Chesapeake Quarterly

MARYLAND SEA GRANT COLLEGE • VOLUME 19, NUMBER 2

Microplastics and the Chesapeake

contents

Volume 19, Number 2

CHESAPEAKE QUARTERLY

December 2020

Chesapeake Quarterly explores scientific, environmental, and cultural issues relevant to the Chesapeake Bay and its watershed. The magazine is produced and funded by the Maryland Sea Grant College. The college receives support from the National Oceanic and Atmospheric Administration and the state of Maryland.

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Cover: *Microplastics collected from the Patapso River by Lance Yonkos, an assistant professor at the University of Maryland, College Park.* PHOTO, CHESAPEAKE BAY PROGRAM

Hazards, Large and Small

These are uncertain and frightening times. We are almost a year into a pandemic that for many of us resembles an endless, Groundhog Day-like loop.

We face a real danger in COVID-19, and we can see the ramifications of the virus. At the same time, we are still grappling with other dangers we cannot see, including the ones from microplastics. The search for scientific understanding of COVID-19 and microplastics will continue for years to come, though with microplastics, there will be no vaccine. Scientists are not sure how long microplastics will be with us—in our water, our air, and our bodies—or what that means for our long-term health.

Plastic debris *collected by the NOAA Marine Debris Program.* PHOTO COURTESY OF NOAA

Microplastics are the tiny particles that are byproducts of manufacturing so many plastic bottles, bags, snack packaging, and other convenience items we use daily. Microfibers and microbeads, too, have become ubiquitous in the marine environment, coming from fleece clothing and personal care products.

Scientists are looking closely at these tiny hazards and trying to assess their harm and reduce their numbers. Neither is an easy task.

In this issue, we explore these dangers invisible to most of us. We'll also talk about how Maryland Sea Grant is working with high school teachers to help them identify microplastics in labs with their students.

We'll introduce you to the newest Maryland Sea Grant Knauss fellows. They are masters or PhD students in marine science or related fields who are spending a year in Washington, DC, learning policy. The placements include positions at the National Oceanic and Atmospheric Administration, the Department of the Navy, and a congressional office. It's not the year they planned; most of our fellows are working remotely. They'll be writing about their work on the Fellowship Experiences blog, which you can find on our website. Also in this issue, you'll meet Amanda Rockler, a longtime member of the Maryland Sea Grant Extension team working in Montgomery and Howard counties as a watershed specialist. She is now also looking into microplastics.

And finally, we're happy to introduce Wendy Mitman Clarke, our new science writer at Maryland Sea Grant. Wendy joins us from Washington College, where she was a writer, editor, and communications manager for eight years. An avid sailor, her award-winning work has appeared in *Soundings, Chesapeake Bay Magazine, Smithsonian Magazine,* and *National Parks*. Welcome aboard!

—Rona Kobell

Note from the editors: Many of the photos in this issue were taken prior to COVID-19. Maryland Sea Grant is strictly following all University System of Maryland COVID guidelines, including masks and social distancing.

Small Particles, Big Problems?

Scientists Grapple with Many Unknowns about Microplastics and Their Impact on the Chesapeake Bay

By Rona Kobell

It is the things she can't see that worry Ana Sosa the most. Sosa is a microbial ecologist, so tiny would describe most of what she examines. It is a large purview and includes bacteria, algae, and investigating how microorganisms interact in the environment and sometimes disrupt natural processes. Many of these microscopic organisms can contribute to creating low-oxygen zones and toxic blooms in the Chesapeake Bay. But for her, the most concerning "micro" of all for the continued health of the marine ecosystem are microplastics, the tiniest bits of human-produced, inorganic matter in the Bay and worldwide.

Sosa's office at the Institute of Marine and Environmental Technology (IMET) is next to the Baltimore Harbor, where microplastics are abundant. There, she takes samples from the water, sequences the DNA of the microorganisms living in it, and determines how plastic may be interfering with their biological processes such as eating, reproducing, and cycling nutrients throughout the system.

"I've always been worried about plastics, and microplastics just seem like the biggest threat to the environment. And they're everywhere," Sosa said. "If you walk along the harbor and you see big plastic, there's definitely also small plastic."

Microplastics are what they sound like—tiny pieces of plastic shed from fabrics, or the remnants of larger objects and materials from our sustained use of everything from candy wrappers to plastic bags. They range from 5 mm to a nanoscale size, with a nanometer being one-billionth of a meter. Long recognized as a problem in the world's oceans, they are an emerging threat to the Chesapeake Bay and its tributaries.

