazing plans, and alternative water sources. Both samples of landowners plan to adopt calculating grazeable acres and grazing plans. Lavaca County landowners already adopted alternative water sources while Goliad County landowners plan to adopt the practice.

There were significant differences ($p < .05$) between Lavaca and Goliad County landowners in relation to their intentions to adopt cross fencing ($p = .01$), alternative feed/salt/mineral locations ($p = .02$), and alternative shade structures ($p = .001$). Lavaca County landowners have already begun to adopt cross fencing and alternative feed/salt/mineral locations while Goliad County landowners plan to adopt these practices. Landowners in both counties plan to adopt alternative shade structures, but Lavaca County held a significantly higher mean.

Lavaca and Goliad County landowners' awareness of USDA NRCS and SWCDs prior to the mailing of the flyer is reported in Table 5. Both Lavaca and Goliad County landowners reported an overall awareness of USDA NRCS and SWCDs. However, landowners reported lack of awareness of offered financial assistance and that working with the agencies is confidential. Fifty-one percent of Lavaca County landowners and 50% of Goliad County landowners were not aware the USDA NRCS offers financial assistance to implement practices on eligible landowner's property. Additionally, 64% of Lavaca County landowners and 59% of Goliad County landowners were unaware technical and financial assistance received from the USDA NRCS is confidential.

The summary of the number of BMPs by year presented in Table 6 includes, for 2021, both practices that have been implemented and practices that are currently planned by the county office. Figure 1 shows the increase of practices from 2016-2021 in Lavaca County upon the mailing of the flyers. Mailing of the educational flyer began in July 2020 and practices adopted increased in both 2020 and 2021 in Lavaca County as compared to previous years.

The GLM indicates significant effects for each model term on the number of practices adopted (Table 7). Figure 2 shows the predicted marginal effects of mailings and year on the number of practices adopted. Based on the limited sample size, the GLM indicates a significant and likely substantial effect of mailings on the number of practices adopted. Holding both year and county constant, the GLM predicted count of practices for counties without mailings is 72.80 (95% CI = 55.60 – 90.20) compared to 228.89 (95% CI = 199.50 – 260.02) for counties with mailings.

Conclusions, Implications, and Recommendations

Results suggest that Lavaca County and Goliad County landowners were overall similar in their knowledge about stocking rates and their awareness of technical and financial resources available through local USDA NRCS and SWCD offices prior to our mailing of the educational flyer. There was, however, a difference between the two groups as it relates to their intention to adopt cross fencing and alternative feed/salt/mineral locations. This result suggests Lavaca County landowners

Table 3. Lavaca and Goliad County landowners' strategies to determine stocking rates, indicators of overstocking, results of overstocking, and advantages to properly stocking.

	Lavaca			Goliad			
Knowledge Items	***n***	***M***	***SD***	***n***	***M***	***SD***	***p***
Strategies to Determine Stocking Rate							
Based on forage availability.	175	5.00	1.06	71	5.11	1.06	0.82
Based on calculated grazeable acres for my pastures.	175	4.62	1.23	69	4.67	1.21	0.62
Based on preparation for change in season.	173	4.48	1.26	70	4.61	1.07	0.07
Based on current or anticipated market prices.	173	3.28	1.50	68	3.50	1.26	0.02*
Based on the county appraisal district's recommendations.	162	3.18	1.48	68	2.88	1.46	0.83
Indicators of Overstocking							
Bare patches on the land.	181	4.86	1.08	73	4.95	0.91	0.06
Weed/brush encroachment.	179	4.63	1.23	72	4.57	1.28	0.65
Visible hooves from a distance.	173	4.49	1.26	70	4.66	1.26	0.46
Noticeable manure visible from a distance.	177	4.40	1.23	71	4.54	1.36	0.69
Less desirable body scores.	171	4.85	1.04	71	4.93	1.09	0.76
Results of Overstocking							
Susceptibility to drought.	179	5.09	0.96	73	5.07	0.86	0.45
Increased soil erosion and rainfall runoff.	179	5.08	0.96	70	5.09	0.90	0.24
Increased external parasites.	174	4.73	0.94	71	4.69	1.05	0.71
Increased feeding period.	179	5.00	0.91	72	5.15	0.69	0.75
Increase in supplemental feeding needs.	180	5.12	0.84	71	5.25	0.65	0.49
Decrease in forage production.	180	5.11	0.89	70	5.19	0.69	0.36
Decrease in herd performance.	180	5.11	0.75	71	5.23	0.66	0.97
Reduced land carrying capacity.	177	5.12	0.74	72	5.19	0.62	0.74
Advantages to Properly Stocking							
Drought resilience.	180	4.99	0.85	72	4.96	0.86	0.78
Protection of soil and water resources.	180	5.19	0.82	72	5.25	0.58	0.15
Decreased feeding period.	179	5.08	0.79	72	5.13	0.60	0.42
Decrease in supplemental feeding needs.	180	5.04	0.88	71	5.18	0.54	0.07
Higher body scores.	175	5.09	0.78	72	5.10	0.59	0.12
Increased forage production.	179	5.21	0.72	72	5.22	0.59	0.28
Increased plant resiliency.	173	5.12	0.74	71	5.27	0.58	0.81

Note. *$p < 0.05$. Scale: 1 = *Strongly Disagree*, 2 = *Disagree*, 3 = *Somewhat Disagree*, 4 = *Somewhat Agree*, 5 = *Agree*, 6 = *Strongly Agree*.

Table 4. Lavaca and Goliad County landowners' intention to adopt.

	Lavaca			Goliad			
Grazing Management Practices	***n***	***M***	***SD***	***n***	***M***	***SD***	***p***
Calculating Grazable Acres for Stocking Rates.	175	3.29	1.01	71	3.08	1.08	0.13
Grazing Plan/Prescribed Grazing.	171	3.30	0.96	69	3.26	1.12	0.09
Cross Fencing.	178	3.60	0.92	71	3.38	1.10	0.01*
Alternative Water Sources.	179	3.60	1.00	70	3.31	1.07	0.11
Alternative Feed/Salt/Mineral Locations.	178	3.53	0.92	70	3.40	1.06	0.02*
Alternative Shade Structures.	180	3.34	1.22	70	3.04	1.48	0.00*

Note. *$p < 0.05$. Scale: 1 = *Will Not Adopt*, 2 = *Undecided*, 3 = *Plan to Adopt*, 4 = *Already Adopted,* 5 = *Not Applicable*.

Table 5. Lavaca and Goliad County landowners' awareness of the USDA NRCS and TSSWCB.

	Lavaca				Goliad			
	--- Yes ---		--- No ---		--- Yes ---		--- No ---	
	n	***%***	***n***	***%***	***n***	***%***	***n***	***%***
Are you aware of Lavaca Soil and Water Conservation District?	149	82	32	18	18	25	54	75
Are you aware of the USDA-Natural Resources Conservation Services?	135	75	44	25	58	78	16	22
Did you know that the agencies mentioned above work to protect and enhance your working lands and natural resources?	144	80	36	20	52	70	22	30
Did you know that the agencies mentioned above offer free technical assistance?	118	66	62	34	45	61	29	29
Did you know that the agencies mentioned above offer financial assistance?	88	49	92	51	37	50	37	50
Did you know that any technical and financial assistance that you receive is confidential?	64	36	114	64	30	41	44	60
Did you know that the agencies mentioned above work with you to develop a water conservation plan that will help attain your goals?	104	59	73	41	36	49	39	51

Table 6. Number of USDA NCRS practices adopted by year for Lavaca and Goliad Counties.

Year	Practice Status	Lavaca County Practices (Treatment Group)	Goliad County Practices (Control Group)
2016	Implemented	92	52
2017	Implemented	95	34
2018	Implemented	82	60
2019	Implemented	59	61
2020	Implemented	136	141
2021	Implemented + Planned	321	53

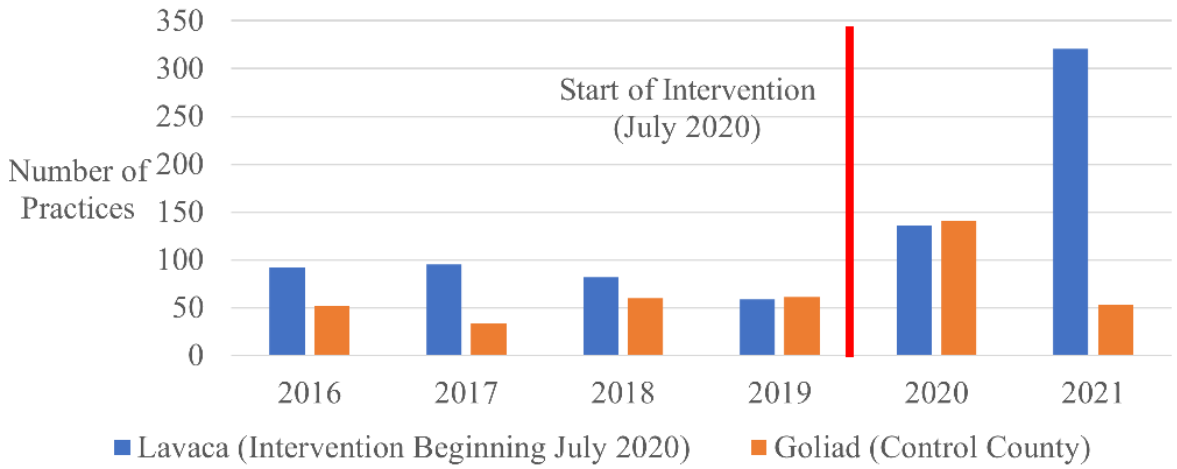

Figure 1. Practices adopted by county from 2016-2021 in Lavaca and Goliad Counties steadily increased. However, a significant increase is visible 2020-2021 in Lavaca County following the mailing of educational flyers.

Table 7. GLM terms and model estimates for USDA NRCS practice counts (estimates and confidence intervals reported on the log scale). Response = Practice Count.

Predictors	Estimate	Confidence Interval	*p*-value
(Intercept)	-235.83	-333.30 – -138.92	<0.001
Year	0.12	0.07 – 0.17	<0.001
Mailings [1]	0.68	0.48 – 0.87	<0.001
County [Lavaca]	0.34	0.18 – 0.49	<0.001

may be more willing to adopt these practices than landowners in Goliad County, but the populations are similar enough to compare adoption rate changes and draw conclusions.

Landowners reported awareness of the USDA NRCS and SWCDs; however, landowners were not aware of the technical and financial assistance and confidentiality they offer, which may explain a lack of interaction with the USDA NRCS and SWCD. Finances are a significant factor in the decision to adopt a practice, just as Rogers (2003) highlights in the persuasion stage of the innovation decision process. Rogers (2003) also emphasizes that trust is an important aspect in the adoption process. If landowners are not aware their interaction with the USDA NRCS and SWCD is confidential, this may be affecting their choice to reach out to the agency.

The GLM provides evidence of substantial correlative increases in practices and mailings. We estimated a nearly 314% increase in the modeled adopted practices following mailing activity. This impact is consistent with the influence of direct mailing as described in the presidential campaign studies (Gerber et al. 2008; Green and Gerber 2008; Gerber et al. 2011) and follows the general demographic communication preferences of a similar demographic identified by Dewald et al. (2018). Although the correlation is compelling, the results should be interpreted with a few caveats. First, the sample size is limited since results are aggregated at the county level. Future work could examine the impacts of mailing at the landowner level or incorporate many more counties in a block testing design. Second, we must consider potential confounders in the analysis, which include landowners with property in both counties, changes in funding levels between years, and unaccounted existing practices. For example, the increase in Goliad County practices in 2020 could have also been a result of 29 landowners on the mailing list owning land in both Lavaca County and Goliad County as well as communication between other landowners about assistance programs. Therefore,

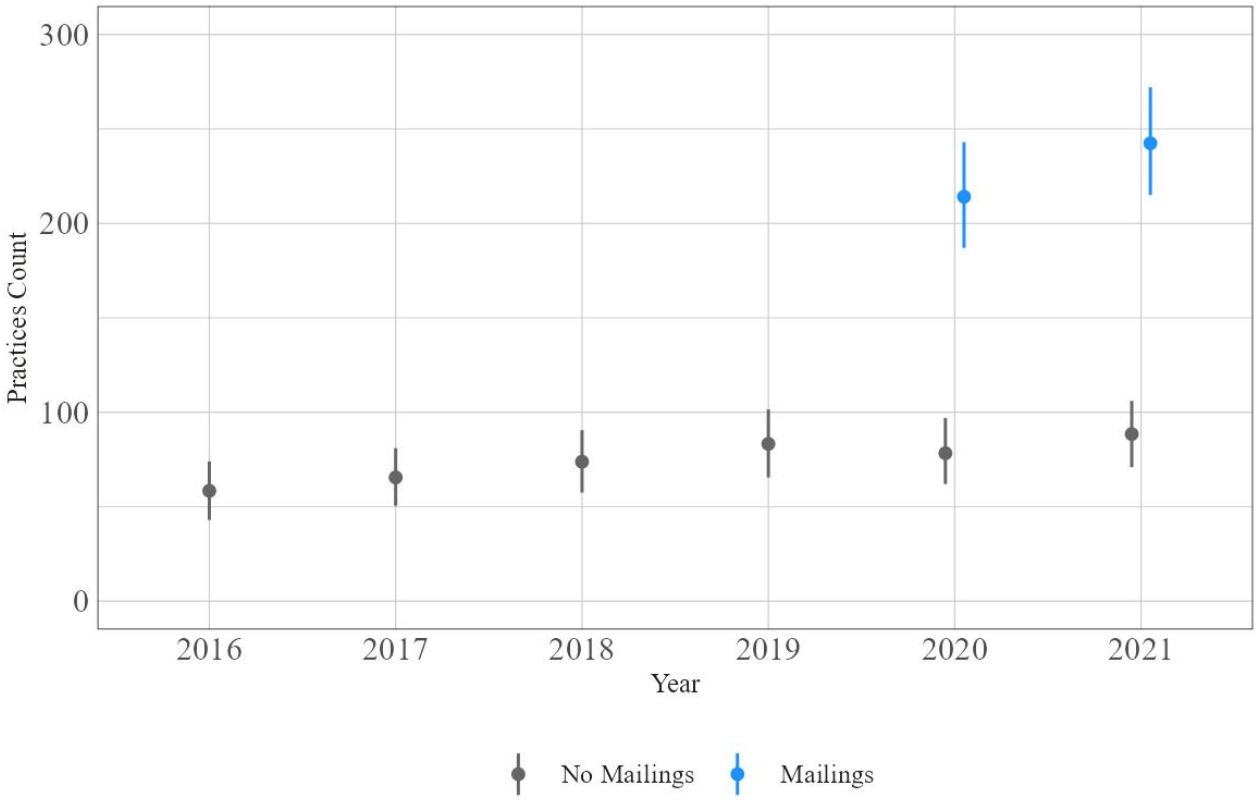

Figure 2. Marginal effects plot displaying the estimated marginal means of the response variable (count of practices) by mailings and year. Points are the model estimated predictions and vertical lines are the 95% confidence intervals.

select Goliad County residents may have also received the educational mailer, but due to privacy rules, researchers were not able to obtain this information.

Through personal communication with K. Isom, USDA NRCS, on March 24, 2021, it was learned that there were no increases in funding available and in fact, total funding for the zone dropped from $11 million to $7.5 million during the course of this study. In considering unaccounted practices, we assume that in counties with already high adoption rates that additional advertising would result in small changes in adoption. For example, an individual that already has operational BMPs on their property is unlikely to approach USDA NRCS for funding after receiving a mailing. Ideally, a dataset with farm-level BMP adoption would be available to compare counties. In absence of that data, we considered the similar responses between county respondents on intention to adopt practice (Table 2) as indicative that there are generally non-significant differences in unaccounted practices between the two counties. USDA NRCS also indicated that there were no changes in advertising for their programs during the study period, so the conclusion is drawn that the increase suggests the educational mailers were effective in increasing the adoption of BMPs.

It should be noted that researchers are unsure how the COVID-19 virus impacted the number of practices that were adopted. It could be speculated that landowners would not want agency personnel to come to their property due to fear of the virus, which could have suppressed potential adoption of practices, or that landowners had more time available which could have inflated the practices adopted. Also because of COVID-19, there was a decrease in the number of in-person education programs delivered by county Extension as compared to previous years.

Due to the slow response to water quality changes from upland and riparian practice implementation, it is yet to be determined whether the change in practice implementation has improved local water

quality in the Lavaca River Watershed. In-stream data will continue to be collected and analyzed, but lag effects, shifts in climate and streamflow, and the high variance in in-stream *E. coli* concentrations can hinder the detection of significant responses of in-stream concentrations and result in many years before significant improvements are detected (Meals et al. 2010; Tomer and Locke 2011; Schramm 2021). Since failing septic systems, wildlife, illicit discharges, and sanitary sewer overflows also contribute to *E. coli* loadings in the Lavaca River Watershed, adoption of conservation practices alone is not anticipated to result in attainment of water quality standards. However, the Lavaca River WPP estimated a load reduction in the Lavaca River of 1.00×10^{15} cfu *E. coli*/year based on the adoption of 100 plans with the practices listed in this study, as well as a reduction of 2.25 x 10^{14} cfu *E. coli*/year in Rocky Creek with the adoption of 30 plans (Schramm et al. 2018).

From this study, there are a few recommendations that can be made. First, working with the local USDA NRCS office in advance is extremely important because if there is an increase in applications but no funding available, landowners could lose trust or interest in working with local agencies and may not return. By also working with the local office, educational information can be sent out in months that align with the application process already in place, and may better align with the end of the fiscal year. Mailing lists will need to be periodically updated, especially if mailing extends over multiple years. Landowner contact information changes rapidly, especially as land is sold or a landowner passes and the property is inherited by someone else. By keeping an up-to-date list, not only do you reduce the number of non-deliverable education mailers but you also reach new landowners that would not have been reached otherwise. It is also important to conduct a survey prior to the development and distribution of an education mailer. Through this survey, barriers to adoption, ideal communication channels, distribution frequency, and other information can be learned to most effectively reach the target audience and alleviate barriers.

More research is needed to determine if this educational flyer mailing approach is effective in increasing the number of BMPs adopted in other regions across Texas and the United States. Additionally, research could focus on what frequency of mailing is most effective in influencing the adoption of practices and which is the most cost effective.

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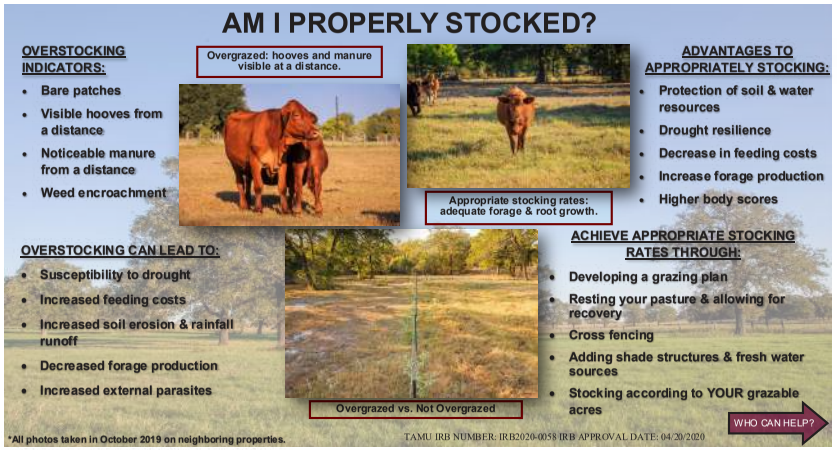
Supplementary Data



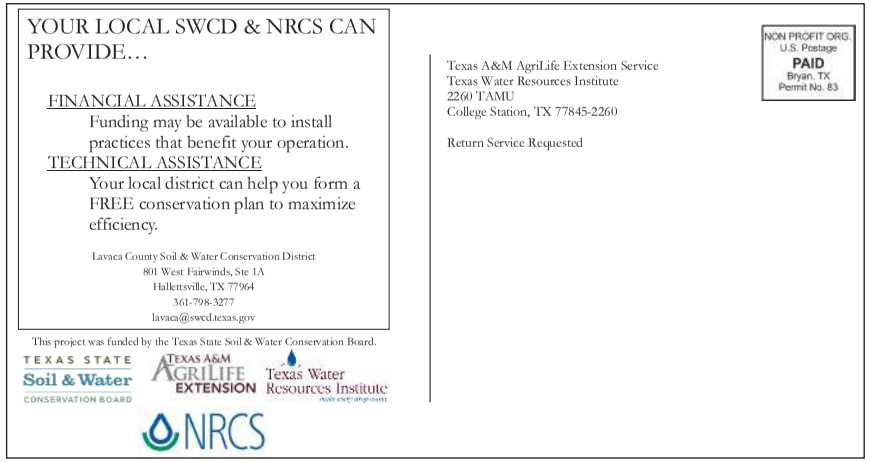


Figure S-1. Educational grazer mailer.

Table S-1. Summary of practices adopted by Golliad County, Texas.

			2016		2017		2018		2019		2020		2021			
Code	Name	Units	Applied Amount	Applied Count	Applied Amount	Applied Count	Applied Amount	Applied Count	Applied Amount	Applied Count	Applied Amount	Applied Count	Applied Amount	Applied Count	*Planned Amount*	*Planned Count*
314	Brush Management	acres	2162.7	8	2572.7	12	1143.1	1	355.5	4	726.4	8	623.3	14	182	5
584	Channel Bed Stabilization	feet					1,795.00	1								
340	Cover Crop	acres	22.9	2												
342	Critical Area Planting	acres					3.5	1								
382	Fence	feet	40352	12	47,499.00	6	75755.4	14	49,820.80	7	20135	14	9083	7		
394	Firebreak	feet	60,692.00	5							107359.8	4				
561	Heavy Use Area Protection	acres	2	2					2	2	16	16	1	1		
315	Herbaceous Weed Treatment	acres	72.6	3	54.7	3	51.3	4	51.3	4	492.2	29				
325	High Tunnel System	sq ft					2,880.00	1								
516	Livestock Pipeline	feet	2,695.10	4	8427.1	4			77672.2	7	24,177.20	10	430	1		
590	Nutrient Management	acres	25.2	1												
512	Pasture and Hay Planting	acres	115.4	4											90	1
338	Prescribed Burning	acres	3,390.00	2	586.6	1					3317.3	4			34	1
528	Prescribed Grazing	acres	39.1	2	2,149.10	2	17967.5	32	12352	17	24705.6	34			2079	22
533	Pumping Plant	number			1.00	1	3	3	4	4	3	3				
550	Range Planting	acres	49.8	3												
578	Stream Crossing	number					1	1								
612	Tree/Shrub Establishment	acres					3	1								
614	Watering Facility	number	4	4	4	4			13	13	17	17				
642	Water Well	number			1	1	1	1	2	2	1	1	1	1		
351	Well Decommissioning	number							1	1	1	1				

Table S-2. Summary of practices adopted by Lavaca County, Texas.

			2016		2017		2018		2019		2020		2021			
Code	Name	Units	Applied Amount	Applied Count	Applied Amount	Applied Count	Applied Amount	Applied Count	Applied Amount	Applied Count	Applied Amount	Applied Count	Applied Amount	Applied Count	*Planned Amount*	*Planned Count*
472	Access Control	acres													47	1
314	Brush Management	acres	167	10	158	8	320	12	64.3	2	224.4	15	145.2	8	513.8	25
E646A	Close structures to capture and retain rainfall for waterfowl and wading bird winter habitat	acres									272.6	3			556	6
342	Critical Area Planting	acres			4.1	1			1.4	1					5.9	2
362	Diversion	feet	4,287.00	4												
E300EAP1	Existing Activity Payment-Land Use	acres									1433.5	16			1433.5	16
E300EAP2	Existing Activity Payment-Resource Concern	number									13	2			13	2
E646B	Extend retention of captured rainfall for migratory waterfowl and wading bird late winter habitat	acres									217	2			190.2	3
382	Fence	feet	16048	12	22,671.90	18	10272	8	5,098.00	5	8032	5	10537	8	21245	19
412	Grassed Waterway	acres	6.00	2												
561	Heavy Use Area Protection	acres	1	5	4	7	1	6	1	6	2	11	1	7	4	25
315	Herbaceous Weed Treatment	acres	168	7	61.6	5	243.1	8	166.7	5	311.3	4	200.9	10	405.8	21
325	High Tunnel System	sq ft			3,024.00	1										
E590118Z	Improving nutrient uptake efficiency and reducing risk of nutrient losses to surface water	acres													272.1	3
464	Irrigation Land Leveling	acres	404.1	5	591.7	7	258.9	3	122.5	2	1258.8	14	399.8	5	318.2	3
466	Land Smoothing	acres									33	3			15	2
516	Livestock Pipeline	feet	15,851.00	10	7769	9	6039	9	4278	7	11,059.20	12	4735	8	19102	25
576	Livestock Shelter Structure	number											5	5		
E647A	Manipulate vegetation on fields with captured rainfall for waterfowl & wading bird winter habitat	acres									489.6	5			272.1	3
512	Pasture and Hay Planting	acres	153.7	7	14.7	2	26.3	4	10.5	1	22.8	2	4.7	1	41	4
378	Pond	number			1	1	1	1	1	1	1	1				
528	Prescribed Grazing	acres	111.9	5	307.90	7	751	8	1150.5	12	136.3	2	172.9	6	660.7	5
E647B	Provide early successional shorebird habitat between first crop and ratoon crop	acres													746.2	9
533	Pumping Plant	number	4	4	2.00	2	1	1	3	3	3	3	1	1	5	5
550	Range Planting	acres													127	7
E595116X	Reduce risk of pesticides in surface water by utilizing precision pesticide application techniques	acres													272.1	3
391	Riparian Forest Buffer	acres													25	1
587	Structure for Water Control	number	32	3	76	11	69	10	30	3	109	20	76	9	74	18
600	Terrace	feet	14,022.00	3												
614	Watering Facility	number	13	12	11	11			8	8	13	12	9	8	32	32
642	Water Well	number	2	2	3	3	3	3	1	1	1	1	1	1	1	1
351	Well Decommissioning	number	1	1	2	2	9	9	2	2	3	3	1	1	2	2

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Ban the Bag: Support for Plastic Bag Reduction Strategies in Northeast Ohio

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Abstract: Society's use of plastic is increasing, while the ability to properly manage plastic waste is decreasing. In response, improved waste management systems and the adoption of reusable products made from sustainable materials are needed. Municipal governments in the United States are beginning to institute policies reducing unlimited free access to plastic products such as bags, straws, and Styrofoam. However, some state governments in the Great Lakes region, and elsewhere, have responded by making these pro-environmental policies illegal. Such policies shift the onus of using less plastic to local businesses and conscious consumers. In response, this project sought to determine the effectiveness of a plastic bag ban, supported by targeted education and outreach, at several local businesses in northeast Ohio. Results suggest that the initial implementation and non-enforcement phase of the bag ban did not lead to a reduction in the use of plastic bags. However, survey respondents indicate they are supportive of policies reducing accessibility and unlimited availability of plastic bags. Results further show most people have access to their own reusable bags and support businesses who charge for, or no longer offer, plastic bags. In conclusion, voluntary reduction of bag use by customers is not effective and store policies or legislation is needed to reduce the use of plastic bags.

Keywords: *plastic pollution, behavior change, single-use plastics, pro-environmental behaviors, sustainable business practices, Extension, education, Great Lakes*

Research Implications

- Inform single-use and disposable plastics reduction legislation at the local level.
- Serve as a case study for businesses looking to adopt sustainable business practices.
- Identify consumer response to government and business plastic bag reduction strategies.
- Determine which reminder strategies, if any, are successful at encouraging customers to bring their own bags.

The majority of products made worldwide contain plastic because of its ability to be shaped into almost anything, its durability, and low production cost (Sigler 2014). Estimates based on prediction models developed by Geyer et al. (2017) suggest over 350 million metric tons of plastic are produced each year, with this number expected to increase by 2050. In the Great Lakes region, plastic accounts for 90% of the litter profile on beaches (Alliance for the Great Lakes 2019) and floating debris (Derraik 2002). Plastic is problematic in the environment because the characteristics making plastic a desirable product (lightweight, malleability, durability) also allow it to wreak havoc on living organisms (ingestion, entanglement, leaching of harmful chemicals) (Katsanevakis 2008; Andrady 2011). Plastic debris makes its way into the water system via land-based activities and through stormwater discharge, runoff, intentional and unintentional littering, unregulated disposal, leakage of waste (industry and residential), recreational activities such as fishing, and the shipping industry (Katsanevakis 2008; Andrady 2011; Lambert et al. 2014). It is estimated that 9,887 metric tons of plastic debris are entering the

Great Lakes each year, with almost half entering Lake Erie alone (Hoffman and Hittinger 2017).

Plastic pollution negatively affects coastal and marine environments (Derraik 2002; Teuten et al. 2009; Thompson et al. 2009) because it poses a risk to wildlife (especially birds) and fish health from ingestion, entanglement, and exposure to toxic chemicals (Moore et al. 2001; Derraik 2002; Moore 2008; Barnes et al. 2009; Cole et al. 2011; Lavers et al. 2014). Improper disposal of plastics also threatens human health (Alabi et al. 2019) by negatively affecting gut health (Lu et al. 2019) and increasing reproductive risks and infertility issues caused by exposure to endocrine disrupting chemicals (Swan and Colino 2021). Plastic in the water or along coasts negatively affects the economy, due to expensive debris removal (Stickel et al. 2012) and loss of tourism revenue because visitors are less likely to recreate on trash filled beaches (English et al. 2019).

Plastic Bag Reduction Legislation in the United States

Beach cleanup data show disposable plastic bags made of polyethylene (hereafter plastic bags) are a major source of plastic pollution in coastal environments (Ocean Conservancy 2020). Plastic bags clog storm drains and pipes causing road (Adane and Muleta 2011; Xanthos and Walker 2017) or basement flooding. In response, government policies at various jurisdictional levels (citywide to statewide) are being implemented in the United States to curb the environmental, economic, and infrastructure issues arising from the improper disposal of plastic bags (Sea Grant Law Center 2020). Although no federal legislation exists in the United States, several countries have implemented countrywide bag bans (Clapp and Swanston 2009). Currently nine states in the United States have laws banning the use of plastic bags, up from one state (California) in 2018. In contrast, there are 15 states that have passed preemption laws making any type of legislation regulating the use of plastics bags illegal. Cuyahoga County, located in northeast Ohio and the project location for this study, passed a countywide bag ban in December 2019 (Sea Grant Law Center 2020). Implementation began in January 2020 with enforcement, through fines and legal action, to begin six months later in July 2020. However, due to the coronavirus (COVID-19) pandemic (hereafter pandemic), use of reusable bags for shopping was paused in northeast Ohio from March 2020 to August 2020, and the moratorium on plastic bags postponed. Reusable bags are now allowed again for shopping in Ohio, but the Governor has prohibited any type of plastic bag ban legislation to go into effect until January 2022 (The Ohio Legislature 2021). Therefore, customers can use their own bags, but are not required to do so by government regulation. All stores that were phasing out plastic bags in response to the pending bag ban are no longer doing so because of the pandemic.

Given the amount of coastal area in northeast Ohio and documented concern from citizens and tourists regarding plastic debris on area beaches and in Lake Erie (Bartolotta and Hardy 2018), this study seeks to better understand the efficacy of the proposed countywide bag ban and explore strategies for helping local businesses transition to more sustainable practices. The study is guided by the following research questions:

1. Are customers willing to support businesses that charge for the use of plastic bags or no longer offer plastic bags?
2. Do businesses that engage in sustainable business practices such as a storewide bagless initiative see an increase or decrease in profits?
3. Do residents support regulatory or incentive-based public policies such as bag bans or bag fees?
4. What are the best behavior change strategies for encouraging customers to use their own bags?

Methods

Data collection for this study included observation, online surveys, and semi-structured interviews since a variety of qualitative data collection methods allows us to understand the complex nature of consumer behavior (Maxwell 2005). The varying methodologies were used to determine bag use preferences by customers when shopping, support for legislation or business practices that reduce access to plastic bags, and

waste management concerns for plastic bags. The study involved the use of human research subjects, and in accordance with protocol established by the Institutional Review Board for The Ohio State University, received exempt status meaning no potential risk to the human research subjects was observed by a panel of experts. The project took place during fall of 2019 through winter of 2020.

Educational Outreach Events (Grocery Stores and Clothing Resale Store)

Ten educational outreach events took place (six at the grocery stores, one at the clothing resale store, and three at community events within the study area) in summer and fall of 2019 (Table 1). Information about the harms of plastic pollution in the environment and options for reusable bag alternatives were presented to shoppers. Customers were asked to choose reminder strategies (store signage, keychains, magnets, and window decals) (Figure 1) to help remind them to bring their own bags when they shop, with the goal of reducing the use of plastic bags. Information on the upcoming countywide bag ban to go into effect in January of 2020, with legal enforcement occurring in July of 2020 (currently paused because of pandemic), was also given to customers. The staff of the clothing resale store was trained on the issue of plastic pollution so they could answer customer questions regarding a storewide, recently enacted, bagless initiative implemented by the store owner.

Observation (Grocery Stores)

Unobtrusive structured observation pro-forma and direct observation were used to analyze customer behavior in a natural setting without interference from the data collectors (Walshe et al. 2011; Guest et al. 2013) to complement other data collection methods (surveys and interviews) (Guest et al. 2013; Robson and McCartan 2016). Observation was chosen because it allowed customer bag use to be studied without participant awareness, which could cause participants to alter their bag use if they were aware of the observers' intentions. To ensure data validity more than one observer was used (four observers were used for this study) and all were trained on the data collection instrument (Table 2). Consumer observation regarding bag preference took place at two grocery markets located within the Lake Erie watershed in northeast Ohio. Each store was observed 12 times (four times pre-educational outreach events, four times post educational outreach events, and four times post implementation, but not enforcement, of the countywide plastic bag ban) for a total of 24 store observations (Table 1). Observations occurred for two hours (48 total observation hours) and took place during various days of the week at various store hours to prevent bias towards one shopping demographic. For example, it was noted that in general elderly customers shopped in the morning and afternoon, whereas younger clientele shopped in the late afternoon and evening hours. Customers were observed for the bag type and quantity used (plastic, paper, reusable, store branded reusable, box, no bag, and no purchase). Plastic bag use changes amongst the three observation periods were observed for statistical significance using a one-way ANOVA test. The test was calculated using Microsoft Excel. Based on standard observation methodology (Schensul et al. 1999; Guest et al. 2013) demographics were only recorded for age, race, and sex. Customer demographics were based on observation only and were not self-reported by the individual. Observers understand the concerns that can arise from observing demographics versus self-reporting demographics but determined it the best strategy to collect demographic information without risking participant awareness. Practice sessions with two observers comparing demographic observations and familiarity with the study area assisted observers in determining accurate demographic observations.

Survey (Grocery Stores and Clothing Resale Store)

Two online surveys were administered to explore customer support for plastic bag reduction legislation and for businesses that no longer offer plastic bags. Both surveys (Appendices) followed standard social science protocols, including creation and testing of the survey instrument, identification of the study population and sampling frame, a set survey response period, and weekly reminders to increase response rate (Dillman 2007). Both surveys were sent to participants via an online platform (Qualtrics). Respondents had three weeks to respond to the survey and weekly

email reminders were used to encourage responses. One survey (Appendix A) was sent to customers enrolled in the messaging platform for a clothing resale store, located in northeast Ohio. Customers shopping in the store were also asked if they would like to participate in the survey by store employees and members of the research team. If a customer said yes, their email was taken, and they were sent the online survey to complete on their own. The other survey (Appendix B) was sent to customers who participated in educational outreach events at the two grocery stores. Demographic information recorded though the surveys was self-reported by survey respondents.

Table 1. Observation and outreach schedule.

Produce Place Grocery store located in Cuyahoga County, OH. Observation Hours (12 observations for two hours each = 24 total observation hours) *Pre-Outreach (July and August 2019)* • 7/30/2019 (1-3 pm, Tuesday) • 8/3/2019 (2-4 pm, Saturday) • 8/6/2019 (3-5 pm, Tuesday) • 8/12/2019 (2:15-4:15 pm, Monday) *Post Outreach (December 2019)* • 12/10/2019 (1-3 pm, Tuesday) • 12/13/2019 (10 am-12 pm, Friday) • 12/14/2019 (11:40 am-1:40 pm, Saturday) • 12/16/2019 (2-4 pm, Monday) *Post Ban Implementation (February 2020)* • 2/8/2020 (9-11 am, Saturday) • 2/14/2020 (4-6 pm, Friday) • 2/17/2020 (2-4 pm, Monday) • 2/19/2020 (10:30 am-12:30 pm, Wednesday) Outreach Events (September and October 2019) Three outreach events in fall of 2019. Survey recruitment occurred at all outreach events. Survey Given Sent via email and taken online. Appendix B survey. Staff Interviews No staff interviews were conducted.	***Sun Plum*** Grocery store located in Lake County, OH. Observation Hours (12 observations for two hours each = 24 total observation hours) *Pre-Outreach (July and August 2019)* • 7/14/2019 (11 am-1 pm, Sunday) • 7/16/2019 (4-6 pm, Tuesday) • 7/20/2019 (10 am-12 pm, Saturday) • 8/8/2019 (9-11 am, Thursday) *Post Outreach (December 2019)* • 12/12/2019 (1-3 pm, Thursday) • 12/14/2019 (9:30-11:30 am, Saturday) • 12/16/2019 (1-3 pm, Monday) • 12/18/2019 (11 am-1 pm, Wednesday) *Post Ban Implementation (February 2020)* • 2/7/2020 (4-6 pm, Friday) • 2/8/2020 (11 am-1 pm, Saturday) • 2/18/2020 (1-3 pm, Tuesday) • 2/20/2020 (10 am-12 pm, Thursday Outreach Events (September and October 2019) Three outreach events in fall of 2019. Survey recruitment occurred at all outreach events. Survey Given Sent via email and taken online. Appendix B survey. Staff Interviews No staff interviews were conducted.
Revolve Kids Fashion Clothing resale store located in Cuyahoga County, OH. Observation Hours N/A Outreach Events (August 2019) One outreach event in summer of 2019. Survey recruitment occurred via store's online email listserv. Survey Given Sent via email and taken online. Appendix A survey. Staff Interviews (December 2019) Seven store staff participated.	

Interviews (Clothing Resale Store and Solid Waste Districts)

Personal interviews were conducted with employees and the owner (seven interviews) of a clothing resale store to determine customer response to the removal of plastic bags from the store. Solid waste district employees for northeast Ohio were also interviewed (one interview with the Lake County Solid Waste District and one interview with the Cuyahoga County Solid Waste District) to determine the fate of plastic bags sent for recycling and the costs associated with managing discarded bags in the area. The interviews included development of an interview guide and randomized participant recruitment, in accordance with standard qualitative protocols (Maxwell 2005; Bryman 2012; Yin 2014).

Results

Bag Use at Grocery Stores

Plastic bags were the bag of choice during each phase of observation at the two grocery stores in this study. A total of 1,081 people were observed, over 48 observation hours, at both store locations. Of the bag choice options, plastic was the most commonly used with 2,205 plastic bags being used for an average of 2.040 bags per person and 45.938 bags used per hour. Using an online survey, 68% of respondents stated on average they most commonly use between one to three plastic bags

Figure 1. Reminder items (keychain, magnet, and window decal) taken by store customers to encourage them to bring their own reusable bags. Reminder signs given to stores reminding people to grab their own bags.

Table 2. Observation data collection sheet.

Total Customers									
Total Spoken to									
Store Branded Bag Total Observed									
Date									
Time									
Temperature									
Cloud Cover									
Plastic	**Paper**	**Reusable**	**Produce Palace Bag**	**Box**	**No Bag**	**No Purchase**	**Race**	**Age**	**Sex**

when shopping. Reusable bags were the second most common bag used with 138 being used, (0.128 per person on average, and 2.875 per hour). As reported by survey respondents, customers do not always use their own bags because they either forget them at home (36% of respondents) or in the car (25% of respondents). The other common reasons for taking a plastic bag from the store include using the plastic bag to pick up pet waste (16% of respondents) or to line garbage bins at home (15% of respondents). Customers stated having access to reusable bags. Survey results indicate that 98% of respondents have access to their own bags with over half of respondents (66%) having access to at least 10 reusable bags.

The third most common bag choice was no bag being used, meaning items were hand carried from the store. This carrying option occurred 32 times for an average of 0.030 occurrences per person and 0.667 occurrences per hour. There were 30 times when no purchase was made for an average of 0.028 occurrences per person and 0.625 occurrences per hour. Paper bags were used 12 times for an average use of 0.011 per person and 0.250 times per hour. Boxes were used nine times for an average use of 0.008 times per person and 0.188 times per hour. Lastly, a store branded reusable bag was used four times for an average of 0.004 uses per person and 0.083 times per hour (Table 3).

To determine the effectiveness of outreach activities and beginning implementation stages of the bag ban, observation of customer bag use behavior was collected pre-outreach activities, post outreach activities, and during the initial implementation but non-enforcement phase of a countywide plastic bag ban. Observation data show plastic bags were the most common bag used during each observation phase, followed by reusable bag, no bag, no purchase, paper bag, box, and store branded reusable bag carrying options (Table 4). Using a one-way ANOVA, it was found that there was no statistically significant difference in plastic bag use amongst the three observation periods, $F(2,1009)=0.612$, $p=0.542$ (Table 4). Therefore, the null hypothesis is accepted and outreach activities and the initial implementation, but non-enforcement phase of the bag ban, do not significantly reduce the amount of plastic bags being used.

The average age of customers observed at the grocery stores were persons determined through observation to be in their 50s with customers primarily being observed as Caucasian with an even representation of male and female sexes. We understand it is difficult to determine exact age, race, and sex via observation. However, we feel the benefits of documenting the demographics for this study outweigh possible miscalculations when assigning demographics for age, race, and sex based on observation. Especially since we want to identify the skewing of the observational data toward a Caucasian population.

Customer Response to Plastic Bag Reduction Strategies

An online survey (Appendix B) sent to 2,116 clothing and grocery store customers received 158 responses (response rate 7.4%), similar to

Table 3. Bag use by customers for all observation periods at both grocery store locations.

