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ACTIVITIES AND PROGRAM MODEL

Helping the Public Understand the Microplastics Issue: Integrating Citizen Science Techniques and Hands-On Education Experiences with Ongoing Microplastics Research

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Marine microplastic (plastic particles smaller than 5 mm in length) pollution is a recognized and growing threat to the environment. Microplastic particle estimates number in the trillions and are under sampled in ecosystems worldwide (Eriksen et al. 2014, Zhao et al. 2019). Sources of microplastics include manufactured particles (fibers, beads, industrial abrasives) or microplastics generated from breakdown of larger plastics through mechanical, photochemical, or biologically mediated degradation (Schwarz et al. 2019). Little is known about the fate or effect of microplastics on marine environments thus emphasizing the importance of scientific research. The University of Georgia Skidaway Institute of Oceanography (UGA SkIO) and Marine Extension and Georgia Sea Grant (UGA MAREX) are mapping the distribution and abundance of microplastics in Georgia's coastal waters. There are many challenges to studying microplastic abundances, including intensive sampling and measurement efforts on a temporal and spatial scale that require trained personnel. Volunteer-based research is well suited for studying microplastic pollution. We have developed a successful volunteer-based monitoring program to assist with research efforts. We have established partnerships with environmental programs and groups including the UGA MAREX volunteer program, and the Satilla, Altamaha and Ogeechee Riverkeepers to assist with monitoring efforts. Everyone involved understands the critical importance of proper research technique, strict protocols and training in order to obtain "believable" data. Our research to date suggests that a dedicated, trained group of scientists and volunteers can provide the mechanism for conducting detailed studies of microplastics on a local to regional scale.

Keywords: microplastics; citizen science; monitoring; research; model

Introduction

Marine microplastic (plastic particles smaller than 5 mm in length (Browne et al. 2007) pollution is a recently recognized and growing threat to the environment. Sources of microplastics in the environment include manufactured particles (fibers, beads, industrial abrasives) or microplastics generated from breakdown of larger plastics through mechanical, photochemical, or biologically mediated degradation (Schwarz et al. 2019). The University of Georgia Skidaway Institute of Oceanography (UGA SkIO) and the University of Georgia Marine Extension and Georgia Sea Grant (UGA MAREX) are currently mapping the distribution and abundance of microplastics in Georgia's coastal waters. Primary challenges in mapping microplastic concentrations include collecting and processing samples in a manner that minimizes contamination, identifying microplastic types, and measuring abundances in complex environmental matrices, and in collecting enough samples to obtain statistically relevant data (Huppertsberg and Knepper 2018, Rambonnet et al. 2019, Yu et al. 2018, Zarfl 2019). These challenges are especially acute in coastal ecosystems like those in Georgia, where the interplay between human activities, large tides, strong currents, and diverse ecosystems makes for a very complex set of forces potentially affecting microplastic abundance patterns. All of these challenges require a skilled labor pool that can collect and process samples consistently without contamination. This is where volunteers can be of great help.

Microplastics research is a relatively new scientific subject that has caught the interest of the public; their curiosity has been piqued by news articles and videos of marine debris and microplastics. However, members of the public have difficulty understanding both the complexity involved with the distribution and behavior of contaminants in a dynamic coastal system and the magnitude of the issue. This has led to individuals and environmentally focused groups asking for further information and looking for ways to get involved with microplastics research and education efforts if opportunities are offered to them.

We have, over the past two years, conducted visually identified microplastic (VIM) abundance mapping along the Georgia intracoastal waterway, by establishing collection sites along the length of the coast that are now being sampled on a monthly basis. These efforts involve three separate Riverkeeper groups as well as our own local sampling group run out of the Savannah area. Roughly 145 samples are generated (and archived for further investigation) monthly. Each sampling effort is accompanied by procedural blanks to assess potential contamination during sampling and processing, and each group is resupplied with sample bottles and filtered, deionized water on a regular basis. Preliminary results have indicated a great deal of heterogeneity amongst sites, even those separated by a few kilometers (**Figure 1**). While we have gained considerable new information and understanding about the distribution of microplastics in the region, research to date has identified new problems worthy of attention and we have implemented new programs to help with these problems, outlined below.

Our efforts to date have illustrated the challenges to studying microplastics. First, providing accurate estimates of microplastic abundances involves intensive sampling and measurement efforts that require trained personnel. However, federal and regional funds for research are scarce and competition for them intense, making traditional graduate student and technician-based research groups difficult to maintain.