A 2014 study confirmed these waters are a large landing spot for the tiniest plastics. Lance Yonkos, an aquatic toxicology specialist at the University of Maryland, led a team that found microplastics in all but one of 60 samples in the study, which became a noted peer-reviewed publication on the issue in the estuary. The Patapsco River, which includes

***Microplastics** collected from a freshwater stream by Florida Sea Grant agent Maia McGuire.* PHOTO COURTESY OF FLORIDA SEA GRANT

***The Potomac River** full of trash (above top). A team of scientists is looking at how microplastics impact food sources in the Chesapeake's second-largest tributary. Watershed specialist Dawayne Garnett (above bottom) from Groundwork Anacostia picks out trash from a litter trap at Kenilworth Park in Washington, DC. The trap gets emptied once a week. It can take close to 20 garbage bags to remove everything.* PHOTO, (ABOVE TOP) DAMIEN OSSI / DOEE FISHERIES AND WILDLIFE DIVISION; (ABOVE BOTTOM) WILL PARSON / CHESAPEAKE BAY PROGRAM

Baltimore's harbor, had the most. A follow-up 2015 University of Toronto survey collected surface samples from 30 sites in the Chesapeake from Baltimore to the mouth of the Potomac River that included inorganic particles, organic matter, and larger trash pieces. Researchers found microplastics in every single sample, said Julie Lawson, the study's principal investigator.

The Birth of Plastics

How did we become a world of plastics? It seems to have begun in 1869, when John Wesley Hyatt invented celluloid, the first synthetic polymer, in response to a challenge to find a substitute for the natural ivory that was used to make billiard balls. The sport's popularity had led to intense demand for ivory tusks, impacting wild elephant populations. Hyatt received a patent for his celluloid, a long chain of molecules arranged in repeating patterns that can be molded into many different products. He produced the first injection molding machine soon after, creating substitutes for ivory-derived, everyday items such as combs and buttons. These products came from the cellulose in trees and other plants, so this ivory substitute was still drawn from natural sources.

That changed nearly 40 years later, when Leo Baekeland invented Bakelite, the first fully synthetic plastic that contained no molecules found in nature. Derived from fossil fuel sources, these new plastics retained their shape when heated, making them ideal for everything from kitchen cookware to electrical insulators. Bakelite marked the switch from plant sources to fossil fuels as the building blocks for these new products, which came of age just in time for World War I. They replaced scarce natural materials, such as wood, and materials that were expensive to turn into useful products, such as hemp.

Today, the vast majority of plastics come from fossil fuels, mostly crude oil but also coal. In a refinery, workers heat these raw materials and distill them into chemicals called monomers, molecules that are the basic building blocks of a polymer. These include carbon, hydrogen, oxygen, chlorine, and sulfur. Chemists can take lighter gases and add more molecules of hydrocarbons through a process called polymerization, transforming the raw materials into moldable plastic units.

Researchers estimate that 8.3 million metric tons of plastic were produced worldwide between 1950 and 2017. It's also estimated that only 9 percent of it has been recycled, leaving much of it still in use or as plastic waste.

The Problems with Microplastics

Plastic pieces enter the marine ecosystem every year, most transported from land through stormwater runoff, wind, and illegal dumping. The smallest are called microplastics. Scientists agree that microplastics are a problem and that they're everywhere: in our water, in our air, in our soil, and in our wastewater. But what researchers can't agree on is how much of a problem microplastics are or how to address them.

Some states have passed laws regulating some of the more problematic particles, such as the microbeads in personal-care products, but such regulations often allow other types of these plastics to go unaddressed. California recently established a drinking water standard and testing protocol for microplastics in water, but there is no similar federal standard. As long as people continue to use plastic items, the tiny-plastics problem will balloon.

Microplastics also present a challenge in the lab. Researchers have often had to purchase glass equipment to examine microplastics because if they use plastic equipment as they do for other experiments, there could be cross-contamination with the sample. Clothing can also be an issue, as microfibers—a type of microplastic—may shed from synthetic fabrics and contaminate the lab. And examining the smallest particles, which can be below 20 microns, requires expensive imaging systems.

Equipment aside, not everyone agrees on even basic parameters, including what a microplastic is in terms of size, how to measure concentrations, and what concentrations constitute a risk and to whom. No federal agency has issued such a regulatory limit for microplastics.

Another aspect of the microplastics conundrum is the sheer variety. They include thousands of different polymers, each with varying chemical concentrations. The key to determining whether they are harmful, and how, is finding a tool to identify the polymer, one of which is transform infrared spectroscopy. This method identifies molecules that vibrate when exposed to certain wavelengths of light over time. The vibrations' intensity is plotted against the light's frequency to create a spectrum. Then, scientists can compare what they have found to the polymers in a signature library, which is filled with typical types.