	Plastic	Reusable	No Bag	No Purchase	Paper	Box	Store Branded Reusable Bag
Bag Use	2205	138	32	30	12	9	4
Average Bag Use Per Person (n=1081)	2.040	0.128	0.030	0.028	0.011	0.008	0.004
Average Bag Use Per Hour (n=48)	45.938	2.875	0.667	0.625	0.250	0.188	0.083

other studies on consumer behavior pertaining to plastic bag use (Crowley 2020; Macintosh et al. 2020). Survey results indicate customers are mostly supportive of businesses reducing the accessibility to plastic bags with either a fee or ban. Many survey respondents (68%) are very likely to support stores charging for plastic bags, while 67% are supportive of removing plastic bags from stores. Ten percent do not support charging for or banning plastic bags, whereas the remaining respondents (23%) are moderately or somewhat likely to support stores that reduce the accessibility of plastic bags (Figure 2).

Customers are more supportive of legislative policies such as bag fees or bans that limit the accessibility to plastic bags (Figure 3). Almost all respondents (95%) are in favor of legislation reducing unlimited access to plastic bags (43% support both a bag fee or ban; 41% support only a bag ban; 11% support only a bag fee). Five percent of respondents do not support legislation reducing the access to plastic bags in stores.

About half of the survey respondents took reminder items during the educational outreach events. Customers (29%) found the keychains to be most helpful, with the magnets and window decals

Table 4. Bag use preference per person, pre and post outreach and during initial bag ban implementation, at both grocery store locations. Statistical analysis to determine if outreach activities and initial implementation phase of a bag ban significantly reduce the use of plastic bags. Differences between the three groups were found not to be statistically significant.

	Plastic	**Reusable**	**No Bag**	**No Purchase**	**Paper**	**Box**	**Store Branded Reusable Bag**
Pre-Outreach	1232	69	18	17	12	1	0
Average Bag Use Per Person (n=618)	1.994	0.112	0.029	0.028	0.019	0.002	0.000
Average Bag Use Per Hour (n=16)	77.000	4.313	1.125	1.063	0.750	0.063	0.000
Post Outreach	516	36	6	8	0	4	1
Average Bag Use Per Person (n=251)	2.056	0.143	0.024	0.032	0.000	0.016	0.004
Average Bag Use Per Hour (n=16)	32.250	2.250	0.375	0.500	0.000	0.250	0.063
Ban Implementation (No Enforcement)	457	33	8	5	0	4	3
Average Bag Use Per Person (n=212)	2.156	0.156	0.038	0.024	0.000	0.019	0.014
Average Bag Use Per Hour (n=16)	28.563	2.063	0.500	0.313	0.000	0.250	0.188

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.511957	2	2.255979	0.612756	0.542057	3.004644
Within Groups	3714.827	1009	3.681692			
Total	3719.339	1011				

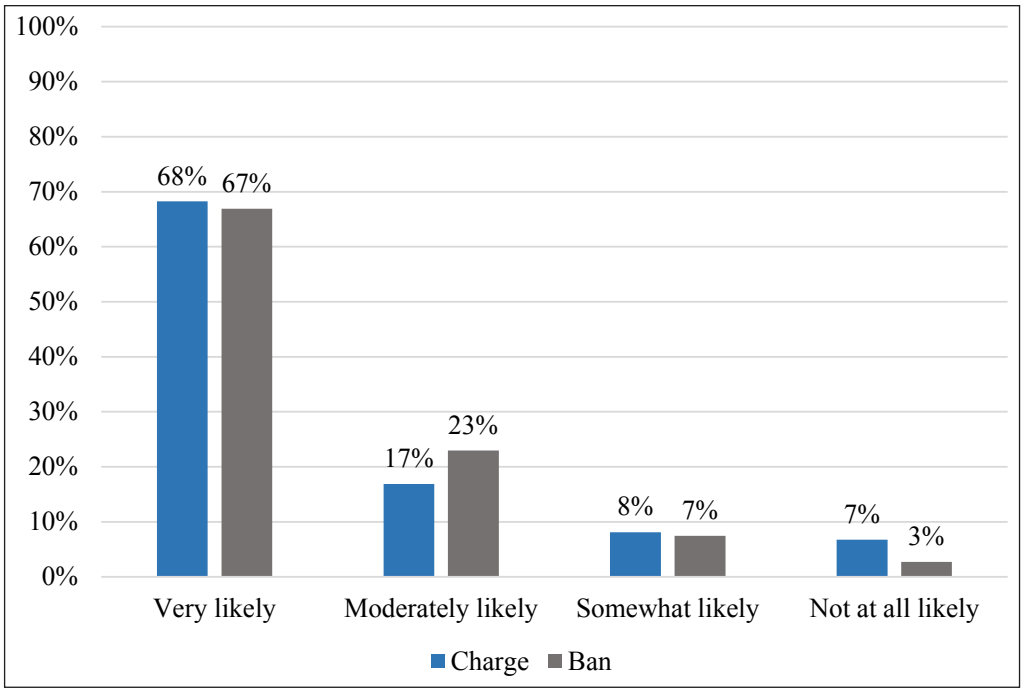

Figure 2. Customer support for businesses reducing the accessibility of single-use plastic bags.

helping 15% of customers. Twenty-two percent of respondents stated none of the items were helpful at reminding them to bring their own bags (Figure 4). Sixty-eight percent of survey respondents said signs were helpful at getting them to bring their own bags from their cars (Figure 5).

Customer Response to Storewide Bag Ban (Clothing Resale Store)

Through an online survey (Appendix A) with shoppers at the clothing resale store and interviews with store staff, it was determined that customers will continue to shop and purchase items from a store that no longer offers any bag type (plastic, paper, or reusable). This survey had additional questions than the Appendix B survey and asked specific questions about the clothing resale store's bagless initiative. The survey was sent to 2,049 customers who enrolled in the online messaging platform for the store. Seventy-four people responded to the survey for a response rate of 3.6%. The majority (80%) of store customers who took the survey were very supportive of the storewide bag ban. The remaining customers were moderately supportive (10%), somewhat supportive (7%), and not at all supportive (3%). Since the store no longer offers plastic bags to customers, they were asked which options they preferred to use for carrying items. Of the options offered in the survey, 82% of responses support the option to bring their own bag, 69% are willing to hand carry items, 57% support being given a reusable bag once to reuse, 34% support having their items wrapped in string (current store offering), 26% support receiving a reusable bag each time they shop, and 22% suggest the store go back to offering plastic bags (Figure 6).

Customers were asked to provide comments on the storewide plastic bag ban. The responses were coded using descriptive coding methods outlined by Corbin and Strauss (1998) and Saldana (2013).

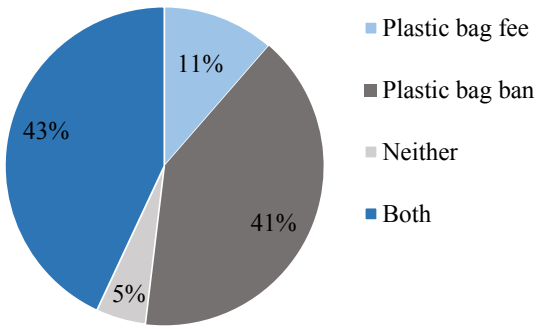

Figure 3. Support for legislation reducing the accessibility of single-use plastic bags at stores.

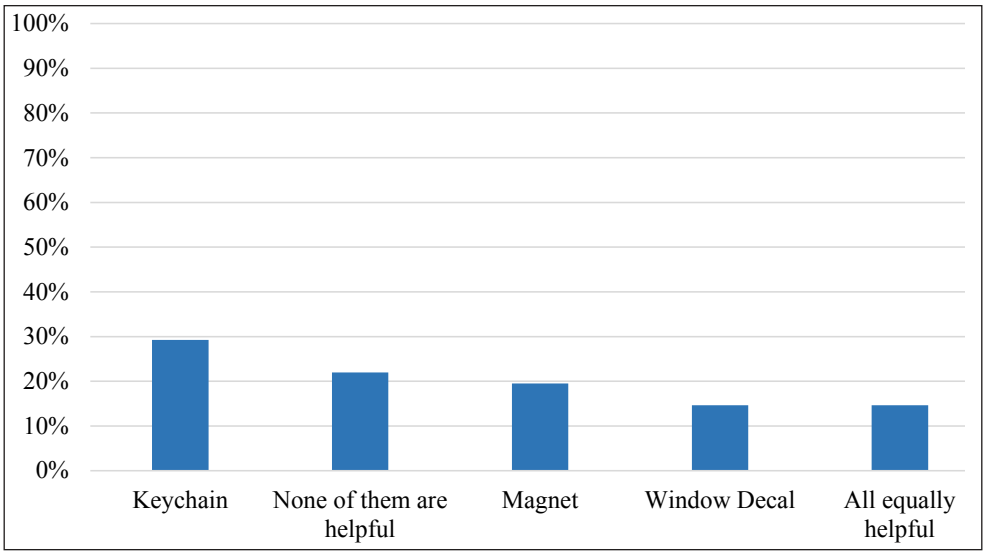

Figure 4. Effectiveness of reminder items taken by store customers.

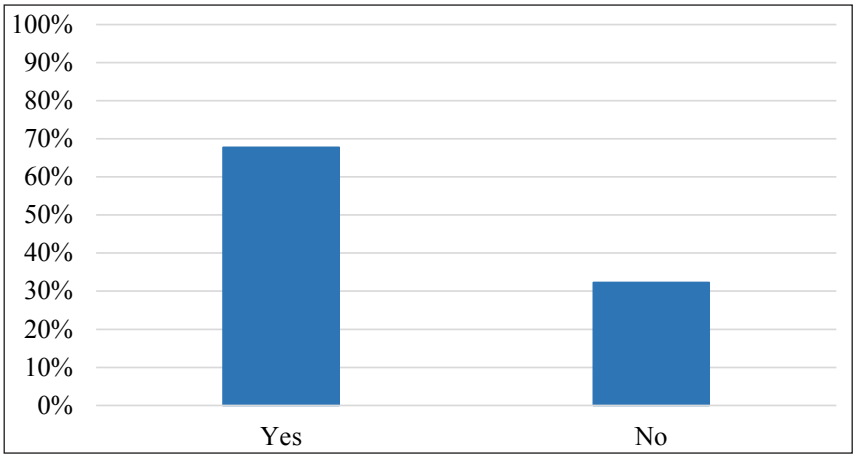

Figure 5. Effectiveness of the signs given to stores.

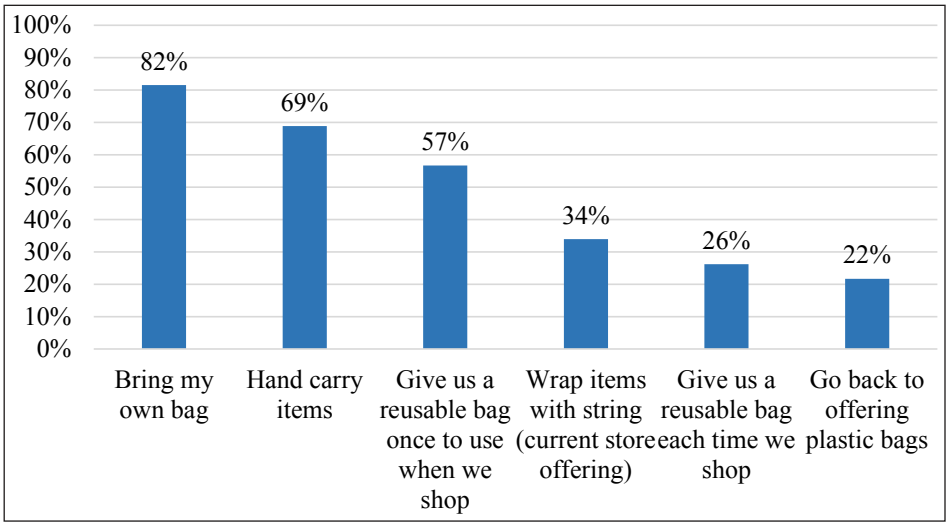

Figure 6. Customer support for options offered by the store to carry purchased items.

Nineteen respondents offered comments coded into the following three categories: supportive of the bag ban, neutral, or not supportive of the bag ban. After coding the comments, we found 68% provided feedback in support of the bag ban with some customers stating:

"*Love it.*"

"*This helps solidify the idea so I might remember to take my bags into other stores.*"

"*I think if forced to use reusable bags I would make the necessary adjustments to do so.*"

Eleven percent of comments were neutral on the subject and 21% of comments were unsupportive of the bag ban. Examples of negative comments include:

"*I just like bags. I DO NOT want to try and remember to bring a bag to a store…At least offer me a paper bag or a $1 bag to buy.*"

"*Sometimes it can be awful without a bag if you are purchasing a lot of items and do not have a bag to put your items in.*"

"*It's one thing to stop plastic waste in water; but it's just downright unsanitary to walk out of a clothing store and bring clothing you've just purchased like a thief.*"

Survey Respondent Demographics

Survey respondents recruited via the grocery stores self-reported demographics at the end of their survey. Respondents primarily ranged in age from 35-74, were Caucasian females, with at least some college education and an average household income of at least $25,000. Customers from the clothing resale store also self-reported their demographics. Clothing resale store survey respondents identified as female only, in the age range of 25-44, with half of the respondents identifying as Caucasian and one-third of respondents identifying as African American. Respondents had at least some college learning and there was an even distribution in income ranges. Survey respondents, for the most part, were environmentally aware (very aware = 40%, somewhat aware = 49%, a little aware = 8%, not at all aware = 3%) with almost all respondents familiar with the amount of plastic pollution in our waterways (very familiar = 44%, somewhat familiar = 33%, a little familiar = 18%, not at all familiar = 5%), and familiar with the effects of plastic pollution on wildlife, human health, and water quality (very familiar = 46%, somewhat familiar = 36%, a little familiar = 16%, not at all familiar = 2%).

Clothing Resale Store Staff Interviews

To assess customer response and staff experience, interviews with seven of the store staff were conducted. Staff interviewed were serving in various positions within the store such as owner, manager, and cashier, and have been with the store for varied amounts of time from one month to several years. Interview questions focused on customer response to the store bagless initiative and advice offered to other businesses who want to adopt pro-environmental business practices.

Of the staff interviewed, all gave similar responses to the questions. When questioned about customer response it was noted that most customers (staff estimate over 75%) are accepting of the bag ban with a few customers being angry. When asked to provide quotes about customer support for, or against, the bagless initiative staff often gave similar responses.

"*Most comments are positive, and they say how good it is that we are bagless.*"

"*Most are fine with it; some are enthusiastic about it. Very few get upset.*"

Staff did note that some African American customers were concerned about not receiving a bag out of fear of being accused of stealing if they do not have a bag and paper receipt from the store to prove their purchase. Staff also indicated that most elderly customers preferred to receive a bag (as opposed to younger customers who were indifferent). Those who take public transportation prefer a bag because it is harder for them to carry items on the bus without a bag. Giving all customers time to adjust was noted as an important way to introduce the new initiative.

The interviews also determined that the store was not losing or gaining customers or seeing a decline or increase in profits because of the bagless initiative.

"*We have not lost customers and they feel offended in the moment, but we offer cheap clothes, so they get over it. If it were very*

upscale it may be different. We have not gained customers because of the bagless initiative."

"*No. No one walked away because they did not get a bag. No. No one is buying more because of the initiative.*"

"*No, we have not lost any customers, the store is growing like crazy (though I do not think it has to do with the bagless stance).*"

Staff were asked how they successfully went bagless and kept a customer base.

"*I think our owner has a strong vision and* [is] *very committed to what she believes in so that made it happen successfully and we got our customers to support what we're doing and cooperate very well.*"

"*Now is the time! As it (countywide bag ban)* [is] *coming to most areas near us, starting to prepare your clientele now is a great service. It makes them aware and gives them time to be adequately prepared.*"

"*Knowing why. If we were just going bagless because the owner wanted to save money it would be harder. We sometimes feel embarrassed telling people who have spent money that we cannot give them a bag. The training* [on the issue of plastic pollution] *helped you understand the why…*"

When asked to offer advice to other stores about going bagless, the staff were positive it can be done elsewhere. Most mentioned the importance of letting customers know about the removal of bags, educating them on the issue of plastic pollution so they understand why bags have been removed from the store, and giving them time to adjust.

"*Place signs, do some social media, training employees on the issues and keep training them so that they are true advocates.*"

"*…educating customers*."

Waste Management Issues for Single-use Plastic Bags

Plastic bags cannot be recycled in curbside recycling in northeast Ohio and must be taken to a store that offers plastic film recycling. There are approximately 200-250 retail store locations within a 60-mile radius of the study area for this project that offer plastic film recycling (American Chemistry Council 2021). Interviews were conducted with the two solid waste districts (SWD) within the study area: Cuyahoga County and Lake County SWDs. Representatives from the SWDs were asked about the financial costs associated with processing plastic bags sent to landfills (entities processing curbside trash) and Materials Recovery Facilities (MRF) (entities processing curbside recycling). Financial costs and processing issues arise when items in curbside recycling are placed in plastic bags or plastic bags themselves are placed in the curbside recycling bin.

"*Plastic bags and potentially recycled material in plastic bags have to be removed from the process at the facilities. They tangle around the sorting equipment, cause equipment downtime and increasing the expense of recycling efforts.*"

Plastic bags can be recycled at local grocery stores and large retails stores (e.g., Kohls, Target, Walmart) that offer plastic film recycling in northeast Ohio. However, very few plastic bags are taken to plastic film drop offs and those that are taken often do not get recycled. Plastic bags sent to the landfill will not be sorted and thus are not able to be recycled.

"*Only 1% of all bags get recycled in retail drop-offs. The rest end up as plastic pollution or in landfills.*" (personal interview, Carin Miller, Cuyahoga County Solid Waste District, January 12, 2021)

Not only do plastic bags cause equipment issues at landfills and MRFs, but they are also costly to manage. The cost to process one ton of landfill material is $41-50 per ton. According to SWD employees, plastic bags comprise 1.4% of the waste stream sent to landfill in Cuyahoga County, equaling 7,061 tons of bags and costing taxpayers $300,000 per year (personal interview, Carin Miller, Cuyahoga County Solid Waste District, January 12, 2021). Bags sent to plastic film recycling facilities will be used to make plastic composite lumber. With a weakened plastic structure and polymer contamination from the recycling process (Demets et al. 2021), plastic composite lumber is not a material that can be recycled and must be landfilled at the end of its lifecycle.

Discussion

Access to Reusable Bags

Consumers have access to their own reusable bags when shopping; however, they forget to bring them into the store (Bartolotta and Hardy 2018). Even if they are given reusable bags to use when shopping, it does not guarantee customers will remember to bring the bags (Hardy and Bartolotta 2021). The best method for getting people to use their own bags is not giving them more reusable bags but helping them remember to bring the bags they already own. However, based on concerns mentioned by clothing resale store staff in their interviews, removal of bags, which can serve as a proof of purchase, may negatively affect communities who are racially profiled for felonious behavior. Removal of bags from a store may also negatively impact those who require a bag to carry items to their car (elderly or persons with disabilities) or those taking public transportation. To our knowledge this is the first study that identifies potential risks associated with plastic bag ban initiatives on certain communities. We continue to suggest policies that limit free access to plastic bags with the caveat of extensive public outreach to and involvement of all racial, age, economic, and persons with disability communities.

Effectiveness of Outreach and Potential Policies

Signs in the store entrance were seen as an effective tool for reminding customers to grab their own bags from their car. However, this reminder strategy is not effective if the person forgets their bags at home. Signs should be used but should not be the only tool used to reduce plastic bag consumption. Store outreach, with customer education and the use of reminder items, and initial bag ban implementation were not seen as effective measures for getting customers to use fewer plastic bags because they were not publicized broadly, and the bag ban was five months away from the enforcement phase. Plastic reduction policies (ban or fee) are effective at reducing the use of plastic bags when there is effective public engagement and strict enforcement (Zhu 2011; Miller 2012; Rivers et al. 2017; Bharadwaj et al. 2021). Results from this study show that voluntary plastic bag reduction by customers is not seen as a successful strategy for reducing the use of plastic bags, as has been suggested by similar studies in the literature (Sharp et al. 2010; Miller 2012). Therefore, other strategies need to be considered. Strategy suggestions include a phone application alerting customers to grab their bags when they enter a store parking lot, placement of bags near car keys or face masks, and lastly, consequences for customers if they do not have their own bag. In most areas in the United States, customers are not affected if they do not bring their own bag into the store because plastic bags are freely available. If no plastic bags were available or there was a fee for use, customer behavior would be encouraged to change because of the incurred consequences. Currently, because of the pandemic, customers are experiencing consequences if they do not wear a mask in some stores across the United States. If a customer does not have a mask (behavior), they may not be able to enter the store (adverse stimulus) leading to a negative reinforcement scenario. Negative reinforcement occurs when a behavior (forgetting mask) leads to an adverse response or stimulus (possibility of not being able to enter the store). Behavior will strengthen as a result of negative reinforcement because the individual will want to avoid an unpleasant experience in the future (Skinner 1938). If we apply this same logic to the use of reusable bags, evidence suggests customers will alter behavior and bring their own bags or other carrying options into the store because they want to avoid possible consequences (i.e., inability to carry items out of the store or increased money spent to purchase a bag). Bag bans or bag fees are recommended as the most effective way to reduce the use of plastics bags, as supported by results from this study, and studies conducted around the world (Clapp and Swanston 2009; Sharp et al. 2010; Zhu 2011; Martinho et al. 2017; Rivers et al. 2017; Bartolotta and Hardy 2018; Hardy and Bartolotta 2021).

Customer Support for Plastic Bag Reduction Policies

To effectively implement a successful plastic bag reduction campaign there must be widespread support for the initiative. As evidenced in this study (with self-selected participants) and supported by

two other studies in northeast Ohio (Bartolotta and Hardy 2018; Hardy and Bartolotta 2021), consumers support policies or businesses that seek to reduce the free availability of plastic bags. How a more general sampling of survey participants would respond is unknown since other studies documenting support for plastic bans do not exist in the literature for the Midwest/Great Lakes region of the United States. However, we can look to other U.S. and global studies to better understand support for plastic bag bans. A study conducted in Rhode Island, with self-selecting participants by Costa (2020), shows similar support rates to our study for plastic bag bans from residents with a bag ban already in place (88%) and residents without a bag ban already in place (82%). One study from Australia, conducted in major store chains, with a more randomized sample, demonstrates a lower support rate (58%) for bag bans at the beginning of a bag ban than our study, and a support rate of 68% eight years into the bag ban (Macintosh et al. 2020). For any policy to be successful, extensive outreach to the affected community must occur for plastic bag ban or fee programs to be successful (Bezerra et al. 2021).

Legislative Support for Plastic Bag Reduction Policies

With an increase in environmental concern for the over and misuse of plastics, municipalities and entire countries are implementing plastic bag reduction policies (Clapp and Swanston 2009). As of 2020, nine U.S. states have bans or restrictions on plastic bag use and 13 states have local ordinances pertaining to bag use (Sea Grant Law Center 2020). In contrast, 15 U.S. states are implementing bag ban preemption laws (Sea Grant Law Center 2020) preventing local governments from enforcing plastic bag bans or bans on other single-use plastic items such as Styrofoam or carryout containers. Recently, Ohio is in the process of eliminating the local plastic bag ban for Cuyahoga County, which has currently been paused by the Governor because of the pandemic. The establishment of preemption laws in Ohio is contrary to what has been shown by several studies in Ohio (Bartolotta and Hardy 2018; Hardy and Bartolotta 2021), including this study, which shows survey respondents are in favor of bag ban or fee legislative policies. Results from these pro-environmental legislative studies have been shared with decision-makers as well as statewide advocacy groups to no avail. Pro plastic and oil lobbying organizations are very powerful in Ohio, and they have been successful at preventing municipalities from implementing plastic ban policies.

Plastic Bag Recycling

Recycling is not seen as a viable option for most plastics, especially low value plastics like plastic bags. As evidenced by interviews with solid waste professionals in this study, a small percentage of bags are sent to be recycled in northeast Ohio, with only 5% of the 1 trillion bags used in the United States being sent for recycling each year (Sivan 2011). Plastics that are recycled are often of low value (Alabi et al. 2019) and therefore, it is often cheaper to make items out of virgin plastic than recycled plastics. Since plastic bags are made of plastic film, they are considered low value and not a desirable material for recycling (Clapp and Swanston 2009). Therefore, a switch away from plastic bags is needed because they are a single-use plastic item, with little market value. There are more sustainable alternatives such as organic cotton bags or the use of bag-like items you already own.

Conclusion

Plastic bags are commonly found in the environment negatively affecting water quality and human and wildlife health and safety. They are costly to manage at the end of their lifecycle, costing taxpayers hundreds of thousands of dollars annually. A simple solution is reusable bags - a readily available and inexpensive alternative that many consumers already own. Yet, voluntary actions by consumers to limit their plastic bag use are not occurring because there are no consequences as plastic bags are readily available for free. Outreach to educate customers and the early implementation phase of a countywide plastic bag ban were not seen as effective tools at limiting use of plastic bags. Therefore, enforced bag reduction policies at the business and government level are important and supported by participants in this study.

A clothing resale store, which adopted a bagless initiative, has seen positive responses from

customers and has not seen a decline in profits or customer base. Educating staff and customers about plastic pollution is seen as an important measure for businesses to take when adopting pro-environmental business practices. Informing customers of upcoming bag ban or bag fee initiatives and giving them time to adjust is another important step in attaining customer support for plastic bag reduction strategies. This practice can be especially important to customers of color, disabled shoppers, the elderly, and users of public transportation. Our study identified concerns around bagless initiatives creating potential risks when these customers take items out of the store without a bag or receipt for proof of purchase. Moving forward, digital strategies proving purchase and encouraging consumers to bring their own bags from their home or car and into the store are needed, as well as the gradual implementation and eventual enforcement of plastic bag reduction government policies or business initiatives.

While we feel this project offers a compelling contribution to work on reducing plastic pollution, especially plastic carrier bags, limitations for this study include a small sample size for survey responses and a bias toward the Caucasian, middle aged population for bag observation. Most respondents had some awareness about the issue of plastics bags in the environment, potentially skewing results as well. Future studies can address these limitations through random instead of self-selection for survey participants, sampling (observation, surveys, and interviews) at more stores with a larger customer base and more diverse clientele, and comparison of results from a smaller store with a larger store. Moreover, additional research is needed to better understand the potential negative impact of bag bans on people of color, elderly, disabled, and users of public transportation, and how retailers and policy makers can support them while also reducing plastic bag use.

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Appendix A: Clothing Resale Store Survey

The Ohio State University Consent to Participate in Research

Study Title: Behavior change and marine debris: What strategies work best to encourage reusable bags instead of single use plastic bags?

Protocol Number: 2019E0438

Researchers: Jill Bartolotta and Scott Hardy, Ph.D.

Sponsor: National Oceanic and Atmospheric Administration

This is a consent form for research participation. It contains important information about this study and what to expect if you decide to participate. Your participation is voluntary. Please consider the information carefully. Feel free to ask questions before making your decision whether or not to participate.

Purpose: This study seeks to determine the effectiveness of education and reminder strategies to encourage people to use reusable bags when they go shopping.

Procedures/Tasks: As a customer of Revolve Kids, you are being asked to complete an online survey. The survey includes questions about your awareness of environmental issues and your willingness to support a bagless store initiative.

Duration: The survey should take no more than 10-15 minutes to complete. You can skip any questions if you prefer not to answer. You may leave the study at any time. If you decide to stop participating in the study, there will be no penalty to you, and you will not lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.

Risks and Benefits: Although risks are minimal in this study, several questions about your demographics are asked. You can skip or choose the "Prefer not to answer" option if desired. There are some questions you cannot skip since they must be answered in a certain order. Individual responses will only be identifiable in aggregate, yet may be traceable to respondents depending on trends within the results. Given the low level of risk associated with the project, the anticipated benefits to participants compare quite favorably. The information from this study will be used to help Revolve Kids reduce their impact on the environment. They will also serve as a model to other businesses in the area. The health, aesthetic, economic, and wildlife benefits that derive from having trash free living environments will outweigh the minimal risk associated with participating in the online survey.

Confidentiality: We will work to make sure that no one sees your online responses without approval. But, because we are using the Internet, there is a chance that someone could access your online responses without permission. In some cases, this information could be used to identify you. Also, there may be circumstances where this information must be released. For example, personal information regarding your participation in this study may be disclosed if required by state law. Also, your records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
- The sponsor, if any, or agency (including the Food and Drug Administration for FDA-regulated research) supporting the study.

Future Research: Your de-identified information may be shared with other researchers interested in conducting similar work, for use in a research publication, or as requested or required by the funding agency.

Incentives: You will receive 20% off one full price item. The discount is available for use one time and will expire on August 15, 2019. Those who complete the survey will be asked to provide their name and number so store staff know who is eligible to receive the 20% off discount. Only those who complete the survey and provide their contact information are eligible to receive 20% off. By law, payments to participants are considered taxable income.

Participant Rights: You may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled. If you are a student or employee at Ohio State, your decision will not affect your grades or employment status. If you choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By agreeing to participate, you do not give up any personal legal rights you may have as a participant in this study. This study has been determined exempt from IRB review.

Contacts and Questions: For questions, concerns, or complaints about the study you may contact Jill Bartolotta at bartolotta.2@osu.edu or 440-350-2267, or Scott Hardy at hardy.116@osu.edu. For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact the Office of Responsible Research Practices at 1-800-678-6251 or hsconcerns@osu.edu.

Providing consent: I have read (or someone has read to me) this page and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study. I am not giving up any legal rights by agreeing to participate. To print or save a copy of this page, select the print button on your web browser.

Please click the button below to proceed and participate in this study. If you do not wish to participate, please close out your browser window.

Environmental Awareness

How environmentally friendly do you consider yourself?

- o Very environmentally friendly
- o Somewhat environmentally friendly
- o A little environmentally friendly
- o Not at all environmentally friendly

How familiar are you with the amount of plastic pollution in waterways?

- o Very familiar
- o Moderately familiar
- o Slightly familiar
- o Not familiar at all

How familiar are you with the effects of plastic pollution on wildlife, human health, and water quality?

- o Very familiar
- o Moderately familiar
- o Slightly familiar
- o Not familiar at all

Use of Shopping Bags

On average how many pieces of plastic trash to you throw away each day?

- o 0
- o 1-5
- o 6-10
- o 11-15
- o 16-20
- o 21 or more

On average how many disposable plastic bags do you use on one shopping trip to the grocery store?

- o 0
- o 1-3
- o 4-6
- o 7-9
- o 10 or more

On average how many disposable plastic bags do you use on one shopping trip to the clothing store?

- o 0
- o 1-3
- o 4-6
- o 7-9
- o 10 or more

Does your household recycle plastic bags?

- o Yes
- o No
- o Do not use them.

If yes, where? (Please select all that apply.)

- o In my curbside recycling.
- o I take them to a grocery store recycling bin.
- o I take them to the recycling center.
- o I use them to make artwork.
- o I use them to line my garbage bins.
- o I use them to pick up pet waste.
- o Other (please explain).

Use of Reusable Bags

Do you have access to reusable bags for shopping?

- o Yes
- o No

If no, why don't you have access to reusable bags? (Please select all that apply.)

- o I do not like to use them.
- o I cannot afford to buy them so I do not have any.
- o I have never considered using them.
- o Other (please explain).

If yes, how many reusable bags do you own?

- o 1-5
- o 6-10
- o 11-15
- o 16-20
- o 21 or more

If yes, which types of reusable bags to you prefer? (Please select all that apply.)

- o Cotton
- o Plastic lined bags
- o Thermal bags for keeping items hot or cold
- o Other (please explain).

On average, how many reusable bags do you use on one shopping trip to the grocery store?

- o 0
- o 1-3
- o 4-6
- o 7-9
- o 10 or more

On average, how many reusable bags do you use on one shopping trip to the clothing store?

- o 0
- o 1-3
- o 4-6
- o 7-9
- o 10 or more

What prevents you from always using your reusable bags? (Please select all that apply.)

- o I always use reusable bags.
- o They are not suitable for the items I carry.
- o I do not think they are clean or sanitary.
- o I take public transportation and do not want to carry them with me.
- o I forget them at home.
- o I forget them in the car.
- o My friends and family do not use them so I do not use them.
- o I use the plastic bag I get from the store to pick up pet waste.
- o I use the plastic bag from the store to line my garbage bins.
- o I use the plastic bag to make art pieces.
- o I like getting a bag that shows the logos or brand names of where I shop.
- o I am spending money at the store and deserve to be given something to put my items in.
- o Other (please explain).

Bagless Initiative at Revolve Kids

Are you aware Revolve Kids has gone bagless as of March 1, 2019, meaning they will no longer offer you a disposable plastic bag for the items your purchase?

- o Yes
- o No

If you are aware that Revolve Kids has gone bagless, how supportive are you of this change?

- o Very supportive
- o Moderately supportive
- o Somewhat supportive
- o Not at all supportive

Which options do you prefer Revolve Kids provide for you to carry your purchased items?

	Prefer	Do not prefer
I will hand carry my items.	o	o
I will bring my own bag.	o	o
I would like my items wrapped together with string.	o	o
I would like Revolve Kids to give customers a reusable bag once that I can use each time I shop.	o	o
I would like Revolve Kids to provide reusable bags to customers with every purchase.	o	o
I would like Revolve Kids to offer disposable plastic bags.	o	o

Please use the space below to offer any thoughts and opinions on the bagless initiative at Revolve Kids.

Environmental Friendliness of Other Businesses

How important is it for businesses to take action to make less of an impact on the environment?

- o Very important
- o Moderately important
- o Somewhat important
- o Not at all important

How likely are you to support a business that no longer offers disposable plastic bags for free, but will charge you for them?

- o Very likely
- o Moderately likely
- o Somewhat likely
- o Not at all likely

How likely are you to support a business that no longer offers any disposable bags in the store?

- o Very likely
- o Moderately likely
- o Somewhat likely
- o Not at all likely

Demographics

We are collecting this information to help inform our communication with customers.

What is your age?

- o 18 - 24
- o 25 - 34
- o 35 - 44
- o 45 - 54
- o 55 - 64
- o 65 - 74
- o 75 - 84
- o 85 or older
- o Prefer not to answer

What is your race/ethnicity?

- o White or Caucasian
- o Black or African American
- o American Indian or Alaska Native
- o Asian
- o Native Hawaiian or Pacific Islander
- o Hispanic or Latino
- o Other
- o Prefer not to answer

What is your gender?

- o Male
- o Female
- o Transgender
- o Gender Neutral
- o Gender Non-conforming
- o Prefer not to answer

What is your highest level of education obtained?

- o Less than high school
- o High school graduate
- o Some college
- o 2 year degree
- o 4 year degree
- o Master's degree
- o Professional degree
- o Doctorate

What is your average household income level?

- o Less than $24,999
- o $25,000-$44,999
- o $45,000-$54,999
- o $55,000-$74,999
- o $75,000-$94,999
- o $95,000-$114,999
- o $115,000-$134,999
- o $135,000 or more
- o Prefer not to answer

Coupon and Continued Involvement

If you would like to help Revolve Kids spread the word about plastic pollution awareness or participate in outreach events such as beach cleanups, please provide your information below. If not, leave it blank. (Your contact information will be used to help the owner of the store, Felice Pierce, reach out to you. The information will not be shared.)

- o Name _____
- o Phone Number _____
- o Email _____

All those who complete the survey will receive 20% off one full priced item from Revolve Kids. The discount is available for use one time and will expire on August 23, 2019. Please provide the information below so store staff can keep track of who is eligible to receive the discount.

- o Name _____
- o Phone Number _____
- o Email _____

To receive your 20% off one full priced item from Revolve Kids please reference the code **Bagless Survey OSU** when you visit the store to make your purchase.

Appendix B: Plastic Bag Survey for Grocery Stores

The Ohio State University Consent to Participate in Research

Study Title: Behavior change and marine debris: What strategies work best to encourage reusable bags instead of single use plastic bags?

Researchers: Scott Hardy, Ph.D., and Jill Bartolotta

Sponsor: Ohio Sea Grant College Program

This is a consent form for research participation. It contains important information about this study and what to expect if you decide to participate. Your participation is voluntary. Please consider the information carefully. Feel free to ask questions before making your decision whether or not to participate.

Purpose: This study seeks to determine the effectiveness of education and reminder strategies to encourage people to use reusable bags when they go shopping.

Procedures/Tasks: An Internet survey will be sent to visitors to Produce Place and Sun Plum Market and those who attended Ohio Sea Grant Programming. Questions will prompt respondents about their awareness of environmental issues and use of bags to carry items purchased at the store.

Duration: The survey should take no more than 15 minutes to complete. You can skip any questions if you prefer not to answer. If you decide to stop participating in the study, there will be no penalty to you, and you will not lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.

Risks and Benefits: Although risks are minimal in this study, several questions about your demographics are asked. You can skip or choose the "Prefer not to answer" option if desired. Individual responses will only be identifiable in aggregate, yet may be traceable to respondents depending on trends within the results. Given the low level of risk associated with the project, the anticipated benefits to participants compare quite favorably. The information from this study will be used to help inform bag use and possible strategies to encourage use of reusable bags. The health, aesthetic, economic, and wildlife benefits that derive from having trash free living environments will outweigh the minimal risk associated with participating in the online survey.

Confidentiality: We will work to make sure that no one sees your survey responses without approval. However, because we are using the Internet, there is a chance that someone could access your online responses without permission. In some cases, this information could be used to identify you. We will work to make sure that no one sees your survey responses without approval. Your de-identified information may be used or shared with other researchers without your additional informed consent. There may also be circumstances where this information must be released. For example, personal information regarding your participation in this study may be disclosed if required by state law. Also, your records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
- The sponsor, if any, or agency (including the Food and Drug Administration for FDA-regulated research) supporting the study.

Incentives: There are no incentives to participate in this study.

Participant Rights: You may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled. If you are a student or employee at Ohio State, your decision will not affect your grades or employment status. If you choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form, you do not give up any personal legal rights you may have as a participant in this study. This study has been determined exempt from the IRB Review. IRB Exemption Number: 2019E075.

Contacts and Questions: For questions, concerns, or complaints about the study, or you feel you have been harmed as a result of study participation, you may contact Scott Hardy via email at hardy.116@osu.edu, or telephone at 216-368-2588, or Jill Bartolotta via email at bartolotta.2@osu.edu, or telephone at 440-350-2267. For questions about your rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in The OSU Office of Responsible Research Practices at 1-800-678-6251.

Signing the consent form: I have read (or someone has read to me) this form and I am aware that I am being asked to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to participate in this study.

By continuing into the survey you are agreeing to participate in this research.

Environmental Awareness

How environmentally friendly do you consider yourself?

- o Very environmentally friendly
- o Moderately environmentally friendly
- o A little environmentally friendly
- o Not at all environmentally friendly

How familiar are you with the effects of plastic pollution on wildlife, human health, and water quality?

- o Very familiar
- o Moderately familiar
- o Somewhat familiar
- o Not at all familiar

How familiar are you with the amount of plastic pollution in waterways?

- o Very familiar
- o Moderately familiar
- o Somewhat familiar
- o Not at all familiar

Do you have access to reusable bags for shopping?

- o Yes
- o No

If no, why don't you have access to reusable bags?

- o I do not like to use them.
- o I cannot afford to buy them.
- o I have never considered using them.

If yes, how many reusable bags do you own?

- o 1-5
- o 6-10
- o 11-15
- o 16-20
- o 20 or more

If yes, how often do you use these bags when you shop?

- o Always
- o Most of the time
- o Some of the time
- o Never

What prevents you from always using your reusable bags? (Select all that apply.)

- o They are not suitable for the items I carry.
- o I do not think they are clean or sanitary.
- o I take public transportation and do not want to carry them with me.
- o I forget them at home.
- o I forget them in the car.
- o My friends and family do not use them so I do not use them.
- o I use the plastic bag I get from the store to pick up pet waste.
- o I use the plastic bag from the store to line my garbage bins.
- o I use the plastic bag to make art pieces.

Reusable Bag Reminders

Did you receive one of these reminder items in the picture above from Ohio Sea Grant?

- o Yes
- o No

Have you placed the reminder items in a place that is reminding to use your own reusable bags?

- o Yes
- o No

If yes, where have you placed them? (Please select all that apply.)

- o My car
- o My keys
- o In my purse or bag
- o On my refrigerator
- o On a door leading out of my house
- o Other (please specify).

If no, why haven't you used them? (Please select all that apply.)

- o I forgot.
- o I lost it.
- o I did not like it.
- o It was too big.
- o It was not helping me remember to bring my bags.
- o Other (please specify).

Which items are the most effective at reminding you to bring your bags? (Please select all that apply.)

- o Magnet
- o Keychain
- o Window decal
- o All equally helpful
- o None of them are helpful

Before you had these reminder items, how often did you use reusable bags?

- o Always
- o Most of the time
- o Some of the time
- o Never

Now that you have these reminder items, how often do you use reusable bags?

- o Always
- o Most of the time
- o Some of the time
- o Never

Have you seen these signs at the store or other signs reminding you to grab your bags?

- o Yes
- o No

Are they helpful at reminding you to bring your own bag?

- o Yes
- o No

If no, why not?

- o I am already in the store and do not want to go back to my car to get my bag.
- o I forget my bags at home and will not go back home to get them.
- o Other (please specify).

How much are you willing to pay for a single-use plastic bag from the store?

- o 1 cent
- o 5 cents
- o 10 cents
- o 25 cents
- o 50 cents
- o 1 dollar
- o 1 dollar or more

How much are you willing to pay for a paper bag from the store?

- o 1 cent
- o 5 cents
- o 10 cents
- o 25 cents
- o 50 cents
- o 1 dollar
- o 1 dollar or more

How much should a store offer off your purchase to encourage you to bring your own bags?

- o 1 cent
- o 5 cents
- o 10 cents
- o 25 cents
- o 50 cents
- o 1 dollar
- o 1 dollar or more

Support for Bagless Businesses

How important is it for businesses to take action make less of an impact on the environment?

- o Very important
- o Moderately important
- o Somewhat important
- o Not at all important

How likely are you to support a business that no longer offers bags for free but will charge you for them?