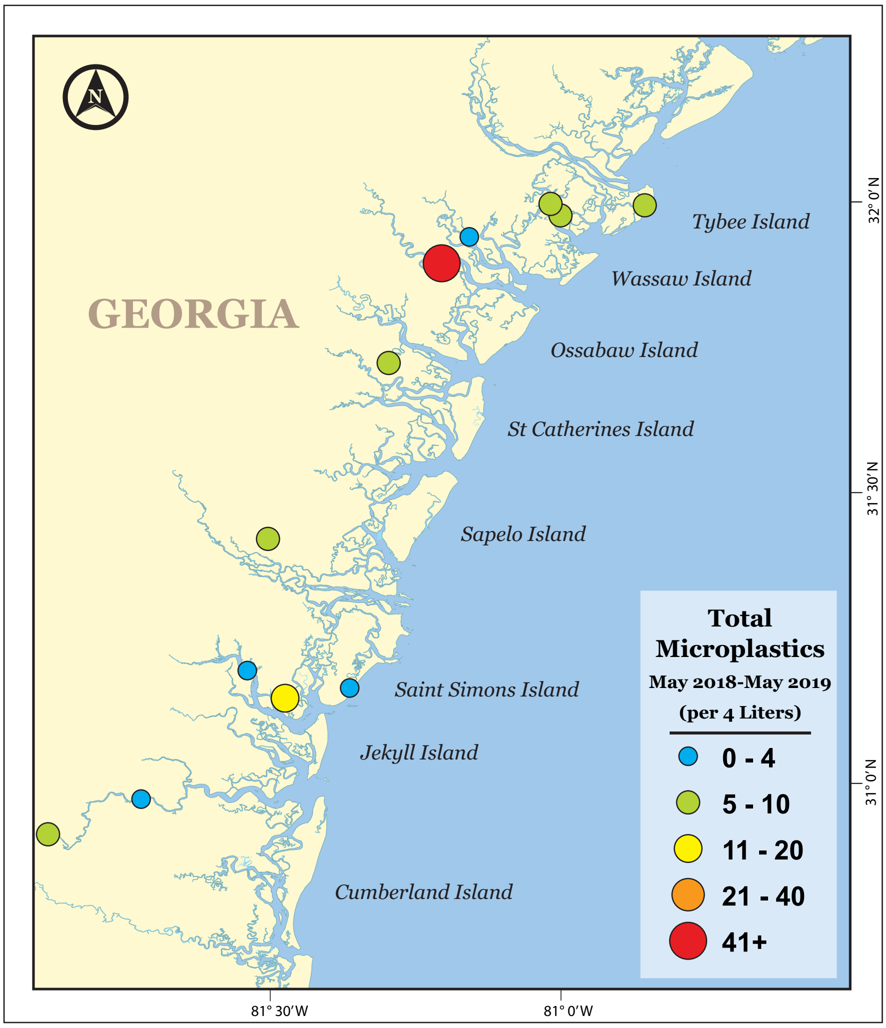

Figure 1: VIM concentration along coast summer, 2018.

Second, unlike larger beach debris, microplastics are not easily measured in environmental samples (they cannot be seen by the naked eye, thus an individual cannot simply walk up and sample them), and positive identification of microplastic type requires sophisticated instrumentation (Elert et al. 2017). Furthermore, samples can be easily contaminated, both by the clothing that sample team members may wear as well as by airborne microplastics and fibers. The spatial and temporal heterogeneity within Georgia's coastal ecosystem also makes it imperative that sampling numbers and spacing be considered. To alleviate the issues of contamination, rigorous protocols with as few steps as possible for the collection, processing, and analysis of samples must be in place and followed. To reduce the effect of heterogeneity, sampling strategies need to consider both adequate spatial and temporal coverage, essentially requiring a greater number of samples than a small research group can process. Even with such a sampling strategy, the results need to be considered carefully to avoid drawing conclusions that might be too broad.

These challenges lead to an inescapable fact: Understanding microplastics distributions and behavior requires a large, skilled labor force. It is possible to involve volunteer members in the community, but everyone involved needs to understand the critical importance of proper research technique, strict protocols, and training in order to obtain uncontaminated samples. Our research to date has indicated that this is possible, and we suggest that a dedicated, trained group of scientists and volunteers can provide the mechanism for conducting detailed studies of microplastics on a local to regional scale. We have referred to these efforts as "citizen science" because it is a well-used term. However, because citizenship is not a necessary factor for participation, we now recommend the term community science.