All chemicals have a spectral fingerprint under different wavelengths that distinguish them. But while the fingerprint identifies the polymer, it doesn't tell how each behaves in the environment. When chemicals have one molecule, or are monomers, they behave a

Microplastics in the Environment

Microplastics is the broad category for several different kinds of plastic bits that are smaller than 5 mm. **Primary microplastics** are manufactured "micro" to serve as the building blocks of many items for modern living. **Secondary microplastics,** on the other hand, are never intended to be tiny. They begin as large plastic objects, and over time in the environment, wind, waves, and energy from the sun help break them down.

Microplastics are pieces of plastic 5 millimeters or smaller.

5 mm scale

PRIMARY MICROPLASTICS

Nurdles
Manufacturers melt down these lentil-sized pellets to create larger plastic items—everything from plastic bottles to car parts. Nurdles can get into waterways through spills at sea as they are being shipped as cargo to plants for manufacturing and transforming into usable products. They can also enter waterways through stormwater near the plants where manufacturing occurs.

Microbeads
Found in toothpaste, shampoos, facial cleaners, and other products, these tiny beads flow into wastewater through sink and shower drains. Treated wastewater is released into freshwater systems, often with no treatment to eliminate or reduce the microbeads. They can also be found in sewage sludge, which many municipalities send to rural areas as fertilizer.

SECONDARY MICROPLASTICS

Fragments
A piece of a once-larger plastic bag, toy, bottle, or other item. Plastic fragments are common sights in urban areas, such as Baltimore's Inner Harbor and the Anacostia and Potomac waterfronts in Washington, DC, and may be ingested by wildlife in those ecosystems. Gathered in trash traps, they can reach an impressive volume given their small size.

Microfibers
These fibers come from clothing that's made of synthetic fabrics, such as nylon, fleece, and polyester. Washing and general wear separates the microfibers from the clothing, and they are flushed into our wastewater systems and released into the air. They are a common microplastic in marine environments and also come from fishing lines and nets, which are a large source of debris in the ocean.

Polystyrene
Expanded polystyrene is used to make the cups and takeout containers often referred to as styrofoam. But Styrofoam is a trademarked name of DuPont; it is an extruded polystyrene, more rigid than the type used in cups, and used as insulation. Of the two, it's the expanded polystyrene that is ubiquitous in the ocean and streams, in part because it is not recyclable.

PHOTOS (TOP TO BOTTOM): NURDLES, TRISTAN BAURICK / NOLA.COM; MICROBEADS, MINNESOTA POLLUTION CONTROL AGENCY; FRAGMENTS, NOAA; MICROFIBER, J. ADAM FREDERICK / MDSG; POLYSTYRENE, WILL PARSON / CHESAPEAKE BAY PROGRAM

***A plastic fiber** encased within the ice crystals of a snowflake. Microplastics are not just in our water but also in our air, and can fall to the ground through precipitation or vapors.* PHOTO, DOUG WEWER / DESERTSNOWPHOTOGRAPHY.COM

certain way. Add complexities and they change. Another complicating factor is that different labs use different spectroscopy techniques to identify polymers.

"It's a complicated subject and there is not enough standardized methodology," Sosa said. "They are in all sizes and all shapes, and they have thousands of additives and polymers. That makes this field really, really difficult. There are so many different ways to attack the problem that it's not clear where scientists should start."

The More You (Don't) Know...

Sosa is far from alone in wrestling with the knowledge gaps in microplastics. Scientists around the country and the world have been struggling with the same issue for decades.

"We really don't have a lot of answers at this time, just many questions about what they will mean for both people and ecosystems," Scott Coffin, a research scientist with California's Water Resources Control Board, said during a recent webinar discussing microplastics.

"I don't think we have enough information to be concerned yet, as far as direct human health consequences regarding microplastics," Coffin said. "But we know if we continue with business as usual, we will see a certainty of ecosystem collapse. It's a guarantee the plastic never goes away, and the inputs are increasing exponentially."

Added Matt Robinson, an environmental protection specialist with the District of Columbia's Department of Energy and the Environment (DOEE) and chair of the Chesapeake Bay Program Plastic Pollution Action Team: "There is difficulty in determining the detection limits, but what scares me more than that is the fact that we don't have uniformity in units of concentration. We don't have standardized monitoring methods for how to measure."

At a National Academy of Sciences (NAS) meeting in Washington, DC, earlier this year that focused on microplastics, the most common refrain was uncertainty regarding microplastics and especially so with regard to human health; about the only thing the group agreed on was a need for further study.