- o Very likely
- o Moderately likely
- o Somewhat likely
- o Not at all likely

How likely are you to support a business that no longer offers any bags?

- o Very likely
- o Moderately likely
- o Somewhat likely
- o Not at all likely

Of the following, which do you support?

- o Plastic bag ban
- o Plastic bag fee
- o Both
- o Neither

Demographics

In which Ohio county do you live?

- o Ashtabula
- o Lake
- o Cuyahoga
- o Geauga
- o Summit
- o Portage
- o Lorain
- o Medina
- o Other (please specify)
- o I do not live in Ohio.
- o Prefer not to answer

What is your zip code?

What is your age?

- o 18-24
- o 25-34

- o 35-44
- o 45-54
- o 55-64
- o 65-74
- o 75 and older
- o Prefer not to answer

What is your race? (Please select all that apply.)

- o White/Caucasian
- o Black/African American
- o Hispanic or Latino
- o Asian
- o American Indian or Alaskan Native
- o Native Hawaiian or Pacific Island
- o Other
- o Prefer not to answer

What is your gender?

- o Female
- o Male
- o Transgender
- o Gender Neutral
- o Gender Non-conforming
- o Prefer not to answer

What is your highest level of education obtained?

- o Less than high school
- o High school or GED
- o Some college
- o 2 year college degree
- o 4 year college degree
- o Master's Degree
- o Doctoral Degree
- o Professional Degree (ex. JD, MD)
- o Prefer not to answer

What is your average household income level?

- o Less than $24,999
- o $25,000-$44,999
- o $45,000-$54,999
- o $55,000-$74,999
- o $75,000-$94,999
- o $95,000-$114,999
- o $115,000-$134,999
- o $135,000 or more
- o Prefer not to answer

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"Putting Suppliers on the Map:" Centering Upstream Voices in Water Funds Outreach

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Abstract: As water funds and other watershed investment programs expand around the world, there is growing interest in designing equitable programs that provide both upstream and downstream benefits. While research demonstrates that diverse values underlie upstream participation, existing communication and outreach materials from non-governmental organizations (NGOs), governments, development banks, and others tend to highlight the goals of downstream actors (e.g., improving water supply for cities), with little attention to upstream perspectives. We present a case study in response to this gap, where we collaborated with a water fund and a river users association in Colombia to co-produce a website entitled "Putting Suppliers on the Map" in which interviews and photography illuminate the perspectives of upstream participants and the intermediary organization. The website offers multiple lessons for communication and environmental education in water funds by shifting focus to the motivations of upstream participants, including trust-building among upstream and downstream participants via intermediary actors, and informing downstream water users of the essential role of these processes for program success. Analyzing the website testimonials, we show that the vast majority of participants were motivated not only by overlapping instrumental and relational values associated with conservation, but also by a variety of personal and community goals. We found that the largest barrier to participation over time was the need to build trust between the water fund and rural communities and to align water fund goals with participants' motivations. By making visible the motivations and challenges of upstream actors, the website reverses the standard direction of environmental education (in which high-level actors or downstream groups educate upstream residents). In-so-doing, the website aims to help downstream actors envision more productive and equitable ways of interacting with upstream participants.

Keywords: *watershed protection, payments for ecosystem services, co-production, equity*

Water funds are a type of watershed investment program—also referred to as Payments for Ecosystem Services (PES) or Payments for Watershed Services (PWS)—that are becoming more common worldwide (Bennett and Ruef 2016; Salzman et al. 2018). In these programs, groups of watershed stakeholders financially support activities to protect and restore upstream watersheds (Goldman-Benner et al. 2012; Brauman et al. 2019). As programs have proliferated, so has interest in better understanding the upstream communities that participate in program activities (Pascual et al. 2014; Blundo-Canto et al. 2018).

Theoretical understanding of water funds and other watershed investment programs often focuses on financial incentives, conceptualizing programs as primarily economic instruments in which participation is contingent on appropriate payment (Wunder 2005). Research on upstream social outcomes, however, has generally found that non-monetary factors, such as environmental and social values, strongly influence participation (Bremer, Farley, and Lopez-Carr 2014; Arriagada et al.

Research Implications

- Collaborative research focused on creating useful products with local institutions can increase the visibility of upstream water fund participants' work, knowledge, and values.
- Co-production of communication and outreach materials positions upstream watershed actors as educators, rather than simply as recipients of financial conservation incentives.
- Co-producing water fund outreach and communication materials with upstream participants expands program narratives to better capture upstream perspectives.
- Upstream participants have complex and diverse motivations and strategies for participating that go far beyond financial and material factors.
- Intermediary organizations are fundamental to the success of water fund programs, as their education and outreach activities are central to recruitment, building trust among upstream participants, and implementation of projects.

2018; Bétrisey, Bastiaensen, and Mager 2018). In addition, water fund effectiveness increases when upstream stakeholders feel that programs provide them with equitable benefits (Pascual et al. 2014; Lliso, Pascual, and Engel 2021). These findings about upstream actors' motivations reveal the importance of better understanding these crucial program participants.

Outreach and educational materials for water funds tend to align with theoretical conceptualizations of watershed investment programs as financial mechanisms, and thus primarily focus on the generation of financial and political support by downstream actors. We reviewed the stated goals and audience of 14 reports from six watershed investment programs, including water funds, that were packaged for the general public (see SI Table 1). All explicitly state their purpose in engaging downstream communities and external investors—for example, "to help water sector stakeholders, policymakers, funders and financiers" (Trémolet and Karres 2020). In contrast, upstream participants are given less attention; only two of the reports we reviewed included upstream participants in their stated audience, and both of those address only U.S.-based programs.

Though engaging downstream actors in water funds is crucial, outreach and educational materials that obscure the role of upstream participants may influence social and environmental outcomes by leading to program designs that weaken enrollment, reduce upstream satisfaction, and undermine practices that sustain biodiversity (Bayrak and Marafa 2016; Blundo-Canto et al. 2018; Milne et al. 2019). Focusing primarily on downstream actors and motivations also raises important equity concerns around program design and outcomes (Corbera and Pascual 2012; Lliso, Pascual, and Engel 2021). For example, a focus on downstream values can influence: who bears the costs and who benefits from hydrological improvements (distributional equity); whose voices, values, and worldviews are represented in water funds design, decision-making, and research (recognitional equity); and whether it is possible for upstream participants, primarily small farmers and Indigenous communities, to participate in decision-making processes (procedural equity) (McDermott, Mahanty, and Schreckenberg 2013). Moreover, efforts to maximize conservation returns on investment for downstream stakeholders may channel payments to wealthy landowners and inadvertently exacerbate existing inequities, with potential impacts on program longevity (Wegner 2016; Loft et al. 2017).

Accordingly, to improve upstream outcomes and enhance program equity and durability, outreach and education materials must be expanded to better capture the motivations, challenges, and strategies of upstream actors and intermediaries. In addition to addressing some of the equity concerns discussed above, such outreach and education materials have the potential to address important "power blind spots" in ecosystem services programs that reduce program equity, including a lack of attention to labor relations in the co-production of ecosystem services (Berbés-Blázquez, González, and Pascual 2016).

We present a research communications project produced in collaboration with a water fund intermediary organization (a river users association) in the Cauca Valley of Colombia. Despite evidence

of the importance of intermediaries in water funds and other watershed investment programs (Pham et al. 2010; Bosselmann and Lund 2013), as with upstream actors, there has been little outreach and educational work highlighting the role of these institutions. In line with emerging trends in environmental education, including an emphasis on practices that engage with the digital world (Ardoin, Bowers, and Gaillard 2020), one of the major goals of this project was to produce an interactive website (Figure 1) that could serve as an educational tool targeting a range of actors, including international funders and NGOs as well as downstream actors—mainly sugarcane growers and other agricultural water users within the Cauca Valley. The collaborative research approach and product design aligns well with current understandings of environmental education as "a conservation strategy" that creates "synergistic spaces, facilitating opportunities for scientists, decision-makers, community members, and other stakeholders to converge" (Ardoin, Bowers, and Gaillard 2020, p. 1).

We first describe the study site and interview approach to examine upstream motivations for participation, their activities and labor towards the program, and the outcomes they expect. This is followed by an analysis of the web testimonials and the function of the website. We argue that by increasing the visibility of upstream actors' motivations and challenges, the website facilitates opportunities for downstream actors to envision more productive and equitable ways of interacting with upstream participants.

Methods

Study Site

Our study focuses on the Fundación Fondo Agua por la Vida y la Sostenibilidad (Water Fund for Life and Sustainability Foundation), a water fund located in the Cauca Valley, Colombia that was established by the Colombian Association of Cane Cultivators (Asocaña), The Nature Conservancy, and other partners in 2009 (Bremer et al. 2016; Nelson et al. 2020; Figure 2). The Cauca Valley is Colombia's main sugarcane-producing region (Pérez, Peña, and Alvarez 2011; Asocaña 2020; Nelson et al. 2020). Sugarcane is water-intensive, and in 2008 the industry held 64 percent of surface water concessions and 85 percent of groundwater concessions (Pérez, Peña, and Alvarez 2011, p. 157; p. 173). The area has a history of high environmental conflict over the industry's water consumption, with longstanding accusations of 'water grabbing' and displacement by the industry (Vélez Torres 2012; Vélez Torres and Varela 2014).

The importance of irrigation to sugarcane revenues (Asocaña 2011) and the risks posed by social and environmental pressures on the industry's water supplies have partially motivated its proactive approach to watershed conservation. At the core of the water fund are 15 (at the time of our research) river user associations established and funded by Asocaña starting in the late 1980s (Nelson et al. 2020). The associations collect user fees from water users, including sugarcane growers, sugar mills, ranchers, and other agroindustries. Along with other intermediary organizations, the associations are the "ejecutores en el campo" or on-the-ground implementers who work closely with upstream communities and land managers on activities designed to protect the watershed (see SI Table 2 for activities). The water fund was restructured as a foundation in 2016 (Nelson et al. 2020). The flow of funding for the water fund is illustrated in Figure 3.

Here, we specifically focus on the Agua Clara sub-watershed within the Bolo watershed, where one association, Asobolo, has worked for over 25 years (Figure 2). Over the five years preceding this work, the second author partnered with the water fund and Asobolo to help establish social and hydrologic monitoring, and in doing so built strong research-management relationships (Bremer et al. 2016; Game et al. 2018). The first and third authors have conducted previous research on the historical and social context of the water fund (Nelson et al. 2020).

The Cauca Valley, and the activities of the water fund and associations like Asobolo, have been deeply affected by the conflict between the Colombian government and the Fuerzas Armadas Revolucionarias de Colombia (FARC), which began in the 1960s (Sánchez and Palau Madriñán 2006). The Agua Clara sub-watershed has been considered relatively safe since the water fund started and has thus become a focus for research on

Figure 1. “Putting Suppliers on the Map” website images.

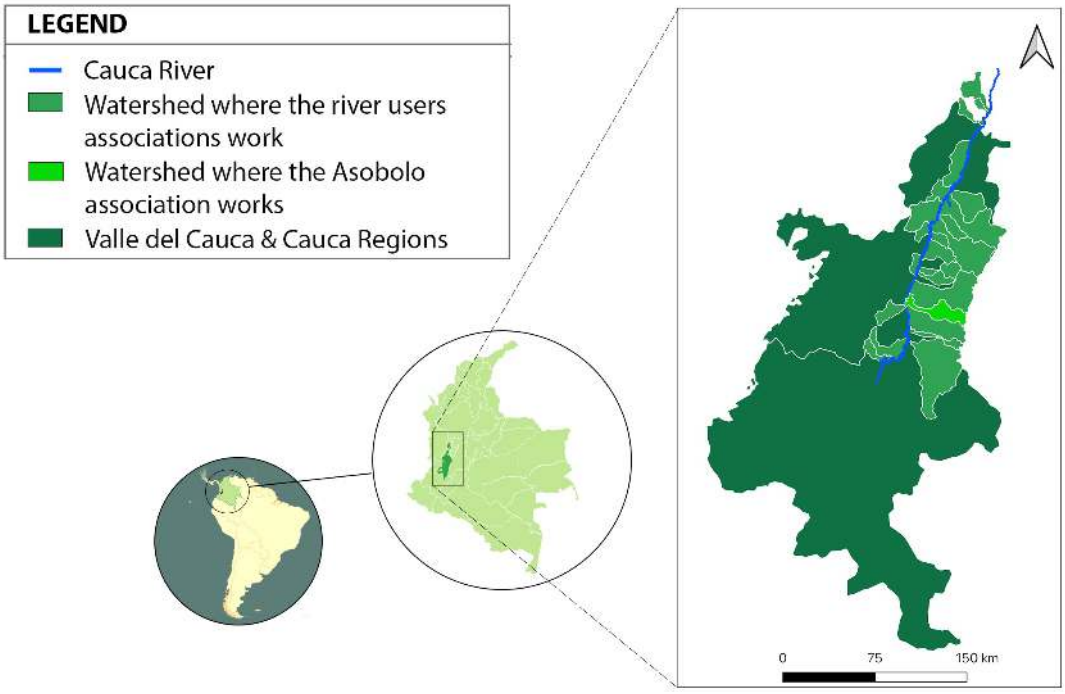

Figure 2. Watershed where the Fundación Fondo Agua por la Vida operates including the Bolo watershed where Asobolo works.

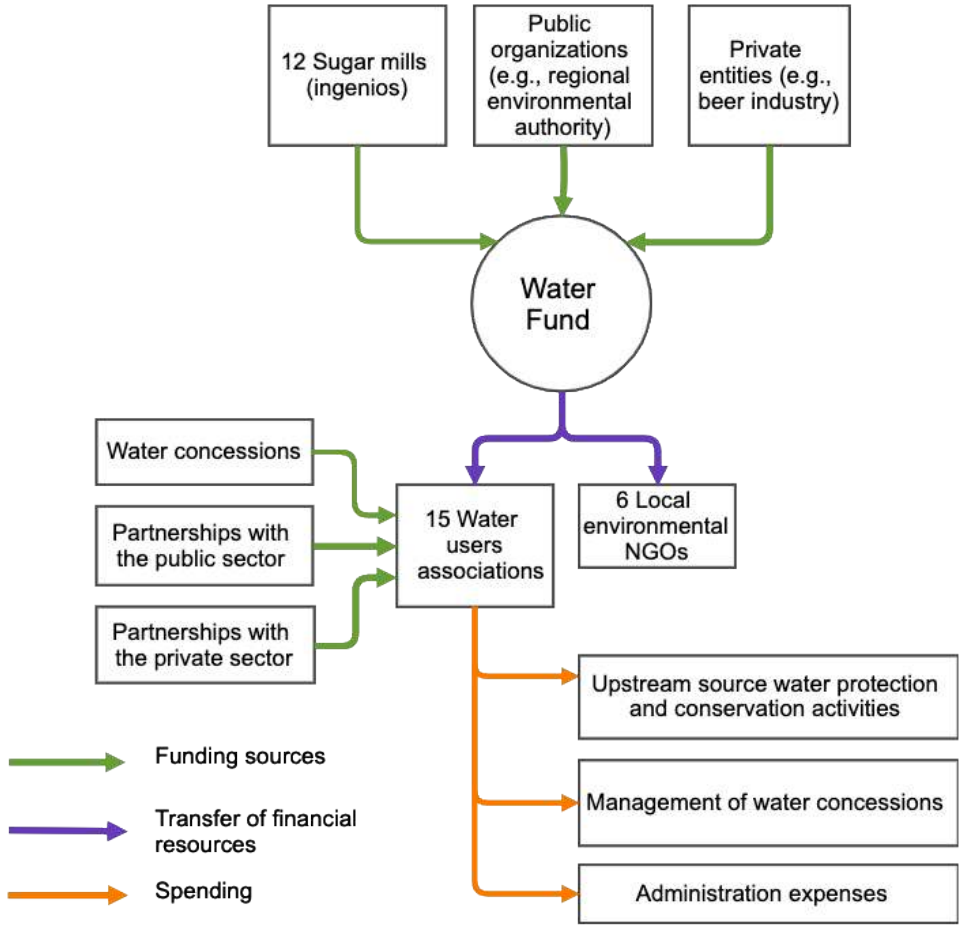

Figure 3. Financial structure of the water fund. Green, purple, and orange arrows represent funding sources, transfer of financial resources, and spending by the associations, respectively.

the social, hydrological, and biodiversity impacts of the water fund (Bremer et al. 2016; Game et al. 2018). Though still considered relatively "safe," special protocols are followed in the field (e.g., researchers are not allowed out after 4 pm), and the vast majority of people in the region have suffered from violence over the last four decades. Virtually all research contacts have been personally impacted by conflict-related violence. The conflict has shaped conservation trajectories (for instance, reforestation following agricultural displacement) and has heightened the importance of the associations as intermediary organizations. As some of the only organizations working in conflict-affected areas, where development investment by the state was largely absent, the associations have become conduits for resources to support community development goals.

Motivation for this Project

Recent work capturing the distribution of ecosystem service benefits has made important contributions to the incorporation of equity into ecosystem services research (e.g., Mandle et al. 2015; Keeler et al. 2019), but the labor and true costs of co-producing ecosystem services, as well as the values and perspectives that motivate these actions, are generally not included in these analyses (Berbés-Blázquez, González, and Pascual 2016; Zafra-Calvo et al. 2020). Accordingly, the current project, conceptualized as "Putting Suppliers on the Map," aimed to create outreach and educational material to highlight the upstream activities critical to co-producing the ecosystem services at the heart of water funds.

A website was conceived as the end product of this research, following trends identified in environmental education research indicating that successful outreach material 1) addresses a collective, community-embedded initiative; 2) focuses on social-ecological systems and links between human well-being and environmental quality; and 3) engages with the digital world (Ardoin, Bowers, and Gaillard 2020). Accordingly, the website showcases the work and perspectives of participants to foster greater understanding and stronger connections between upstream and downstream stakeholders. The website thus blurs the lines between education and outreach, increasing public awareness of the fund while also amplifying participants' values and knowledge to educate downstream beneficiaries about the social-ecological relations that sustain their water supplies. These efforts fit within Asobolo's premise that water conservation is the responsibility of the broader community rather than that of water fund participants alone, and it complements the association's educational activities upstream (e.g., environmental workshops in schools), which emphasize the links between upstream water protection and the well-being of residents.

Although Asobolo has been working in the watershed for over 25 years, it had never publicly communicated its work due to the risks posed by armed conflict in the region and was just starting to develop their online presence. We agreed that the website would be considered a "snapshot in time" that did not need updating due to limited local capacity to sustain online products.

Interviews

To document participant experiences, we combined a semi-structured questionnaire with walking interviews (Drever 1995; Carpiano 2009) conducted around the areas where participants were carrying out conservation activities (e.g., riparian forest stewardship, spring protection, agroforestry, etc.). We chose semi-structured and walking interviews to create open conversations whereby participants could express their perceptions and motivations to participate in the program, and where the landscape might prompt reflections and connections.

In total, we interviewed 10 participants of Asobolo, selected using purposive sampling by farm size (three small: 3.8 to 4 ha; four medium: 10 to 44 ha; three large: 120 to 576 ha). Interviewees included three representatives from one Indigenous community, who were interviewed as a group. Additionally, the director of Asobolo was interviewed. The interviews were arranged by the Asobolo director but were conducted without the presence of Asobolo staff. Interviews focused on three broad themes: 1) motivations to participate in the program, 2) perceived benefits and challenges of participating for themselves, their community, and their surrounding environment, and 3) advice for potential future participants. As participants

generally viewed themselves as participants in Asobolo rather than participants in the water fund, questions focused on their experience with Asobolo.

The website was co-produced with Asobolo, which resulted in much more interaction between researchers and practitioners than would normally occur in conventional research. We met frequently with the association while constructing the website to fact-check, share data (e.g., spatial data), and determine the most effective communication strategy. Though the overall project was collaborative, the researchers analyzed interviews and identified overarching themes that motivated participation independently, with the goal of portraying the interview data as objectively as possible (e.g., not altering findings for the purpose of promoting the program). The researchers and Asobolo then collaborated to create the website.

Interviews were transcribed by the first author and analyzed for emergent themes using a grounded theory approach (Ellis 1993). Representative stories and summaries of interviewees were organized and presented on the website. Once finalized, the website was presented to all participants in a gathering at the Asobolo office.

Results

In this section, we describe the main findings of interviews that are presented on the "Putting Suppliers on the Map" website (Figure 1). We then describe the use of the website by Asobolo as a communication and education tool.

Asobolo: An Intermediary Organization Creating a "Water Culture"

Our interviews emphasized the important role of Asobolo as an intermediary organization that recruits upstream participants and sustains enrollment through constant field visits and one-on-one relationships. Accordingly, "Putting Suppliers on the Map" begins with an interview with the director of Asobolo, as the main point of contact between upstream participants and the water fund. She states that "*the water funds provide the financial resources and the associations* [like Asobolo] *provide presence in the field.*"

Beyond direct water funds participants, however, Asobolo has sought to involve the broader community as much as possible by promoting the idea of a "cultura del agua" (water culture), which emphasizes the impacts of watershed conservation for upstream participants and their communities instead of for downstream beneficiaries. This approach has included partnering with local schools for environmental education workshops; running community-wide social cartography exercises to establish a common vision for the future of the watershed; and supporting community activities that are not necessarily linked to conservation, such as road repair and aiding people in need (SI Table 3). This work has also positioned the association as a trusted organization in the watershed, serving the critical function of building sustainable upstream-downstream social-ecological linkages. Today, Asobolo does little individual recruitment of landowners, as there are now more people who desire to participate than the program can finance.

Diverse Motivations for Participation

Interviews revealed that participants are driven to join the water fund by multiple, overlapping motivations. For the purpose of the website, we identified three broad categories of motivations: 1) connections with the land and desire to care for it, 2) conserving water as a necessity, and 3) creating a sustainable future. Stories and perspectives are organized into one of these categories based on the most salient motivations identified in each interview.

Connections with the land and desire to care for it.

> "*According to the uses, customs, and cultures that we practice, within the territory we manage the sacred sites that for us are the connection with Mother Earth and the spiritual beings.*"
> *-Kwet Wala Indigenous Community*

We included narratives from a small landowner (~4 ha) with off-site income sources, a small farmer (~10 ha), and an Indigenous community (~280 ha). A connection to land and a desire to care for it was common among participants but differing livelihoods and socio-cultural identities shaped how each viewed the benefits from participating in the program.

In the first example, a small landowner did not generate income from the land where restoration

activities took place; he had substantial income from a downstream sugarcane farm and was one of the two highest-income interviewees. The participant explained that growing up in the area and having childhood memories tied to it inspired his decision to return as the armed conflict subsided in the region. His connection to the land inspired a sense of responsibility to care for the river that flows through the property, and he expressed interest in working with riparian forests and buffers but had less interest in (and at times has rejected) activities producing marketable products (e.g., agroforestry). For example, while Asobolo recommended planting riparian trees with four meters spacing to facilitate the use of trees as timber, he explained:

> "*But I decided to plant them with 3-meters of distance because I have the experience that trees planted within 3-meters of distance are tall and thin. The timber is not commercial. ...But when you plant them at 4-or-5 meters distance, they turn out to be wide and are commercial, and can produce timber. The idea is that 20- or 30-years from now, the forest is grown, not exploitable and that simply is not viable* [as a source of timber]."

Implementing restoration activities in a way that reduces the likelihood of riparian trees being cut for timber stemmed from his interest in the long-term ecological benefits of restoration rather than the monetary or production value.

In contrast, a small-scale farmer of Nasa (an Indigenous group) descent, who relied on his land for income, was interested in conservation activities that simultaneously supported watershed conservation and generated income. He explained that he was born and raised in the area and his strong connection to his family's land led him to stay in the area even as others left during the height of the armed conflict. Much of his farm is on steep slopes, and he worked with Asobolo to establish an agroforestry system that simultaneously reforests his land and provides marketable products such as avocado and lulo (a local fruit). From the perspective of both Asobolo and the participant, agroforestry systems offer more equitable land management options than simple restoration. However, our interview with the participant also revealed his desire for additional incentives to participate in restoration, such as access to electricity, and his vision of long-term compensation for forest managers rather than project-based funding.

In the final example, representatives from the Kwet Wala Indigenous community, which participates in the program as a communal landowner, described their connection to the land in terms of their homecoming to their territory. This land was only recently returned to them, and the water fund provided necessary resources to manage it in ways that aligned with their cosmovision (belief system) as Indigenous peoples. For example, they explained that "*according to the uses, customs, and cultures that we practice, within the territory we manage the sacred sites that for us are the connection with Mother Earth and the spiritual beings.*"

The type of work the Kwet Wala community chose to engage in with Asobolo was based on their worldview and their own "plan de manejo" (land management plan). Kwet Wala representatives described this as a more holistic view, explaining that "*we do not talk about the forest or water* [only]*; we talk about nature.*" They considered conserving their land to be a connection with their heritage and ancestors and characterized themselves as natural caretakers of the land. In addition, Kwet Wala representatives described their participation in conservation programs such as Asobolo as a strategic tool to make their identity as Indigenous peoples and conservationists recognized and valued by local authorities.

> "*When we do these types of exercises* [this interview] *we tell the community why it is important to get out to talk with the CVC* [environmental authority]*, and with Asobolo, and with Asofrayle* [another association]*, and with the environmental authorities. It's because we try to be included, to be recognized, that we are here, and that our position is of environmental conservation, because we are environmentalists, and that by being there they are obliged to recognize us.*"

They emphasized that a relationship built with Asobolo was built on mutual agreement to follow that community's autonomous conservation goals; however, they emphasized that "*we will continue conservation because we are not only those who are here, but the entire Indigenous community,*

in general, that is committed to conservation regardless of whether Asobolo or another institution wants to support."

Highlighting the role of connection to the land for water fund participants is a critical educational role that websites like "Putting Suppliers on the Map" can play. Without this understanding, water funds may design or fund incentives that are not equitable or of interest to participants, as with the first landowner's disinterest in agroforestry programs, or that even have negative consequences for participants, for example a project that conflicted with the Kwet Wala "*plan de manejo.*"

Conserving water as a necessity.

> "*Water is more valuable to me than* [the cost of] *removing a piece of land from the farm. I don't mind fencing it [a water springs] off, but I care more about water because even water adds value to the property. It* [the ranch] *has great value because it has water.*" *-Small farmer*

Interviewees expressed deep concern about decreasing water flows, especially during the summers. These concerns were articulated in testimonies from a small farmer (~3 ha), a medium-sized farmer (~44 ha), and a cattle rancher (~11 ha). Each spoke of water insecurity, including the impact of decreased water availability on land value, as an important motivation to participate.

First, a small farmer chose to fence and protect almost one hectare of his three-and-a-half hectare farm for water protection. This participant, like several others, was not connected to municipal piped water and relied on springs for agricultural and domestic water supply. The threat of dry springs during the summer was a constant concern, and he felt that working with Asobolo was his only tool to avoid "*having to bring water in buckets from elsewhere.*" Concerns about water supply may stem, in part, from the outreach efforts of Asobolo, but participants, including this small farmer, described observations of the specific hydrological changes on their own lands (e.g., good water flow during the summers) as an ongoing motivation to participate.

Second, a medium-sized farmer emphasized both the importance of protecting water and productive activities for economic and food security. This farmer worked with Asobolo to implement a silvopasture system and protect the two springs on his farm. He was also the representative of the *El Edén* aqueduct that delivers water to farms in his area. In this position, he worked with Asobolo and other environmental organizations to protect the stream that feeds the aqueduct and to advocate for resources for families in the area, who were impacted by the armed conflict. Before work with Asobolo, the farmer led efforts to obtain resources to fence off two kilometers of the streams that feed the aqueduct. With Asobolo, he has continued this work and together they have initiated development projects for the families in the area.

Even when participants felt that joining the program benefited water along with their land, they were aware of the costs and tradeoffs of participation and associated equity and justice implications. This was illustrated by the third example, a rancher, who acknowledged the water benefits of working with the program but also emphasized having to confront costs in the form of labor and resources. Asobolo supported landowners with initial materials to fence off water sources, grow riparian forests and green corridors, and implement agroforestry and silvopasture systems. However, participants were then responsible for maintenance and replacement costs. Although maintenance and ceding land for water conservation is a costly activity, many, including this rancher, saw this as a good trade-off:

> "*I do not see it* [fencing water springs] *as losing a piece of the farm, but rather as adding value to the farm. Like I said, cattle used to roam here* [around springs]*, but what does that give me? A little bit of grass, which at the end...Now, as I was saying, I have fewer cows in less space, and I have water.*"

Like this rancher, other participants highlighted that land without water has no value and that working with Asobolo to ensure water flow was a critical element in securing the value of their land. At the same time, these participants were aware of their role in watershed conservation and the costs that this work implies in terms of land, time, and paying for materials (e.g., fences, seedlings, etc.). They pointed to the inequities related to the distributions of costs associated with upstream conservation.

Creating a sustainable future.

"*Implementing all of this is arduous but rewarding—not only in economic terms, but also in terms of what I contribute to humanity.*" *-Large farmer*

The economic benefits of restoration activities that shift conventional farming and ranching operations to more sustainable practices such as agroforestry provide additional motivation to participate in the program. We highlighted three participants from two large (~120 and 576 ha) and one medium size farm (~12 ha) who articulated "*creating a sustainable future*" as a key motivation for participation. These farmers spoke of the negative impacts of conventional farming for the business itself and the environment.

Referring to years of deforestation for grazing and agriculture in the area, one of these farmers stated that "*the culture here has been to clean the forest,*" which he said reduced shade for livestock, leaving them more prone to heat stress, and left birds without trees to rest on. For this group of participants, economic benefits—articulated as long-term farm sustainability, not in direct monetary terms—were central to their participation. In particular, large farmers reported four economic benefits from activities with Asobolo. First, activities were seen to increase vegetation cover and soil retention, especially in high-slope farms, which helped to keep fertilizers on the ground, thereby reducing input costs. Second, practices such as silvopasture were seen to increase shade and protect livestock from heat stress, which compromised nutrition and reproduction, and which participants perceived to have intensified due to climate change. Third, silvopasture and agroforestry practices that included marketable products such as wood, avocado, or fruits, were valued as an extra source of income. Fourth, for farms that had springs or rivers flowing through their property, protecting these resources was seen as a way of protecting water independence and key to securing the value of land.

Though these three landowners highlighted the economic benefits of restoration practices, they also discussed additional motivations. Some indicated the desire to be viewed as more sustainable. One participant spoke about the "*identity*" of his farm as one of "*the best conserved in the area and characterized by our concern for the environment,*" which the participant linked to conservation practices on his land, including silvopasture, riparian forests, and spring protection. Participants also emphasized the benefits of their on-farm sustainable practices for the broader local environment. Planting trees through practices such as silvopasture, agroforestry, and living fences, especially when using native species, was understood to provide ecological corridors that helped local biodiversity. Common sightings of local birds and mammals such as deer, coatis, and armadillos were interpreted as a sign that these animals were "*coming back to the area*" and this was perceived to be a direct consequence of sustainability efforts on these farms. Bequest values—the desire to care for the environment for future generations—were also articulated as an additional motivation for participating in the program, albeit to a lesser extent. Another one of the large farmers who implemented silvopasture and riparian forest practices articulated his motivation to participate as serving the common good: "*Implementing all of this is arduous but rewarding—not only in economic terms, but also in terms of what I contribute to humanity.*"

The website highlights that concerns about sustainability are present among water fund participants, a long-term perspective that downstream actors need to understand and support for the water fund to operate effectively.

Discussion

A link to the "Putting Suppliers on the Map" website is currently featured on Asobolo's webpage (Figure 1). It is an important part of their strategy to communicate with those beyond the communities with whom they work, from academics to potential funders. Interested parties are directed to that website as a place to start learning about Asobolo and upstream participants.

The goal of creating a website fundamentally impacted the way participants engaged with our interviews. Participants knew from the outset that interviews would be translated into a website to teach viewers about their conservation work with Asobolo. Thus, they often approached the interviews as "*educators*," with the goal

of demonstrating and explaining their work to others in ways that conveyed both successes and challenges. One explicit goal was to take pictures of the areas that they wanted others to see; these are displayed on the website. This also gave participants the opportunity to choose how they wanted to be portrayed; for instance, one of the interviewees from the Indigenous community chose to wear a traditional vest, as he explained, "*to look more Indigenous.*" In this way, participants were elicited as experts on their own land and work, and encouraged to answer questions with the aim of teaching others about their experience and expertise.

The website highlights participants' diverse motivations and challenges, which are rarely included in water fund communication materials, and by extension, high-level water fund planning, in an in-depth way. In addition, the website helps those downstream, as well as water fund designers, envision more equitable and productive ways of interacting with upstream actors. Many participants emphasized the ways people downstream benefit from their conservation efforts and, thus, ought to contribute to protect the watershed from both a practical and a just perspective. For example, when asked if he would recommend others joining the program, one farmer explained, "*I would recommend it as long as there are economic benefits. Because it is not fair...I say to 'La Buitrera' (downstream municipality): you take and sell the water, and what? If we are the ones taking care of the watershed, we are the ones concerned.*" The sense that his work is going unrecognized even when it benefited him too has shaped his work with Asobolo, which focuses on development projects for the community as much as watershed conservation. As he explains, "*I do believe that it's important to make people aware of the importance of conservation and water management, but to also help them do this management with resources.*" These concerns raise the need to advance procedural equity in water funds by bringing people to the table to inform how the water fund can better support the goals of participants and diverse notions of sustainability and equity. We suggest that co-produced communication and outreach materials that give voice to ecosystem service "suppliers" are a critical first step toward more equitable, and therefore more effective, water fund design, compensation structure, and spatial targeting.

Water funds could be considered a form of environmental learning initiative given that two primary aims are to increase awareness of environmental processes and increase pro-environmental behavior. Thus, when considering the educational dimension of water funds, the website also aligns with calls from environmental education scholars to foreground people's emotional reactions to environmental learning initiatives (Russell and Oakley 2016) and to understand environmental movements within "the contexts in which people live and work" (Ardoin, Bowers, and Gaillard 2020, p. 501) (Table 1). By showcasing upstream participants' perspectives in a public forum, the website increases visibility and understanding of how conservation practice is embedded in people's lives and shaped by their broader values.

The focus of most outreach materials (see Appendix A) on downstream interests tends to simplify the portrayal of upstream participants. Rather than straightforward stories of upstream land managers motivated by economic incentives, participants we interviewed expressed complex agency and strategic use of the water fund/Asobolo. Value recognition is important to equity in environmental programs (McDermott, Mahanty, and Schreckenberg 2013), and the website makes this possible. The Kwet Wala community, for instance, deliberately chose to engage with the website as an educational tool because they perceived the need to educate environmental authorities and relevant organizations about their land management strategies.

We also find that trust (or lack of trust) is a key component of willingness to participate, and is largely mediated by associations like Asobolo, yet the central role of intermediaries is rarely communicated in water fund outreach material. The website begins with a focus on Asobolo and insights from an interview with the director because, like other intermediaries, Asobolo has developed strategies to gain and maintain the trust and support of participants and their communities. Broader understanding of this needs to be more central in communication, outreach, and equitable PWS design.

Table 1. Alignment between this project and environmental education principles.

Principle of or trend in environmental education	How the project described here aligns with principle
Emphasize contextual knowledge, expertise, and practices (Ardoin, Bowers, and Gaillard 2020)	Highlights upstream actors' rich place-based knowledge
Address collective learning (Wals 2007)	Allows upstream actors to educate other actors about their roles
Focus on social-ecological systems (Stevenson et al. 2014)	Stories portray integrated social-ecological systems and support these systems by increasing understanding of upstream knowledge and values
Encourage active civic engagement (Stevenson et al. 2014)	Increases recognition of upstream actors' crucial roles in the operation and success of water funds and their associated social endeavors

Targeting efforts and program design need to consider power relations, political context, and social goals, alongside hydrologic ecosystem service goals, to avoid marginalizing the values of those living in the watershed at the expense of (often higher income and more powerful) downstream interests (Nelson et al. 2020). Using novel educational tools such as websites to highlight the goals and values of communities, individual landholders and intermediary organizations can help produce more equitable and effective watershed investment programs.

Conclusion

Environmental education is increasingly conceptualized as a reciprocal and participatory process, so there is a critical need to expand the range of outreach and communication materials on water funds and other types of watershed investment programs. Through the "Putting Suppliers on the Map" website, we make one of the first attempts to represent the voices of upstream participants in an outreach product. Centering them as educators and communicators, we highlight the role of upstream participants in co-producing the ecosystem services that water funds are designed to protect and enhance. We hope that the website and similar materials can facilitate outreach and communication strategies that align with visions of environmental education as the creation of "synergistic spaces, facilitating opportunities for scientists, decision-makers, community members, and other stakeholders to converge" (Ardoin, Bowers, and Gaillard 2020, p. 1). Understanding the perspective of upstream participants is essential for water funds to support the recognition and 're-valuing' of rural spaces and livelihoods (Shapiro-Garza 2013). Most importantly, understanding upstream perspectives and integrating them into water programming is key to advance linked equity and conservation goals.

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Supplementary Data

SI Table 1. Watershed investment reports reviewed.

Report	Primary Organization	Regional Focus					Stated Readership			Quotes	Full Citation
		Global	Latin America	US	Europe	Asia	Funders (outside watershed)	Downstream	Upstream		
Alliances for Green Infrastructure: State of Watershed Investment 2016	Forest Trends	1	0	0	0	0	1	1	0	The State of Watershed Investment report is offered to a range of audiences including water utility and other government policy makers, engineering and construction firms, public and private investors, and other stakeholders working on access to clean, reliable water supply.	Bennett, G. and F. Ruef. 2016. Alliances for Green Infrastructure: State of Watershed Investment 2016. Forest Trends, Washington, D.C.
Natural Infrastructure in São Paulo's Water System	World Resources Institute	0	1	0	0	0	1	1	0	While many natural infrastructure proponents are already calling for restoration of the Cantareira, the question remains, who will invest? These proponents can use these financial results to build a more investment-ready strategy for the Cantareira System. They can utilize the maps in this report to target the most high-impact areas and use the roadmap to ensure important social and political enabling conditions are in place for their success. Importantly, they must prepare to address the inherent uncertainty in working with natural infrastructure—efficient and wise program design can ensure a return for investors even if improvements to water supply are on the low end of the range estimated in this study. We hope that water managers, political and business leaders, and civil society groups will use it to spark a renewed effort to restore forests in this region, and beyond.	Ozment, S., R. Feltran-Barbieri, P. Hamel, E. Gray, J.B. Ribeiro, S.R. Barrêto, et al. 2018. Natural Infrastructure in São Paulo's Water System. World Resources Institute, Washington, D.C.
State of European Markets 2017. Watershed Investments	Forest Trends	0	0	0	1	0	1	1	0	This report seeks to capture the scale and performance of incentives and market-based mechanisms for green infrastructure for water. It includes not only public finance for watershed health, but also local-scale initiatives driven by water users themselves to address shared water challenges. We use the term "watershed investment" in the sense of a long-term investment in an asset, just as a city would "invest" in upgrades to its wastewater treatment plant.	Bennett, G., A. Leonardi, and F. Ruef. 2017. State of European Markets 2017: Watershed Investments. Forest Trends' Ecosystem Marketplace, Washington, D.C.
Eco-Compensation for Watershed Services in the People's Republic of China	Asian Development Bank	0	0	0	0	1	1	1	0	The central and the provincial governments across the People's Republic of China (PRC) have been investing in and seeking new ideas and methods for improving both supply-side and demand-side management of water resources. This has included numerous national, provincial, and local experiments over the past decade in market-based environmental policy tools under the broad heading of "eco-compensation," with this trend culminating in central government uptake wherein the National Development and Reform Commission (NDRC) has been tasked with developing a national eco-compensation ordinance. This paper makes three key recommendations for the design of the Eco-Compensation Ordinance as it relates to water.	Zhang, Q. and M.T. Bennett. 2011. Eco-Compensation for Watershed Services in the People's Republic of China. Asian Development Bank, Mandaluyong City, Philippines.

SI Table 1 Continued. Watershed investment reports reviewed.

Report	Primary Organization	Regional Focus					Stated Readership			Quotes	Full Citation
		Global	Latin America	US	Europe	Asia	Funders (outside watershed)	Downstream	Upstream		
Insights from the Field: Forests for Water	World Resources Institute	0	0	1	0	0	0	1	0	Working with partners to identify beneficiaries and their water-related dependencies.	Talberth, J., E. Gray, E. Branosky, and T. Gartner. 2012. Insights from the Field: Forests for Water. WRI Issue Brief 9, Washington, D.C.
Urban Water Blueprint: Mapping Conservation Solutions to the Global Water Challenge	The Nature Conservancy	1	0	0	0	0	1	1	0	Cities should consider investing jointly with competing water users in a water fund, a process that establishes a financial mechanism to direct funds toward watershed conservation investments based on impartial science. Alternatively, cities can monetize the extended benefits of watershed conservation. While the multiplicity of benefits increases the chances of mobilizing funds, it also makes establishing a reliable payment model more challenging.	McDonald, R. and D. Shemie. 2014. Urban Water Blueprint: Mapping Conservation Solutions to the Global Water Challenge. The Nature Conservancy, Washington, D.C.
Protecting Drinking Water at the Source: Lessons from Watershed Investment Programs in the United States	World Resources Institute	1	0	1	0	0	0	1	0	Think of this report as a roadmap to help guide your planning and implementation of natural infrastructure projects. We hope the stories of successes and challenges compiled here will inspire and guide utilities and communities as they work together to protect precious source waters.	Ozment, S., T. Gartner, H. Huber-Stearns, K. DiFrancesco, N. Lichten, and S. Tognetti. 2016. Protecting Drinking Water at the Source: Lessons from Watershed Investment Programs in the United States. World Resources Institute, Washington, D.C.
Water Funds: Field Guide	The Nature Conservancy	1	1	0	0	0	1	1	0	While other cities were inspired, a key challenge was creating a standardized methodology.	Zyla, C., et al. 2018. Water Funds: Field Guide. The Nature Conservancy, Arlington, VA.
Forests and Water: Valuation and Payments for Forest Ecosystem Services	United Nations	1	0	0	0	0	1	1	0	Analysis shows that PWS schemes based on a partnership model are more successful in accessing multiple sources of funding, increasing organizational resilience to changing political support, and ensuring that forest owners and managers engage in these schemes over the long term.	United Nations. 2018. Forests and Water: Valuation and Payments for Forest Ecosystem Services.
Resilient European Cities: Nature-based Solutions for Clean Water	The Nature Conservancy	0	0	0	1	0	1	0	0	This report examines how European cities can turn to nature-based solutions (NbS) to protect the water resources on which they depend; To help water sector stakeholders, policymakers, funders, and financiers identify practical ways to prioritise and deploy investments in nature-based solutions for water security (NbS-WS) in Europe.	Trémolet S. and N. Karres. 2020. Resilient European Cities: Nature-Based Solutions for Clean Water. The Nature Conservancy, London, United Kingdom.