Community science examples for integration into research efforts

Our initial efforts to map microplastics in Georgia's intracoastal estuaries indicated the presence of a trillion or more VIM particles in the region, primarily of the microfiber category (**Figure 2**). Most of the samples collected in Georgia's intercoastal waterways in this initial sampling (June–July 2017) contained microplastics, but the samples exhibited considerable variability in the number of microplastic particles found. VIM concentrations varied from none present to greater than 80 particles per 4 liters. In addition, while there was an apparent relationship between their concentrations and urban areas, even samples from rural sites contained VIMs (**Figure 3**).

Over the past two years, in order to address the issues raised above, we have developed experiences to engage and educate the public about microplastics in the coastal zone. Participants move from awareness to understanding how human activities produce microplastics and the potential negative impacts on oceanic systems, and finally, to taking positive actions, both on their own and in concert with our community science sampling program. We believe that there is a critical synergy between scientific research and education, and our community science-based programs incorporate useful and successful strategies that connect community members to global environmental issues.

Community science engages the public in scientific inquiry and research endeavors. Volunteer driven, community science brings benefits and challenges to the research field. Community science programs offer benefits to research groups, monitoring agencies, and policymakers and can positively impact communities (Bosker et al. 2017). In our case, engaging the community scientist provides 'force multipliers' who can greatly increase the spatial and temporal detail possible in studying microplastics by increasing our ability to sample extensively along the Georgia coast. Community science-based programs also face challenges. In our program, most important are potential contamination during sample collection and processing and lack of consistency in following protocols. However, when implemented they can bring worthwhile benefits (Hidalgo-Ruz and Theil 2015).

Community science is critical to our current research efforts. We have established partnerships with like-minded environmental programs and groups, including the UGA MAREX volunteer program and the Satilla, Altamaha, and Ogeechee Riverkeepers to assist with the monthly monitoring efforts. The Riverkeepers

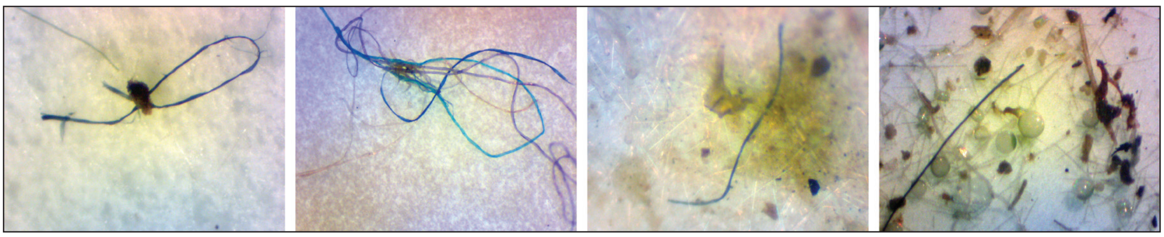

Figure 2: Examples of VIM microfibers collected from Georgia estuarine waters. Photographs by D. Sanders.