Tiny Particles in the Air?

The process of making the plastics, as well as their eventual disposal, comes at a price not just for our water but also for our air.

Janice Brahney, an assistant professor of watershed sciences at Utah State University, collected data on air particles through the National Atmospheric Deposition Program. By examining the microplastics chemistry in wet (rain and snow) and dry (vapors and aerosols) deposition in the United States each week since 2017, Brahney attempted to figure out how many plastic particles were falling from the sky and where they were coming from. Most were microfibers from nylon, but the team also found microbeads far smaller than the ones in cosmetics, which they determined had come from acrylic paint.

Plastic reaches the atmosphere through a number of different processes, similar to those that produce dust or other aerosols. They include wind, wave action on the ocean, and erosion of soils that contain plastic. The Brahney team found that the sources of plastics deposited with rain were generally from nearby areas, such as regional cities, whereas the plastics that fell out dry were coming from far away. The greater plastic deposition occurred when the polar jet stream moved further south, toward the monitoring sites. The deposits fall when an airmass slows because of gravity or when it intersects with an obstacle, like a mountain range, Brahney said.

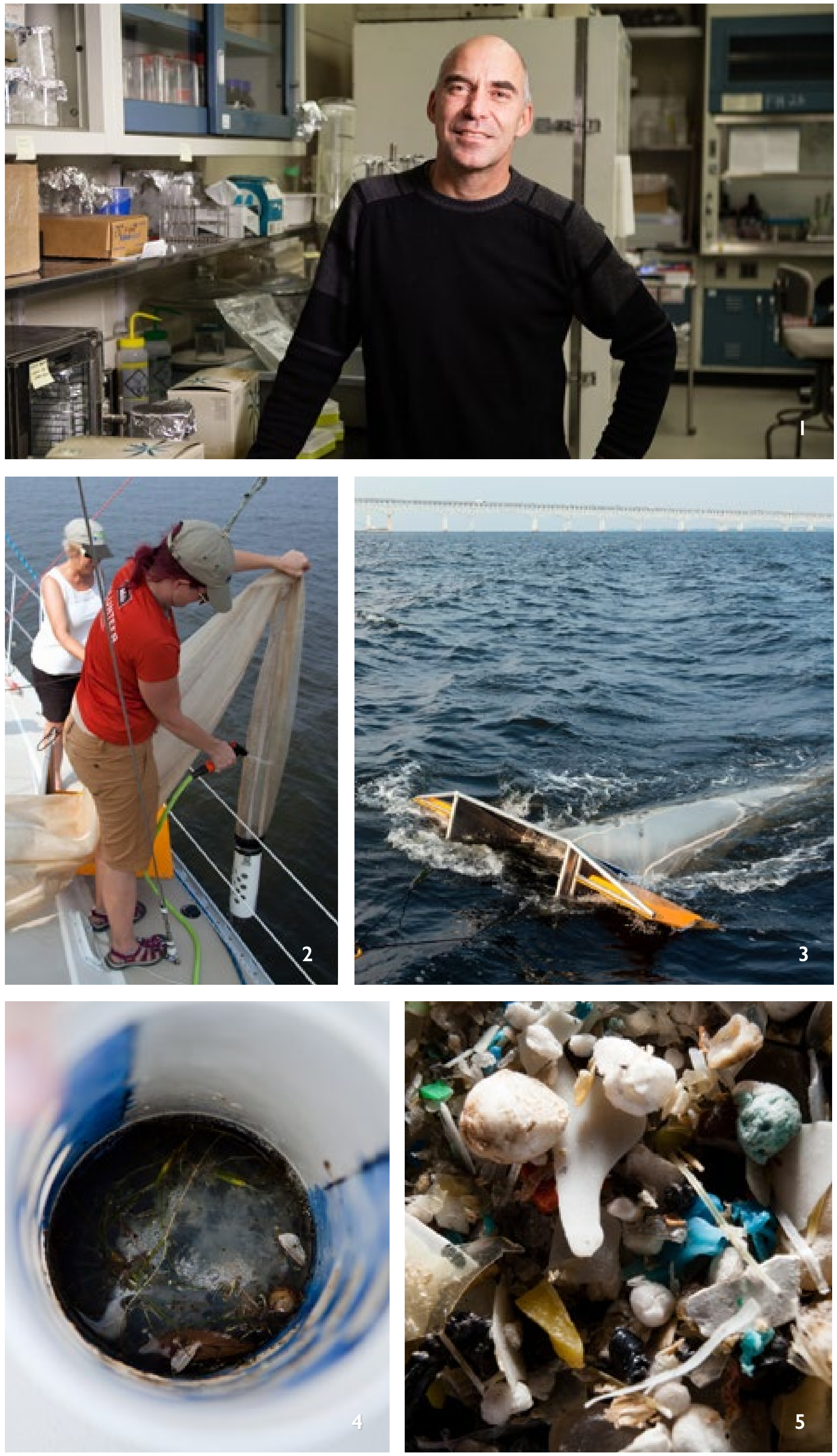
On average, Brahney said, 4 percent of atmospheric dust is from plastic sources, with aerosols, insect parts, soils, and minerals making up the rest.