SI Table 1 Continued. Watershed investment reports reviewed.

Report	Primary Organization	Regional Focus					Stated Readership			Quotes	Full Citation
		Global	Latin America	US	Europe	Asia	Funders (outside watershed)	Downstream	Upstream		
Beyond the Source: The Environmental, Economic and Community Benefits of Source Water Protection	The Nature Conservancy	1	1	0	0	0	1	1	0	Beyond the Source seeks to illustrate the value of nature to cities looking to secure water supplies while adding a number of benefits that address global challenges we face. By restoring forests and working with farmers and ranchers to improve their land management practices, we can improve water quality and reduce water treatment costs for four out of five downstream cities serving 1.4 billion people.	Abell, R., et al. 2017. Beyond the Source: The Environmental, Economic and Community Benefits of Source Water Protection. The Nature Conservancy, Arlington, VA, USA.
Forests to Faucets: Protecting Upstream Forests for Clean Water Downstream	American Rivers	0	0	1	0	0	0	1	1	Promote the concept of downstream benefits of upstream forestland conservation and management by educating forest landowners, forest managers, and water users about how they can work together. Provides an introduction for community leaders, including water providers and forest managers, as they seek to protect, manage, and maintain source-water forests.	Edmonds, K., M. DeBonis, and P. Sunderland. 2013. Forests to Faucets: Protecting Upstream Forests for Clean Water Downstream. American Rivers, Forest Guild and Mountain Conservation Trust of Georgia.
Fondos de Agua: Conservando la Infraestructura Verde. Guía de Diseño, Creación y Operación	The Nature Conservancy	0	1	0	0	0	1	1	0	Create financial mechanisms that offer users, in the lower areas of a watershed, the opportunity to become proactively involved in conserving the high and medium altitude zones of the watershed. Although there have been many watershed investment and management efforts, few of them create a direct link with the protected areas and private properties that generate water environmental services.	Calvache, A., S. Benítez, and A. Ramos. 2012. Fondos de Agua: Conservando la Infraestructura Verde. Guía de Diseño, Creación y Operación. Alianza Latinoamericana de Fondos de Agua. The Nature Conservancy, Fundación FEMSA y Banco Interamericano de Desarrollo. Bogotá, Colombia.
Forests for Water: Exploring Payments for Watershed Services in the U.S. South	World Resources Institute	0	0	1	0	0	1	1	1	This issue brief is intended as an introductory resource primarily for entities that depend upon stable supplies of clean freshwater in the southern United States and are looking for cost-effective approaches to sustain this supply. This brief also provides information to southern landowners interested in potential revenue streams generated by conservation and sustainable management of forests.	Hanson, C., J. Talberth, and L. Yonavjak. 2011. Forests for Water: Exploring Payments for Watershed Services in the U.S. South. WRI Issue Brief 2, Washington, D.C.

SI Table 2. Watershed management tools employed by associations. Adapted from (Moreno Padilla 2017) and interview with Asobolo director.

Watershed management tools	Description
Fencing	Use of wooden pickets plus barbed wire and living fences to fence off riparian and native forests and streams. When using living fences, 400 trees are planted per km.
Spring protection	Fencing of water sources and planting trees for water regulation.
Agroforestry	Integration of forestry into agriculture and husbandry systems to obtain environmental and economic benefits. Farmers often mix coffee crops with fruit trees, especially avocado, citrics, and lulo. Ranchers employ silvopasture where livestock production is combined with forestry and forage.
Passive restoration and natural regeneration	Restoration of degraded land mainly from cattle grazing. The land is fenced off to allow trees and other vegetation to grow naturally.
Erosion management	Construction of check dams or other in-stream blockades, wooden barriers complemented with vegetation to slow the flow of water and increase infiltration.
Forest enrichment	Expansion of trees in private forests to produce timber in the future. Up to 100 trees per ha are planted.
Protected forests (accelerated natural regeneration)	Tree planting in areas formerly used for husbandry where more than 600 timber trees are planted per ha to accelerate regeneration.
Forest for domestic use	In these areas, timber trees (1372 per ha) of fast growth (e.g., pine, eucalyptus, cedar) are planted for commerce or domestic use. These areas are usually distant from water springs and streams.

SI Table 3. Strategies used to promote a "Cultura del agua" (water culture) in Asobolo, a river users association.

Strategy	Definition	Purpose
Ecological inventories	Outings with watershed residents, guided by a local biologist, to do ecological inventories of tree species in the forest, medicinal plants, and riverine organisms.	Shape a sense of belonging among residents and connect them with the natural resources of the watershed. Change attitudes and practices that degrade the local environment (e.g., throwing trash in rivers, felling of trees, and letting livestock graze around springs).
Social cartography	Workshops with residents of different generations to reconstruct how the ecology of the watershed was in the past, how it looks in the present, and how they would like it to look in the future.	Build environmental awareness and nurture a sense of ownership of the restoration work of the watershed.
Nurseries of native trees	Supported watershed residents to start nurseries of native trees that are sold to the association for their restoration activities.	Have a local supply of native trees and fruit trees to use in restoration activities. Position the association as a job provider for local residents.
Radio program	"Eco ambiente: para vivir mejor" (Eco environment: to live better) is a show on the local radio hosted by the association. It focuses on the weekly work of the association, special environmental topics (e.g., climate change and importance of trees), hydrological monitoring, and celebration of environmental awareness days.	Share the association's work, promote awareness of the local natural resources, strengthen a sense of belonging, and change negative habits that degrade the environment.
Partnership with local schools	Partnerships with local schools to support their environmental education syllabus. This includes tree planting, painting workshops related to environmental topics, and field trips to forests and rivers to do ecological inventories (see above).	Long-term investment to shape pro-environmental attitudes in children, so they maintain them as adult residents of the watershed and landowners.
Workshops for women (Talleres para mujeres)	Gather women through non-environmental activities (e.g., cooking and embroidery) to hold conversations about their role in the community and the local environment, for example, through wood fuel usage, and how to contribute to the environment from home (e.g., cooking oil disposal).	Strengthen gender equity in participation in the program and highlight women's importance in water use and forest resources, especially related to tree felling for cooking fuel.
Supports the community in non-environmental activities	Supports community with their own development projects. For instance, providing meals in *mingas*—an Indigenous system of communal work to improve aspects of the community, such as repairing roads and bridges. Provides aid to community members in need.	Cement the association as a member of the watershed and its community. Inspire feelings of reciprocity from the community, so they can also support the association's work.
Water quality and quantity monitoring	Partners with landowners along tributaries to install sediment and water flow monitors on their land and to be stewards of them.	Strengthen sense of pride and belonging for the local area. Provide first-hand observations of positive and negative hydrological changes. Show that everyone can help in conservation.

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Legal Extension Strategies to Increase Awareness of Drinking Water Contaminant Regulatory Framework

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Abstract: It is important for stakeholders, scientists, industry, lawyers, and decision-makers to understand the varying approaches to regulating drinking water contaminants. To increase awareness and understanding among stakeholder audiences of the legal framework for drinking water protection, the National Sea Grant Law Center (NSGLC) at the University of Mississippi School of Law has developed and implemented research and extension projects for lead, nitrates, and per-and polyfluorinated substances (PFAS). The NSGLC's mission is to encourage a well-informed constituency by providing legal information and analysis to the Sea Grant community, policy makers, and the general public through a variety of products and services. For each contaminant, the NSGLC conducted legal research to identify relevant laws, regulations, policies, and court decisions to gain an in-depth understanding of the existing legal framework. The NSGLC then translated its information on the current legal framework, identified gaps, and potential solutions into a variety of outreach programming. For each of the relevant drinking water contaminants, the NSGLC has taken different outreach approaches. For lead, the NSGLC has worked with an interdisciplinary academic team to conduct community-based research and outreach directly to families. With nitrates, the NSGLC has focused more on professional development for attorneys, natural resource managers, and other policy makers. With PFAS, the NSGLC is proposing a hybrid approach, drawing on lessons learned from its previous projects and the COVID-19 pandemic, to disseminate information to both professionals and communities. This case study will synthesize key findings on the legal overview, potential legal issues, and outreach efforts for lead, nitrates, and PFAS.

Keywords: *drinking water, lead, nitrates, PFAS, Contaminants of Emerging Concern*

The Safe Drinking Water Act (SDWA) is the primary federal law that ensures the quality of Americans' drinking water. Entities operating a Public Water System (PWS) must comply with the requirements of the SDWA. PWSs are systems with at least 15 service connections or serving at least 25 people for at least 60 days a year (42 U.S.C. § 300f(4)).

The U.S. Environmental Protection Agency (EPA) sets standards for the monitoring and treatment of water for regulated contaminants. Under the SDWA, the EPA adopts regulations for contaminants in drinking water that can adversely affect health and that are known or could occur in public water supplies (42 U.S.C. § 300g-(b)(1)). The level at which PWSs must act to address regulated contaminants is known as the Maximum Contaminant Level (MCL). For each contaminant, the PWS must monitor drinking water to ensure that the MCL is not exceeded and take prescribed steps if it is exceeded.

Since Congress passed the SDWA in 1974, the EPA has issued regulations for over 90 drinking water contaminants, including two well-known substances: lead and nitrates (Humphreys 2021). However, due to regulatory gaps in the SDWA, individuals and communities still face health risks related to their drinking water. For instance, the SDWA does not cover private wells. Further, MCLs are often not based on health but on what is technologically feasible, and compliance is determined based on limited sampling.

Gaps also exist with respect to contaminants of emerging concern (CECs). Federal law has not

Research Implications

- Increased awareness of how drinking water contaminants are regulated in the United States.
- Increased understanding of how contaminants of emerging concern in drinking water can be addressed by the U.S. Environmental Protection Agency and state agencies.
- Increased understanding of the value of legal extension and types of outreach strategies to communicate information on legal and regulatory issues to non-legal audiences.

been able to keep up with emerging research on the health risks associated with CECs in drinking water. To regulate a contaminant under the SDWA, the EPA must publish a National Primary Drinking Water Regulation (NPDWR) for that contaminant (42 U.S.C. § 300g-1(a)). To begin this process, the EPA must periodically publish a list of unregulated contaminants expected or known to be in PWSs known as the Contaminant Candidate List (CCL). After a research and data collection phase, which can be quite lengthy, the EPA determines whether to develop a NPDWR. In 2016, the EPA added two per-and polyfluorinated substances (PFAS), Perfluorooctanesulfonic acid (PFOS) and Perfluorooctanoic acid (PFOA), to its fourth CCL (U.S. EPA 2016a).

The EPA does not have to regulate a CEC as a listed contaminant under the SDWA in order to provide some protection; rather, it can employ tools like health advisories and unregulated contaminant monitoring rules, as has been done with PFAS (U.S. EPA 2016b). In addition, states can take their own actions in the absence of or in addition to federal regulations. For instance, many states have begun regulating PFAS using a variety of approaches.

It is important for stakeholders, scientists, industry, and decision-makers to understand the varying approaches to regulating drinking water contaminants. To increase awareness and understanding among stakeholder audiences of the regulatory framework for drinking water protection, and the gaps in this regime, this case study will synthesize the National Sea Grant Law Center's (NSGLC) key findings on the legal framework, potential legal issues, and outreach efforts for lead, nitrates, and PFAS.

Methods

This case study provides an overview of the research and extension projects for lead, nitrates, and PFAS implemented by environmental attorneys working for the NSGLC, located at the University of Mississippi School of Law. These three contaminants were selected because they are major issues nationally, have different sources in drinking water (respectively, lead pipes, fertilizers, and industrial manufacturing), and as yet have not been fully addressed through the regulatory process. The NSGLC's mission is to encourage a well-informed constituency by providing legal information and analysis to the Sea Grant community, policy makers, and the general public through a variety of products and services. Through this mission, the NSGLC has gained vast experience in translating complex legal concepts and analysis into language non-lawyers can understand. Further, due to NOAA Sea Grant's overall efforts to serve as honest brokers of scientific information, the NSGLC is looked to as a trusted source of non-advocacy legal information (Center for Research Evaluation 2021).

For each contaminant, the NSGLC implemented the following research methodology. First, the NSGLC conducted systematic keyword and subject matter searches of legal databases to identify relevant federal and state regulations, policies, and court decisions. Then, the NSGLC reviewed the compiled provisions to gain an in-depth understanding of the existing legal framework for each jurisdiction. Finally, the NSGLC conducted a comparative analysis of the various frameworks across jurisdictions to identify similarities, inconsistencies, and gaps that may need to be addressed to protect public health. These research findings are summarized in traditional legal memorandum or law review articles.

Upon completion of the legal research, the NSGLC then developed outreach programming to translate its research results for a wider audience. The NSGLC has implemented different outreach approaches for each drinking water contaminant.

The NSGLC based these choices on a variety of factors, including the project partners, funding source, and primary audience for the outreach materials.

Lead and Community Engagement

The dangers of lead have long been well-known. Lead exposure in adults can cause hypertension, reproductive problems, and decreased kidney function, and recent research shows an association with heart disease (Neltner 2021). However, fetuses, infants, and young children are the most vulnerable to lead exposure. The World Health Organization estimates that young children absorb 4-5 times more lead than adults, when ingested. At high levels of lead exposure, a child is susceptible to coma, convulsions, and even death. Low levels of lead exposure have been linked to lower IQ, decreased ability to pay attention, and underperformance in school (NIEHS 2021).

There is no safe blood level for lead, and the Centers of Disease Control and Prevention (CDC) states that all sources that can expose children to lead should either be controlled or eliminated (CDC 2020). Since 1978, when the use of lead-based paint was banned in the United States, environmental and health policy has focused on reducing childhood exposure to lead-based paint and the dust produced as it deteriorates. Lead additives to gasoline were banned in 1996, addressing ambient air exposures. Policy makers have focused much less attention to lead exposure through other sources like drinking water, despite the fact that in up to 30% of cases of children with elevated blood lead levels (EBLL) there is no immediate lead paint hazard (Mayans 2019).

Legal Overview

The 1986 SDWA banned, starting in June of that year, the use of lead pipes, plumbing fittings and fixtures, solder, and flux in PWSs and any facility, both residential and non-residential, that provides drinking water. It also required that the EPA regulate lead levels in drinking water. The EPA issued regulations under the SDWA in 1991 to address lead and copper contamination in drinking water, known as the Lead and Copper Rule (LCR). The LCR focuses on preventing lead from leaching from plumbing into the drinking supply by requiring PWSs to use optimal corrosion control treatment. Once the appropriate treatment option is determined by the state, the PWS is required to install and operate that corrosion control throughout the distribution system (40 C.F.R. § 141.82).

Unusually, the EPA did not establish a MCL for lead. Instead, the EPA set an action level (AL) for lead at 15 parts per billion (ppb) (.015 mg/L). The 15 ppb AL is not a health-based standard, but rather was chosen due to technical feasibility regarding corrosion control treatment systems. While 0 ppb is ideal to prevent lead health effects since there is no safe level of lead exposure, the EPA determined that it was not technically feasible for PWSs to reach this level when the AL was set in the 1991 LCR.

The monitoring of lead is done through sampling household tap water. Samples are to be collected from sites that are at high risk to have lead in their plumbing materials. For PWSs that serve greater than 100,000 people, the system is required to test the water at 100 sites in two successive six-month periods (40 C.F.R. § 141.81(d)). As the system size decreases, so does the number of required samples. PWSs can reduce the frequency of sampling events and number of sampling sites if they meet certain criteria, such as reporting lead levels below the AL for three consecutive years.

If the results of this monitoring show that more than 10% of samples are above the lead AL, the AL is exceeded and certain actions are triggered under the LCR (40 C.F.R. § 141.85-6). These actions include requirements to optimize corrosion control treatment, engage in public education, and, if necessary, replace lead service lines (LSL).

Gaps

There are some significant gaps in the SDWA and LCR. While required by the LCR to sample from locations with lead in their plumbing materials, PWSs do not always know the location of lead materials or may not adequately comply during sample site selection (Goovaerts 2017). Further, PWSs are not legally required to sample at schools within their service areas, despite the presence of vulnerable populations. To address some of these gaps, the EPA recently finalized an updated LCR, which is scheduled to become

effective in December 2021. The changes focused on the following:

- Requiring a LSL inventory to identify customers at risk and concentrated areas of LSLs.
- Requiring LSL replacement plans to systemically replace LSLs.
- Creating a new trigger level of 10 ppb. The AL remains at 15 ppb, but PWSs that exceed the trigger level must take new steps to address lead levels.
- Increasing sample reliability with an increased focus on having samples come from sites with LSLs.
- Improving risk communication by adding more and faster notice requirements.
- Protecting children in schools by including provisions for testing school and childcare facility drinking water (U.S. EPA 2021b).

Outreach Strategy: Community Engaged

The University of Mississippi Lead in Drinking Water Project (UM Lead Project) was founded by an interdisciplinary team focused on furthering research and available data on lead exposure through drinking water (NSGLC 2021). Each year more than 200 Mississippi children are diagnosed with lead poisoning (EBLL > 5g/dL) (MSDH 2018). However, research and data on lead exposure from drinking water in Mississippi are limited. The UM Lead Project aims to increase awareness of the risks of lead exposure and access water testing for lead for Mississippi residents. The NSGLC is a member of the UM Lead Project, contributing expertise on environmental law and policy. Other members of the UM Lead Project include professors from the sociology, biomolecular sciences, and engineering departments at the University of Mississippi. The team's range of expertise provides project participants with a multi-layered perspective on how, why, and what happens when a person is exposed to lead in their drinking water.

The UM Lead Project follows a Community-Based Research (CBR) model to incorporate community expertise and concerns into its research as well as to provide resources to address these concerns. CBR seeks to open up the line of communication between researchers and residents. Further, in similar studies where drinking water was tested for toxic metals, community involvement has resulted in benefits such as accelerating research, identifying and meeting social needs, preventing environmental injustices, and enhancing STEM education. (Segev et al. 2020). Community partnerships are essential to developing relevant research that not only informs scientists, but also increases knowledge of and helps mitigate certain risks for community members.

Community Sampling Events. With funding from the University of Mississippi and the Mississippi Water Resources Research Institute, the UM Lead Project held 11 collection events in the Mississippi Delta over the course of two years (Sept. 2016 – Oct. 2018) (Willett et al. 2021). The Mississippi State Department of Health (MSDH) has classified 20 of Mississippi's 82 counties as high-risk for lead poisoning, nine of which are located in the Mississippi Delta region (MSDH 2017). Further, the drinking water distribution system in Mississippi is incredibly fragmented. For instance, there are 168 PWSs in nine Mississippi Delta counties (Bolivar-28, Coahoma-20, Humphreys-11, Leflore-17, Panola-30, Quitman-14, Sunflower-14, Tallahatchie-16, and Washington-18). These PWSs serve over 244,000 customers. However, due to the small size of most PWSs in the region, each PWS is only required to sample a small number of taps – usually just 5 or 10. This means that for many of the PWSs, less than 1% of the homes they serve are tested for lead (Otts and Janasie 2017).

These events were hosted in partnership with various community organizations, including community health centers, a hospital-affiliated wellness center, churches, and a Mississippi State University Extension private well program. Working with community partners allowed the team to build on pre-existing relationships, which fostered a strong foundation for the project's research and outreach. This also allowed a high level of trust between the participants and researchers (Fratesi 2018).

The structure of each sampling event varied depending on the community partner, but all incorporated outreach on lead risks. A strength of the project was that it not only engaged the community partners, but students, families, and other community members as well, allowing them to learn more about the dangers of lead. Prior to the

distribution of sampling kits, a UM Lead Project team member would give a presentation about the health risks of childhood lead poisoning, how lead gets into our drinking water, and low-cost mitigation measures families can take to reduce exposure. Hard copies of informational handouts on lead risks, produced by the CDC, EPA, and the MSDH, were included with sampling kits. Families who returned water samples for testing received their results via U.S. mail, and those letters also included guidance on how to mitigate exposure.

The UM Lead Project team tested 213 sample bottles for lead concentrations. Of those 213, 184 were from PWSs and 19 from private wells. All of the returned water samples the UM Lead Project tested had lead concentrations below the 15 ppb AL. However, nearly two-thirds of the samples had at least some detectable lead. Forty-one of the 215 samples (19.2%) had concentrations of 1 ppb or higher. Nine samples exceeded the Food and Drug Administration's bottled water limit of 5 ppb, and those families were provided with a water filter free of charge. Notably, the samples with the highest lead concentrations were from private wells. (Willett et al. 2021).

MSDH Referral Program. Blood lead screening tests are required for all children enrolled in Medicaid in Mississippi at 12 and 24 months (MSDH 2015). Due to limited funding and staff capacity, the MSDH only conducts environmental home assessments to identify possible sources of lead for children with an EBLL at or above 15 µg/dL. Doing a home assessment at this EBLL is consistent with CDC recommendations that were released in 1991, though current recommendations urge action at lower EBLL levels (Gilbert and Weiss 2006). To help increase the services provided to families of children with EBLLs, the MSDH and the UM Lead Project are currently partnering to test the drinking water of Mississippi families whose children are diagnosed with lead poisoning but do not qualify for a home assessment.

In 2020, the UM Lead Project sent 53 water sample kits to Mississippi residents in 31 counties. In addition to a water sample bottle and instructions for sample collection, these kits contained outreach materials developed by the team to provide information on lead exposure risks from drinking water and steps families can take to reduce children's exposure. These materials are provided in both English and Spanish. Twenty samples were returned to the UM Lead Project for testing, nine of which had detectable levels of lead. Two samples, both from private wells, had lead concentrations significantly higher than the lead AL (approximately 28 ppb and 81 ppb). Families with lead concentrations in drinking water over 5 ppb were provided with water filters free of charge.

SipSafe. The LCR does not currently require lead testing in schools. In 2017, Congress began addressing testing gaps in schools with the passage of the Water Infrastructure Improvement for the Nation (WIIN) Act (Public Law 2016). This legislation provided funds to states to increase voluntary testing in schools and childcare facilities, and to further protect American children from lead exposure.

WIIN grant funds in Mississippi are administered by the Mississippi State University Extension Service through its SipSafe program. The SipSafe program aims to eliminate as many obstacles to lead in water testing as possible by providing testing at no cost, education and training for staff and parents, and low-cost methods of reducing lead exposure should any exposure sources be identified.

The UM Lead Project is a partner in this effort and handles recruitment and sampling for schools and childcare facilities in the Mississippi Delta. SipSafe recruitment involves cold-calling, email and internet advertisement, and community outreach. Sampling is conducted by a UM Lead Project team member who goes to the facility to collect first-draw samples from all water fixtures where children drink from or have access to, and where food is prepared. Sampling results, along with recommendations on mitigation measures, are shared and discussed with facilities.

Nitrogen Pollution and Professional Development

While nitrogen is a nutrient that naturally occurs in aquatic ecosystems, the presence of these nutrients in excessive quantities causes risks to human health and results in substantial economic and environmental harms. In fact, nutrient pollution is one of the most significant

and difficult environmental problems in the United States, affecting the water quality in over 100,000 miles of rivers and streams and around 2.5 million acres of waterbodies (U.S. EPA 2017). Nutrient pollution is primarily caused by human activities such as stormwater runoff, wastewater discharges, septic systems, fertilizer use and improper nutrient disposal in residential areas, and agricultural sources.

Agriculture is one of the largest contributors to nutrient and sediment pollution. Currently, there are over 15,000 distinct water bodies classified as "impaired" due to pollution from agricultural sources (Perez 2017). From 1988-2015, the U.S. Geological Survey's National Water Quality Assessment (NAWQA) Project sampled the principal groundwater aquifers accessed by public and private drinking water wells. The project found that nitrate levels in groundwater under agricultural land were roughly three times the national background level (Ward et al. 2018). Further, while 6% of private wells exceeded the nitrate MCL, the percentage jumps to 21% in agricultural areas (Ward et al. 2018).

Nitrates can be harmful to human health. Blue baby syndrome, or methemoglobinemia, is a severe risk for infants exposed to drinking water with elevated levels of nitrates. With methemoglobinemia, ingested nitrates are reduced to nitrite, which binds to hemoglobin and forms methemoglobin. Methemoglobin interferes with the blood's capacity to carry oxygen. When methemoglobin levels exceed roughly 10%, methemoglobinemia can be a life-threatening condition for infants (Ward et al. 2018). Excess nitrate levels have also been linked to certain cancers, such as colorectal, bladder, and breast, thyroid disease, and birth defects (Ward et al. 2018).

Legal Overview

Nitrogen is a regulated contaminant under the SDWA. Under the SDWA, the MCL for nitrate are as follows: nitrate - 10 mg/l; nitrite - 1 mg/l; and total nitrate and nitrite - 10 mg/l (40 C.F.R. § 141.62(b)). These levels were set to protect against methemoglobinemia, but not the other health risks associated with ingesting excess nitrate levels in drinking water (U.S. EPA 1991). The FDA has set the same levels for nitrate and total nitrate and nitrite in bottled water (21 C.F.R. § 165.110).

PWS violations of the nitrate MCL are prevalent in the United States. From 1994-2004, nitrate had the most MCL violations in the National Safe Drinking Water Information System (SDWIS) (Pennino et al. 2017). Nitrate remains one of the most violated MCLs (Pennino et al. 2017). Treating water to remain below the nitrate MCL can be very costly, and many towns need to install upgrades. For instance, the Des Moines Water Works (DMWW) has claimed that it expects to expend between $76 million to $183 million to increase its nitrate removal ability and capacity (Board of Water Works 2015).

Gaps

Under the Clean Water Act (CWA), discharges from point sources require a permit under the National Pollutant Discharge Elimination System (NPDES) program. A point source is a discrete conveyance, like a pipe, ditch, or tunnel (33 U.S.C. § 1362(14)). NPDES permits are not required for nonpoint source discharges. Thus, the regulation of nonpoint source pollution, including runoff, has mostly been left to the states. Further, the CWA expressly excludes "agricultural stormwater discharges and return flows from irrigated agriculture" from the definition of point source (33 U.S.C. § 1362(14)). By regulating point source and nonpoint sources differently, Congress created what some view as a regulatory gap that makes nutrient pollution difficult to control.

The exemption of nonpoint source pollution from the CWA permit program was a driving force behind the DMWW litigation (Board of Water Works 2017). DMWW is a PWS that obtains its raw water source from the Raccoon River. DMWW claimed the nitrate levels in the river threaten its ability to deliver safe drinking water despite its implementation of control strategies and construction of a $4.5 million nitrate removal facility (Board of Water Works 2015). DMWW identifies the subsurface drainage system infrastructure operated by the county drainage districts, which drains water from agricultural fields, as a major source of nitrate pollution in the Raccoon River (Board of Water Works 2015). Because the system transports nitrate pollution to open ditches and

streams which then convey pollution to the river, the DMWW alleged the drainage districts are point sources under the CWA, rather than diffuse runoff from agriculture (Board of Water Works 2015).

Ultimately, the case was dismissed based on the Iowa Supreme Court's determination that the drainage districts were immune from liability (Board of Water Works 2017). While the case never addressed the merits of DMWW's claims, it is an indicator of how compliance costs for utilities to meet the SDWA's nitrate limits may be a continuing driver of new ways to think about regulating agricultural runoff.

Outreach Strategy: Professional Development

The NSGLC initiated its research and outreach on nutrient pollution as part of its work with the Agricultural and Food Law Consortium, a national, multi-institutional collaboration that operated from 2014 to 2019 (NSGLC 2019). The Consortium was formed to aid in the development and delivery of authoritative, timely, and objective agricultural and food law research and information. In comparison to the interdisciplinary UM Lead Team, the Consortium included attorneys at universities in Arkansas, Mississippi, Ohio, and Pennsylvania. The narrower disciplinary focus and greater national scope influenced the projects, audience, and outreach methods chosen by the NSGLC.

The NSGLC's nutrient pollution outreach focused primarily on professionals, attorneys, natural resource managers, and other policy makers interested in the agricultural law field, and sought to leverage the pre-existing outreach mechanisms and partnerships of Consortium members. For example, the Consortium organized and hosted a webinar series that had an existing audience base of attorneys and other professionals, such as soil and water conservation professionals. This existing audience base was a driving force in the NSGLC's decision to focus its outreach on professionals in the agricultural field.

Through partnerships with other Consortium partners, the NSGLC submitted abstracts for multiple professional meetings to discuss legal issues regarding nutrient use and management. The NSGLC, the National Agricultural Law Center (NALC), and Ohio State University Extension Agriculture and Natural Resources (OSU Extension) hosted a 4-hour workshop on nutrient management at the Soil and Water Conservation Society (SWCS) annual meeting on July 30, 2017. The workshop, titled "Agricultural Nutrient Management and Water Quality: Emerging Solutions and Ongoing Legal Challenges," covered the following topics:

- Balancing agricultural nutrient use with the impacts on water quality;
- An overview of the CWA; and
- State actions

After these informational overviews, the focus of the workshop shifted to a discussion of the issues faced by Des Moines, IA and other cities that are facing rising costs to treat their drinking water. This section of the workshop was meant to be interactive, with the NSGLC facilitating a discussion with the workshop participants on potential solutions for managing agricultural nutrient runoff; however, the participants were reticent in the discussion. Participants noted after the session that they were not interested in brainstorming, but rather, had hoped the workshop would have solutions already laid out for them.

The SWCS workshop was a follow-up to a similar panel discussion by the NSGLC and OSU Extension at the Universities Council of Water Resources (UCOWR) 2017 meeting in Fort Collins, CO. Titled "Beyond dead zones: the impact of agricultural nutrients on drinking water and associated legal policies, planning, and challenges for successful water quality management," the format of the panel was similar, with an overview of the legal framework followed by an interactive panel discussion. The discussion and brainstorming at the UCOWR session was much more robust. Perhaps this can be accounted for by the nature of the forum − the SWCS workshop was designed and advertised as a professional development/ continuing education event which may have led participants to expect the presentation of ready-made solutions, while the UCOWR panel was advertised as an interactive event.

PFAS − A Proposed Hybrid Outreach Approach

Per-and polyfluorinated substances are a family of emerging contaminants that includes hundreds

of individual compounds. Two common PFAS compounds are PFOS and PFOA. PFAS molecules include strong chains of carbon and fluorine atoms, and this molecular structure makes PFAS resilient and resistant to dissolving or breaking down (Lustgarten 2018). PFAS have been widely used in industrial, commercial, and household products including packaging, water-repellent fabrics, nonstick products, firefighting foam, and cleaning products.

Because PFAS are resistant to breaking down or dissolving, the compounds can accumulate in the environment and in the human body. The EPA reports that PFAS can be found in drinking water, soil, and food (U.S. EPA 2021a), and humans can ingest PFAS through various sources. According to the National Health and Nutrition Examination Survey, the CDC, and the National Groundwater Association, approximately 95% of the U.S. population has measurable concentrations of PFAS in their blood (NGWA 2017). Scientists associate elevated levels of PFAS in blood with health concerns and diseases including various types of cancers, liver and kidney disease, hormone disruption, and increased cholesterol levels. Most recently, studies have linked PFAS to reduced vaccine efficiency (ATSDR HHS 2021).

An increasing number of communities have found PFAS contamination in their drinking water. The Environmental Working Group (EWG) recently published data finding that there was evidence of PFAS contamination in 2,337 sites across 49 states (EWG 2021). As more information is learned about health risks associated with PFAS, there is a greater demand for the federal government and states to meaningfully regulate PFAS compounds.

Legal Overview

Under the SDWA, there are two methods available to regulate PFAS: issuance of a lifetime health advisory, or, listing as a regulated contaminant with an MCL. A lifetime health advisory is a non-regulatory standard that identifies the concentration of a contaminant in drinking water at or below an anticipated lifetime exposure level with no adverse health effects (U.S. EPA 2016b). Because a health advisory is non-regulatory, this means the standard is not legally enforceable and PWSs are not required to comply with the set limit (42 U.S.C. § 300g-1(b)(1)). Alternatively, the EPA may set enforceable MCL standards that set a threshold limit on the allowable level of a contaminant delivered to water users. Generally, the EPA must balance both the cost and public benefits of regulating a contaminant by setting a MCL that is feasible and takes into consideration health risk reductions (42 U.S.C. § 300g-3).

Federal Regulation of PFAS in Drinking Water

The federal government has not implemented comprehensive PFAS regulatory requirements. Beginning in 2002, the EPA initiated a priority review of PFAS and invited eight manufacturing companies to voluntarily phase out all PFOA in their products, which they did. However, the companies replaced PFOA with alternative PFAS compounds. In 2016, the EPA published lifetime health advisories for PFOA and PFOS at 70 parts per trillion (ppt) (U.S. EPA 2016b). More recently, in 2019, the EPA published a PFAS Action Plan that explained how the agency planned to address PFAS contamination (U.S. EPA 2019). In February 2020, the EPA published a proposed notice to set national drinking water standards for both PFOA and PFOS (U.S. EPA 2020). The SDWA rules will likely influence state efforts and regulations regarding PFAS as well.

State Action

A growing understanding of PFAS contamination and negative health effects, combined with a lack of comprehensive federal PFAS regulation, has led to limited and inconsistent PFAS regulation. States have taken a variety of approaches to regulating PFAS, resulting in a patchwork effect with some chemicals and locations regulated more stringently than others. Normally, federal standards act as a floor and states are free to enact stricter guidelines under state law.

To date, many states have not pursued regulation of PFAS. As Table 1 shows, the approaches of states that have chosen to regulate PFAS vary, as do which PFAS chemicals are regulated. Each approach has strengths and weaknesses. Some states have set non-enforceable advisory levels, while other states have set strict, enforceable MCLs. Others have classified PFAS contaminants as a hazardous

substance, prohibiting discharges. States have additionally considered monitoring, reporting, and remediation guidelines and requirements.

The patchwork PFAS regulatory approach has resulted in hundreds of lawsuits using different legal approaches to recover costs and damages from PFAS contamination. While many parties have successfully recovered damages or reached settlement agreements, some PFAS cases have been dismissed on procedural grounds or failed to establish a legal injury (Golden State Water Co 2021). Additionally, some companies have challenged the regulatory procedure used to set PFAS standards (MCOC 2021). Further, there is a growing recognition of the need for a comprehensive regulatory approach (Bjornlund and Dillon 2020).

Outreach: A Hybrid Approach

Building from lessons learned from the lead and nutrient pollution extension efforts, as well as providing outreach during the COVID-19 pandemic, the NSGLC is implementing a hybrid approach to its PFAS outreach programming. Due in part to the pandemic, the NSGLC's initial focus is on outreach through presentations at scientific conferences. This year, the NSGLC presented virtually on PFAS at the Emerging Contaminants in the Environment Conference, hosted by Illinois Sustainable Technology Center and Illinois-Indiana Sea Grant, and at the 2021 UCOWR meeting. The NSGLC's presentations help inform conference participants, which include scientists, engineers, educators, extension agents, state agency staff, and other policy makers, about the current status of PFAS regulation in order to help identify potential mechanisms to address PFAS contamination, especially as it applies to drinking water.

Community-based outreach projects have been harder to implement during the COVID-19 pandemic. However, due to the impact of its

Table 1. Examples of State PFAS Regulatory Actions.

State	PFAS Chemical Regulatory Approaches
Michigan	The legislature adopted MCLs for seven PFAS contaminants: PFNA, PFO, PFHxA, PFOS, PFHxS, PFBS, and HFPO-DA. The MCLs took effect in August 2020, and compliance is determined by an annual average sampling point for each compound. The Department of Health and Human Services adopted groundwater standards of 8 ppt for PFOA and 16 ppt for PFOS.
Minnesota	The Department of Health issued advisory values for PFOA at 15 ppt and PFHxS at 47 ppt. The advisory values are a non-binding recommendation set at a limit "that is likely to pose little or no risk to human health." In February 2021, Minnesota's Pollution Control Agency introduced a "PFAS Blueprint" to set health-based guidance values for PFAS drinking water chemicals and include PFAS as a hazardous substance. If implemented into regulation, the PFAS Blueprint would be one of the most comprehensive state regulatory efforts. However, the PFAS standards would continue to be health-based guidance and not enforceable MCLs.
New Jersey	In 2020, the Department of Environmental Protection adopted MCLs for PFOA at 14 ppt and PFOS at 13 ppt. Groundwater standards for PFOA were set at 14 ppt and PFOS at 13 ppt. Beginning in December 2021, private well owners will be required to test for PFOA, PFOS, and PFNA under the New Jersey Private Well Testing Act. PFOA and PFOS are listed as a hazardous substance.
New York	In 2016, New York became the first state to regulate PFOA as a hazardous substance. A hazardous substance designation requires proper storage and limited release of the chemical. State MCLs for PFOA and PFOS are 10 ppt.
Vermont	Vermont Act 21 provided a framework for identifying PFAS water contamination and issued standards for acceptable levels of PFAS in drinking water. The Vermont Water Supply Rule establishes state MCLs for PFOA, PFOS, PFHxS, PFHpA, and PFNA. The sum total of the five PFAS chemicals cannot exceed 1 ppt. Annual water quality sampling is required.

community-based lead project, the NSGLC is continuing to brainstorm ways to inform and work with communities on PFAS issues. In future efforts, the NSGLC plans to work with Sea Grant personnel working on PFAS around the country, to share information with their stakeholder communities about the legal framework through fact sheets, webinars, social media, and virtual meetings. These efforts will be aimed at areas with known PFAS contamination (EWG 2021).

Although the COVID-19 pandemic has made it difficult to meet in person, the NSGLC has gained experience in virtual meetings during the pandemic and learned valuable lessons along the way. Based in part on wanting to encourage more audience participation than occurred at its SWCS nutrient pollution workshop, the NSGLC has begun to integrate Poll Everywhere technology (polleverywhere.com) into webinars and virtual meetings. The NSGLC surveyed webinar participants and received positive feedback on the Poll Everywhere technology. Poll Everywhere can be integrated into PowerPoint, Keynote, or Google Slides. Once the host shares his or her screen during the presentation, the poll questions appear on a special webpage or through messages on a smartphone. Presenters are able to choose from a variety of activities to engage participants, such as open-ended or multiple-choice questions, or the ability to create word clouds based on participants' answers. Further, the software captures participant answers to help better track the feedback/answers given during the webinar. Finally, while there are paid subscriptions available, users can access Poll Everywhere for free for meetings of up to 25 participants.

To enhance virtual meetings, the NSGLC has also used on-line tools Miro (https://miro.com/) and Mural (mural.co) to create collaborative workshop spaces outside of Zoom. Miro and Mural are both online collaborative whiteboard platforms that enable individuals participating remotely to collaborate as if they were in the same meeting room. The whiteboard spaces mimic many aspects of attending an in-person meeting – posting sticky notes on virtual flipcharts, voting on priorities, and adding ideas to a virtual parking lot. The virtual workspaces also allowed fuller participation by participants whose organizations disallowed the use of Zoom on a computer. Those participants were able to call-in to the meeting on the phone and view the presentation slides through the virtual workspace. Like Poll Everywhere, Miro and Mural do have paid subscription services. However, users can create a limited number of whiteboards – 3 with Miro and 5 with Mural – for free, and educators can apply for free access to further services.

A final lesson learned in hosting meetings in a virtual setting is to work with a professional facilitator on lengthier meetings if financial resources allow. During COVID-19, the NSGLC had two meetings that were originally scheduled to be in-person go virtual. The hired facilitators for both meetings worked extensively with the NSGLC staff to develop the workshop agenda with a particular focus on the needs of a virtual meeting, create the virtual whiteboards, and facilitate the meetings. One meeting also engaged a separate "tech host" facilitator whose specific role was to help participants with any technological issues.

Conclusion

The federal and state governments' varying approaches to regulating drinking water contaminants are complex and often confusing to non-experts. To increase awareness and understanding of this legal framework among stakeholder audiences, the NSGLC has developed and implemented research and extension projects for lead, nitrates, and PFAS. It is critical that these types of legal outreach programs and strategies provide current and accurate information in a manner that is accessible to both attorneys and non-legal audiences.

These projects have allowed the NSGLC to gain knowledge in the effectiveness of different outreach methods. The NSGLC's interdisciplinary, community-engaged project on lead has helped families mitigate risks and improved the data available to policy makers. The project has also enabled the NSGLC to improve its approach for developing outreach materials for the general public and see first-hand how its work benefits communities in Mississippi. With nitrates, the NSGLC has learned more about the expectations and best practices related to the delivery of professional development programming for

attorneys, natural resource managers, and other policy makers. While the impacts of this work for reducing exposures to contaminants are less direct than when working with individuals and communities, identifying regulatory gaps to this audience is essential for policy change.

As a result, the NSGLC is proposing a hybrid approach for addressing PFAS, drawing on lessons learned from its previous projects to disseminate information to both professionals and communities, with the hope of broadening its impact. While the COVID-19 pandemic has limited community events, the NSGLC will employ outreach methods that it has learned during the pandemic in its future, virtual outreach efforts. These approaches include utilizing audience participant software like Poll Everywhere and virtual whiteboards. While these services offer more advanced options for subscribers, limited use of the technology is available for free. Importantly, educators can apply for additional free services. The NSGLC believes that these outreach techniques can also be employed by other professionals as we continue to work in a mostly virtual space.

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42 U.S.C. § 300g-3.