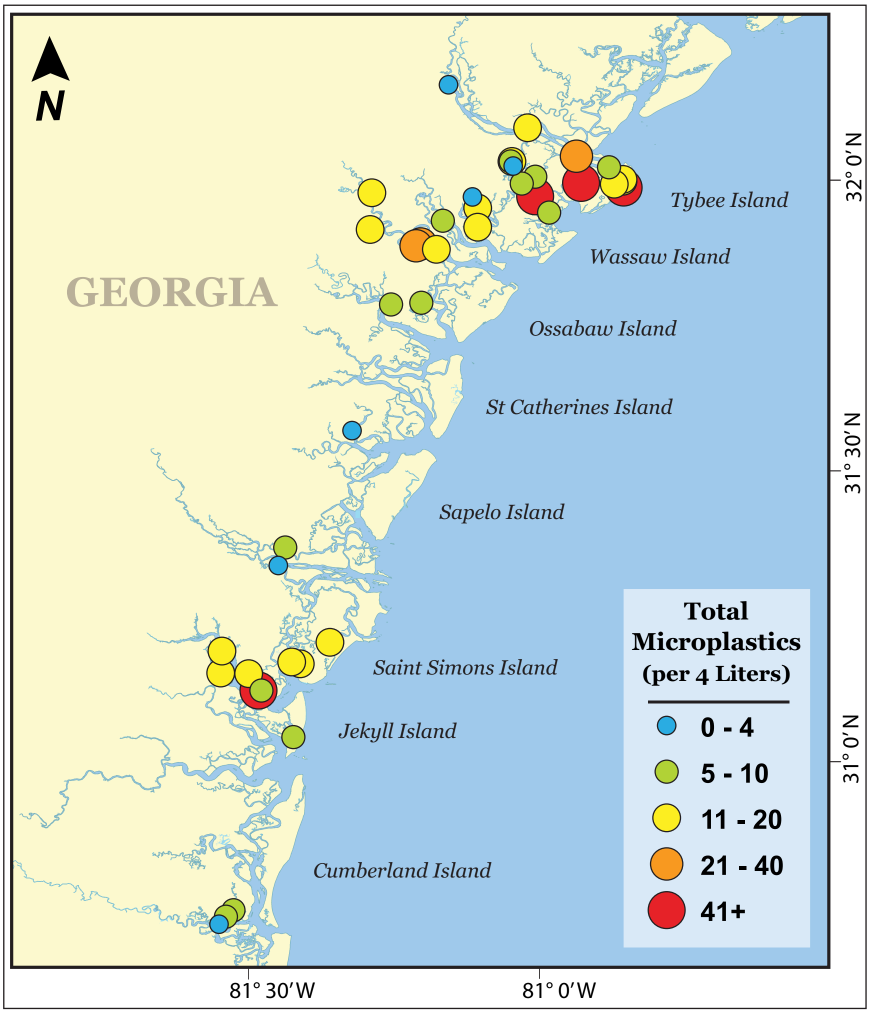

Figure 3: VIM abundances in Georgia estuarine waters, June–July 2017.

are grassroots organizations that are dedicated to the protection, defense, and restoration of their river ecosystems and are natural partners in this project. Recruitment efforts involved approaching Riverkeepers and their volunteers, along with recruiting community scientists through MAREX's robust volunteer program. After recruitment, 16 volunteers received a four-hour, extensive training on the collection of monthly samples to ensure that we were building a cohort of dedicated volunteers that understood the importance of following well-defined established protocols. During volunteer training, scientists and professionals conduct oversight to assess each individual's skills. The procedural blanks processed with each set of samples provide a check as to potential contamination in the field during sampling and as the samples are processed. Additionally, final sample examinations are performed by the core research team, ensuring consistency in VIM identification and quantification. Post-training reminders of continued proper collection technique have provided additional assurances that samples are being collected in the correct manner. To ensure that the project also met the community needs of the Riverkeeper groups, they each chose three of their many coastal sampling sites for their monthly monitoring.

We have provided each Riverkeeper and UGA MAREX group with a sampling kit containing reasonably inexpensive sampling gear, data sheets for collecting information at sampling sites, and a written protocol to eliminate contamination of samples. Each group has three locations that are sampled monthly during an outgoing tide. All sampling materials (sampling vials and stainless steel sieves and funnels) are pre-cleaned before use and are rinsed with 0.2 micron filtered deionized water after each sample. Triplicate four-liter samples of seawater are collected in pre-rinsed stainless steel buckets and are poured through a series of stainless steel sieves of varying sizes (355 micron, trapping the largest particles; 106 micron, trapping particles between 106 and 355 microns in size; and 63 microns, trapping the smallest particles between 63 and 106 microns in size) to concentrate the samples (**Figures 4** and **5**). The samples captured by each sieve and a set of triplicate procedural blanks are stored in pre-cleaned, muffled vials in a cool dark environment and collected for transport to our Skidaway Laboratory for analysis.

Figure 4: Samples of seawater are poured through a series of stainless steel sieves. Photograph by D. Sanders.

Figure 5: Samples rinsed from stainless steel sieves. Photograph by D. Sanders.

In the laboratory, the concentrated samples and blanks are filtered through 3-micron pore size cellulose acetate filters that have been previously visually inspected for contamination under a microscope. Samples and blanks are processed using a strict protocol to eliminate contamination of samples: Samples are filtered within a laminar-flow hood, using pre-cleaned and muffled (400°C for four-plus hours) glassware and 0.2 micron-filtered deionized water. The filtration process can be done by the community scientists after more rigorous training. The analysis process involves using a compound microscope to visually inspect the entire filter for microplastic particles at 40 times magnification. Characterization of particles are determined using Hildago-Ruz guidelines (Hildago-Ruz et al. 2012). Briefly, microplastics can be visually identified by consistent color throughout, no cellular structures, and fibers or sheets that are the same thickness throughout. Number, color, and morphology of VIMs are documented.