"Four percent is huge," Brahney said. "That is an enormously high percentage of dust."

The View from the Chesapeake

In 2014, Lance Yonkos and his team, along with the NOAA Marine Debris Program, were the first to quantify the problem in the Chesapeake's tributaries, according to Sosa and Robinson. Yonkos described his team's process in the resulting paper published in *Environmental Science & Technology*. The researchers trawled for microplastics on five trips in the Chesapeake from July to December 2011. Using a manta net—designed to capture samples at the water surface via a wide opening similar to that of the surface-feeding manta ray it is named after—researchers collected 15 samples at each site. Materials passed through nested 5.0 mm and 0.3 mm stainless steel sieves, with holes about the size of a pencil top eraser and the thickness of a sheet of foil. Microplastics were found in all but one sample—a lone test from the Corsica—and the abundances were highest in the Patapsco, supporting the author's theory that the closer a river is to urban industrial sites, the more likely it is to have high concentrations of microplastics.

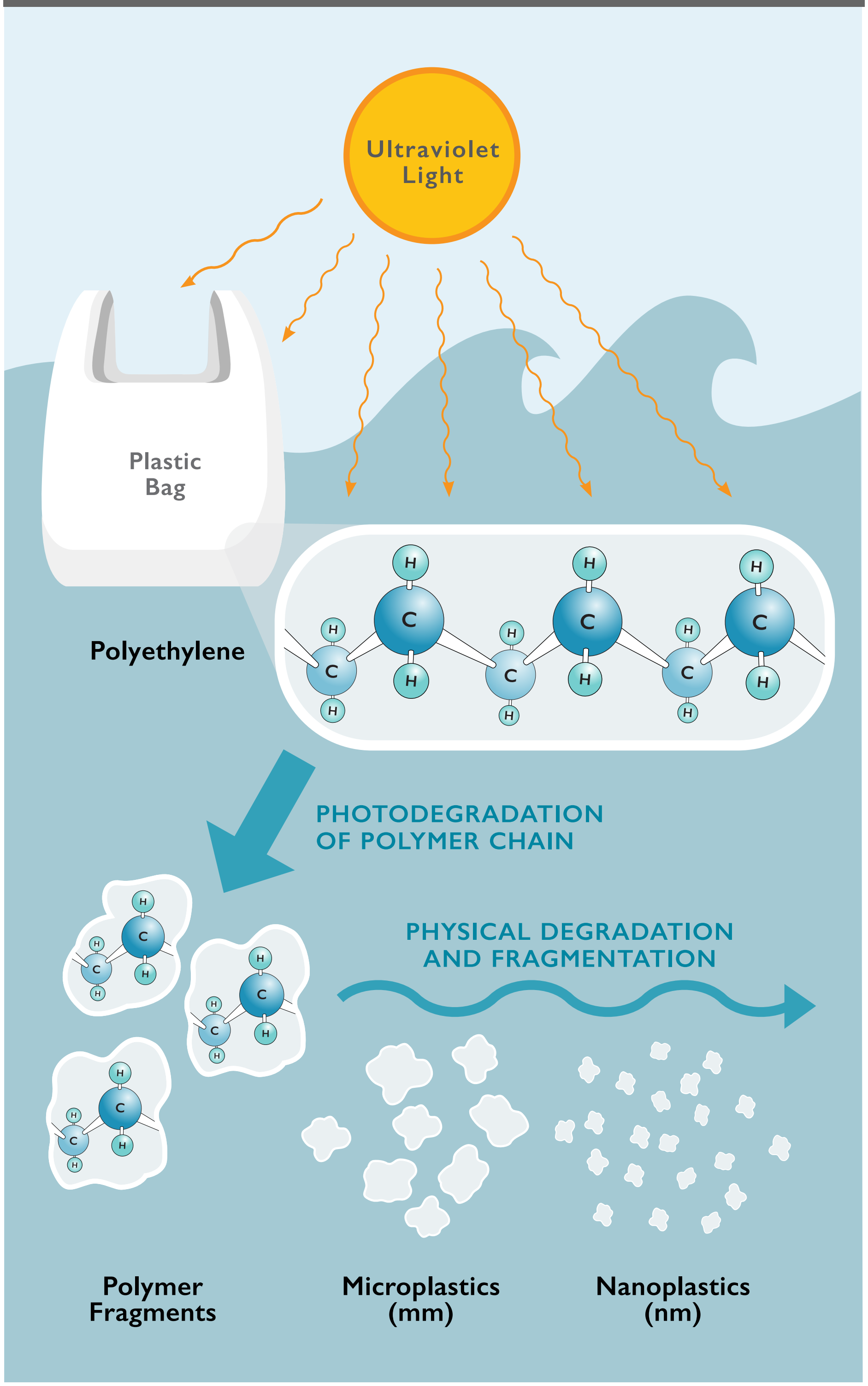
Yonkos' work led researchers working in the Anacostia River and the Chesapeake Bay to press for more answers on how to measure microplastics. They believed that a better sense of plastics' concentrations and locations could help regulators pass laws and policies limiting plastics and hopefully reducing microplastics' prevalence. In 2020, a paper by Jacqueline Bikker and C.M. Rothman of the University of Toronto, as well as Julie Lawson, then of Trash Free Maryland, and Stiv Wilson of the Story of Stuff Project, followed up on Yonkos' work by looking at microplastics in Chesapeake Bay surface water from data collected in 2015 in a Bay-wide trash trawl. The University of Toronto team found the most frequent chemical identified was polyethylene, used in sandwich bags, grocery bags, and plastic food wrap, and considered the most common plastic. Studies by the National Institutes of Health have found no known carcinogens in polyethylene,