Appendix: Glossary of Terms

AL – Action Level

CBR – Community Based Research

CCL – Contaminant Candidate List

CDC – Centers for Disease Control and Prevention

CEC – Contaminants of Emerging Concern

CWA – Clean Water Act

DMWW – Des Moines Water Works

EBLL – Elevated Blood Lead Levels

EPA – Environmental Protection Agency

EWG – Environmental Working Group

LCR – Lead and Copper Rule

LSL – Lead Service Lines

MCL – Maximum Contaminant Level

MSDH – Mississippi State Department of Health

NALC – National Agricultural Law Center

NAWQA – National Water Quality Assessment

NPDES – National Pollutant Discharge Elimination System

NPDWR – National Primary Drinking Water Regulation

NSGLC – National Sea Grant Law Center

OSU Extension – Ohio State University Extension Agriculture & Natural Resources

PFOA – Perfluorooctanoic acid

PFOS – Perfluorooctanessulfonic acid

PFAS – Per-and polyfluoroalkyl substances

PWS – Public Water System

SDWA – Safe Drinking Water Act

SDWIS – Safe Drinking Water Information System

SWCS – Soil and Water Conservation Society

UCOWR – Universities Council of Water Resources

UM Lead Project – University of Mississippi Lead in Drinking Water Project

WIIN – Water Infrastructure Improvement for the Nation

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Informing the Development of the Coast Model of the Watershed Game

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Abstract: Since 2006 the Watershed Game, a role-playing simulation and serious game focused on managing nonpoint source pollution at the watershed scale, has been used across the U.S. to improve understanding of, commitment to, and involvement in watershed-scale management. Stakeholder or student participants manage a fictitious watershed to meet a "Clean Water Goal." Designed for freshwater watersheds, the game is available in local leader and classroom versions, and play is led by trained facilitators or educators. To inform the expansion of the Watershed Game to include coastal watersheds, a needs assessment was conducted to identify water quality and management challenges in coastal regions, using the Gulf of Mexico and South Atlantic as a case study. Several methods for assessing critical coastal management challenges and key land uses to prioritize in the game were employed: a review of reports, expert focus group, survey of Gulf and South Atlantic regional experts, second survey of coastal experts from the National Sea Grant Network to verify widespread applicability, and finally pilot tests of the draft game. Results showed high agreement among assessment methodologies regarding the most critical coastal challenges and important land uses to feature in the game. As a result, the Coast Model of the Watershed Game focuses on three primary nonpoint source pollutants, excess nitrogen, excess phosphorus, and excess sediment. Additionally, results indicated a need to integrate a new game element, resilience to flooding, which has been added to the challenge of winning the game by meeting the Clean Water Goal.

Keywords: *watershed management, nonpoint source pollution, flooding, community resilience, Watershed Game, serious games, stakeholder engagement, extension*

Water resource challenges are increasing in severity and frequency, resulting in negative ecological, social, and economic impacts to communities. This is particularly true for the impacts of nonpoint source pollution, despite efforts to mitigate it in the United States (e.g., Stets et al. 2020). Nonpoint source pollution cannot be managed effectively on a community-by-community basis. Rather, management must occur on a watershed scale. This can be problematic, given that land and water management traditionally have been based on jurisdictional boundaries, whereas watersheds cross multiple political and jurisdictional boundaries (Uitto and Duda 2002). In transitioning to watershed-level management, managers often struggle to balance the competing and sometimes divisive interests, cultures, and perspectives of stakeholder groups while seeking to sustain and improve the health of water resources at a watershed scale (Medema et al. 2016). These challenges are compounded in coastal regions. Relative to other areas, coastal watersheds are among the most densely populated, biologically rich, and economically important. They are also highly vulnerable to water-related threats (Gray 1997; Lotze et al. 2006). Transitioning from managing within political boundaries to managing watershed-wide requires managers to employ methods that increase the understanding,

Research Implications

- The complexity and interrelated nature of issues affecting coastal watersheds from both upstream environments and coastal waters, make the intensive approach to information gathering prior to game development described in this paper worthwhile.
- Though water quality challenges vary in relative importance in different coastal regions, experts throughout the coastal United States consistently rated excess nitrogen, phosphorus, and sediment as critical nonpoint source water pollutants.
- Watershed management issues and the associated land uses are similar throughout the U.S. coastline, making it possible to create a generic coastal watershed game that can be used across coastal regions, including the freshwater systems of the Great Lakes.
- This paper demonstrates the value of querying local experts and the literature prior to designing content, elements of play, critical challenges, and game goals to ensure that serious games help consolidate learning around the issues that are most influenced by stakeholders and depend on collaboration.

investment, engagement, and collaboration of a wide range of stakeholders, many of whom are new to or resistant to such changes.

The successful engagement of stakeholders can be supported through interactive methods of teaching and learning. These methods, often called experiential learning, can be traced back as far as John Dewey (1938) and have been supported as an effective means to educate audiences since the 1950s (Rusca et al. 2012). Gaming and simulations as forms of experiential learning are documented in the extension literature as early as 1978 (Boehlje and Eidman). Though many terms (e.g., gaming models, games, role-play simulations, or science-based role-play simulation exercises) have been used to refer to games designed to engage adults in learning or collaboration (Rumore et al. 2016), "serious games," which are played for reasons beyond entertainment (Bathke et al. 2019), have a strong track record of being used to help engage people in discussions about difficult challenges (Rumore et al. 2016), stimulating collaborative learning and knowledge sharing, spawning negotiation and joint decision-making, and building trust, despite sometimes conflicting interests (e.g., Uitto and Duda 2002; Reckien and Eisenack 2013). These games appeal to adult and professional audiences, while the basic tenets of games as fun and engaging experiential tools remain one of the benefits to their use in extension (Boehlje and Eidman 1978; Rumore et al. 2016). Specifically, games, simulations, and in particular, serious games, are useful for encouraging social learning around issues such as transboundary water management (e.g., Van Bilsen et al. 2010; Hoekstra 2012). Serious games may be particularly helpful when addressing difficult and potentially divisive environmental issues, as games can promote dialogue, civility, and mutual respect. In this context, small-group simulations encourage teamwork, cooperation, and enhanced understanding of management challenges and solutions, while building collaboration skills across various stakeholder groups (Bathke et al. 2019).

The Watershed Game, a nonpoint source water pollution educational program and serious game, was designed with the specific intent of breaking down barriers among diverse stakeholder groups involved in watershed management. The game increases understanding of how human alterations to land within a watershed impact downstream water quality, while introducing tools and practices that are commonly used to prevent or ameliorate those impacts. The Watershed Game was developed for freshwater environments by Minnesota Sea Grant, University of Wisconsin Extension, and the Lake Superior Research Institute. Minnesota Sea Grant and the University of Minnesota Extension enhanced and expanded the concept 15 years ago, and the Watershed Game and its supporting program have now expanded to 22 states. Early designs focused on inland waters impacted by excess phosphorus and sediment. In 2018, the authors initiated a case study to inform the development of a Coast Model of the Watershed Game, as described in this paper.

The Watershed Game is a face-to-face, serious game that involves teams of participants in a simulation of real-life challenges faced by local communities and land and water owners/managers when addressing water quality at an individual land use and watershed scale. Designed to allow

participants to "see" representative aspects of their communities, lives, and livelihoods in the game board and through gameplay, the game allows players to learn about and test actual management and policy tools with authentic, yet fictitious management challenges. The game offers an opportunity for dialogue among and across teams, uses repetition to deepen learning and understanding, and requires collaboration across teams for ultimate success—to "win" the game. A facilitator actively manages the interaction and relates the experiences to local challenges during the game and during a post-play discussion.

These characteristics of the Watershed Game embrace many of the documented benefits of games. It offers a fun and enjoyable activity that entices individuals to engage with a larger group (Falk et al. 2001; Burby 2003; Bathke et al. 2019). It allows for a controlled and safe environment from which to learn about and test complex concepts (Mayer 2009; Rusca et al. 2012; Rumore et al. 2016; Bathke et al. 2019) that are directly relatable to specific challenges being faced in participants' communities and watersheds (Peters and Vissers 2004; Arndt and LaDue 2008; Rumore et al. 2016; Bathke et al. 2019). Participants see the challenges their communities face within the context of the whole watershed, and visualize the positive, collective changes that result from collaboration with other watershed stakeholders and communities as they work to improve water quality by applying solutions on the land. The visual elements and hands-on actions of the game allow participants to connect to their sense of and attachment to place. This, in turn, triggers emotional bonds and personal meaning to the lessons learned (Hidalgo and Hernanez 2001; Brehm et al. 2004; Nanzer 2004; Thompson and Prokopy 2016). The act of role-playing and the repetitive rounds allow participants to experience and test different actions and observe the ensuing results (Oblinger 2004). Repetition also allows individuals to see how actions build over time and across land uses for the good of the whole (Rusca et al. 2012).

Description of the Watershed Game

Prior to the development of the Coast Model, the primary focus of the Watershed Game was nonpoint source pollution (see Table 1 for descriptions of key components of the Watershed Game). Game facilitators had the option to play with either of two critical freshwater pollutants: phosphorus as the key excess nutrient; or sediment, one of the most common causes of pollution in rivers and streams (U.S. EPA 2017). The goal of the game was, and continues to be, to use limited financial resources to reduce excess sediment and/or excess phosphorus to levels that meet a "Clean Water Goal," even as participants encounter "Unanticipated Events" such as severe storms that can cause setbacks in teams' progress in pollution reduction. Participants work in land use teams around a large, stylized watershed map (the "Watershed Game Board"). The gameboard is organized into land use areas, which include graphical elements representing water quality impacts. As participants play, they experience how each land use impacts water quality, increase their knowledge of best management practices (BMPs) represented on "Tool Cards," and learn how specific choices can reduce adverse impacts. "Unanticipated Events" introduced during play provide additional teaching opportunities and allow the facilitator to control funds available to land use teams. Limited funds force participants to work collaboratively across land use teams in the final round if they are to meet the Clean Water Goal and collectively win the game. In so doing, participants experience the necessity and benefits of considering, involving, and cooperating across land uses within the watershed, illustrating that collaboration at a watershed scale is an essential part of effectively managing water and land use.

The learning objectives of the watershed game are to:

- Understand that all land uses within a watershed contribute pollutants and impact water quality.
- Identify specific sources of pollutants from each land use.
- Apply best management practices (plans, practices, and policies) to prevent or reduce impacts.
- Choose solutions based on available funds, benefits, and feasibility.
- Understand that solutions that benefit the whole watershed require collaboration across jurisdictions and land uses.

The Watershed Game is available as a Local Leader Version for use with elected and appointed officials, community leaders, watershed organizations, and other adult audiences who have a role in water resource management. In addition to the new Coast Model, the Local Leader Version is available in three models: headwater stream, lake, and large river, which can be linked together to represent an entire watershed basin. The Classroom Version is a modification of the headwater stream (known as the "Stream Model") of the Local Leader Version, adapted for use with middle to high school students in formal and nonformal learning settings.

Need for a Coast Model of the Watershed Game

Over the 15 years of its use across much of the United States, water resource professionals and educators have recognized the value of the Watershed Game as an extension, education, and engagement tool. As game use expanded beyond the Great Lakes Region, multiple requests were made to add excess nitrogen to excess phosphorus as a second nutrient of concern, while retaining excess sediment as a critical water quality nonpoint source pollutant. Additionally, requests from several coastal regions were made for coastal models in both the Local Leader and Classroom versions, and for a stronger emphasis on planning in the face of climate change (Bilotta and Hagley 2017; Minnesota Sea Grant 2019). Strong interest expressed at game facilitator training workshops in the southeastern United States provided an opportunity for a case study to frame the development of a new coastal model. Coast Model game development was initiated in 2018 with the formation of the project development team. The goal was to identify critical environmental challenges impacting U.S. coastal watersheds (including the Great Lakes) that could be addressed within the existing structure of the Watershed Game.

The Coast Model of the Watershed Game adds a missing element to an existing set of game models, allowing the combined models of the Watershed Game to encompass the entirety of a watershed from its headwaters to its coastal outlet. To ensure consistency with previous models of the game, the team approached the needs assessment with

Table 1. Key components of the Watershed Game.

Component	Description
Watershed Game Board	The game board is a fictional landscape showing typical land uses that include graphical elements to represent key potential sources of pollution to different waterbodies.
Clean Water Goal	The goal of the game is to reduce nonpoint source pollution to levels that protect human health and aquatic ecosystems. This is achieved by selecting and implementing tools to meet a Clean Water Goal and is modelled after the Federal Clean Water Act Total Maximum Daily Load (TMDL) program.
Tool Cards	Tool Cards represent policies, plans, and practices (often referred to as best management practices) that prevent or reduce nonpoint source pollution. Each land use has a set of Tool Cards, and each Tool Card fits in a specific location on the game board to show what implementation might look like.
Plan Cards	Plan Cards can be purchased by individual land use teams and are used in the game to introduce the concept of planning and its benefits and costs. Plan Cards are introduced with minimal background, and land use teams decide if they want to invest a portion of their limited funds in a plan. The benefits are only realized if teams can articulate how their plan benefits their efforts to meet the Clean Water Goal.
Unanticipated Event Cards	Unanticipated Events include unplanned natural or human-caused events that can impact progress toward the Clean Water Goal. Examples include floods or other natural disasters as well as negligence or mismanagement that result in resources being diverted to address a different, urgent issue. During the game, Unanticipated Events are used as needed by facilitators to affect one or more land use teams by removing or rewarding funds or change the upstream pollutant load or Clean Water Goal.

two constraints: 1) existing game components (see Table 1) would be retained in the Coast Model; and 2) water quality parameters previously included would remain (i.e., excess sediment and phosphorus) to ensure the ability to cascade impacts across an entire watershed basin.

The needs assessment described in this paper explored what, if any, new water quality parameter(s) could be included to increase the game's relevance in coastal waters, without greatly lengthening the time required to play. Environmental challenges in coastal regions are complex and vast. As such, the needs assessment was also designed to broadly identify additional challenges, beyond water quality, that could be integrated, while recognizing the need to focus on challenges that are relevant to all U.S. coasts (including the Great Lakes). This assessment was designed to gather general information on the topic to inform game development and was not designed for statistical inferences. Results were interpreted with the intent of guiding the selection of additional parameters to include in the Coast Model, either as Unanticipated Events, sources of pollution, challenges to be addressed with Tool Cards, or in other ways to support learning and generate discussions with participants.

Methods

The project development team used five methodologies (the first four of which are described in detail in this paper) to gather and consolidate knowledge, research, and expert opinions to guide game development regarding critical coastal challenges and key land uses for addressing coastal land and water issues. Table 2 outlines the methods used, timing, and geographic focus of each method. The results of the fifth methodology, pilot workshops, will be summarized in a future publication.

Review of Reports

In fall 2018, 30 coastal reports, studies, and documents were reviewed to gain a foundational understanding of priority coastal issues, including water quality parameters most detrimental to U.S. coasts. Salient documents were identified through online research and recommendations from coastal professionals and practitioners. The initial internet search for reports focused primarily on the Gulf of Mexico and South Atlantic and used a variety of impact-related keywords (e.g., coastal stressors, coastal drivers, coastal impacts, coastal zone), along with state names (i.e., Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, and South Carolina). Sources were selected according to their potential relevance and usefulness in shaping the future focus of the tool, and included national, regional, and state reports. Examples of reports reviewed include National Estuarine Research Reserve Management Plans, State Coastal Management Program Section 309 Assessment and Strategies, the Gulf of Mexico Alliance

Table 2. Overview of methods used to inform the development of the Coast Model of the Watershed Game.

Approach	Method	When	Geographic Focus
Review of Reports	Review of reports with regard to coastal issues	Fall 2018	Predominantly the Gulf of Mexico and South Atlantic (with two National reports)
Focus Group	Regional experts convened online via an interactive virtual platform	December 5, 2018	Gulf of Mexico and South Atlantic
Online Regional Survey	Respondents sought through relevant known contacts, listservs, conferences, etc.	October 31-December 3, 2018	Gulf of Mexico and South Atlantic
Online Sea Grant Survey	Respondents sought through National Sea Grant Network	March 19-April 9, 2019	Coastal regions nationwide, including the Great Lakes
Pilot Workshops*	Trial gameplay and focus group discussions	February 18 and 19, 2020	Gulf of Mexico and South Atlantic

*Will be summarized in subsequent publication.

Governors' Action Plan III, and local watershed management plans (see Appendix A for a list of reports). Key information from each report was summarized, grouped, and coded to generate a broad understanding of regional priorities.

Focus Group

In December 2018, the project team conducted a two-hour, virtual focus group with coastal professionals from the Gulf of Mexico Region. Participants, selected from Sea Grant and other coastal management and education networks, were identified based on expertise in coastal environmental challenges. Twelve individuals participated (24 invited), representing four coastal states (Florida, 3; Alabama and/or Mississippi, 4; and Louisiana, 5) and a variety of backgrounds, including academia, nonprofit organizations, and federal, state, and local government. Participants were provided a short presentation on the Watershed Game and an overview of the preliminary investigations before participating in a facilitated group discussion. Questions focused on whether preliminary survey results resonated with participant understanding of key coastal challenges, the primary impacts associated with those challenges, and the most significant land uses impacting water quality in their area. Two team members took comprehensive notes during the discussion. These notes were transcribed, reviewed, grouped by theme (coastal issues, potential unanticipated event cards, potential tool cards, game development items, and items for further research), and scored by frequency.

Gulf of Mexico and South Atlantic Survey and National Sea Grant Network Survey

Qualtrics-based surveys were administered to coastal professionals in the Gulf of Mexico and South Atlantic Regions in fall-winter 2018 and then to the National Sea Grant Network in spring 2019 (see Appendix B for survey instruments). Surveys had the dual objectives of identifying critical water-related environmental challenges and primary land uses contributing to those challenges in estuaries and coastal areas. The Gulf of Mexico and South Atlantic (Regional) survey was pilot tested among the project development team and by two other survey experts within Sea Grant.

The Regional survey was distributed via email to colleagues with expertise in coastal research, education, or management in the region. Recipients were encouraged to share the survey with regional colleagues. In addition, the survey link was distributed broadly at the Bays and Bayous Symposium in Mobile, Alabama, November 28-29, 2018. The survey was open from October 31, 2018 through December 3, 2018.

The National Sea Grant Network (Sea Grant) survey was distributed to approximately 50 Sea Grant professionals (e.g., researchers, outreach professionals, educators, communications specialists) who represented the breadth of coastal issues across all U.S. coastal areas (including the Great Lakes). Recipients were encouraged to share the survey with other Sea Grant colleagues. The survey was open from March 19, 2019 through April 9, 2019.

The Sea Grant survey was nearly identical to the Regional survey and served to verify that findings from the Regional survey were relevant to all U.S. coastal areas (including the Great Lakes). It also served to identify opportunities for game expansions or modifications that might increase the relevance of the Watershed Game beyond the Gulf of Mexico and South Atlantic.

Pilot Workshops

In February 2020, pilot workshops were held in New Orleans, Louisiana and Mobile, Alabama to play the game and to gather input that informed refinement of the game components and the process of game play. Forty-one participants provided critical feedback. Detailed results of the pilot workshops will be summarized in a future publication.

Results

Review of Reports

Of the 30 reports reviewed, two were National in scope and three focused on the Gulf of Mexico. The remainder were state-specific, with a subset focusing on individual sites within states. States included Georgia (five reports); South Carolina, Florida, Alabama, and Louisiana (four reports each); Mississippi (three reports); and Texas (one report). Most reports identified multiple coastal

challenges as priority issues. In total, the reports identified 25 priority issues (see Figure 1).

Five topics were identified in at least 10 of 30 reports, including land use change and development (60%), water quality degradation (43%), sea level rise (43%), impact of storms (43%), and flooding (33%). An additional three topics, including stormwater management-runoff, the influence of climate change, and erosion, were identified in nine reports (30%).

This review did not represent a comprehensive or quantitative analysis of all coastal impact assessments and reports, nor were all impacts independent of one another. Instead, the review served as an initial guide and baseline of information about potential coastal issues for consideration in the subsequent focus group and surveys, and for possible inclusion in the new Coast Model. Results showed coherence among reports regarding issues that negatively affect water quality (e.g., water quality degradation, erosion, sediments, hypoxia, nutrients), and modifications that contribute to and impacts associated with flooding (e.g., land use change and development, sea level rise, impact of storms, flooding, stormwater management).

Focus Group

The collective views of participants shared in the focus group discussion yielded rich data that were grouped into themes. Excess nutrients in water was the most discussed coastal issue, followed by flooding, climate change and sea level rise, coastal erosion, marine debris, and water pollution. There was general agreement that excess nutrients, flooding, climate change/sea level rise, and coastal erosion were common problems across multiple states in the region. Some topics raised were highly localized, state-specific issues (e.g., phosphate mining in Florida), rather than high priorities across the region. There was recognition that to ensure applicability of the Coast Models of the Watershed Game to coastal professionals across the U.S. (including the Great Lakes), the highly localized topics should not be considered as a primary focus of the game. More locally-specific challenges were retained as possible Unanticipated Events or other game elements that could be used where and when appropriate.

Gulf of Mexico and South Atlantic Survey and National Sea Grant Network Survey

The 117 respondents of the Regional survey represented a wide variety of affiliations and professional roles, although the survey did not collect respondents' specific locations within the region. The 30 respondents of the Sea Grant survey represented each of the five coastal regions of the U.S., including the Great Lakes (12), Gulf of Mexico (7), Southeast (5), Northeast (3), and Pacific (3). While a larger response rate would

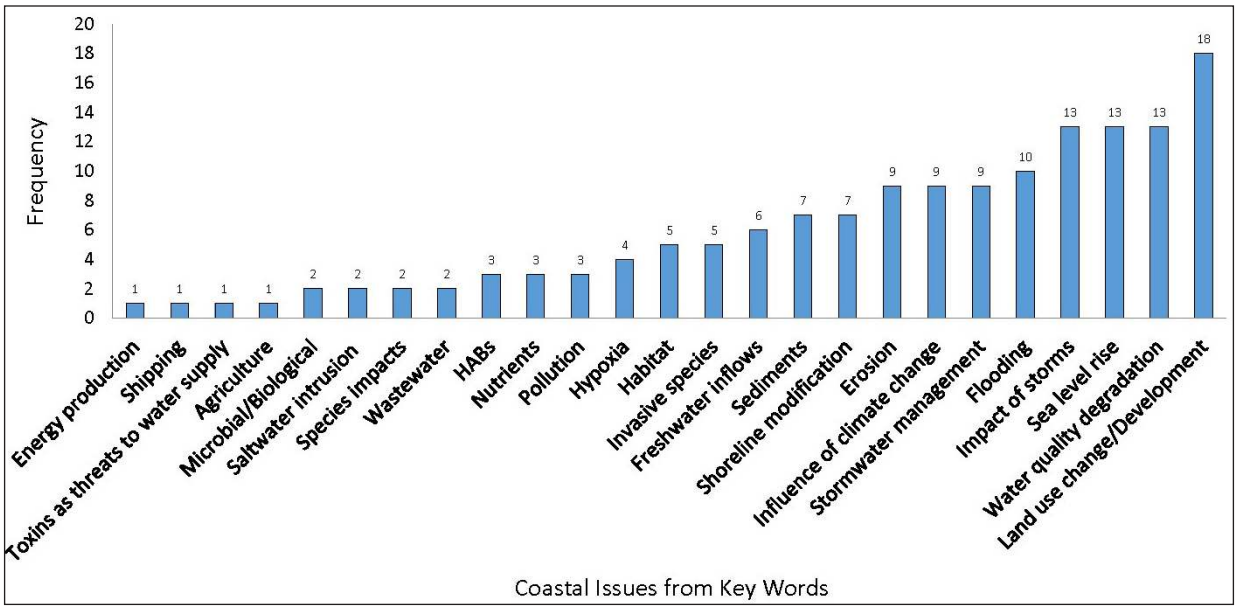

Figure 1. Coastal issues identified in the review of reports.

have been preferred, it is worth noting that results reflect input and representation from professionals from each of the U.S. coastal regions.

Coastal Challenges. The surveys provided a list of 14 specific coastal challenges, generated in part by results of the review of reports. Participants were asked to mark all issues they considered to be challenges impacting their coastal lands and waters. Table 3 compares the percent of respondents in each survey that selected each challenge (respondents could choose as many as desired, and on average chose 7-8 each). Erosion, flooding, nutrients, and harmful algal blooms (HABs) stood out as the top four most often-selected challenges in both the Regional and Sea Grant surveys. Each challenge was identified by a minimum of 67% of respondents from each survey. Excess nitrogen (55% Regional and 57% Sea Grant) and fecal coliform (47% Regional and 50% Sea Grant) were close behind and in close agreement across the two surveys. Coastal land loss was selected as a challenge by 68% of Regional survey respondents and by 60% of Sea Grant survey respondents. Resilience, excess phosphorus, and excess sediment were chosen as challenges by a markedly higher percentage in the Sea Grant survey than in the Regional survey, whereas saltwater intrusion was markedly more important in the Regional survey.

Top Three Critical Coastal Challenges. Respondents were asked to consider the list of challenges they identified in the previous question and choose three they considered most critical in terms of potential impacts to the natural and socioeconomic environments along the coast in their area. Figure 2 shows the percent of respondents who selected any of the most often identified challenges as one of the top three critical challenges impacting their coast. The percentage of respondents selecting each challenge as one of the top three challenges in their area ranged from 2% (excess flow) to 58% (coastal land loss) in the

Table 3. Challenges and critical challenges impacting coastal lands and waters identified by respondents to the Regional survey and Sea Grant survey.

Coastal Challenges	Regional Survey (117 Respondents)		Sea Grant Survey (30 Respondents)	
	Identified as a coastal challenge	Identified as one of the "top three critical challenges"	Identified as a coastal challenge	Identified as one of the "top three critical challenges"
Erosion	**71%**	23%	**73%**	30%
Flooding	**68%**	34%	**73%**	52%
Coastal land loss	**68%**	58%	**60%**	29%
Nutrients	**67%**	38%	**87%**	32%
Harmful Algal Blooms (HABs)	**66%**	30%	**87%**	30%
Saltwater intrusion	**61%**	23%	33%	6%
Excess nitrogen	**55%**	21%	**57%**	6%
Fecal coliform	47%	15%	50%	10%
Resilience	43%	n/a	**67%**	32%
Pathogens	40%	10%	40%	13%
Excess phosphorus	38%	7%	**57%**	13%
Elevated water temperatures	35%	11%	27%	10%
Excess sediment	30%	11%	**60%**	(16%)
Excess flow	8%	2%	20%	(3%)

Note: Bolded items were selected by more than 50% of respondents in each survey.

Regional survey and from 3% (excess flow) to 52% (flooding) in the Sea Grant survey.

As Figure 2 demonstrates, coastal land loss, flooding, nutrients, HABs, and erosion rose to the top in both surveys as critical challenges. However, there were notable differences between survey groups. Though coastal land loss was considered to be a coastal challenge by a high percentage of respondents in both surveys (see Table 3), it was considered a critical challenge by more respondents in the Regional survey (58%) than in the Sea Grant survey (29%). This is not a surprising result, particularly given that 39% of Sea Grant survey respondents were from the Great Lakes Region where coastal land loss is relatively limited and driven by periodically-high water levels and major storm events rather than by the rising sea levels and other factors causing land loss in the low-lying Gulf of Mexico. In contrast, Sea Grant respondents chose flooding as a top critical challenge at a higher percentage than Regional respondents (52% versus 34%, respectively).

Resilience was chosen as a coastal challenge by 67% of respondents and as one of the top

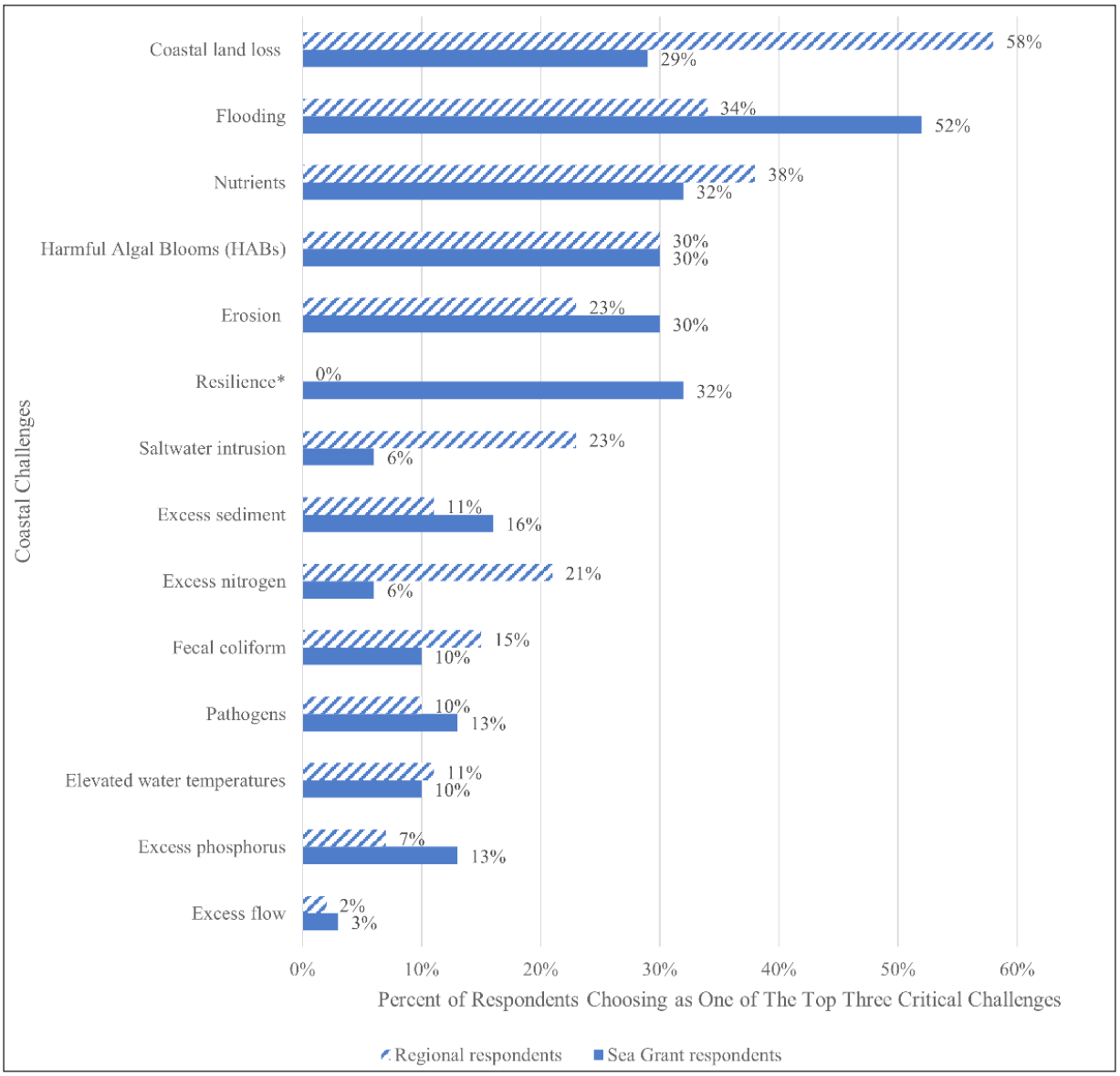

Figure 2. Percent of respondents choosing each item as one of three critical challenges in Regional and Sea Grant surveys. *Note: Resilience was inadvertently omitted from the Regional survey as a choice for the top three critical challenges.

three critical challenges by 32% of respondents in the Sea Grant survey. In the Regional survey, 43% selected resilience as a coastal challenge. Resilience was inadvertently omitted from the Regional survey as one of the choices for the top three critical challenges, but the high level of interest evident in the Sea Grant survey as well as the importance of increasing coastal resilience to flooding along all coasts suggested it was worthy of further consideration in game design.

Though excess nutrients were considered a top critical challenge in both surveys, there were clear differences in the two surveys in terms of which nutrient was of most concern to survey respondents. A higher percentage of Regional survey respondents than Sea Grant respondents ranked nitrogen as a top challenge (21% and 6%, respectively) whereas the reverse was true for excess phosphorus (7% and 13%, respectively).

It is important to note that recognition by survey respondents that something is a challenge to their coasts did not necessarily equate with the degree of agreement that it is a critical challenge in terms of overall potential impacts to the natural and socioeconomic environments along their coasts. For example, erosion was chosen as a coastal challenge by 71% of Regional respondents (the highest percent of the 14 options), yet it was identified as one of the critical challenges by only 23% of the same group (see Table 3, column 2).

Identification of Land Uses Contributing to the Top Ranked Critical Coastal Challenges. Respondents were asked to consider the top three critical challenges they identified and then select the primary land uses from a list (Appendix B: Survey Instrument Q5,6,7) that contribute to those challenges. Table 4 reports the top five land uses associated with the top three critical challenges identified, except where the fifth and sixth land uses were tied.

Excess nutrients and HABs are closely related challenges. Land uses identified by respondents as contributing most to both were urban and residential, including wastewater (56% of Regional survey respondents and 88% of Sea Grant survey respondents) and agriculture (73% Regional and 89% Sea Grant). Heavy industry was considered to be a contributor to excess nutrients by 43% (Regional) and 40% (Sea Grant), and to HABs by 37% (Regional) and 11% (Sea Grant) of respondents. Other land uses seen as contributing to nutrients and HABs, though to a lesser extent, included forestry and silviculture, ports and harbors, and recreation and tourism.

Flooding was considered to be most affected by urban and residential land use (58% of Regional respondents and 50% of Sea Grant respondents). Agriculture and heavy industry were considered to be major contributors to flooding by a smaller percentage of Regional survey respondents (15% each) than in the Sea Grant survey (31% for agriculture and 38% for heavy industry). Similarly, ports and harbors were considered important influences on flooding by fewer respondents in the Regional survey (10%) than the Sea Grant survey (25%). Flood control, though not a "land use" as defined in the Watershed Game, was considered important to the challenge of flooding in both surveys (50% Regional and 56% Sea Grant).

Pilot Workshops

In February 2020, pilot workshops were held in New Orleans, Louisiana and Mobile, Alabama, to play the draft Coast Model of the game and gather input to inform refinement of the game components and the process of game play. Forty-one participants provided feedback. As a result of the feedback received from workshop participants, the Coast Model of the Watershed Game includes two major scoring components. Like the original Watershed Game, participants work in land use teams and finally as a collaborative watershed group to reach a Clean Water Goal. Simultaneously, each Tool Card also describes and scores the Tool Card plans, practices, or policies in the context of how they will influence community resilience to flooding. Unanticipated Events place more emphasis on extreme flooding and nonpoint source, HAB-related events. Workshop participants indicated that these modifications provided a more comprehensive, realistic simulation of the challenges encountered in managing watersheds in coastal regions.

Discussion

The combined results from the literature review, focus group, and surveys constituted a needs

assessment to inform the development of the new Coast Model of the Watershed Game. They were not designed for statistical inferences. This case study shows how these methods ensured that the Coast Model will resonate across all U.S. coasts, offers flexibility to address educational needs in any region, and can be coupled with the other game models to encompass the entirety of a large, multi-faceted watershed basin from its headwaters to its coastal outlet. Expanding the Watershed Game's geographic scope to include coastal watersheds provided an opportunity to evaluate the importance of additional nonpoint source pollutants, particularly nitrogen, and to integrate other coastal challenges. Based on the results of this assessment, the development team prioritized the issues of nutrients, flooding, and HABs as critical coastal issues for consideration in the Coast Model, along with resilience.

Pollutants

The importance of phosphorus or nitrogen as the limiting nutrient varies widely in different geographical regions and in freshwater versus oceanic systems. Factors such as upstream soils, land uses, nutrient sources, and nutrient loads impact the relative importance of nitrogen versus phosphorus in triggering excess algal blooms, HABs, and subsequent water quality degradation (Oelsner and Stets 2019). Similarly, the role of sediment varies widely across coastal regions of the U.S. Some areas are confronted by excess sediment, while others are challenged by a loss of sediment inputs. For example, the latter is particularly true in the Mississippi River Delta, where flood control, river rerouting, erosion, and channelization have resulted in a lack of sediment, causing significant land loss. Finding a way to encompass these variabilities and link all three (nitrogen, phosphorus, and sediment)

Table 4. Primary land uses contributing to the critical challenges from the surveys.

	Regional Survey (117 Respondents)			Sea Grant Survey (31 Respondents)		
Top land uses identified as contributors to top challenges identified in the surveys	**Respondents identifying this as a land use contributing to nutrients**	**Respondents identifying this as a land use contributing to flooding**	**Respondents identifying this as a land use contributing to HABs**	**Respondents identifying this as a land use contributing to nutrients**	**Respondents identifying this as a land use contributing to flooding**	**Respondents identifying this as a land use contributing to HABs**
Urban and residential, including wastewater	82%*	58%*	86%*	80%*	50%*	56%*
Agriculture	73%*	15%*	86%*	80%*	31%	89%*
Heavy industry	43%*	15%*	37%*	40%*	38%*	11%
Forestry/ silviculture	20%		20%			22%*
Ports and harbors	18%	10%		20%	25%	11%
Recreation and tourism	18%		17%	30%		11%
Flood control		50%*		20%	56%*	
Oil and gas exploration and extraction		10%				

*Starred items were the top three primary land uses contributing to the identified critical coastal challenges in each survey.

pollution challenges across a watershed basin was paramount.

One of the most important design parameters behind the Watershed Game is flexibility. The inclusion of all three pollutant options furthers that flexibility and maximizes the educational potential of the game by allowing facilitators to select the pollutant most important to manage in order to improve water quality in their region. For example, a game facilitator in the Mississippi Delta Region would most likely choose nitrogen rather than excess sediment as their pollutant of concern when leading the game; however, they could incorporate discussion about coastal land loss and reduced sediment loads in the context of increases in severity of coastal flooding as discussed in the "Flooding and Resilience" section below.

Harmful algal blooms (HABs) were noted as a significant coastal challenge and are associated with excess nutrients, specifically nitrogen and phosphorus (Anderson et al. 2002). Thus, the project development team determined that HABs are an outcome of excess nutrients and could be addressed explicitly in the game as an Unanticipated Event. This allows the game facilitator the opportunity to draw particular attention to this challenge and its health risks and make connections to how land uses in specific geographic areas contribute to their occurrence.

Land Uses

Results guided the development team's selection of the five land uses included on the Coast Model gameboard: industry and ports, agriculture, urban, residential, and rural coast. Primary land uses identified by respondents from both surveys as heavy contributors to nutrient impacts, HABs, and flooding include urban, residential, agriculture, and to a lesser extent, heavy industry. Recreation and tourism, forestry and silviculture, and ports and harbors were also considered to be contributors to nutrient impacts and flooding by a smaller percentage but are common land uses in most coastal environments. Practical considerations of game design limited the team to five land uses (see Figure 3), so land uses were consolidated, incorporating other traditional coastal uses less highly rated in the results, when possible. For example: Industrial Port combines heavy industry with ports and harbors, and integrates environmental justice issues by including a small, shoreside subsistence community dependent on fishing and shellfish; Agriculture includes forestry and silviculture;

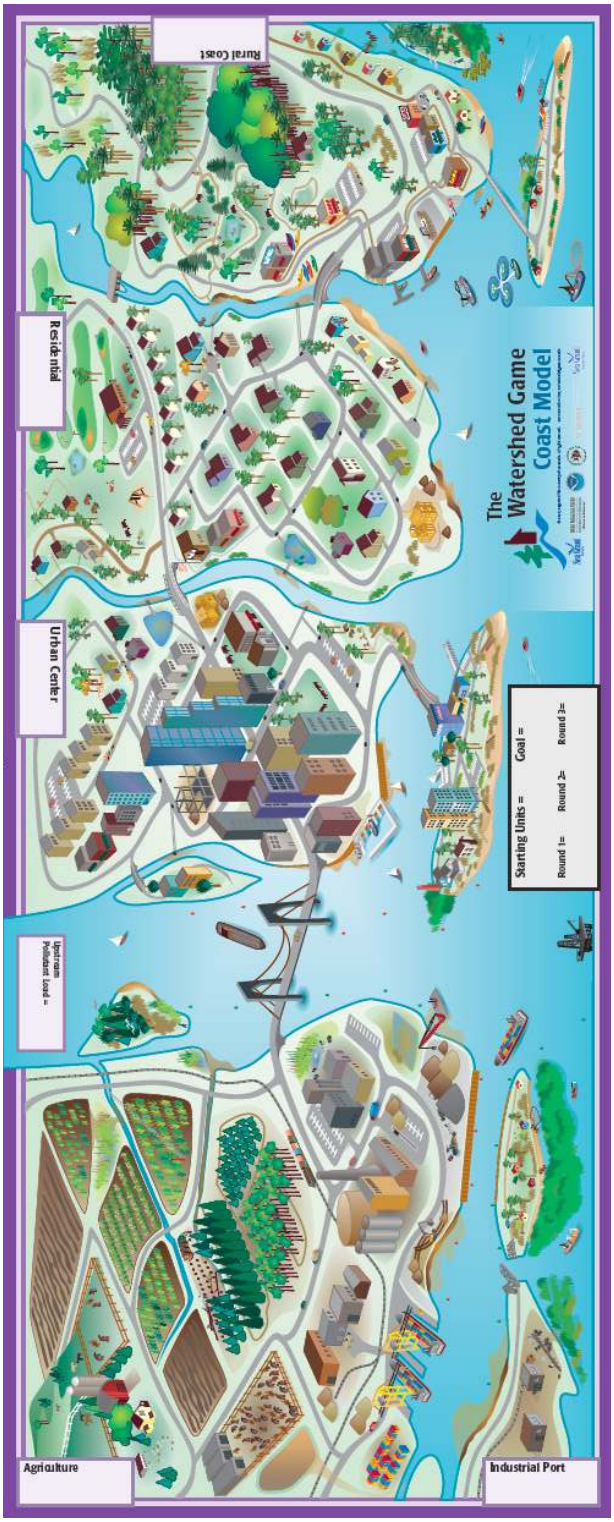

Figure 3. Watershed Game Coast Model game board.

Urban Center includes a marina, recreation, and barrier island with heavy tourism; Residential incorporates wastewater issues and water supply issues by including a dam; and Rural Coast includes a traditional working waterfront, aquaculture, recreation/tourism, and undeveloped areas. The design of the coastal game board also allowed the team to incorporate coastal impacts not ubiquitous to all coasts, but critical regionally (e.g., an oil drilling platform, aquaculture pens, channelized wetlands) that could be used as teaching opportunities where appropriate.