Data from the community scientist efforts have resulted in VIMs observed throughout Georgia's surface estuarine waters. Collected samples further highlighted the intrinsic temporal and spatial heterogeneity of these contaminants in Georgia estuaries. No decrease in concentrations in upper estuary locations was noted, although spatial coverage was limited. Work is ongoing to further differentiate the composition of VIMs using Raman microscopy. Continued monitoring efforts by the community scientists will further our understanding of distribution and abundance of microplastic pollution along the coast.

Conclusions

Our efforts, similar to the Sea Grant supported Florida Microplastic Awareness Project (http://sfyl.ifas.ufl.edu/flagler/marine-and-coastal/microplastics/), have created a model for building capacity to establish a successful microplastic monitoring program. Integrating community science into our research efforts has illustrated that this type of research is well suited for expanding the capacity to understand microplastic pollution. Utilizing community partnerships with like-minded groups, ensuring well-trained and dedicated volunteers, implementing a straightforward protocol, and using reasonably inexpensive sampling gear are vital components to the program. Positive outcomes have resulted in the ability of the community scientists to increase the workforce. With them we can increase the spatial and temporal efforts of our samples, and they become advocates for the science. In essence, they 'own' the issue and spread the word to friends and even more widely. Community scientists are engaged in important environmental issues and gain knowledge and understanding – a valuable asset that will influence larger decisions about science policy. As others have noted (https://www.nap.edu/catalog/25183/learning-through-citizen-science-enhancing-opportunities-by-design), our project activities with community members support learning outcomes related to scientific practices, content, data, and reasoning.

We have outlined our protocol and suggestions for equipment for sampling microplastics in water on our website (https://gacoast.uga.edu/marine-debris/). We are coastal in our focus, working with brackish to full strength seawater, but similar techniques will work in any water body. Our protocols in terms of volume of water collected may have to be altered somewhat depending upon factors such as contaminant loads; e.g., smaller for wastewater and larger for pristine lakes. Our community scientists are adults, however, we have implemented over twenty onsite programs for students that illustrate that the protocol may be able to be implemented by middle and high school audiences.

In conjunction with the community science monitoring program, we have developed laboratory and field-based learning experiences for the public and school groups on microplastic pollution. UGA MAREX and Georgia Sea Grant educational programs reach thousands of participants statewide annually and provide unique learning experiences to explore the global issue of microplastics closer to home. For example, our 'Microplastics in the Aquatic Environment' activity explores the topic of microplastics in aquatic systems including sources and ecological impacts on the ocean and coastal zone. It is offered to school and other interested groups (https://gacoast.uga.edu/education/schools-and-groups/laboratory-studies/).

As an interconnected entity, our microplastics community science monitoring and education programs provide mechanisms to:

1.) engage students, teachers, and the general public about ongoing non-point source pollution research, particularly with respect to microplastics,
2.) implement monitoring and prevention programs along the coast of Georgia using scientists and volunteers,
3.) highlight microplastic pollution and its negative impacts on the environment,
4.) provide a platform to showcase the results of microplastic monitoring efforts statewide and beyond, and
5.) provide an opportunity for volunteers to help alleviate the impacts of non-point source pollution by being environmental stewards.

Funding Information

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

Dorothea Sanders led recruiting and training activities, correspondence, and scheduling with community scientists, upkeep on equipment and supplies, leading MAREX community scientists sample collection trips, processing and analyzing samples, educational development and implementation. She also co-led protocol development for sample collection and analysis.

Dr. Jay Brandes led all research activities, data management, co-developed protocols, and provided lab space and resources for sample analysis.

Author Information

Dodie Sanders is a marine educator and boat captain for the University of Georgia Marine Extension and Georgia Sea Grant. One component of Sanders' job as an environmental educator is creating educational programs based on current research. Her collaborative microplastics project has resulted in several field and lab-based programs that we offer to students and teachers. The experiences provide opportunities to explore the global issue of microplastics closer to home with the goal of instilling in the public the concept that scientific research is critical to further understanding and knowledge of marine systems.

Dr. Brandes is a Professor at the Skidaway Institute of Oceanography, University of Georgia. He received dual Bachelors of Science degrees in Chemistry and in Oceanography from Humboldt State University in California, and a Ph.D. in Chemical Oceanography from the University of Washington. Dr. Brandes studies carbon and nutrient cycling in the environment as well as marine debris and microplastics in coastal Georgia's waters.

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