1. Assistant Professor Lance Yonkos *in his laboratory at the University of Maryland, College Park. Yonkos' study shows microplastics are more common in densely populated areas.* ***2.*** *Julie Lawson (in red), then-director of Trash Free Maryland, and Elvia Thompson (in white) of Annapolis Green, lead a research effort to collect microplastic samples from the Chesapeake Bay.* ***3.*** *The team used a manta trawl for the study, which sought to quantify and identify microplastic waste in the Chesapeake Bay.* ***4.*** *Looking down at the sample in the collection net's receptacle.* ***5.*** *A closer look at that sample reveals a variety of microplastics.* PHOTOS, WILL PARSON / CHESAPEAKE BAY PROGRAM

Plastic Breakdown

Microplastics often come from larger pieces of plastic waste that enter an ecosystem. Plastic shopping bags are a common source, and are usually manufactured from polyethylene, a long, simple polymer chain composed of a carbon backbone with hydrogen atoms attached. Once exposed to the elements, the chemical bonds in these chains are weakened and broken by ultraviolet (UV) radiation from sunlight in a process called photodegradation. Further fragmentation can then occur due to other forces, like the physical forces of wave action, breaking the chains down into smaller and smaller pieces.



but plastic detritus can result in other issues including wildlife entanglement and harm to marine life that consume it. The Chesapeake's concentration of microplastics overall was lower than that found in San Francisco Bay and similar to that of the Great Lakes in studies conducted around the same time and using similar methodology. As was consistent with Yonkos' work, the team found higher concentrations in urban areas.

Jesse Meiller, a marine ecologist and environmental toxicologist at American University, began studying plastics about five years ago after noticing high concentrations of microplastics and potential toxins within them in water and sediments in Rock Creek, as well as the Anacostia and Potomac rivers. Until Yonkos' paper, she said, most of the research focused on marine environments rather than riverine ones, and few looked at possible neurological and reproductive effects of ingesting the small particles.

Meiller hoped to learn more about the concentrations and the different risks inherent in combining substances to make a bendable, pliable product. The DOEE was working on a project with the U.S. Fish and Wildlife Service to monitor brown bullhead for tumors from exposure to polychlorinated biphenyls, or PCBs. But DOEE was only interested in the mouths and livers, while Meiller needed the gastrointestinal (GI) tracts to isolate microplastics the fish may have digested. Meiller and her students looked at 90 GI tracts in all and used a papaya extract to digest organic material in the samples so they could isolate, examine, and count any small plastic particles found in each gut tract. This technique was novel, and has been used since by other scientists, with good results. Meiller's team found plastics in the guts of the brown bullheads, mostly from a site on the upper Anacostia near Bladensburg, Maryland.