Flooding and Resilience

Based on the review of reports, focus group discussions, and surveys, the project development team noted that a variety of the coastal challenges identified through this study contribute to or manifest as flooding. This includes stormwater-related flooding from upstream (exacerbated by land uses, wetland destruction, and climate change effects on storm frequency and severity) and coastal flooding (exacerbated by severe storms, sea level rise, loss or degradation of coastal lands and wetlands, and development practices). As the team considered how to best address flooding in game design, the concept of coastal resilience emerged as a critical aspect, and an issue that many Sea Grant programs and local governments are addressing in coastal regions. In reviewing survey data, the team concluded that there was sufficient evidence to support integrating resilience into the Coast Model. Riverine and coastal flooding (including coastal land loss and sea level rise) could best be addressed by helping communities increase their ability to plan for, respond to, and recover from flooding events (i.e., increase their resilience to flooding). Thus, each Tool Card, in addition to featuring scores for pollution reductions (PUs) for nitrogen, phosphorus, and sediment, includes a score for increased resilience (RUs). During game play, teams are incentivized to increase their land use's resilience by selecting tools that decrease the likelihood of possible damages from flooding, while also reducing their nonpoint source pollution load. The system is modeled after the Federal Emergency Management Act's Community Rating System, a voluntary incentive program that recognizes and encourages community floodplain management practices that exceed the minimum requirements of the National Flood Insurance Program.

Conclusions

We anticipate that the Coast Model of the Watershed Game will be used as an extension tool throughout U.S. coasts to help decision-makers and students learn how to better manage complex coastal ecosystems through collaborative, informed problem-solving. As such, it meets Sea Grant's mission to support and communicate science in a practical, actionable manner and to integrate research into engagement. We envision that the new Coast Model of the Watershed Game will join the original games as tools for resource managers, planners, and educators to empower communities, helping individuals learn about practices, plans, and policies that improve and protect the health of the environment, the quality of the water, and the ways communities can prepare for, respond to, and recover from flooding in coastal areas.

Used in combination, the multiple data collection methods described in this paper provide a case study of how to effectively query a variety of researchers, outreach professionals, and practitioners about the priority water resource management challenges. In this case, results provided a solid foundation for developing an interactive outreach tool, the Coast Model of the Watershed Game. The variety of methods offered a greater range and depth of information for enhanced understanding and credibility of findings. Results from the assorted approaches helped elucidate different aspects of coastal issues from varying perspectives, provided an enhanced understanding of the nuances of the challenges related to coastal environments, and allowed the project development team to identify issues common across multiple coastal areas of the U.S. When viewed together, the combined results showed a high level of agreement across methodologies and revealed important opportunities to facilitate the integration of water quality and resilience to flooding. Resilience to flooding is a significant addition to the Coast Model of the Watershed Game and allows game facilitators to introduce and discuss the diverse challenges associated with flooding, community

resilience, and ultimately, climate change. The Coast Model of the Watershed Game is a serious game that supports collaborative, inclusive approaches to watershed management in coastal areas. The sequential, multi-pronged approach to gathering and synthesizing coastal expertise provides a model for others seeking to unify communities around watershed-scale management challenges.

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Appendix B: Survey Instrument

Q1: Which of the following items do you consider to be critical challenges currently impacting the lands and waters along your coast? (check ALL that apply)

- Excess sediment
- Coastal land loss
- Excess phosphorus
- Excess nitrogen
- Nutrients
- Pathogens
- Harmful algal blooms
- Fecal coliform
- Erosion
- Flooding
- Excess flow
- Resilience
- Elevated water temperatures
- Salt water intrusion
- Other (please specify)

Q2: Of the challenges you identified in Question One, which do you consider to be the NUMBER 1 CHALLENGE in terms of overall potential impacts to the natural and socioeconomic environments along your coasts? (choose ONE)

- Excess sediment
- Coastal land loss
- Excess phosphorus
- Excess nitrogen
- Nutrients
- Pathogens
- Harmful algal blooms
- Fecal coliform
- Erosion
- Flooding
- Excess flow
- Resilience (*omitted from Regional Survey)
- Elevated water temperatures
- Salt water intrusion
- Other (please specify)

Q3: Of the challenges you identified in Question One, which do you consider to be the NUMBER 2 CHALLENGE in terms of overall potential impacts to the natural and socioeconomic environments along your coasts? (choose ONE)

- Excess sediment
- Coastal land loss
- Excess phosphorus
- Excess nitrogen
- Nutrients
- Pathogens
- Harmful algal blooms
- Fecal coliform

- Erosion
- Flooding
- Excess flow
- Resilience (*omitted from Regional Survey)
- Elevated water temperatures
- Salt water intrusion
- Other (please specify)

Q4: Of the challenges you identified in Question One, which do you consider to be the NUMBER 3 CHALLENGE in terms of overall potential impacts to the natural and socioeconomic environments along your coasts? (choose ONE)

- Excess sediment
- Excess phosphorus
- Excess nitrogen
- Nutrients
- Pathogens
- Harmful algal blooms
- Fecal coliform
- Erosion
- Coastal land loss
- Flooding
- Excess flow
- Resilience (*omitted from Regional Survey)
- Elevated water temperatures
- Salt water intrusion
- Other (please specify)

Q5: Considering the #1 challenge you identified in Question Two, what are the primary land uses that contribute to this challenge? (check ALL that apply)

- Agriculture
- Forestry/silviculture
- Heavy industry
- Urban and residential, including wastewater
- Aquaculture
- Fishing (subsistence, recreational, or commercial)
- Ports and harbors
- Beaches and marinas
- Oil and gas exploration and extraction
- Flood control
- Recreation and tourism
- Other (please specify)

Q6: Considering the #2 challenge you identified in Question Three, what are the primary land uses that contribute to this challenge? (check ALL that apply)

- Agriculture
- Forestry/silviculture
- Heavy industry
- Urban and residential, including wastewater
- Aquaculture
- Fishing (subsistence, recreational, or commercial)
- Ports and harbors
- Beaches and marinas
- Oil and gas exploration and extraction
- Flood control
- Recreation and tourism
- Other (please specify)

Q7: Considering the #3 challenge you identified in Question Four, what are the primary land uses that contribute to this challenge? (check ALL that apply)

- Agriculture
- Forestry/silviculture
- Heavy industry
- Urban and residential, including wastewater
- Aquaculture
- Fishing (subsistence, recreational, or commercial)
- Ports and harbors
- Beaches and marinas
- Oil and gas exploration and extraction
- Flood control
- Recreation and tourism
- Other (please specify)

Q8: Please share any other clarifying comments about or descriptions of the challenges that concern you relative to coastal environments.

Q9: In your opinion, what are the highest priority practices, plans, or policies that are used or should be used to address these challenges (e.g., restoration of impacted habitats, improved resiliency planning, pollution trading, etc.)? Please be brief with your answers.

Regional Survey Q10: How would you best characterize your professional or organizational affiliation? (check ALL that apply)

- Sea Grant or Cooperative Extension
- Research/Academia
- NGO/Non-Profit
- State Government
- Private Sector
- County Government
- Federal Government
- Local Government
- National Estuary Program
- Regional Government
- National Estuarine Research Reserve
- Media
- Military
- International
- Tribal Government
- Other

Regional Survey Q11: How would you describe your professional role? (check ALL that apply)

- Teacher/Educator

- Outreach Specialist
- Research Scientist
- General Stakeholder/Resident
- Natural Resource Manager
- Environmental Consultant
- Planner
- Journalist/Communications Specialist
- Policymaker
- Tourism Specialist
- Business Owner
- Land Conservation Specialist
- Member of the Fishing Community or Industry
- Public Land Manager
- Agricultural Community Member
- Emergency Responder/Manager
- Elected Official
- Energy Industry Member
- Health Professional
- Port or Harbor Manager
- Public Health Official
- Tribal Representative
- Other

Sea Grant Survey Q10: What state do you primarily work in?

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Adaptable University-Agency Early-Career Fellowship Program Creates a Win-Win-Win for Wisconsin's Waters

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Abstract: Many of today's water resources challenges are wicked problems, demanding innovative solutions across the science-policy-management nexus. Simultaneously, early-career researchers in water resources face a shifting professional landscape in which academic career paths are sparse but where versatile skill sets relevant to water resources issues in governments, non-governmental organizations, and the private sector are in high demand. Here, we describe an adaptable fellowship model that has proven to be a "win-win-win" for early-career researchers, government agencies, and universities tackling wicked water resources challenges in Wisconsin, USA. The fellowship program recruits post-masters and post-doctoral fellows to lead research on a water resources challenge identified as a high priority by a government agency partner. Fellows receive mentorship from both academic and agency mentors and co-produce actionable knowledge. Costs and administrative responsibilities are shared by the university (Sea Grant/Water Resources Institute) and the host agency. Since its inception in 2015, this program has trained 24 fellows across 11 host programs on issues that range from highly quantitative water quality and hydrogeological questions to qualitative assessments of fisheries management and coastal hazards. In this arrangement, fellows receive collaborative and cross-disciplinary training that prepares them well for diverse career paths, government agencies benefit from new knowledge targeted at pressing water resources management questions, and university institutions accomplish their missions of training researchers and developing actionable knowledge. We describe this model's applicability to other regions and institutions. Ultimately, this type of program benefits society by building long-term capacity for collaboration which addresses wicked water problems.

Keywords: *wicked water problems, professional development, actionable science*

Communities around the world are struggling to tackle sustainability challenges for water resources arising from environmental change at local to global scales. Many of these water resources challenges—such as climate change, harmful algal blooms, groundwater depletion, or emerging aquatic contaminants like per- and polyfluoroalkyl substances (PFAS)—are wicked problems inherently resistant to clear definitions and easily identifiable, predefined solutions (Rittle and Weber 1973). These challenges encompass environmental, social, and public health problems that span broad temporal, spatial, and administrative scales (DeFries and Nagendra 2017). Such underlying complexity generates barriers for traditionally siloed early career researchers, government agencies, and universities attempting to build solutions to contemporary wicked water problems.

Partner Challenges

Early career researchers (ECRs; graduate students and postdocs) in water resources

Research Implications

- Post-graduate fellowships supported by Water Resources Research Institutes or Sea Grant Programs (or other university programs) in collaboration with government agencies create "win-win-win" for early-career scientists, universities, and agencies.
- Early-career fellows conduct water resources research and gain experience that makes them well-rounded and prepared for diverse career paths.
- Agencies can meet high-priority and hard-to-tackle research needs at low cost.
- University institutions support high-level training and mentorship of early-career scientists, and research efforts that can have immediate real-world impact.
- This fellowship framework can be adapted in other states, regions, and countries with wicked water challenges and collaborative and engaged academia-government relationships.

programs and positions face a shifting professional landscape in which academic career paths are sparse, and where there is a growing gap between the knowledge, skills, and attitudes employers want and ECRs have (Fiore et al. 2019; Gardner 2021). In navigating graduate and post-graduate life, ECRs must decide how best to prioritize their many tasks, such as writing scientific publications, building social networks, interacting with stakeholders, connecting their science with end users, and learning new skills. Therefore, as the most vulnerable group in the science system (Laudel and Gläser 2008), ECRs need training and experience in collaborating across boundaries and working across the science-policy interface (Cheruvelil et al. 2014; Maitland et al. 2015). This preparation will best position them for success in a cross-disciplinary future in which wicked problems are tackled in team science settings (Bridle et al. 2013).

Government agencies are tasked with managing and conserving natural resources based on the best available science. However, each agency may have hundreds of outstanding science questions and insufficient funding, staff, equipment, or facilities to answer them internally (Twyman and Contractor 2019). There is thus a need to recruit skilled staff and enable co-productive relationships that produce actionable science; that is, collaborations where scientists, managers, and other stakeholders jointly define a scientific problem, design research to address it, and propose strategies that use the research in management decisions (Beier et al. 2017). Agency professionals find fulfillment in public service and in the complexities of various wicked water challenges. These challenges require understanding and managing difficult technical problems within a tapestry of diverse societal and political perspectives, which can be appealing to some ECRs. But even ECRs with diverse scientific backgrounds oftentimes do not apply to positions in the public service sector. Many factors may account for this disconnect, including perceptions of limited salary flexibility, a sense that the skills and experiences required or rewarded do not match their graduate training, the complexities of the hierarchical structure of government, and/or a lack of awareness of career opportunities beyond the traditional academic path (Muir and Schwartz 2009; Blickley et al. 2013).

Universities are places for pedagogy and intellectual freedom, and serve as hubs for theoretical and applied research aimed at tackling wicked problems. Accordingly, universities are challenged with developing future generations of the scientific workforce for impactful careers, and with linking that workforce to society through relationship-building among government and local stakeholder communities. Part of this challenge rests in preparing ECRs for increasingly common and important non-academic career paths, but such training can inherently be more difficult for faculty who have spent their careers within academia (Hansen et al. 2014). For example, while traditional mentoring of ECRs at universities may include training in team or interdisciplinary science and often emphasizes some engagement outside the university, it is professionals at government agencies that deal with the political and social complexities surrounding water resources challenges on a daily basis. Thus, it can be difficult for university researchers to build stakeholder and community connections for ECRs.

Fellowship as a Solution

As water resources problems increase in severity (DeFries and Nagendra 2017; Reid et al. 2019), innovative solutions are needed that cut across the science-policy-management nexus and engage diverse stakeholders to achieve a goal of building long-term collaborative problem solving capacity (Weber and Khademian 2008; Elliot et al. 2018). Cross-disciplinary team science and co-productive science are two approaches to achieve that goal (Wuchty et al. 2007; Soranno and Schimel 2014; NRC 2015; Van Noorden 2015; Beier et al. 2017). Cross-disciplinary team science is an iterative process that brings together actors from multiple fields to engage in mutual learning with the intent to produce new knowledge and solutions unattainable within disciplinary silos (Steger et al. 2021). Co-productive science provides a framework aimed at actionability, wherein researchers and practitioners collaborate to identify questions, design and execute studies, and identify options for implementing changes that appropriately use the science (Beier et al. 2017). The Wisconsin fellowship model adopts principles from both cross-disciplinary team science and co-productive science to provide novel training for ECRs that prepares them for a future collaboratively dealing with wicked problems (Read et al. 2016; Fiore et al. 2019), and produces actionable science in the process.

In what follows, we describe and share lessons from an adaptable fellowship program model, built to encourage cross-disciplinary collaboration and co-productive science, that has proven to be a "win-win-win" for early-career scientists, government agencies, and universities tackling wicked water challenges in Wisconsin, USA. The fellowship program trains ECRs to collaborate among partner groups and stakeholders and emphasizes translating research into actionable, practical solutions, which positions ECRs well for diverse career paths. In the process, agencies can meet high-priority and hard-to-tackle research needs at low cost, and university institutions support high-level training and mentorship of early-career scientists and research efforts that can have immediate real-world impact.

The Fellowship Model

Philosophy

The fellowship program can be conceptualized as a hub for knowledge exchange and social capital (i.e., trust, connections, and shared understanding) embedded in a larger collaboration network between the university and several state or federal agencies (Figure 1). In similar university-government collaboration networks, a small subset of government employees typically serves as a critical but vulnerable link connecting an otherwise highly-fractured network of researchers, managers, and policy experts (Kuehne et al. 2020). From the perspective of Social Network Analysis, this fragmentation is a weakness because strong network cohesion is important for integrating science into policy and management (Roux et al. 2008; Kuehne et al. 2020). Our fellowship program was designed under the hypothesis that strategically adding new nodes in the collaboration network (i.e., fellowships) would enhance the flow of information, resources, and experience (i.e., forms of knowledge exchange; Kuehne et al. 2020) and increase the capacity of the larger collaboration network to address wicked water challenges (via enhanced social capital; Gustaffson et al. 2020).

In our conceptual model, the fellowship program represents a point of convergence for flows of information, resources, and experience from both the university and the agencies (Figure 1). From the agencies, important information flows include identification of actionable research needs, and access to data and the regulatory frameworks that underlie the relevant science-policy issues. From the university, information flows relate to prior work on university research and extension priorities. Both entities provide resources (finances and staff) to support the fellow. Exchanges of experience occur at multiple levels, including between the mentor and fellow as well as between the fellow and stakeholder communities (e.g., regulated groups). The fellowship increases social capital and cohesion by intentionally forging a new link between the university and agency via the fellow-mentor relationship, which enhances the capacity of the larger network to identify solutions to wicked water challenges embodied in the fellowship project.

Both the generation of social capital and the knowledge exchange that take place as part of the fellowship program are supported by pre-existing agreements and partnerships established due to the long-term relationship between the university and the agencies, all of which are reinforced and grow because of these fellowships. In our example, these relationships rest on the operationalization of the "Wisconsin Idea," which is a long-standing tradition that the knowledge produced at the University of Wisconsin should touch the lives of people throughout the State of Wisconsin. The fellowship program contributes to the percolation of these values across different levels of the collaboration network (Figure 1).

Logistics

In Wisconsin, the fellowship program was implemented by the University of Wisconsin-Madison Aquatic Sciences Center (ASC) which houses the Wisconsin Sea Grant College Program and University of Wisconsin Water Resources Institute. Recognizing that these programs had funds available to help pursue actionable water

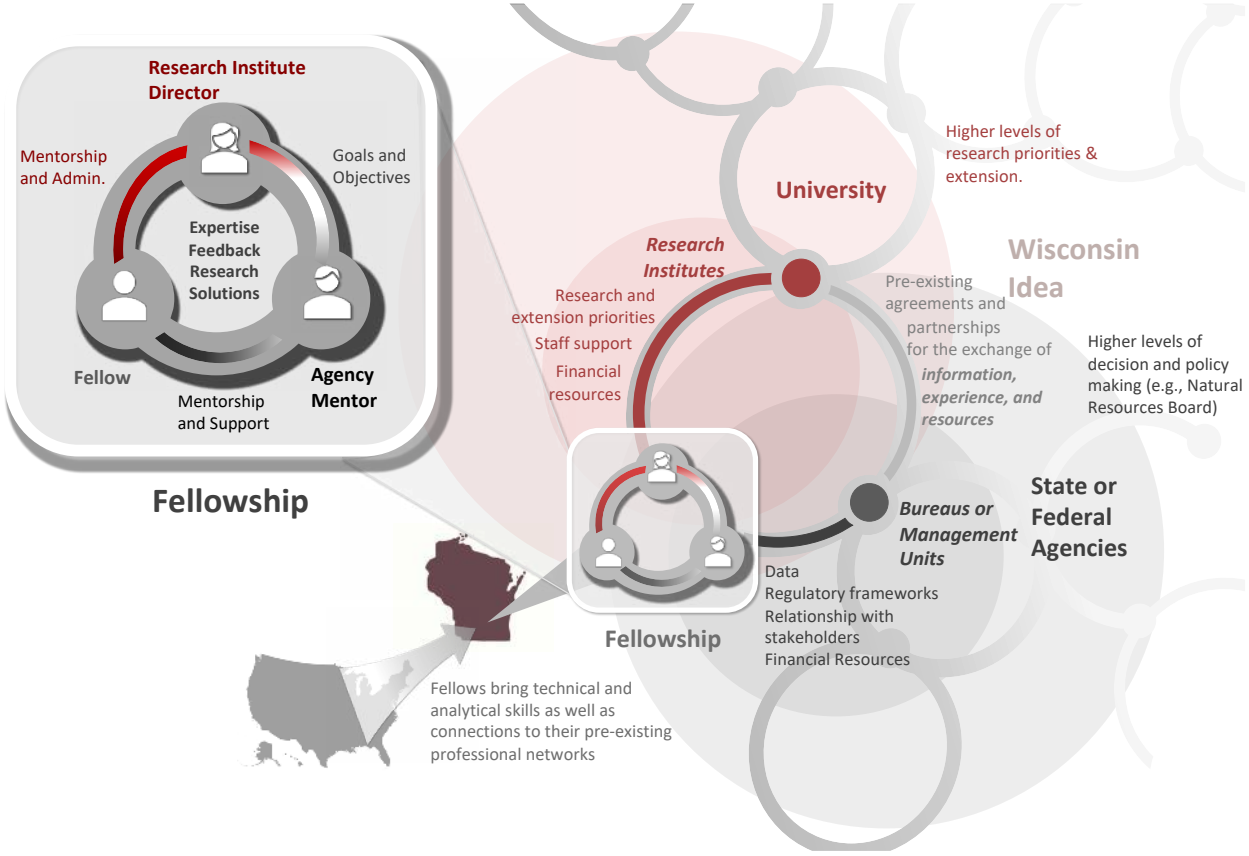


Figure 1. The fellowship program operationalizes the "Wisconsin Idea" across different organizational levels. This program is modeled after the national Sea Grant Knauss Fellows Program and is intended to help attract some of the state and nation's best graduate students in water resources management and analysis to gain key experience in applied actionable science. At the core of the program, there is a close exchange of knowledge (e.g., technical support, definition of goals and objectives), experience (e.g., mentorship), and resources (e.g., administration) within the limited term of the fellowship (1-2 years). Both the Research Institute Director (RID) and the Agency Mentor (AM) are key nodes that connect the fellow (FW) with a larger network within their respective organizations (e.g., Research Institutes and Bureaus and Management Units). The RID also embodies and facilitates the communication of research and extension priorities, liaise and coordinate staff support, and secure financial resources. The AM embodies and facilitates the communication of regulatory frameworks, the relationship with regulated communities, and can help to find additional financial support when needed. The longevity of the program is achieved, partially, by leveraging the results of different fellowships and connecting them with higher levels of research priorities, extension, and policymaking.

science, the ASC formed partnerships with local agencies beginning with the Wisconsin Department of Natural Resources (WDNR) Bureau of Water Quality and the Department of Administration's Coastal Management Program. In later years, a number of additional agencies became involved, including the Bureaus of Fisheries Management, Drinking Water and Groundwater, and Office of Great Waters at WDNR, the U.S. Environmental Protection Agency, and the Wisconsin Department of Health Services. Each of these agencies partners with the ASC and may cost-share to fund, recruit, supervise, and mentor a fellow that leads co-productive research and other activities of value to the agency and relevant to Wisconsin's wicked water challenges (Figure 2). Much of the framework for these fellowships follows recommended best practices for co-productive science (Beier et al. 2017). Throughout this paper, we refer to examples from four primary themes that relate to wicked water issues in Wisconsin (Figures 3-6).

Most agencies develop or maintain a list of research needs—typically water challenges with underlying scientific questions—that could

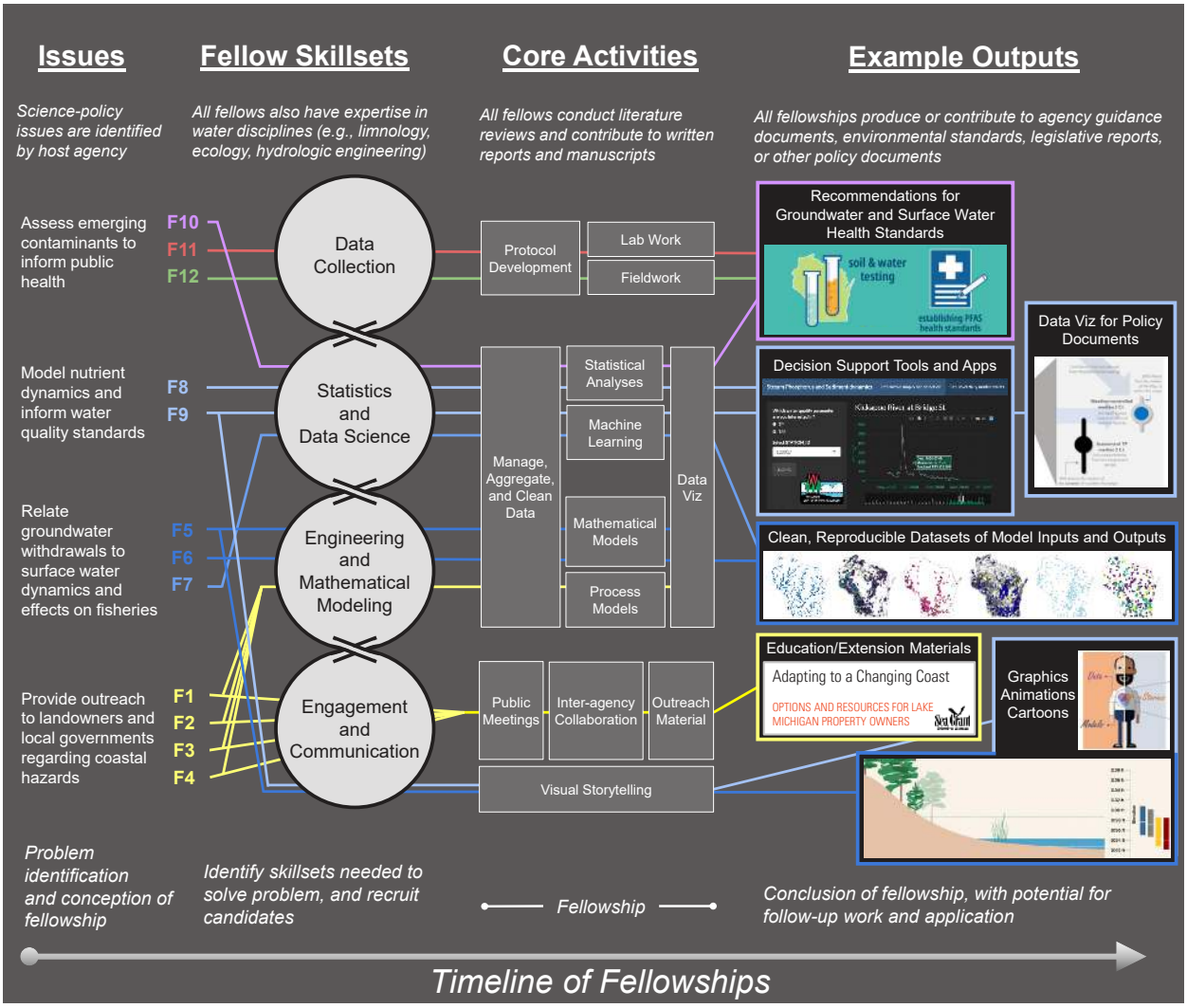


Figure 2. Conceptual layout of fellowship timelines highlighting some different wicked water issues, the key skill or skills of fellows recruited to tackle those issues, the fellows' core activities and some example outputs they produced. Specific fellows and their dominant skillsets, activities, and at least one output per fellow are shown as lines, with colors and numbers matching those in figures 3-6. Variable routes through this matrix highlight the flexibility of approaches to single fellowships and the usage of multiple skillsets to produce different products. Output images adapted from publications from WDNR and WI DOA or provided by authors.

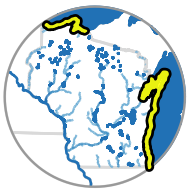
directly inform management decisions or policy, and the university institutions and its funders often have overlapping goals. Finding fellowship projects within this overlap is mostly an organic process, where conversations between agency and university staff converge on research needs that are high-priority, actionable, eligible for all funds to be used, and well-suited for an early-career researcher to tackle. Before a fellowship is formalized, one to three potential projects are identified.

Funding must also be arranged and agreed upon in advance, as fellowships would not occur without sharing of administrative and financial responsibilities. In many cases, neither agencies nor the university institutions have enough funds available to support full-time fellowships independently, but can often support anywhere from 25-75% of their costs annually (Figures 3-6). While the university formally houses the fellow and pays their full salary, agencies go through their own internal budget approval processes and enter into Memoranda of Understanding or issue Purchase Orders to the University for their portion of the costs. Typically, the total cost of a fellowship includes full-time salary, fringe benefits, indirect costs depending on the funding source, and any travel funds the agency deems necessary for conferences or off-site meetings, although the agency can also pay those charges directly.

Once a fellowship project and funding arrangements are agreed upon, fellow recruitment proceeds as a joint effort. First, a primary mentor and mentorship team are identified across the agency and university. Often a subset of this team—at least the mentor and usually one or two subject matter experts—will serve as the core technical working group in partnership with the fellow. This core working group collaborates on a job posting that is nationally advertised by the university and shared by all partners, and then collectively ranks and interviews qualified applicants to best match the disciplinary expertise and key skill sets suited

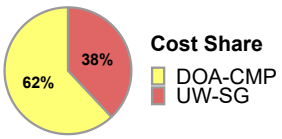
Coastal Processes

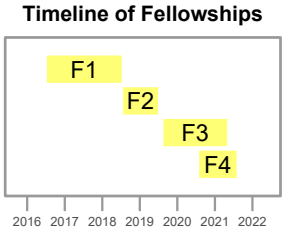
Coastal hazards such as erosion, flooding, and coastal storms are an increasing concern for Wisconsin's coastal communities. Fellows engage with technical staff at local and state governments and interested coastal property owners to provide technical guidance on understanding and estimating the risk of these coastal hazards.



Fellowship Logistics

All fellows stationed with Wisconsin Costal Management Program and Mentor 1, providing a continuous line of support and new expertise for key WCMP initiatives, like the new update of the Wisconsin Coastal Processes Manual.





	Fellow:	Mentor:	University:
What was your goal for the fellowship?	"To understand the needs of stakeholders facing coastal hazards. This knowledge will help me better connect the latest hazards science to inform action and policy (F1)."	"Assistance with the years-long effort and very heavy lift of updating the Wisconsin Coastal Processes Manual (M-F1,2,3,4)."	"To add to the capacity of both WCMP and Sea Grant staff to tackle challenges related to Great Lakes water levels and other hazards."
What did you get out of the fellowship?	"The opportunity to pursue science communication that encourages informed decision making (F4)." "Relationships with local, state, federal and university partners in WI and across the Great Lakes (F1)."	"The expertise the fellows brought and their ability to work with scientists and experts throughout the writing, editing, and reviewing process is leading to what I think will be an incredible product (M-F1,2,3,4)."	"Sea Grant has always had a great relationship with WCMP, but we've been able to leverage our efforts even better by having fellows with a presence in each office."

Figure 3. Description, logistics, and testimonials from current and past fellowships associated with a theme of Coastal Processes.

for the particular water challenge (Figure 2).

After an offer is accepted, the partner roles diverge. Because the university administratively houses the fellows, they work directly with the fellow and agency on negotiations, start date, and formally hiring the fellow. Once hired, fellows are physically stationed at the host agency and focus the majority of their time on their core research or related activities, but they also gain science-policy exposure by attending agency meetings, participating on teams and working groups, and becoming generally integrated within the agency's work setting (Fellows Section, Figure 2). In most cases, the agency provides mentorship, institutional and technical training, and supervision (Agency and Mentors Section), while the university and its institutions take on an administrative and professional development support role (University Section). Many fellows also network across university faculty and other researchers, or with external stakeholder groups, local units of government, and non-profit organizations. Due to the distributed nature of the mentorship team, fellows keep their collaborators and cohort of fellows up-to-date with weekly emails summarizing their main activities, upcoming activities and events, and the "coolest thing" from the week. First month and quarterly meetings led by the fellow are scheduled to highlight progress and next steps, and to gather feedback and suggestions from the host agency and university mentor team to enhance co-production at all steps of the project. The fellowship timeline may be extended to better accommodate project or fellow needs, but is generally not longer than one or two years.

Fellows

Fellows are selected for their scientific expertise, ability to manage projects and work independently, and interest in actionable research. Each fellow is a recent masters or doctoral graduate with a strong background in a field related to the priority

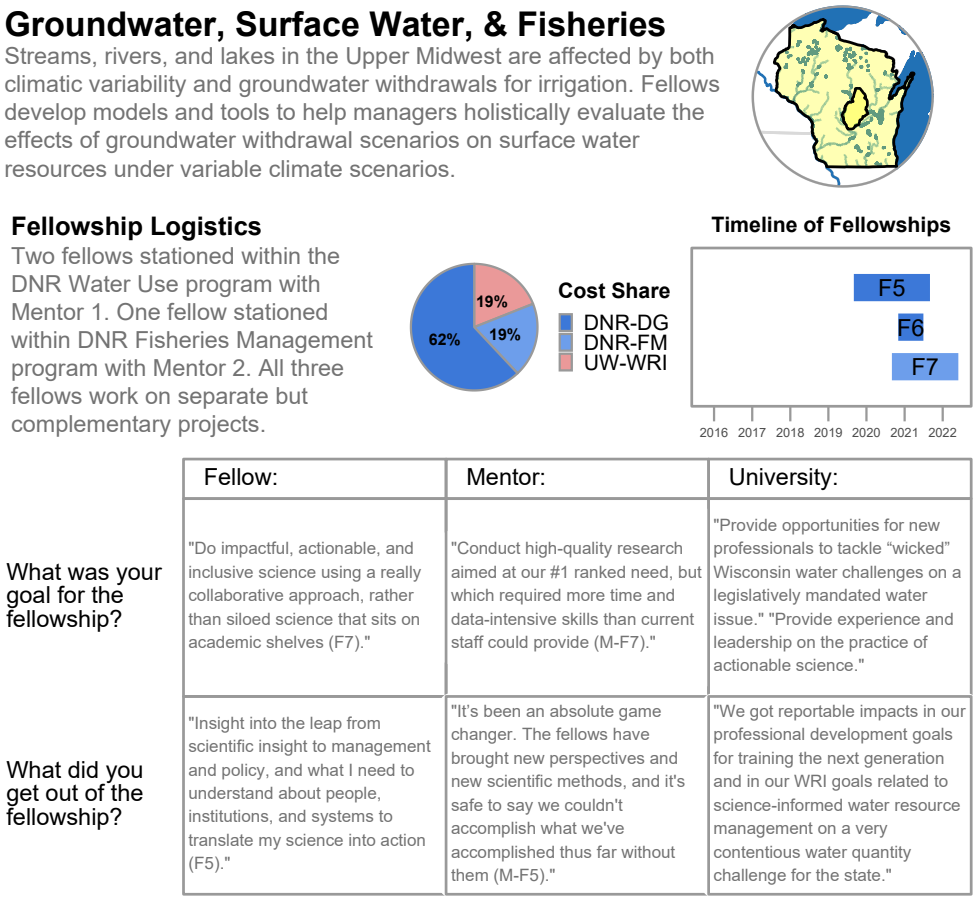


Figure 4. Description, logistics, and testimonials from current and past fellowships associated with a theme of Groundwater, Surface Water, and Fisheries.

water challenge and excellent written and verbal communications skills. They may also have specific analytical skills deemed important by the agency mentor(s), such as proficiency in R, Python, or other coding languages, expertise in physically-based or statistical modeling, or experience designing laboratory experiments. Although these are science-policy fellowships, fellows rarely enter with a formal background in policy; instead, most are recruited on the basis of their technical skills in aquatic sciences- or water resources-related fields, but tend to have an appreciation for and interest in policy. As recent graduates, the fellows typically bring close ties to academic communities and a fresh perspective on the water resources challenges with which the agency is dealing. Because fellows are employees of the university, they also enter with some measure of independence from the political pressures facing the agency, which can be an asset when working on some wicked water challenges.

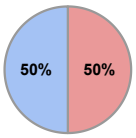
In return for the investment of their time and skills, fellows learn how to combine applied technical work with stakeholder engagement in a co-productive research environment to make their science actionable. Fellows expand their professional networks to include new local, state, federal, and university partners and become skilled at communicating across disciplines to these partners and other stakeholder communities. They also gain considerable breadth in their scientific skills, since projects often tackle broad water resources challenges that require fellows to step outside their comfort zone to answer questions. The breadth of this experience contrasts with the highly specialized training of traditional academic positions and makes fellows marketable to a wide range of jobs. Of the ten fellows who have completed or are nearing the end of their fellowship, three have become specialists at an agency or university program with which they worked as a fellow (WDNR, Wisconsin Sea Grant), three are (or will soon be) faculty members at a

Water Quality

Two of the most common causes of impairment in WI streams are phosphorus and suspended solids. But both of these are highly dynamic, fluctuating with precipitation, runoff, and stream discharge. Fellows developed models and tools that predict stream water quality to lay groundwork for setting new water quality standards.

Fellowship Logistics

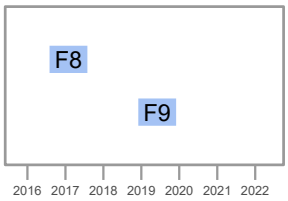
Two fellows at the DNR Bureau of Water Quality, with the second fellow's models building off those of the first. Additionally, the first fellow built an online application, and the second incorporated visual story-telling techniques into policy communications.



Cost Share

DNR-WQ
UW-WRI

Timeline of Fellowships



	Fellow:	Mentor:	University:
What was your goal for the fellowship?	"Dip a toe into science-policy in an agency setting to see how it felt, while adding to my analysis and application development skill sets and research portfolio (F8)."	"My goal was to conduct cutting-edge research and package the results in a format that would be directly usable by agency staff (M-F8,F9)."	"Provide an opportunity for fellows to make scientific contributions and to develop relationships and trust with water resource managers across the state so that they learned how to make the science actionable."
What did you get out of the fellowship?	"I haven't left the DNR since my fellowship. I've found a work setting where my skills and knowledge help make a difference, while maintaining work-life balance (F8)."	"Both water quality fellows brought new perspectives to our program. Their contributions over a short timeframe will have lasting benefits in a wide variety of program activities (M-F8,F9)."	"Fellows provided leadership in understanding stream water quality, learned how to do science that served stakeholders, and learned how to do science in a way that leads to societal impacts, a Sea Grant and WRI goal."

Figure 5. Description, logistics, and testimonials from current and past fellowships associated with a theme of Water Quality.

range of institutions (M1, D/PU, R1), one is in a traditional academic postdoctoral position, one is a science communications liaison at an independent research institute, and one is a data scientist at a disaster response start-up.

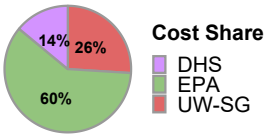
Although each fellow's scientific expertise is unique, all fellows share an ability to manage projects and work independently and an interest in connecting their science with stakeholder and community needs. These traits are key to success because, although fellows usually have a main project on which they focus, they experience more competing demands for their time than would be typical in a traditional academic post-graduate training experience or an entry level position. In those settings, shepherding research through the policy-making process is rarely pursued due to lack of professional incentives or lack of access to the policy-making process. In these fellowships, policy impact is an overarching objective, but the process can be frustrating unless the fellow appreciates the broader social, political, and economic contexts in which policies are created. On a day-to-day basis, fellows are routinely looped into other agency initiatives and meetings and often spend as much time and energy on relationship building and scientific communication as they do on the science itself. Many fellows are able to publish peer-reviewed papers, write grants, or walk away with other traditional markers of academic success, but these are generally not the main goals or outputs of the fellowship. Fellows must understand this, manage their time carefully, and value the additional skills they develop in co-productive science. Guidance from agency mentors is also critical in helping fellows learn to be realistic about what can be accomplished in the short 1-2 year time frame of a fellowship and helping them prioritize the experiences that will best position them for future success in careers focused on actionable science.

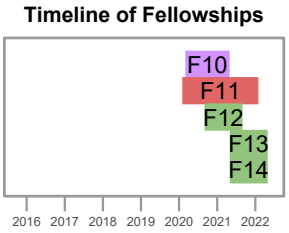
Emerging Contaminants

Emerging contaminants (e.g., pesticides, PFAS) are of concern in Wisconsin, but by definition much is unknown about their extent and toxicological effects. Fellows develop protective groundwater standards, delineate the extent of contamination, and improve toxicological understanding of new and emerging contaminants.

Fellowship Logistics

One fellow at WI-DHS developed groundwater standards, another at UW-Madison investigated the extent of PFAS contamination in Green Bay, and three fellows at the US EPA explored toxicological effects on ecosystems and human health.





	Fellow:	Mentor:	University:
What was your goal for the fellowship?	"To work with EPA experts to apply my scientific and technical expertise to develop quantitative tools to improve ecological risk assessment of contaminants (F12)."	"To contribute to the development of an early career scientist with interest in ecotoxicology and to hire someone with a high degree of expertise to further develop an ecotoxicological model for fish (M-F12)."	"Provide an opportunity for a scientist to apply expertise to statewide challenges and learn how to do science that informs policy, as it is done in collaboration with resource managers with whom the fellow has built trust."
What did you get out of the fellowship?	"Keeping an open line of communication and being part of this bridge between academia and a state agency has really pushed us to accomplish mutually beneficial work (F11)."	"Without the fellow's insights & expertise, this would not have been a successful project. We were also able to apply for a CDC grant to enhance our capacity to address health hazards (M-F10)."	"The fellow provided leadership in helping the state develop PFAS groundwater standards. We made great connections with a new state agency that has led to new fellowships in other water areas and hired the fellow as a permanent scientist."

Figure 6. Description, logistics, and testimonials from current and past fellowships associated with a theme of Emerging Contaminants.

Agency and Mentors

The host agency and its designated mentor(s) serve multiple key roles to support the fellowship. The agency's investment includes operational funding, workspace and supplies, and supervision and mentorship. Funding is often cost-shared across the host agency and university institutions which helps cement the collaborative relationship. It has been typical of agencies to provide at least 50% of the costs for the fellows (e.g., Figures 3-6), including salary, benefits, travel funds, and indirect fees. Agencies have viewed these financial expenses as worthwhile and have taken on more of the costs as the program has grown. Six fellows have been extended after their initial appointment at 100% cost to the agency, and one fellow was recruited and appointed for two years entirely on agency funds. A key attribute that makes these fellowships appealing to early-career scientists interested in engaged, actionable research is the close connection they develop with their host agency. For this connection to form, agencies often provide office space, a computer, software, institutional credentials, and other supplies to integrate the fellow into their work setting. Finally, and most importantly, the agency and its staff serve the role of day-to-day supervisor and mentor—their level of commitment and involvement in this role determine how successful the fellowship will be in meeting agency needs and in developing the skills and experiences of the fellow. In all fellowships to date, agency mentors help the fellows understand the management context for their problem. Mentors also assist with the fellows' core work responsibilities (Figure 2), ensuring that they have access to and an understanding of relevant data, equipment, policies, and external stakeholder groups. Finally, agencies must be prepared to involve the fellow in activities beyond the scope of their core work. These activities create synergistic opportunities for the fellow to expand their professional networks and to experience how the agency and staff conduct their core work and how policy and management decisions are made.