Since then, Meiller said, she and her American University colleagues, especially microscopist Barbara Balestra, have refined the methods to look at concentrations and not just counts. Being able to determine the concentration of microplastics helps researchers understand the problem because they can know how much exists in a given volume of water or tissue. She is now working with her students on a larger study of the Anacostia that she hopes will add to the growing conversation about microplastics.

"In recent years, there has been an explosion in microplastic studies," she said. "We are learning a lot from this research, and I would say that it's great, but it's not all great, because it speaks to how ubiquitous microplastics are in the environment."

Tracking Microplastics in the Bay

Microplastics have a way of inserting themselves into so many facets of marine life. The pathogens in the microplastics can hitch a ride on the polymers; research from Old Dominion University showed microplastics can serve as substrate for all four species of *Vibrio* found in the Chesapeake Bay that are pathogenic to humans. That includes *Vibrio vulnificus,* which can contaminate oysters and result in major stomach discomfort.

Submerged aquatic vegetation (SAV) is also a major concern. Microplastics stick to underwater grass blades. Epiphytes are little plants, like algae, that grow on those underwater grasses. They thrive on nutrient loading, and they're often covered in sediment—and that sediment contains microplastics. Researchers in Scotland published a paper in 2020 that found microplastic particles adhered to seagrass blades in grass beds; another study out of Belize found parrotfish consumed microplastics found in grass beds. Some preliminary work has shown that microplastics can harm grass beds in the Chesapeake, particularly the Potomac, where the grasses have had a resurgence in recent years.

"We know that nitrogen, phosphorus, and sediment reduce water quality and clarity. Microplastics have the potential to have a similar but different sort of impact. Sheer volume is a concern, of course, but we're also worried about what those plastics are carrying," said Brooke Landry, the Maryland Department of Natural Resources biologist who chairs the Chesapeake Bay Program's SAV workgroup.

> *"If we continue with business as usual, we will see a certainty of ecosystem collapse. It's a guarantee the plastic never goes away, and the inputs are increasing exponentially."*
>
> *—Scott Coffin, Research Scientist*

Landry and the DDOE's Robinson have been working with biologist Bob Murphy from the engineering firm Tetra Tech to determine if SAV beds in the Potomac serve as microplastics sinks—areas in which materials settle—just as the SAVs do for suspended sediments. Murphy, already concerned about this question, had conducted a previous microplastics pollution study with Phong Trieu of the Metropolitan Washington Council of Governments. A member of the Chesapeake Bay Program's SAV workgroup, Murphy approached Landry with an idea to hold a workshop on microplastics pollution.

Murphy, Landry, and Robinson teamed up to determine what kinds of knowledge gaps they had, and they convinced the Bay Program's Science and Technical Advisory Committee (STAC), which advises the multi-state program on science issues, to hold a workshop in the spring of 2019. The workshop aimed to determine the threat to the Chesapeake Bay—and its grasses—and to see what actions the community or the legislature could take to lessen the problems from plastics. The STAC report came out in fall 2019.

Robinson, who leads the Chesapeake Bay Program's Plastic Pollution Action Team (PPAT) that formed as a result of the STAC Workshop, wants microplastics to become part of the Chesapeake-wide pollutant monitoring efforts. The PPAT's first priority, Robinson said, is to conduct a preliminary microplastics ecological risk assessment, the Bay's first. They will research the sources of microplastics, contextualize the risk, and assign a value to the risk. They're conducting the assessment in the Potomac, looking at potential effects in striped bass' food webs.

They hope this work will express the risk in a way that people can understand. For example, if they determine that a certain concentration of polymer harms striped bass, they can potentially implement a policy to reduce that concentration. The team will look at pathways for microplastics to enter striped bass' food webs (whether the fish ingest them directly, or whether their prey does), highlight data gaps, and build a strategy to address them.

Robinson said he's also looking forward to results from work Maryland Sea Grant has funded for Yonkos and biochemist Carys Mitchelmore to investigate the occurrence of microplastics in Bay sediments, oysters, and surface waters in select areas and point sources.

"Once we determine what the gaps are, the PPAT will formulate a science strategy that will guide future research that will help provide a more complete picture on the risks associated with plastic pollution in the Bay and its watershed," Robinson said.

For Sosa, who grew up in Mexico and began her career in industry, new findings on potential harm from microplastics and robust data to support limits on plastics can't come soon enough. Even so, reducing plastics in our marine systems is going to require big changes in patterns of behavior. To reduce plastic pollution, she said, manufacturers have to make less plastic. And our lifestyles have to become less disposable so we demand less of it.

"It's not something that's going to change just because we want it to change," she said.