The return on this investment is substantial: the agency meets high-priority needs through co-productive research leading to crucial knowledge and deliverables that can immediately be acted upon or used to inform future work. At any given time, an agency may have numerous research-related needs. For example, the WDNR undergoes a biennial research agenda-setting process, in which each program determines all its current outstanding research needs or questions that could inform management or policy. In 2021, the WDNR Bureau of Fisheries Management, for example, identified and ranked over 200 research needs, only 10 of which were then assigned to existing research staff, leaving many questions unanswered unless pursued through external collaborations. Even high-priority questions may not be addressed by existing staff if skill sets do not align, or if the question may be better pursued by an external, independent partner. Some research needs are well suited for more traditional academic projects with less engagement from agency staff, or through other relationships like U.S. Geological Survey (USGS) Cooperative Research Units, but others require more agency involvement and/or a fresh perspective. Fellowships can help solve each of these limitations. Between 2015 and 2020, after several court cases regarding high-capacity wells, two DNR programs identified high-priority research needs aimed at better understanding well effects on streams and trout fisheries. In fact, one study on the effects of wells on lake levels was mandated by the state legislature. But this study and others on streams demanded a great deal of time and expertise, and could benefit from an outside, independent perspective. Therefore, three fellowships were created to focus on different aspects of these questions (Figure 4). Moreover, fellows often submit grant proposals for follow-up research that ties in additional priorities. One of these three fellows was recently invited to submit a full proposal for a $400k federal grant, and other fellows have brought in $250-750k to work on issues related to their fellowships. Agency representatives have expressed that fellows tend to bring fresh ideas that can "shake up" long-standing and potentially outdated ways of thinking within the agency.

The research in which these and all fellows partake is cross-disciplinary, team-based, and co-productive, with the mentor and host agency involved and invested in the research outcomes. This means that like any professional or supervisory relationship, the mentor-fellow dynamic must be collegial with open lines of

frequent communication. Most fellows and their primary mentors have worked in the same office and had informal meetings or work sessions on a weekly basis. This level of investment is rare when research is conducted externally. However, this participatory framework allows host agency staff to be more engaged with the research, helping ensure that questions, methods, and management recommendations are relevant, and is critical for the fellow's fresh perspectives to gain traction. Ultimately, management staff are more likely to understand and use the resulting information in subsequent processes, management decisions, and policies.

One attribute of these fellowships that allows for the research to be actionable is the possibility for outputs and deliverables to be designed to meet agency needs (Figure 2). While all fellowships create or contribute to the development of guidance, policy, or law and often result in manuscripts, other specific outputs are flexible. They can range from usable, reproducible datasets to decision support tools, outreach materials, innovative graphics, and visualizations. Often, these outputs are not prescribed at the beginnings of fellowships and tend to emerge organically depending on the fellow's expertise and the agency's needs. For example, both water quality fellows frequently met with local resource managers and policymakers to identify new outputs that met their needs (Figure 5). The first fellow tackled the challenge of making statewide modeling results useful at local scales through the design and implementation of a customized Shiny application tailored to specific questions posed by managers. This effort led to an agency-wide implementation of Shiny and other data visualization and dashboarding tools. The second fellowship coincided with policy writing and related outreach, in which it became a challenge to describe the science underlying the proposed policy. The fellow was able to use his background in science communication and innovative custom graphics to develop visual appendices that made complex statistical models and data understandable to lay readers.

University

The university serves as the central hub of the program and provides coordination, publicity, funding, and human resources support for each fellowship. In the Wisconsin fellowship model, the university is represented by the University of Wisconsin-Madison Aquatic Sciences Center (ASC), which hosts both the Wisconsin Sea Grant College Program and University of Wisconsin Water Resources Institute. ASC staff regularly reach out to agency contacts to pitch the program and help identify agency needs that are well-suited for a fellowship project. As word has spread about the value of the fellowship program, less outreach to agencies is required. In fact, ASC staff are now often approached by agency staff with ideas for new fellowships. The university covers up to 50% of the costs for the first year of a fellowship, with the agency covering the remaining costs, though sometimes the agency will cover up to 100% of costs (e.g., if a fellowship is extended for a second year or if the agency has funding and the university has already allocated all of its fellowship funding for the fiscal year). In all cases, the university employs the fellow as a postdoctoral fellow or research intern (for post-master's fellows) which provides the fellows with access to university employee resources and benefits (e.g., healthcare, libraries, seminar series, bus pass program). Human resources support is provided by the ASC. At key milestones during the fellowship, the ASC communications team provides publicity for the fellow and project. Cohort-building activities (e.g., weekly update emails, joint conference presentations, biennial recognition ceremonies) are generally coordinated by the ASC as well.

In return for this investment, the university advances its mission of training and supporting scientists in conducting impactful, actionable research. While the traditional model of post-graduate academic training focuses exclusively on research skills, this fellowship model places new scientists in positions where they develop a diverse portfolio of skills by doing co-productive science. Embedded in agencies and working side-by-side with agency staff, fellows learn to communicate across disciplines, build trust with communities, and orient their research to address questions with both scientific and management relevance. This prepares fellows for a more impactful future career, thus fulfilling the university's core mission with additional tangible benefits for centers like the

ASC, which compete for federal merit funding that is awarded based on performance and community impact. In addition, the fellowship program can lead to new or stronger relationships between current staff at the university and agencies. For example, while the Wisconsin Sea Grant and Wisconsin Coastal Management Program have always had close ties, having a fellow connected with both offices has helped both programs stay abreast of emerging initiatives and better leverage outreach blasts to promote each program (Figure 3). Wisconsin Sea Grant has thus far hired two former fellows as new outreach/subject-matter experts after national searches, in part due to the unique skills and relationships the candidates formed with agencies and stakeholders during their fellowship experience. Another fellow was hired by the agency they worked with (WDNR) for the same reasons.

In the Wisconsin fellowship model, the university's ability to fund fellowships has benefited from support and synergies between the Sea Grant and Water Resources Institutes. First, because ASC administers both the National Oceanic and Atmospheric Administration (NOAA)-funded Sea Grant program and the USGS-funded Water Resources Research Institute for Wisconsin, nearly all water resources-related challenges fall within its purview. Second, leaders at the ASC value the program and set aside approximately $35-40k of the federal NOAA and USGS base funds each year. Between the commitment of leaders at the ASC and the flexibility of the dual programs, thus far it has always been possible for the university to match agency funds as needed to support the first year of most new fellowships. Last, the dual fellowships provide, at minimum, a two-fellow cohort and twice the impact of a single program fellowship. The rapid growth in the fellowship program is, in part, due to the diversity and impact that two programs have accomplished together; in addition, there is increased efficiency in all aspects of fellowship administration.

The fellowship model has evolved substantially over time, so it has also been important for the university to be opportunistic and flexible when pursuing new fellowships. Although the intention was always to cost-share a post-graduate fellow with an agency, the pilot fellowship was a graduate student project assistant entirely funded by the ASC in order to demonstrate the potential of the program. Subsequent fellowships have generally included a 50% cost-share with an agency and employment at UW-Madison, but exceptions are routine. For example, two fellows are primarily associated with Wisconsin Sea Grant-funded research projects (i.e., 100% funded by the university). In addition, the ASC partnered with a prestigious legal scholar to provide partial funding for two new law school graduates hired by UW-Milwaukee's Center for Water Policy. These fellows will be employed through UW-Milwaukee, but were recruited in conjunction with the ASC and will be a part of the ASC cohort of fellows. This partnership between the ASC fellowship program and a top legal scholar was valuable for attracting outstanding law-policy candidates who are capable of approaching wicked Wisconsin water challenges from a policy/legal angle with a legal skillset.

Strong personal and professional connections between ASC staff and agency staff have helped build trust and smooth potential stumbling blocks. An inelegant aspect of the program's design is that a fellow's formal supervisor is at the university, but their project, mentor, colleagues, and desk are at the agency. If a fellow or mentor is not working out, it can be difficult for the university supervisor to identify or correct the issue without strong relationships and good communication. Occasionally, mentors have left the agency or changed roles mid-fellowship, requiring the university supervisor to find other agency staff to step in as mentors and continue to move the project forward. This has worked best when the university supervisor has good relationships with other agency staff who are also invested in the project.

Extending the Fellowship Model

Comparable Programs

There are other fellowship programs operating around the country that endeavor to match highly qualified ECR candidates with non-academic mentors and host agencies to tackle wicked problems. Many federally funded fellowship programs are administered through NOAA and USGS. At the federal level, NOAA supports fellowship programs through Sea Grant (Knauss

Fellowship), through a partnership between Sea Grant and the National Marine Fisheries Program (Marine Resource Economics / Population and Ecosystem Dynamics), and through the Office of Coastal Management (the Coastal Management, Coral Reef Management, Digital Coast, and Margaret A. Davidson Fellowships), as well as myriad state fellowship programs run by state-level Sea Grant College Programs. The USGS oversees the Pathways Internship program which provides high school- to graduate-level students with opportunities to work in agencies that provide scientific support for decision making, as well as the Mendenhall Research Fellowship Program, which provides post-graduate fellows with cutting-edge research experiences in partnership with USGS scientists.

Scientific societies also play an important role in overseeing fellowships intended to train future researchers and practitioners to cut across the science-policy-management nexus. At the graduate level, the fellowship program run by the Great Lakes Environmental Observation Network (GLEON) trains cohorts of graduate students to exploit the rich information content of large and diverse data sets, operate effectively in diverse international teams, and communicate outcomes to a broad range of audiences (Read et al. 2016). The American Association for the Advancement of Science hosts six fellowships that, while not restricted to ECRs, provide firsthand learning experiences at the intersection of science and society to train better scientists. At the post-graduate stage, the Smith Conservation Research Fellowship Program in the U.S. and the Liber Ero Fellowship Program in Canada support ECRs for two years to conduct and communicate world-class research that informs conservation and management issues.

An important drawback of some society-based fellowships is that they do not have explicit agency partners involved in the project. For example, the GLEON Graduate Fellowship program is more centered on formal transdisciplinary training for students through workshops than "on-the-job" training. Where there is an explicit agency partner, the onus is often on the fellow to develop a project, which in turn can result in a loss of continuity and longevity when a fellow completes or moves on from the project. For example, society-based programs like the Smith and Liber Ero Fellowships have fellows explicitly identify a practitioner mentor during their proposal, but the individual projects are independent from one another with very little overlap. The above issues result in deeper problems for fellowship programs operating within the researcher-agency-university interface and attempting to solve systemic, societal challenges: a lack of continuity between fellows tackling similar problems (i.e., vertical project integration through time), and a lack of synergy among projects (i.e., horizontal integration across projects). In other words, typical fellowship programs and projects, despite substantial effort, often operate as a fractured network of researchers, managers, and policy experts that can stymie the development of long-term collaborative problem-solving capacity. In contrast, the Wisconsin fellowship model is structured around a coordination hub (in our case, the university) such that new fellows are strategically added to a broader—and continually growing—collaboration network to enhance knowledge exchange and social capital. Accordingly, we suggest the overall structure of the Wisconsin fellowship model as a robust option for other regions and jurisdictions aiming to holistically address wicked water challenges.

Adapting the Model Elsewhere

The first step in adapting this fellowship model beyond Wisconsin is identifying which entity serves as the coordination hub (i.e., the "university" role). This entity should be relatively insulated from shifting political pressures and thus able to provide critical continuity across fellowship projects. We suggest that university programs are well-suited to this role for several reasons. Importantly, universities have well-established mechanisms for hiring postdoctoral and post-master's degree researchers (including international researchers) and there is almost always an ability to hire for these roles provided funding can be obtained. In addition, many university programs serve as hubs for researchers in other ways, which can facilitate connections between academic experts and fellows who are physically located in government agencies. University programs also tend to have broad missions that allow for flexibility in addressing water resources challenges.

University centers which jointly administer Sea Grant and Water Resources Research Institutes are clearly well-suited to serve as the coordination hub, but land-grant extensions, fisheries and wildlife cooperative research programs, and university-specific umbrella groups such as water consortiums or environmental research institutes may also be good fits for the role. Many private research institutes, scientific societies, and non-profit organizations already administer fellowship-type programs and may also make good coordination hubs, particularly at the national level. Administering and recruiting for the fellowship program should be an explicit part of someone's job description, with others in the organization supporting the fellowship program in the same way that other long-standing initiatives are supported (e.g., via human resources, financial management, and communications assistance). It is ideal if the main point person is well-connected to university-based research; in the Wisconsin fellowship program, the university point person is also responsible for overseeing the ASC's research portfolio and identifying critical research needs related to the ASC's mission.

Once an appropriate coordination hub and point person are identified, the next step is for the point person to begin establishing connections with agency partners. Importantly, the groundwork for university-agency partnerships and the scoping of individual fellowship projects must occur before a fellow is identified. This ensures that ultimate responsibility for the collaboration rests with established staff and can persist beyond the short tenure of the fellow. It also allows for higher-level strategizing and problem solving; short-term projects done by individual fellows can be vertically integrated through time and horizontally integrated across major themes or challenges. When a fellow at last arrives on the scene, they are free to be a true innovator and disruptor; a new node in the larger collaborative network that can infuse new ideas into established ways of thinking. At the same time, the fact that the agency has identified the project as a priority, committed resources to the fellow, and invested in developing a close, personal relationship with them ensures that the fellow's ideas are not dismissed, but instead gain traction. This overarching emphasis on enhancing social capital within the collaboration network, in addition to generating new knowledge targeted at critical needs, is key to building long-term collaborative problem-solving capacity for societies.

Conclusion

To tackle the world's wicked water problems, society needs collaborative teams of scientists working across the science-policy-management nexus to effectively co-produce knowledge and solutions across disciplinary and jurisdictional boundaries. Multiple cohorts of Wisconsin water resources fellows have completed their fellowships with bolstered confidence in collaborative capacity, leadership, communication skills, and scientific expertise. They have produced a wealth of peer-reviewed research manuscripts, government reports, software products, and data visualizations, and have parlayed their experiences into a wide range of jobs in academia, government, and the private sector. From the agency perspective, the program has been "an absolute game changer" due to the new perspectives, new scientific methods, and new knowledge fellows have contributed to key agency priorities. The university and its institutions have developed a training program that prepares early-career researchers for non-academic positions and for co-producing actionable science. Thus, each partner involved in the Wisconsin Water Resources Fellowship Program achieves their own "wins." But more importantly, a gestalt has emerged: By growing a collaboration network of early career researchers, agency staff, and university experts, the Wisconsin fellowship program has fostered strong relationships that have ultimately bolstered long-term capacity to collaboratively tackle wicked water problems across the state and beyond.

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Minnesota Stormwater Research and Technology Transfer Program - A Comprehensive Approach to Collaborative Research

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Abstract: The University of Minnesota Water Resources Center (UMN WRC) in collaboration with the Minnesota Stormwater Research Council (MSRC) has developed a robust program to advance urban stormwater management and policy through the completion of research. Through this unique collaboration, stormwater professionals and researchers across Minnesota are engaged in multi-sector research to prevent, minimize, and mitigate urban stormwater impacts by studying existing and innovative structural and non-structural practices, policies, and management techniques. The center and the council have evolved a comprehensive approach by:

- Obtaining diversified funding resulting in an annual average $1M budget.
- Coordinating and building partnerships at local, regional, state, and federal levels to leverage stormwater research resources.
- Using the council to engage with stormwater researchers, professionals, policymakers, and stakeholders.
- Identifying strategic priorities through assessments of needed research (i.e., the Minnesota Stormwater Research Roadmap).
- Providing a process for prioritizing, soliciting, submitting, approving, and implementing stormwater-related research proposals.

The program also invests in technology transfer seeking the effective and efficient dissemination of research results to those who can best benefit from it. The council is an organization of stormwater professionals, practitioners, managers, engineers, researchers, and others established in 2016 to work with the center to facilitate relevant, applied research and support education and technology transfer. This paper summarizes the efforts of the program, the future outlook, and highlights the collaboration and the connection of the University and the center to agencies, local units of government, and private engineering consulting businesses, who all were integral to the success of the program.

Keywords: *practices, policies, management, urban, water, pollution*

Urban stormwater, runoff from largely impervious surfaces including streets, sidewalks, parking lots, roofs, and in some cases, turf grass, is a major source of nonpoint source pollution. As runoff flows across and down the landscape, it collects and transports sediment, nutrients, chlorides, pathogens, toxic contaminants, and debris. In excess, these pollute our communities' lakes, rivers, streams, wetlands, and groundwater resources (UMN WRC 2011; Subramanian 2016; Baker et al. 2018). Stormwater runoff can also lead to flooding concerns as both the quantity and rate of runoff flow is increased from urban landscapes.

Urban stormwater requires specialized study and control technologies because of the vastly altered hydrology in developed landscapes as well as the numerous contaminants from different land uses that can be carried with urban runoff. While research has advanced our understanding of

Research Implications

- The Minnesota Stormwater Research and Technology Transfer Program (MSRTTP) results in discoveries that will help researchers, stormwater practitioners, professionals, and policymakers: 1) evaluate and design more effective stormwater practices; 2) revise stormwater policies and guidance materials; 3) manage urban runoff to prevent, reduce, and mitigate impacts to lakes, rivers, streams, and groundwater; and 4) maintain investments in stormwater infrastructure for efficient, effective, and continued operation.
- The research program can serve as a model of stormwater research collaboration and grow to address local, regional, and national needs.

stormwater processes and treatment technologies, much remains unknown about the sources and fate of contaminants in urban watersheds and the most effective forms of treatment. Treatment technologies for emerging contaminants such as hydrocarbons remain in an exploratory stage.

Managing urban stormwater is a continuing challenge in Minnesota, around the nation, and throughout the world. Developed areas have a disproportionate impact on water resources, leading to an estimated 22% of the nation's impairments in lakes and 14% of impairments in streams, while accounting for only 3.1% of land area (Strassler et al. 1999; Bigelow and Borchers 2017). A body of water is considered impaired if it fails to meet one or more water quality standards. These standards are set to maintain beneficial uses such as drinking water, recreation activities such as swimming and fishing, and healthy wildlife and biota. Impairments from urban stormwater are locally concentrated in urbanized watersheds, which have become the source of water for a majority of public drinking water systems (Robbins et al. 1991).

Approximately 40% of the nation's waters do not meet water quality standards. Minnesota fares no better (UMN WRC 2011). The Proposed 2020 Impaired Waters List for Minnesota has 5775 impairments. Twenty-five percent of lakes in the state do not meet water quality standards and more than 17,000 stream miles are impaired for one or more designated uses (Minnesota Pollution Control Agency 2020a; 2020b). Long-term trends from climate change and land-use development in cities, towns, and municipalities will increase the threat from urban stormwater impacts (National Research Council 2009). Moreover, Minnesota faces additional challenges in stormwater management due to its seasonal cold climate with continuous winter snow cover and water quality concerns related to deicing agents.

The Minnesota Water Sustainability Framework (referred to as framework hereafter) and the 2020 State of Water Plan highlight the extent to which Minnesota's residents highly value water resources and recognize these pollutants as a threat to the quality of water for drinking, recreation, wildlife and biota, and aesthetics. The framework was a legislative-directed activity to describe the needs and goals that would need to be accomplished to achieve a sustainable water future for Minnesota. At the time it was published, it was the nation's first state-level plan for ensuring that waters would be preserved, protected, and available for generations to come. As part of the development of the framework, Minnesotan's attitudes and beliefs about water were evaluated. Using the results from more than 4,500 surveys and nine listening sessions across the state, the Framework team concluded, in part, that Minnesotans want to address water pollution concerns (UMN WRC 2011). The Minnesota Legislature, through state statutes, also directed the Environmental Quality Board to establish a plan for aligning state agencies, legislative priorities, and local government policy, programs, and actions to protect and improve water resources, and to update that plan every ten years. The 2020 update to this plan (2020 State Water Plan: Water and Climate) also provided evidence that Minnesotans valued clean water. In a 2018 survey of more than 1,400 residents, more than 90% believed clean and safe drinking water was extremely important and more than 80% supported multiple actions to protect and restore water resources (Minnesota Environmental Quality Board 2020).

Urban stormwater runoff challenges are further complicated by the increased intensity of rain events associated with climate change (National Research Council 2009). Recent monitoring

indicates changes in climate and precipitation are already occurring. For example, Minnesota has experienced 11 mega-rain events since 2000, events in which six inches of rain covers more than 1000 square miles and the core of the event tops eight inches of rainfall. Furthermore, scientific evidence projects Minnesota will see significant future changes including warmer winters, more frequent, larger rainfall events, and the potential for longer dry spells (Minnesota Environmental Quality Board 2020). This same trend is reflected in forecasts for other parts of the country. Modeled future high and low emission scenarios both forecast more frequent extreme events for certain parts of the country. The Northeast, Great Lakes, and North Central regions are projected to have the greatest possible impacts. For example, the Northeast region is projected to experience a 40% increase in heavy rain events by the end of the century (Scott 2019).

The impacts of urban stormwater runoff reflect challenges in both water quality and quantity. These coupled with expressed support from citizens, professionals, policymakers, and agencies suggest we need effective and efficient urban stormwater management and we must do more to prevent, minimize, and mitigate the impacts of urban stormwater runoff.

The University of Minnesota Water Resources Center (UMN WRC; referred to as center hereafter) is well suited to address these needs. The center is one of the nation's 54 water resources research institutes authorized by Congress. The center provides leadership in freshwater management by 1) conducting, facilitating, and funding cutting-edge research, 2) providing graduate and undergraduate education, including masters and doctoral programs in water resource science, and 3) engaging with community stakeholders, citizens, policy leaders, and professionals. An example of the critical role of the center in regional water management includes the development of the Minnesota Water Sustainability Framework previously mentioned. Based upon its mission, multiple past successes, and effective partnerships, in 2015 the center began more formal collaboration efforts with stormwater practitioners, professionals, and researchers to assess urban stormwater challenges in Minnesota and strategies to address them. In particular, the group explored the impact urban stormwater runoff has on the state's water resources, the gaps in information needed to address those impacts, and how a state-led comprehensive approach to research would help increase the effectiveness and efficiency of urban stormwater management practices and policies.

One of the components of those efforts, the Minnesota Stormwater Research Roadmap (Baker et al. 2018), articulated five key reasons why developing a coordinated stormwater research strategy could reduce urban stormwater pollution.

1. There are many impaired urban waters in Minnesota that receive much of their pollution from stormwater.
2. The cost of meeting Clean Water goals is very high − estimated to be $317 million per year.
3. There is a perception among stormwater professionals that current stormwater management is not as efficacious as it could be.
4. Past research in Minnesota to improve urban stormwater management has resulted in the implementation of improved stormwater management practices.
5. Future research would likely be even more productive because it would be informed by our constantly improving capacity to acquire, store, and process information and because it will build upon lessons learned from previous research and implementation.

Gathering more information on current stormwater practices and management schemes and developing new mechanisms to prevent, minimize, and mitigate the impacts from urban stormwater runoff would require a robust, comprehensive approach to collaborative research.

The Minnesota Stormwater Research and Technology Transfer Program

In 2017, in response to these needs for more information, the center established the Minnesota Stormwater Research and Technology Transfer Program (program) to lead a comprehensive approach to urban stormwater research and facilitate the transfer of science to practitioners, professionals, and policymakers. Establishing the

program did not happen overnight. It was built on a foundation of past and current partnerships, collaborations, and committees. Minnesota is fortunate to have diverse state agencies, local units of government, academic units, and private industry environmental engineers that collaborate to address urban stormwater management. For many years, partnerships and collaborations of professionals, researchers, and practitioners worked together formally and informally on research projects, revising policy, and on stormwater related implementation projects.

Two such examples include the Minnesota Stormwater Steering Committee and the Minnesota Minimal Impacts Design (MIDS) Committee. The steering committee was a collective of professionals, researchers, practitioners, and policymakers brought together by the Minnesota Pollution Control Agency that provided input to the agency and, more importantly, worked together to discuss critical stormwater management needs and seek collective solutions. The steering committee was instrumental in the first version of the Minnesota Stormwater Manual, published in 2005, and provided insights for the Assessment of Stormwater Best Management Practices published by the University of Minnesota in 2008. The MIDS Committee was established as a result of Minnesota legislative action in 2008 requiring the agency to develop new stormwater performance standards. As a result, the MIDS Committee was formed to guide the agency and operated for three years.

These efforts are two prominent examples of how Minnesota experts collaborated and influenced the establishment of a research program by providing insights on research needs, options, and alternatives to the formation of the program, and by serving as links to active engagement with stakeholders. A partial list of these influencers includes representatives from:

- UMN Water Resources Center
- UMN St. Anthony Falls Laboratory
- UMN Sea Grant Program
- UMN Natural Resources and Research Institute
- Minnesota Pollution Control Agency
- Minnesota Department of Natural Resources
- Minnesota Board of Water and Soil Resources
- Minnesota Department of Health
- Minnesota Department of Transportation
- Local units of government including cities and counties
- Watershed districts and organizations
- Minnesota Cities Stormwater Coalition
- The Watershed Partners
- Many engineers, designers, and professionals from private consulting firms

Over the several years pre-dating the creation of the program in 2017, individuals and groups representing professionals, practitioners, and policymakers gathered informally to discuss the need to form an urban stormwater research council, to support additional research increasing the efficacy of current stormwater practices, and to develop new, innovative practices. Two simultaneous and significant events followed that eventually became the cornerstones of the program.

One of the initial events instrumental to establishment of the program was to recognize and establish urban stormwater as one of the five focus areas in the new Center Strategic Plan (UMN WRC 2018; Figure 1). The center developed its strategic plan by gathering input from a broad group of researchers, stakeholders, center staff, and university leadership. All of this information was analyzed to identify areas where the center and its surrounding community were well positioned to advance water science to address state needs. Stormwater emerged from this process as a clear priority, reflecting an alignment of research needs with scientific expertise and established relationships. Having named stormwater as a strategic priority, the center committed to working with its partners to propel urban stormwater research and technology transfer forward.

Simultaneously, the Minnesota Stormwater Research Council (MSRC; hereafter referred to

Figure 1. Urban Stormwater is one of the five focus areas of the center's strategic plan adopted in 2018 (UMN WRC 2018).

as council) was established in recognition that partner collaboration and stormwater stakeholder engagement with the center were essential. Following years of discussion, and after considering alternative models for a research program such as forming a not-for-profit organization, stormwater practitioners, professionals, and policymakers asked the center to form, lead, and administer a council.

The council is an organization of stormwater professionals, practitioners, managers, engineers, researchers, and others established to:

- Facilitate the completion of needed applied research that enables more informed decisions about the use, management, and protection of our water resources in urbanized areas.
- Periodically assess the status of research, identify consensus research priorities, and communicate these to Minnesota's public and private research agencies and organizations.
- Promote coordination of research goals, objectives, and funding among the research agencies and organizations.
- Facilitate technology transfer of stormwater research to practitioners, agencies, organizations, and others. For the council, technology transfer includes support for and facilitation of education, outreach, and training, as well as translation of research results into related manuals and policies.

One of the first steps in forming the council was developing the Guiding Framework to establish the purpose and objectives of the council and articulate the roles and responsibilities of an advisory board (UMN 2021). The framework was developed over a period of more than twelve months by the advisory board, with robust input from stakeholders.

The advisory board, the decision-making body of the council, sets research priorities, acquires funds to support research, and chooses projects to award and complete. The board consists of a diverse set of twenty individual stakeholders representing cities, watershed districts or organizations, private industry, research institutions, and state agencies (UMN 2021). Board members provide representation and continual engagement of stakeholders critical to completion of the work and continuation of funding and ensure the relevance of research results for end-users. Additional detail about the role of the council in obtaining funding is discussed later in this paper. The Council Framework is subject to annual review and moderate changes have been made over the years, but the objectives and mission of the council remain fixed. More information about the council is available online at www.wrc.umn.edu/msrc.

The program situated at the center works in unison with the council. This cooperative and comprehensive approach, combining a formal research program at the University and a robust external stakeholder council, provides a unique foundation that has led to successful endeavors addressing critical urban stormwater issues. This partnership requires dedicated leadership, transparent communication, and efficacious administration. Therefore, in 2019 the center established a full-time director to administer the program.

Research Priorities

One of the first efforts of the council was to examine urban stormwater research needs. An interim report of needs was completed in 2017 (Erickson et al. 2017). The 2017 report included a literature review and compilation of research needs identified in previous reports, past surveys, and stakeholder discussions. In addition, the 2017 report presented a list of stormwater knowledge gaps and research needs, and documented challenges to meeting those research needs. With the program newly created and situated in the center, funding and capacity were dedicated toward development of a next generation report that would expand and further describe research needs and establish methods to prioritize those for Minnesota. This endeavor was much more comprehensive than the previous effort. It included literature reviews, surveys, focus groups, and interviews of stormwater professionals, practitioners, researchers, and policymakers across the state. The result was the Minnesota Stormwater Research Roadmap (Baker et al. 2018).

The Roadmap identifies research priorities that serve as the main pillars of the program. The Roadmap was developed by examining gaps

in knowledge about urban stormwater − gaps that if filled, could help practices, policies, and management schemes become more effective and efficient to prevent, minimize, and mitigate the impacts from urban stormwater runoff. In short, it described Minnesota's urban stormwater research needs. Given the extensive list of research needs and the limited funding and capacity existing to address all of them, the Roadmap also identified prioritization indices. The Roadmap employed multiple strategies including focus groups, surveys, interviews, and reviews of past published research, reports, and projects to distill eight major research priorities (Figure 2).

Additional details under each of the eight major priorities identify specific information needs or research advancements that could benefit practitioners, professionals, and policymakers. For example, under the *Improve performance and reduce maintenance on structural BMPs* category, specific research on stormwater ponds such as the fate of dissolved phosphorus, the extent of polycyclic aromatic hydrocarbon (PAHs) pollution, and effective pretreatment practices for bioretention are identified as very high priorities. These eight major priorities and the specific needs for each of them provide focus for organizing research activities and allocating investment in the program.

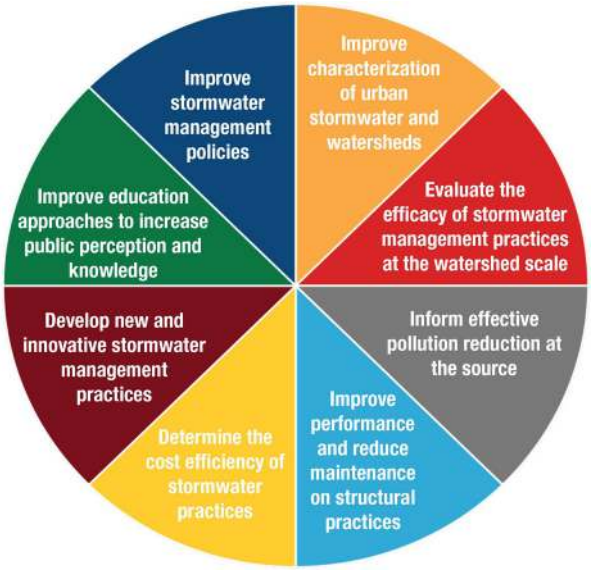

Figure 2. The eight major categories of Minnesota's urban stormwater research priorities (UMN WRC 2018).

The Roadmap provides an overall structure to address dynamic research priorities. New individual research needs emerge as research is completed, problems surface in communities, or new challenges are encountered. The center and the council will embark on an update to the Roadmap in 2022. In the upcoming research portfolio section of this manuscript, the connection of these eight categories emerges in the descriptions of the projects that have been funded and implemented.

Research Portfolio

Since the program's inception in 2016, 19 research projects have been funded, completed, or are in progress (Table 1). The portfolio consists of two categories: rapid response projects and discovery projects. Rapid response projects address specific questions that can be answered with applied research in one to two years, whereas discovery projects have longer durations involving multiple years of data collection and often larger interdisciplinary teams. This categorization allows for timely response to specific questions and challenges, and also recognizes the need for in-depth observations or trends that require more time and broader expertise.

Rapid Response Project Example:

Effectiveness of Sump Manholes for Pretreatment Particulate Removal (Chapman 2020). Initiated January 2019 and completed in March 2020. This project evaluated sediment characteristics in urban stormwater runoff and recommended sediment concentrations for use in the SHSAM model. It went on to recommend inspection and maintenance frequency to ensure the practice functions as designed.

Discovery Project Example:

Detecting Phosphorus Release from Stormwater Ponds to Guide Management and Design (Janke et al. 2021). Initiated in 2019 and completed in 2021. This project evaluated the factors that influence phosphorus release in urban stormwater ponds. Results showed that dissolved oxygen levels, stratification and mixing, and vegetation within and adjacent to the pond all play critical roles in

Table 1. Research program portfolio 2017-2021.

Title	Start - End Date
2020 Research Cycle Projects	
Biofiltration Media Optimization – Phase II: Multi-Year Performance, Impacts of Road Salt, and Optimized Organic Ratio	2020 - 2022
Equipping Municipalities with Climate Change Data to Inform Stormwater Management	2020 - 2021
Evaluation of Microbial and Chemical Contaminant Removals in Different Stormwater Reuse Systems	2020 - 2021
Field Evaluation of Stormwater Best Management Practices to Characterize the Comprehensive Contaminant Removal Performance of Biochar-Augmented Filter Media	2020 - 2022
Leveraging Minnesota's Stormwater Data for Improved Modeling and Management of Water Quality in Cities	2020 - 2022
Monitoring Methods for Prioritization and Assessment of Stormwater Practices	2020 - 2021
Pollutant Removal and Maintenance Assessment of Underground Filtration Systems	2020 - 2021
Understanding Solids Loading in Minnesota Stormwater	2020 - 2022
2019 Research Cycle Projects	
Biofiltration Media Optimization - Phase I	2019 - 2020
Detecting Phosphorus Release from Stormwater Ponds to Guide Management and Design	2019 - 2021
Developing a Street Sweeping Credit for Stormwater Phosphorus Source Reduction	2019 - 2020
Draft Stormwater Geospatial Data Standard: Pilot and Proof-of-Concept	2019 - 2020
Effectiveness of Sump Manholes for Pretreatment Particulate Removal	2019 - 2020
Identifying Sources of Contaminants in Urban Stormwater and Evaluation of Their Removal Efficacy Across a Continuum of Urban Best Management Practices	2019 - 2021
Inspiring Community Action for Stormwater Management	2019 - 2021
Pond Treatment with Spent Lime to Control Phosphorus Release from Sediments	2019 - 2021
Temporal Dynamics of Pathogens and Antibiotic Resistance in Raw and Treated Stormwater	2019 - 2020
2017 Research Cycle Projects	
Capture of Gross Solids and Sediment by Pretreatment Practices for Bioretention	2017 - 2019
Determining which Iron Minerals in Iron-enhanced Sand Filters	2017 - 2019

the release of phosphorus, and management and design should take these into account.

Proposal Solicitation, Review, Selection, and Management

Research needs exceeded the available funding for the past three research proposal cycles (Figure 3). Acknowledging this early on, the program leaned heavily on the stormwater research priorities in the Roadmap and established criteria to solicit and evaluate proposals. Priorities evolved from one research cycle to the next by referencing the Roadmap in discussions with the council's advisory board. Acknowledging immediate and higher priority needs allowed for requests for proposals (RFP) to be balanced between rapid response and discovery projects, and these were clearly identified in the RFP.

Following the first RFP cycle in 2017, one of the adaptations required researchers to identify a primary and secondary research priority during the application process. This allowed the center and council to evaluate the distribution of proposals across needs and topics. It also allowed for various ways of grouping proposed work, such as pollution prevention compared to pollution mitigation, or quantitative stormwater sampling research compared to social and policy related sciences. Funding decisions then could be based upon the specific topics projects would address as well as

the balance across larger categories of research and management needs, such as science in water chemistry, monitoring, social studies, and behavior and policy.

Criteria for Review and Ranking

The criteria used to evaluate proposals evolved over time. Clearly-stated criteria in the RFP offered researchers the opportunity to focus their proposals and provided the reviewers the benchmarks by which they could evaluate them. The individual criteria are weighted equally. These are the criteria that were used for the 2020 research cycle:

- **Relevance** - Does the proposed project relate to urban stormwater management or concerns in Minnesota? Does it benefit Minnesota waters? Is it applicable and does it have high value to Minnesota stormwater professionals, managers, engineers, and policy leaders? Does this project evaluate, improve, or innovate the performance and effectiveness of stormwater BMPs? Does the project evaluate or innovate standards and guidance? Does the work avoid duplicating previous efforts?
- **Priority Research** - Does the research examine specific ideas or concepts well-suited under the research need? Does the proposal address one of the more specific 2020 priority focus areas? Does the research and do the deliverables sufficiently address the priority research need identified?
- **Scientific Merit** - What is the quality of the research plan? Is the approach scientifically valid? Are the objectives and activities clearly explained? Will proposed activities achieve objectives? Will the research activities result in a significant advance in knowledge? Will this research provide us with new information needed by managers or stakeholders?
- **Technology Transfer** - How strong is the technology transfer plan? Are audiences and objectives of education and outreach identified? Will the education and technology proposed lead to changes in learning or actions for an identified audience?
- **Capacity and Collaboration** - Do the personnel and institutions have the capacity and expertise to effectively complete proposed work? Are the budget and timeframe realistic and reasonable for completing activities and objectives? Does the proposal identify collaborations that strengthen the work? Does the proposal identify and discuss connections or communication with any of the major agencies involved in urban stormwater management in Minnesota?

Figure 3. Total requested research funding compared to total actual funding awarded, by research cycle year. For each of the three competitive research cycles conducted since the program's inception, total stormwater research financial support requested exceeds the funds available and number of projects that can be chosen for funding and completed.

- **Cost** - How does the proposed budget compare to the work proposed? Is the budget within the specifications of rapid response and discovery projects? Is there specification of how the project could be phased?
- **Project Timeline** - Is the proposed timeline appropriate, with time allowed for completion of final reports? Are project benchmarks identified? Is there an indication of how the project could be phased?

Multi-tiered Review Process

A three-tiered approach is used to evaluate proposals. First, center staff evaluate proposals to ensure they meet eligibility criteria and are complete. This includes reviewing specific components such as the budget and budget justification. Budget review includes evaluation of whether the budget is fair and reasonable and whether the expenses can be justified and are allowable from the perspective of the funding sources and University policy. Staff also review and summarize the topics and concerns addressed by the entire suite of proposals.

In the second tier, the council's advisory board completes a thorough review and scoring of each proposal. Numerical scores are assigned for each criterion and review comments are submitted. Simultaneously, a third-tier review by external peers is completed for all discovery proposals. External peer reviews are not sought for rapid response projects. The expertise of the advisory board is sufficient to evaluate these smaller, less intensive projects. External peer reviewers are most often from experts in the specific area of content from other research institutions and agencies. Three external peer reviews are sought for each proposal, with the number of reviews sometimes adjusted for the level of depth and specialization of the proposed work. While external peer reviewers do evaluate all the criteria, they are asked to focus on the science, methodology, data collection, and analysis components. External peer reviewers also assign numerical scores and submit review comments.

This information is not the sole selection method. With the summarized review scores and comments in hand, the advisory board meets to discuss all the projects, assessing their merit, methodology, and priority. The broad diversity of the board ensures substantial stakeholder input from cities, watersheds, local units of government, and agencies that will ultimately most benefit from the work. Using the available funding for the research cycle, the board also considers the cost-benefit as it prioritizes the projects, ultimately choosing a balance of rapid response and discovery projects. In some instances, the center and board have asked for proposal revisions and clarifications before a project can go forward.

Employing a Proposal and Project Management System

This three-tiered review approach generates substantial information on each proposal. During the first two proposal periods (2017 & 2018), a combination of emails, document exchanges, and online survey tools such as Survey Monkey and Qualtrics were used to gather information. The center team was immediately challenged by the growing amounts of data resulting from the review of the proposals, the inefficiencies in review collection, and less-than-ideal processes to compile, analyze, and review the growing number of proposals and their reviews.

After research of their own, over the course of more than six months, the center invested in a proposal and project management system to aid in these processes. The chosen online software package, WizeHive, brings a full lifecycle management system for grant proposals and projects. For the program, such a system has provided benefits and has added value for applicants, reviewers, and program staff. Applicants have found the system user friendly, as they can construct their proposal in routinely used software (Microsoft Word and Excel) and copy and paste (or upload) those contents into well-identified sections in an online application portal. Features include the capacity for applicants to adjust a submission up to the application deadline, and for center staff to easily request revisions to one or more sections of the proposal.

Perhaps the greatest advantages of such systems are found in the review process. Reviewers, including the advisory board, can repeatedly log in and out to complete reviews as they have time. Well-designed systems also make it easier

for reviewers to work with electronic documents, avoiding the need to print sometimes lengthy proposals. WizeHive provides a split-screen approach in the review stage, allowing reviewers to see a specific section of the proposal with the scoring selection immediately adjacent to it. For example, when reviewing and scoring the budget, the left side of the computer screen displays the budget and budget justification (or links to the PDF) and the budget scoring matrix appears on the right side of the screen. The reviewer can continually reference the budget while entering their scores and comments on the same screen.

The proposal management system also increases the efficiency of program staff. WizeHive allows program staff to quickly assign submitted proposals to reviewers. Reviews then can be conducted simultaneously by all twenty advisory board members and external peer reviewers. Meanwhile, program staff can access the system and see which reviews are complete and which reviewers might need reminders. Reminders can be pre-programmed to be sent to any of the reviewers. Once reviews are complete, review scores and comments can be summarized and analyzed quickly and easily (Figure 4). The various graphic and text summary outputs from the system provide program staff the necessary information for the advisory board meetings where discussion results in selections for project funding or potential revision. The system can quickly summarize proposals by title, principal investigator, submitting organization or department, research track, total of funds requested, or any of the submission entries.

PI	Short Title	Criteria Total Avg Score*	Relevance	Priority Research	Scientific Merit	Technology Transfer	Capacity And Collaboration	Cost	Project Timeline	Overall Avg Score	Track	Total Budget
Name	*Title*	25.8	4.2	4.0	3.6	3.8	3.7	3.4	3.4	3.8	Discovery	$300,000
Name	*Title*	19.8	3.2	2.7	3.2	2.4	3.1	2.4	3.0	2.5	Discovery	$259,000

**Numbers are averages of twenty advisory board member scores.*

Criteria scoring rubric. *Maximum total score is 35			Overall score rubric	
0	Unacceptable	Does not meet the criteria or elements in this category.	0	Unacceptable. We absolutely should not fund this.
1	Poor	Weakly satisfies a few elements, does not satisfy others.	1	Poor. Proposal has serious deficiencies in one or more areas and should not be funded.
2	Fair	Satisfies most elements to a minimum standard.	2	Fair. Marginal approach but does not address topics in the RFP. Major deficiencies.
3	Good	Adequately satisfies all elements.	3	Good. This is a good candidate for funding. Acceptable quality. May have some revisions.
4	Very Good	All elements satisfied, some exceeding expected standards.	4	Very Good. This is a great proposal to consider supporting with funds.
5	Excellent	Exceptional. All elements satisfied beyond expected standards.	5	Excellent. We should definitely fund this proposal.

Figure 4. Example of how the proposal and project management system can generate reports of review scores for program staff and the advisory board.

Finally, WizeHive also provides for overall project management. Once a project is selected, the system can notify applicants, request revisions to a particular component, request mid-project updates, and other staff directed inquiries.

Financing Urban Stormwater Research

The annual budget of the program is approximately $1 million. The majority of the budget (80%) funds research projects, most of which are chosen on a competitive basis. The remaining 20% funds technology transfer, including education, training, and outreach, and supports administrative costs for the program. Legislative language and the goals of the MSRC require the majority of the budget to be spent on research to fulfill the program's primary mission; to discover new science and revise technologies and practices that will prevent, minimize, and mitigate the impacts from urban stormwater runoff. A diversified approach to funding the program helps deliver stability, builds stakeholder support and buy-in, and creates momentum.

Over the past three biennia, the Minnesota Legislature has made a multimillion-dollar investment into the program (Figure 5). These funds are sourced from the Minnesota Clean Water, Land and Legacy Amendment, which was enacted to protect drinking water sources; to protect, enhance, and restore wetlands, prairies, forests, and fish, game, and wildlife habitat; to preserve arts and cultural heritage; to support parks and trails; and to protect, enhance, and restore lakes, rivers, streams, and groundwater. The Legacy Amendment increased the state sales tax by three-eighths of one percent beginning July 1, 2009 and continuing until 2034. Funds for the stormwater research program are specifically provided by the Clean Water Fund, which is one of the areas the Legacy Amendment supports. The budget and investments of the Clean Water Fund are recommended by the Clean Water Council. The Clean Water Council consists of seventeen governor appointed legislators, agency representatives and other local units of government, and community organization representatives and was established to advise the Legislature and the Governor on the administration and implementation of the Clean Water Fund. The stormwater research program makes a biennial request to the Clean Water Council for funding and provides regular updates on research funded and accomplished. More importantly, the program communicates the implications and usefulness of its research for Minnesota communities, professionals, and policy leaders.

Additional funds to support the program are sought from and contributed by local units of government, including cities, watershed districts, organizations, and by private industry (Figure 5). These relatively small, individual amounts (compared to the total cost of a research project), add up quickly when pooled together. On average, pooled funds from cities, watersheds, and private industry have totaled $150,000 per year and are steadily increasing. In Minnesota, watershed districts and watershed organizations are special-purpose local units of government, authorized by the Legislature in 1955. Many of these local watershed units have funds available for investment into the program through taxing authority or other revenue sources. Many cities that meet the qualification of owning, operating, or maintaining a municipal separate storm sewer system (MS4), have stormwater utility fees or other financial resources which they may use to support the program. Minnesota is also fortunate to have talented and highly engaged private environmental consulting businesses that support the program. These local units of government, and the professionals, practitioners, and policymakers that work within them, find high value in applied urban stormwater research. Contributors see the benefits of large-scale, coordinated research that they could not afford to support and conduct alone. The information and recommendations resulting from the program's research ultimately help everyone to manage urban stormwater more effectively and efficiently.

Administering the program through the center provides the ability to leverage additional university, state, and federal programs. As part of the National Institutes for Water Resources, the center receives base support from the U.S. Geological Survey (USGS) and manages a number of USGS-sponsored grants for Minnesota researchers. Additional base support for the

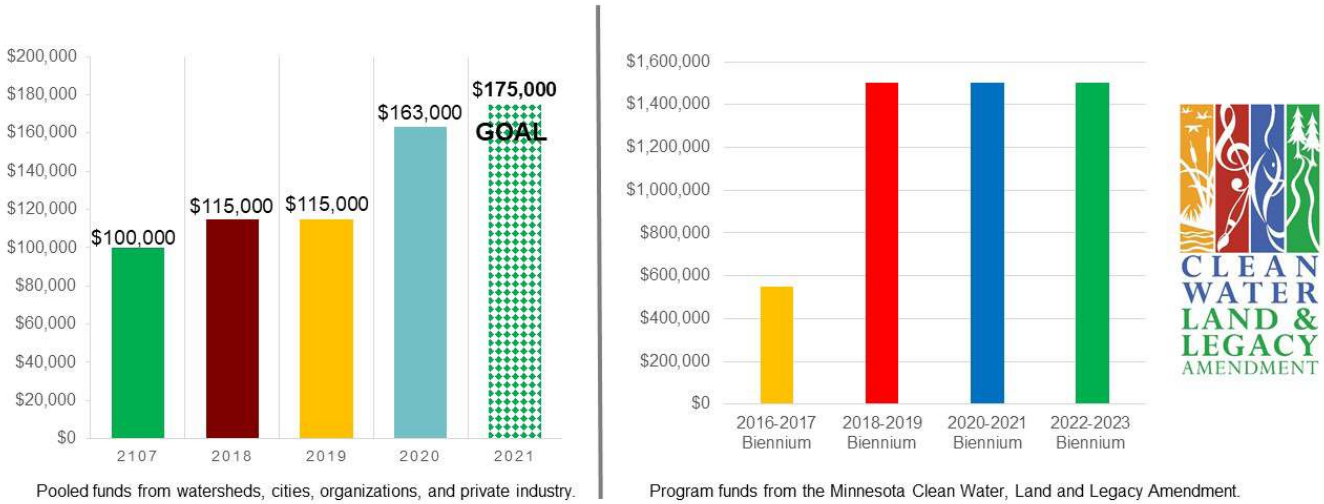

Figure 5. Annual totals of pooled funds from cities, watersheds, and private businesses, 2017-2021 (left side) and biennial financial support from the Minnesota Clean Water, Land, and Legacy Amendment, 2016-2023 (right side). The center provides additional in-kind support for administrative functions.

center comes from university sources, including University of Minnesota Extension, the College of Food, Agricultural, and Natural Resource Sciences, and the Minnesota Agricultural Experiment Station. Base support from all these sources sustains the center's capabilities for office activities and financial functions, providing a core of administrative support that can be leveraged for individual programs such as the MSRTTP. The center's multiple affiliations also provide access to overlapping networks of expertise and stakeholders.

The fulltime administrative leader for the program and the advisory board members are responsible for soliciting and securing financial resources. Board members often provide testimony to the Clean Water Council about the value of the program and also participate in presentations to watershed governing boards, cities, and groups of private industry professionals. Overall financial budget management is provided through the center.

This diversified funding approach provides a substantial budget on an annual basis, while maximizing the share of sponsored funding for research and technology transfer. Of equal importance, the diversified funding approach increases stability and creates ownership and buy-in across the very units of practitioners, professionals, and policymakers that will use and benefit from the research.

Project Reporting

Principal investigators and research teams are required to provide annual mid-project reports and a final report. The annual mid-project reports consist of a short summary of progress in reflection of the activities and deliverables designated in the research plan. It also includes an update on the budget, expenses incurred to date, and adjustments that may need to be considered. In 2020 and 2021, mid-project reports helped both the center and the research teams adjust for impacts due to the Covid 19 pandemic. For example, some research activities were unable to be completed or were significantly delayed as researchers navigated social distancing requirements.

Mid-project reporting is not merely an administrative exercise. The MSRC holds an annual meeting for its advisory board and members. Research teams funded by the MSRTTP are required to present mid-project reports at this event. While the reporting provides communication to stakeholders about the work, it also provides a valuable opportunity for the research teams to gather feedback or solicit additional field sites. Furthermore, information from the mid-project reports is used in a feedback loop to the financial providers, helping the program solicit and secure future funding.

A final research report is required for all projects. This includes the traditional literature

review, abstract, methodology, results, and conclusions. It also requires data and other information to be included as appendices. Teams are required to present their findings to the council, often scheduled as part of the Minnesota Stormwater Seminar Series, discussed in the Technology Transfer section that follows. Principal investigators are required to enter their final report into the University of Minnesota Digital Conservancy Library and/or the Minnesota Water Research Digital Library. This ensures the results and data are publicly available.

The administrator of the research program manages the reporting process and is in frequent communication with all principal investigators and their team members. We believe we have designed a reporting process that helps us know the status of projects and communicate the impacts, all while not being laborious for investigators. Reports are most often submitted through a program-administered email account, although the project management software WizeHive also provides for this activity. Final reports are not the end of this program's story.

Technology Transfer

Technology transfer has been recognized as being a critical component of the program since its inception. While completing priority research is an essential first step, implementation of research results by practitioners, professionals, and policymakers is equally essential for the program to have its intended impact. This takes a commitment to education, training, and outreach, as well as integration into design manuals and policies. The program accomplishes this by:

1. Requiring all funded research projects to have a technology transfer component.
2. Designing and delivering a variety of research transfer events.
3. Establishing a full time Extension Educator position jointly funded by the center and the Minnesota Sea Grant College Program.

Research project investigators must have a defined approach to deliver their results to the practitioners, professionals, and policymakers who will most benefit from the work. Research teams must describe an approach to transfer the science and results including methods for education, outreach and training, desired outcomes, and the intended audiences. Their technology transfer plan is reviewed and taken into consideration when choosing projects for funding. Adopting this strategy places some responsibility on the research teams rather than solely on the center and its Land-Grant and Sea-Grant Extension programs to help achieve dissemination of results. A portion of the project's overall budget can be and often is used to support researchers' technology transfer efforts. One such example is financially supporting the researchers and often their graduate students to present their work at the annual Minnesota Water Resources Conference led by the center. This event draws more than 800 water professionals from across the state and provides a perfect opportunity to discuss the results of these stormwater projects.

Research teams are not on their own in regard to technology transfer. The program in cooperation with the center, Land-Grant and Sea-Grant Extension, and other units and organizations, designs and delivers a variety of research transfer events. One example is the partnership with the St. Anthony Falls Laboratory that has led and offered the Minnesota Stormwater Seminar Series and Minnesota Research Spotlights on a monthly basis for more than two years. Alternating by month, one month features a national expert coupled with a local panel, and the next month features the program's funded research projects in Minnesota. The seminars have been well attended and well received. In 2020, there were more than 1700 participants in these events. The breadth and depth of the topics presented appeal to a wide audience of stormwater practitioners, researchers, and professionals (Figure 6).

As research is completed and where applicable, results are also incorporated into professional training. One such example includes the Inspection and Maintenance of Permanent Stormwater Treatment Practices Certification Course led by the Erosion and Stormwater Certification Program through the Department of Bioproducts and Biosystems Engineering.

Urban stormwater concurrent sessions are also featured during the annual Minnesota Water Resources Conference, which is attended by more than 800 Minnesota water resource professionals,

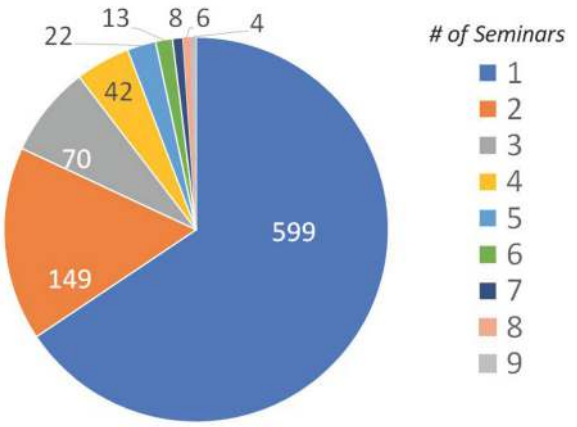

Figure 6. Participation in the Minnesota Stormwater Seminar Series by the number of seminars attended. While most participants join for one specific seminar, likely for a presentation on a unique and specialized topic, many others join repeatedly.

experts, researchers, and managers. The conference has served historically as a gathering forum for the stormwater community, building momentum toward formation of the MSRC. More recently, advances in stormwater have been featured at the conference in plenary talks and special sessions, as well as in regular technical sessions. The Covid pandemic of 2020 provided an opportunity to deliver both the seminar series and the conference virtually, with more participants in attendance than when held in person.

The council has an annual meeting, which was held in person in 2018 and 2019 and was adapted to a virtual format in 2020 and 2021. Funded research teams are required to provide updates on their projects to the full council. This also allows for researchers to solicit input on methods, project field sites, or present draft findings and gather stakeholder feedback. The program also provides frequent presentations and email communication about the status of projects and maintains an individual webpage for each project.

To further help fulfill the goals of technology transfer, the program established a full time Extension Educator position jointly funded by the center and the Minnesota Sea Grant College Program. The educator was brought on board in August 2021 and will develop, lead, teach, and evaluate Extension programs, education, and outreach on urban stormwater practices and policies. The educator will work closely with researchers who have recently completed their projects. This uniquely collaborative position also allows for the educator to network with other Extension Educators in both the Minnesota Land Grant and Sea Grant Extension programs, expanding the delivery team and its reach across the state and region.

Conclusions

Program Future

The program is having impact in Minnesota and in the field of urban stormwater management. Although the program is only a few years old and only the initial wave of research has been completed, there is evidence that practitioners, professionals, and policymakers are beginning to integrate research findings into their work. One example is research that the program supported on urban street sweeping. Cities are now adopting targeted street sweeping strategies to increase efficiency and effectiveness of this common pollution prevention practice. At the same time, the Minnesota Pollution Control Agency and researchers are continuing their work to develop pollution reduction credits for cities that have TMDL reduction goals and that adopt and implement robust enhanced street sweeping programs (Hobbie et al. 2021).

The program has established a base of support for future sustainability, and it also has opportunities to grow. The impacts and relevance of existing projects are leading to growing capital investments and support for the program. As the program emerges from its infancy, explorations are underway to collaborate with and leverage in-state programs and resources working within the stormwater arena. At the same time, the research outcomes have regional and national implications. Ample opportunity exists to collaborate with and leverage resources from the National Institutes for Water Resources, the National Sea Grant Programs and Land Grant Extension Programs across the region and country, the U.S. Environmental Protection Agency, and the National Oceanic and Atmospheric Administration, as well as other like-minded stormwater programs, centers, and groups such as the Water Environment Federation Stormwater Institute. The program has the potential to serve as a model of stormwater research

collaboration and grow to address local, regional, and national needs.

Program Changes

Given both the successes and lessons learned since the program's inception, we anticipate exploration of changes and enhancements to the program in the future. Some of these are related to administrative functions and others are related to providing greater focus on future research priorities and project investments.

- Process changes under consideration include adoption of a pre-proposal stage and applicant presentations, both of which would assist in improving and enhancing proposals and in focusing research investments.
- Proposal review enhancements under consideration include weighting review and selection criteria, adding some type of cost-benefit criteria during review, and lengthening overall project timelines for future work, especially given the lessons learned from the Covid pandemic.
- Future allocation of funds may include a directed research pool to study specific stormwater practices that are long-term priorities. For example, in 2021 the council and center established a research pool specifically for advanced research on needs relating to stormwater ponds. This creates an avenue to work directly with experts to address very high, critical needs without an extensive competitive process.

For more information about the Minnesota Stormwater Research and Technology Transfer Program and the Minnesota Stormwater Research Council, visit https://www.wrc.umn.edu/projects/stormwater.

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Role of Sea Grant in Establishing Commercial Oyster Aquaculture through Applied Research and Extension

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Abstract: Sea Grant programs, both separately and in collaboration, have supported growth of the off-bottom oyster industry in all five U.S. states in the Gulf of Mexico. Here, we review the history of the Mississippi-Alabama Sea Grant Consortium (MASGC) investments in research and extension to support the growth of this industry (particularly in Alabama and Mississippi). Notably, the integration of applied research with strategic extension efforts was essential to the success of this industry. The MASGC enabled the establishment of commercial off-bottom oyster aquaculture in Alabama and Mississippi using a series of strategic, outcomes-focused investments in applied research and extension efforts through an array of partnerships. In Alabama, the first commercial off-bottom oyster farm was established in 2009. The industry grew to 22 farms by 2020 with a farmgate value of nearly $1.5 million, employing over 30 full time equivalents (FTE). Over 12 farms have been established in Mississippi in the last two years. The MASGC also leveraged additional support from other funding agencies that has multiplied the outcomes and impacts.

Keywords: *aquaculture, oyster, outcomes, applied research, extension*

Off-bottom oyster farming refers to the culture of oysters usually held in some type of mesh containers (basket, bag, cage, etc.) that are kept above the seafloor (Figure 1). Oysters grown this way are typically hatchery-reared, single-set oysters instead of the clumps of oysters normally found in the wild. When properly operated, the containers provide protection from predators and eliminate burial in sediment, allowing oysters to be cultured in areas where oysters would not survive on the bottom (e.g., high salinity areas where predation rates are very high or where the substrate is too soft). Off-bottom oyster culture is distinct from public commercial and recreational fisheries on public oyster beds and traditional on-bottom oyster farming on private oyster grounds. Off-bottom oyster culture focuses on commercial harvesting, unlike oyster restoration efforts focused on establishing reefs for the various ecosystem services that they provide, and oyster gardening, which is non-commercial culturing of oysters often associated with restoration efforts (see Walton et al. 2013a for a more detailed description of off-bottom oyster farming on the coast of the Gulf of Mexico).

While off-bottom culture of oysters is well established on the Atlantic and Pacific coasts, both globally and domestically, this technique is relatively new to the Gulf of Mexico. In contrast, on-bottom culture has been practiced throughout the region from Texas to Florida and is the predominant method of production in Louisiana and Texas. On-bottom oyster farming in the Gulf of Mexico typically relies on management of private oyster grounds, which includes placing cultch (oyster shell, limestone, etc.) on an oyster reef to harden the substrate and relies on recruitment of wild oysters via spat fall that attaches to the cultch. While on-bottom culture in the Gulf of Mexico allows for very high levels of production,

Research Implications

- Investments by the Mississippi-Alabama Sea Grant Consortium (MASGC) enabled the establishment of commercial off-bottom oyster aquaculture in Alabama and Mississippi.
- Through partnerships and collaboration with other Sea Grant programs, the Cooperative Extension System (CES), and other partners, these investments helped commercial off-bottom oyster aquaculture become established throughout the U.S. Gulf Coast.
- This case study suggests that a combination of applied research projects, extension projects, and ongoing extension efforts, as exemplified by the MASGC's approach to off-bottom oyster farming, can yield measurable outcomes with significant impacts in communities.

production levels are also highly cyclical, subject, for example, to high levels of predation, dramatic salinity changes, and/or years of poor recruitment. Because the oysters form irregular shapes, these oysters are primarily targeted for the shucked market (Walton et al. 2013a).

Off-bottom production systems take advantage of the availability of food (phytoplankton) throughout the water column. Because farmers have more control over the farming practices, off-bottom production systems have the following potential advantages over other production methods like bottom culture (Walton et al. 2013a):

- Promote faster growth by raising oysters in food-rich waters and controlling stocking density within a cage or bag;
- Increase survival by providing protection from predators, burial, and potential anoxia at the seafloor;
- Allow control of fouling (e.g., barnacles, overset oysters, mud worms);
- Improve shell shape and appearance, using various culture techniques; and
- Increase product consistency.

Oysters produced using off-bottom culture techniques are typically sold to the premium half-shell market by count. Off-bottom culture of oysters requires significant investments of time, labor, and money, but has the potential to provide a consistent supply of premium quality oysters for the half-shell market. In contrast, traditional on-bottom production from either public oyster reefs or private oyster grounds yields larger quantities of oysters that obtain lower prices. On-bottom oysters are sold by weight or volume and are primarily intended for the shucked meat market.

Growth of Off-bottom Oyster Farming in the Gulf of Mexico

Off-bottom oyster farming was attempted in the 1990s in Alabama and Florida but was rejected due to concerns about the high labor costs and ability to get a profitable price (C. Nelson, Bon Secour Fisheries, pers. comm.). With a series of public and private investments, collaborative research, and extension efforts (described below), commercial off-bottom oyster farming was initiated in 2009, with one commercial oyster farm each in Alabama and Louisiana.

Initially, growth of the industry was slow and confined to Alabama and Louisiana. With the first harvest and sales in 2010, interest began to grow. As of 2019, there were 31 farms in Alabama and eight farms in Louisiana (R. Grice, pers. comm.). In 2015, Florida implemented regulations that allowed the use of the water column for oyster farming, leading to a rapid increase in the number of leases permitted to produce oysters with off-bottom methods (Walton, pers. obs.). In 2018, Mississippi permitted a zone for off-bottom aquaculture and began training classes for oyster farming, with the first commercial farms in operation in 2019. In 2018, Texas changed the laws to allow off-bottom oyster farming, and permit applications are currently under consideration.

From 2010, regional production has generally increased (Table 1) and is now around 12% of total off-bottom oyster production in the southern U.S. (which is dominated by Virginia). This rapid rise in regional production has been fueled by both an increase in the number of farms producing oysters and the increase of production per farm, with variations within each state. There also have been numerous challenges to the industry that have led to drops in production, including environmental challenges (tropical storms, freshwater events, rainfall closures, etc.), regulatory hurdles, unusual

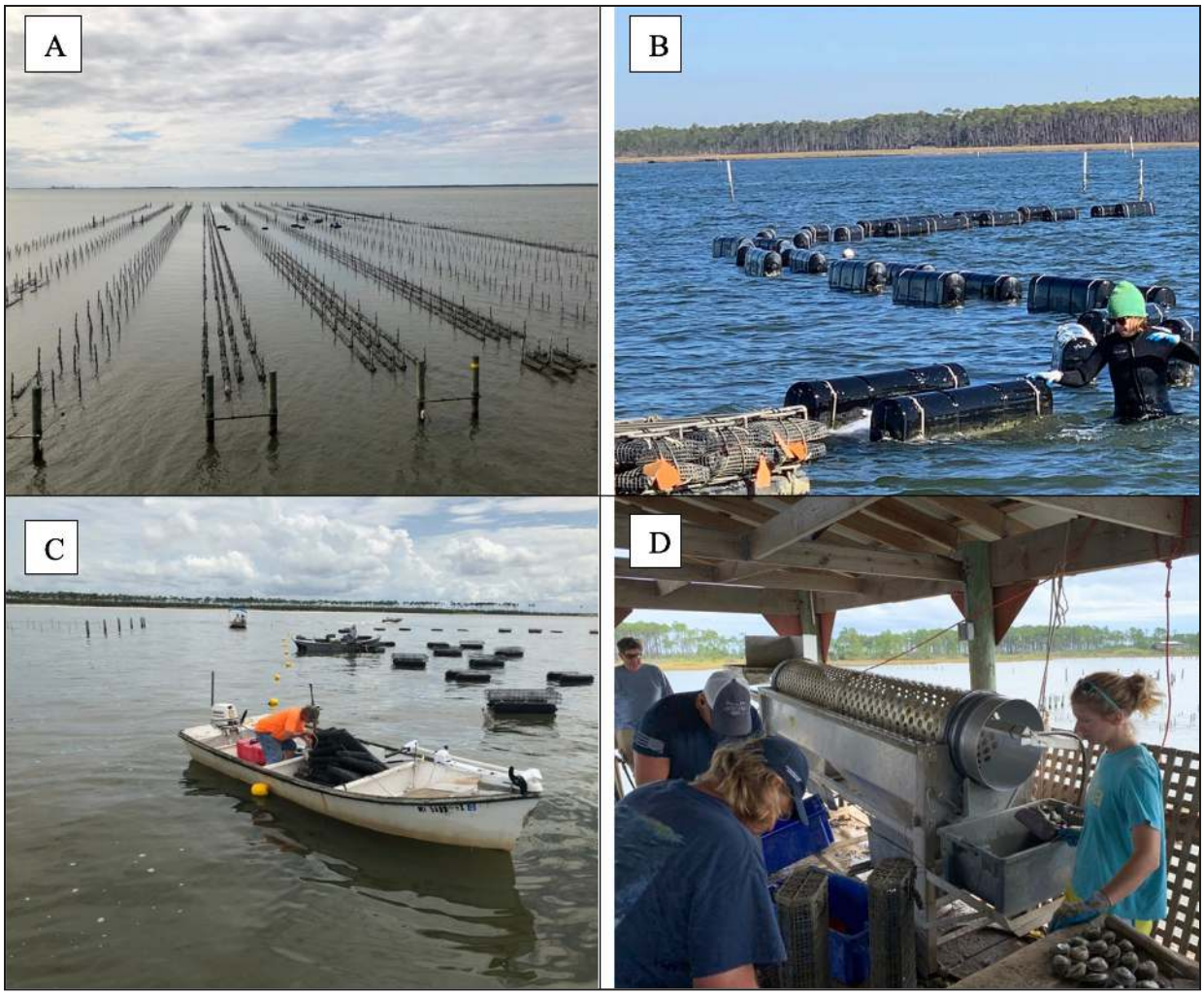

Figure 1. Off-bottom oyster farming in the Gulf of Mexico, illustrating common culture methods and grading. A.) Adjustable long-line system farm in Alabama. B.) Working floating cage system, with one cage (forefront) flipped up to allow oysters and gear to air-dry (Alabama). C.) Working floating cages from a boat at a Mississippi training area. D.) Grading, sorting, and splitting oysters with a mechanized tube sorter at a commercial farm in Alabama.

crop mortality events (including mortalities associated with the use of triploid oysters), and most recently the Covid pandemic, with the closures of restaurants and raw bars imposed in most states (van Senten et al. 2021).

There is no doubt that several factors, organizations, and individuals have contributed to the establishment and growth of commercial off-bottom oyster aquaculture in Alabama and Mississippi (and the U.S. Gulf Coast more broadly). However, we believe Sea Grant programs (in partnership with industry, the CES, academia, and regulatory agencies) played a critical role, with investments in applied research and extension. Here we review the timeline of the investments made and then discuss the implications of this case study.

Timeline of Investments

Assessment of Feasibility

The concerns raised about the commercial feasibility of off-bottom oyster farming hinged on two factors: the labor costs associated with controlling the heavy overgrowth by other organisms such as barnacles and seaweed (bio-fouling), and concerns about market price. To address the first issue, the Mississippi-Alabama

Table 1. Current best available data for recent off-bottom oyster production by millions of pieces in U.S. Gulf of Mexico, with Virginia and the southern U.S. total (Maryland south to Texas) for comparison.

Year	Estimated Off-bottom Oyster Production, Pieces (Millions)								
	AL	FL	LA	MS	TX	Gulf of Mexico Total	VA	US South Total	Gulf of Mexico Percentage
2013	ND	0	ND	0	0	0	31	33.2	0%
2014	ND	0	ND	0	0	0	40	45.2	0%
2015	ND	0	ND	0	0	0	35	41.2	0%
2016	2.7	2.8	ND	0	0	5.5	40	52.7	11%
2017	1.5	2.2	ND	0	0	3.7	39	51.8	7%
2018	1.6	3.9	ND	0	0	5.6	32	45.8	12%
2019	2.4	4.8	ND	0.4	0	7.5	ND	12.7	ND
2020	2.2	3.6	ND	0.6	0	6.4	ND	ND	ND

Note: ND indicates need for data. Data should be viewed as incomplete and subject to change with additional data. Data for Virginia are estimated from Figure 2 in the Virginia Shellfish Aquaculture Situation and Outlook Report (Hudson 2019). Data for Louisiana were reported in meat pounds for 2018 and 2019 (with values of $130,039 and $55,728, respectively) with all other years listed as confidential due to privacy concerns with limited harvest.

Sea Grant Consortium (MASGC) funded a 2010 research project through Auburn University, in partnership with industry member Point aux Pins, titled "Oyster farming in Alabama: Identifying most viable practices." This study experimentally compared how four different culture methods affected oyster survival, growth, and quality. Of these, three methods (suspended adjustable long lines, floating cages, and floating bags), were demonstrated to control bio-fouling through periodic desiccation, while also producing high yields of quality oysters (Walton et al. 2013b). Critically, this work led to media attention for the industry partner, which in turn led to other stakeholders expressing interest in learning more about off-bottom oyster farming.

Demonstration, Education, and Hands-on Training

In response to this new interest, Auburn University and Louisiana State University pursued, and were awarded in 2010, a National Sea Grant Extension award titled, "Aquaculture Extension NSI 2010 - Farming the Fertile Crescent: Intensification of Oyster Culture in the Northern Gulf of Mexico." This bi-state effort supported site selection, permitting of demonstration farms and 'oyster farming parks,' and training programs for potential oyster farmers. In Alabama, the training course was offered in partnership with the Organized Seafood Association of Alabama, which was critical to successful recruitment of the first class. The training course offered in Alabama was a 15-hour series of informal lectures and demonstrations, capped by each of the trainees raising at least 10,000 oyster seed in the demonstration area to gain valuable hands-on experience prior to starting their own commercial operations.

This three-year effort resulted in five measurable outcomes.

1. In Alabama, an oyster farming park was permitted that includes twelve 2-acre farm sites for commercial production and another seven 2-acre sites were permitted by the Grand Isle Port Commission, for a total of 38 acres permitted for commercial production;
2. A commercial demonstration site was established in both Alabama and Louisiana, serving as hands-on exposure for potential oyster farmers;
3. By the end of the grant, five individuals

had begun commercial production with an additional six initiating the permitting process (with permitting challenges identified as a barrier to growth);
4. Nine individuals participated in the Oyster Farming Fundamentals training program with dozens of other individuals getting exposure to this new industry; and
5. At least 20 stories were generated in the media, including local television and national radio (NPR), with thousands of individuals increasing their awareness of the availability of off-bottom farm-raised oysters.

Addressing Production Challenges

In a series of research grants, several academic institutions partnered with the new commercial oyster farmers to address challenges to production. In 2010, Louisiana State University led a National Sea Grant funded study, "Evaluation of oyster stocks and grow-out methodologies for commercial production of Eastern oysters in Gulf of Mexico estuaries" to determine if different stocks performed better for oyster farmers. The results suggested that selective breeding has the potential to improve survival and growth though the benefits may be site-specific (Casas et al. 2017).

Researchers from Dauphin Island Sea Lab, funded by the MASGC in 2016, responded to concerns by growers about how to manage mud blister worm infestations of their crop with a research project titled, "Maximizing the return on investment of oyster aquaculture by managing mud blister worm infestation." Mud blister worms blemish the oyster shells which some growers were concerned about in terms of perceptions of product quality. Researchers identified times of year where farmers need to exercise extra control methods to avoid infestation (Cole et al. 2020; Dorgan et al. 2021).

Similarly, with some growers reporting high mortalities of triploid oysters in 2016, researchers sought to respond. In 2018, National Sea Grant awarded researchers at Louisiana State University a grant titled, "Decreasing mortalities of triploid eastern oysters in commercial grow-out in Gulf of Mexico estuaries." As with the mud blister work, this applied research was driven by explicit concerns from commercial oyster farmers. This work is in progress, but preliminary results have suggested that initial attempts at selective breeding to reduce these losses were not fruitful. Researchers are seeking to identify what steps might be taken to address this problem (Wadsworth et al. 2019; Bodenstein et al. 2021).

Addressing Regulatory Challenges

Beyond challenges to production, Sea Grant played a critical role in addressing regulatory concerns with timely, focused research and an ongoing role facilitating communication among stakeholders. In Alabama, permitting fees for riparian easements initially exceeded $6,000/acre/year, as shellfish farms were equated with private marinas; these fees discouraged investment. With a 2012 National Sea Grant award to Auburn University and the National Sea Grant Law Center ("Economic value of ecosystem services of oyster farming as offsets to regulatory fees"), research was conducted to provide regulators better information about the value of oyster farming. During the course of this work, the fees dropped to $250/acre/year, prompted by the dialogue among stakeholders about the public benefits of oyster farming (Walton, pers. obs.).

In Alabama, public health concerns caught the industry off-guard with regulatory requirements to submerge their oysters for 30 days prior to harvest (Walton, pers. obs.). This was later reduced to 14 days, but many growers were concerned about the effect of this required resubmersion on their operations. The MASGC funded "Effects of aquaculture practices on *Vibrio* spp. in the Eastern oyster, *Crassostrea virginica*: Test of fouling control practices" with an award to Auburn University in 2014. This research directly led to a reduction to seven days of resubmersion for certain culture methods in Alabama and has been used to guide practices in other states around the U.S. (Grodeska et al. 2017; Grodeska et al. 2019).

Addressing Marketing Challenges

One of the main challenges to industry expansion was the fear that consumers would not be willing to pay enough for oysters from the Gulf of Mexico. This was compounded by perceptions by some consumers about risks associated with consuming raw oysters from the region. To provide existing

and potential growers a better sense of market perceptions and willingness to pay, the MASGC funded a research project led by Mississippi State University titled, "National survey of consumer preferences for branded Gulf oysters and risk perceptions of Gulf seafood." While there were some differences among regions, the study found that consumers' willingness to pay was sufficient to support off-bottom oyster farming in the region (Petrolia et al. 2017).

To help seafood servers increase sales of farm-raised oysters, Sea Grant also partnered with the Auburn University Shellfish Lab to develop and provide 'Oyster Essentials,' a short training program intended to increase knowledge of farm-raised oysters. Chefs and distributors have provided very positive feedback, with qualitative descriptions of increased oyster sales (Walton, unpub. data).

Sharing Knowledge and Building Community

In addition to applied research, Sea Grant's efforts stand out for the investments into peer-to-peer learning and community building, which have been critical building blocks in the growth of off-bottom oyster farming in the region. In the first years, knowledge exchange among states was coordinated through Sea Grant agents, including grower workshops and farm site visits.

More formally, National Sea Grant supported the Oyster South Symposium with an award to Auburn University in 2016, "Sea Grant symposium for OysterSouth: A submission to the 2016 aquaculture Sea Grant conferences and workshops competition." This funding allowed growers to both attend and present at this industry-focused meeting. National Sea Grant, seeing value in this exchange of knowledge, provided additional funding to Auburn University in 2017 ("Enhancing Peer-to-Peer Learning Opportunities for Southern Oyster Farmers") to allow oyster farmers to visit other oyster farms around the country and world, as well as attend industry symposia. Though difficult to quantify, many growers throughout the region regularly note that the community around Oyster South, a 501(c)(3) dedicated to advancing oyster aquaculture in the southern U.S., has been a boon to the growth of the industry. The Oyster South community (growers, distributors, chefs, media writers, etc., all sharing an interest in southern oyster farming) has further networked Sea Grant agents and Extension specialists across the region as a common platform. Specialists regularly shared information and resources, working together on workshops and products.

Responding to Disasters

Finally, Sea Grant has played a critical role in responding to disasters that have affected this new industry, including the Deepwater Horizon Oil Spill, hurricanes, harmful algal blooms (e.g., Sempier et al. 2019), and the Covid-19 pandemic. Disasters often demand immediate responses that are not suitable for typical request for proposal timelines, but Sea Grant programs adapted and provided the information requested by stakeholders. With hurricanes, Sea Grant has assisted with recovery of gear and coordinated post-storm debriefings to help growers share lessons learned. Recently, several Sea Grant programs in the region collaborated to produce a series of fact sheets to help oyster farmers prepare for tropical storms and hurricanes (Callam et al. 2020; Grice et al. 2020; Sturmer et al. 2020; Walton et al. 2020a; Walton et al. 2020b; Walton et al. 2020c). With the loss of sales in 2020 due to the Covid-19 pandemic, many growers were faced with the challenge of holding oysters that had grown past the desirable market size. In Alabama and Mississippi, the MASGC provided a program that purchased oysters from participating growers to donate to stock enhancement programs. Five other Sea Grant programs in the Northeast and the Gulf of Mexico regions implemented similar programs to buy surplus oysters for restoration.

Beyond the discrete, funded research projects, Sea Grant agents have regularly worked with stakeholders in the region, with the National Sea Grant Law Center responding to multiple requests for information.

Discussion and Conclusions

At its core, off-bottom oyster farming in the Gulf of Mexico is the result of the hard work and ingenuity of numerous individuals. Certainly, a wide array of individuals in academia, regulatory agencies, industry associations, and other groups contributed to the development of this industry.

Could off-bottom oyster farming in the Gulf of Mexico have occurred without the investments made by various Sea Grant programs? Perhaps, but we believe that Sea Grant programs played a critical role in the growth of the industry in this region through the integration of applied research with strategic extension efforts.

The critical nature of the role of the MASGC is perhaps most clear in the initial assessment of feasibility. At the time, there was very scattered interest in off-bottom farming along the U.S. Gulf Coast. The private sector had little motivation to undertake the initial costs of exploring the practicality of off-bottom oyster farming, particularly given the outcomes of earlier attempts in the 1990s. In Alabama, Sea Grant was essential in bringing together a local coastal property owner that had participated in a MASGC oyster gardening program (and had recognized that the site had good growth and survival) with the Auburn University Shellfish Lab. This relationship led to a proposal sent to a competitive research call for proposals from the MASGC. This proposal, testing and comparing the performance of four different production methods, was selected for funding. During and after the study, the PIs engaged stakeholders locally and regionally; at the very least, this active engagement was encouraged by the MASGC. The study also resulted in the establishment of Point aux Pins, the first commercial oyster farm in Alabama, by the cooperating property owner. Without this initial investment, it is not clear that off-bottom farming would be established along the U.S. Gulf Coast.

Were any other Sea Grant investments critical to the growth of the industry in this region? The investment in training and demonstration may not have been critical to the establishment of off-bottom oyster farming but very likely played a strong role in the rate of growth of this industry. Many of the individuals trained went on to establish commercial oyster farms, in many cases launching their farms in the oyster farming parks. In addition, the awareness of this program in Alabama and Louisiana appears to have generated interest in neighboring states. In the case of Florida, a community college instituted a training program inspired at least in part by these Sea Grant training programs and demonstrations (with the leaders of that program having visited the demonstration site in Alabama) and Mississippi explicitly adopted the training program established in Alabama. This training program is currently completing its third class, and a large oyster farming park is permitted near Deer Island (Biloxi, MS). Texas engaged Sea Grant specialists from other states in its initial exploration of off-bottom oyster farming, passed legislation to allow off-bottom oyster farming, and is currently processing applications.

These two investments (one applied research, one extension) are the investments most readily identified as essential to the establishment and growth of the industry. The additional investments, however, should not be discounted as providing benefit to the industry that allowed or enhanced industry growth. Research applied in a timely manner to address important production and marketing questions has provided information useful to industry members. Additionally, research into the value of ecosystem services was associated with a drastic reduction in the easement fees charged by the state of Alabama (from over $6,000/acre/year to $250/acre/year). Research into managing the risk of *Vibrio* spp. through different culture methods was used to improve industry regulations.

What distinguishes Sea Grant's role in this case study and in many other programs? In our assessment, the following characteristics lend themselves to directed, measurable outcomes.

- First, Sea Grant programs have 'boots on the ground' in many coastal communities, with established relationships with stakeholders. This has allowed many Sea Grant agents to build relationships and trust with stakeholders.
- The Sea Grant culture encourages listening to stakeholders' concerns and interests and using this information to guide programmatic investments.
- Many Sea Grant programs include 'relevance' in their reviews of competitive grants after technical reviews, prioritizing technically sufficient proposals based on stakeholder input.
- Sea Grant measures success in terms of outcomes, rather than outputs, focusing on how research is used to change behaviors.

- Finally, Sea Grant programs tend to be nimble and can respond to stakeholder needs in a fashion that produces outcomes in a timely fashion.

This model of investment stands as an example of how applied research and extension efforts can be used to respond to stakeholder concerns and cultivate a new industry. Investments by the MASGC enabled the establishment of commercial off-bottom oyster aquaculture in Alabama and Mississippi, and in turn, through partnerships and collaboration with other Sea Grant programs, Cooperative Extension, and other partners, these investments helped commercial off-bottom oyster aquaculture become established throughout the U.S. Gulf Coast. This case study suggests that a combination of applied research projects, extension projects, and ongoing extension efforts, as exemplified by the MASGC's approach to off-bottom oyster farming, can yield measurable outcomes with significant impacts in communities.

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The authors gratefully acknowledge the efforts of the many individuals who have undertaken the hard work and risk associated with starting and operating oyster farms along the U.S. Gulf Coast. The applied research and extension here would be meaningless without their efforts. We also thank our numerous collaborators and colleagues who helped accomplish the work described here. Finally, we are grateful for the time and effort of anonymous reviewers that improved this manuscript with their suggestions.

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2022 UCOWR/NIWR Annual Water Resources Conference
June 14-16, 2022
Hyatt Regency, Greenville, SC

The planning committee is busy developing the 2022 conference to be held June 14-16. Please note, the health and safety of our attendees is of utmost importance. The UCOWR staff, planning committee, and hotel are working together to ensure a safe in-person conference amidst the potential pandemic impacts through June 2022. We look forward to seeing you next June!

Join us as we head to the Southeast in 2022. Nestled up against the foothills of the Blue Ridge Mountains in the heart of South Carolina's Upcountry, Greenville is a social distancing dreamland. The region's rich history, state parks, national forests, and wilderness areas provide endless opportunities for outdoor exploration. UCOWR is a family-friendly organization and we invite you to extend your conference participation and enjoy the abundance of opportunities a trip to Greenville offers.

Attendees will delve into current perspectives on a range of contemporary water resources challenges and solutions (at community, watershed, regional, national, and/or global scales). In addition to the vast range of water-related topics and disciplines that are typical of a UCOWR conference, a special focus will be on Water Resilience.

Check out the Call for Abstracts and submit abstracts by January 24. Registration will open in February.

For more information on the conference, please visit https://ucowr.org/conference/.

General questions about the conference can be directed to Karl Williard (ucowr@siu.edu), Executive Director of UCOWR.

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