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The Evolution of Plastic

Plastics are ubiquitous. How did we get here? Slowly, it turns out. Only over the past century or so have plastics taken over from other materials to become common in our homes, businesses, cars, and toy boxes. While the first plastics came from natural sources, including trees, over time petroleum became the primary ingredient used to produce plastics. Thus, modern plastics can become an environmental hazard as they are made as well as a disposal problem after they've been used. Here is a look at how we molded plastic, and plastic molded us.

1873: Celluloid

John Wesley Hyatt registers the trade name **Celluloid** for the first synthetic plastic material. He created his version of this tough, flexible material when he combined solid nitrocellulose, camphor, and alcohol under pressure. The resulting polymer, or long chain of molecules arranged in repeating patterns, could be molded into diverse products.

1945: Teflon

DuPont registers **Teflon** as a trademark. Now synonymous with nonstick pans, the material is made out of polytetrafluoroethylene (PTFE) and is a common coating in industrial products.

1949: Tupperware

Tupperware becomes a staple of U.S. households, ushering in an era of plastic dishware.

PHOTO, GLENN O. TUPPER / NATIONAL MUSEUM OF AMERICAN HISTORY

1951: Dacron suit

The **Dacron suit** goes on sale in New York City. Made from polyethylene terephthalate, a type of polyester, Dacron is lightweight, doesn't wrinkle, and is easy to pack. Polyester fabrics become standard in modern American wardrobes.

1955: Plastic syringe

The **disposable plastic syringe** changes modern medicine, providing an alternative to sterilizing and reusing glass syringes.

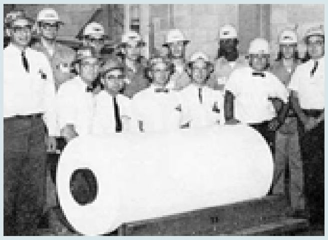
1965: Plastic shopping bag

Swedish company Celloplast is granted a U.S. patent for a concept that becomes the **polyethylene plastic shopping bag**, the design for most plastic bags used in grocery stores today. Quickly popular throughout the world, these bags have now been banned in several cities and countries because of their ubiquity and impact to the environment.

1967: Tyvek

DuPont begins selling **Tyvek**, a completely synthetic material made from high-density polyethylene fibers, which can be used in a variety of applications. It is used as a moisture barrier in construction and manufacturing, made into protective clothing for laboratory, cleaning, and hazmat operations, and used in medical packaging.

PHOTO COURTESY OF DUPONT



1969: GORE-TEX

Expanded polytetrafluoroethylene, or ePTFE, is created when Bob Gore rapidly stretches PTFE under precise conditions. The strong, versatile new polymer is used in a number of applications in fabric, biotechnology, engineering, electronics, and automotive products. One of these products, **GORE-TEX**, becomes a popular waterproof, breathable material for gloves, winter boots, and all-weather jackets.

1907: Bakelite

Leo Baekeland invents **Bakelite**, the first fully synthetic plastic that contains no molecules found in nature. It retains its shape when heated, making it ideal for everything from kitchen cookware to electrical insulators. To make Bakelite, he used phenol, the waste product from burning coal. His invention changes the industry from making items like toothbrushes out of natural products to making them out of fossil fuel byproducts.

PHOTO: 1) FLASHLIGHT CASES; 2) JEWELRY; 3) RADIO RECEIVER CABINETS; 4) FLEXIBLE PLASTIC SHEETING. COURTESY OF SCIENCE HISTORY INSTITUTE

1908: Cellophane

Swiss chemist Jacques Brandenberger invents **cellophane**, seeking a clear and flexible film to put on fabric to reduce stains. It turns out to have many more uses. Four years later, he begins mass manufacturing the wrap in Paris, and it remains common in millions of kitchens around the world today.

1926: Polyvinyl chloride (PVC)

Waldo Lunsbury Semon of the B.F. Goodrich Company produces what is known as plasticized **polyvinyl chloride (PVC)**, a synthetic polymer used in construction, automotive, plumbing, and many other industries. It's commonly used in sewer and discharge pipes, flooring, and cables.

1930: Cellophane tape

A young engineer at Minnesota Mining and Manufacturing Company (3M) figures out how to apply adhesive to cellulose—later renamed cellophane—to create **tape**—a transparent, moisture-proof way to seal packages—revolutionizing the packing industry.

1933: Polyethylene

Chemists at Imperial Chemical Industries PLC, in Norwich, England, make a solid **polyethylene** quite by accident. It is the most widely used plastic today.

1938: Nylon

The DuPont Company and chemist Wallace Hume Carothers secure a patent for **Nylon**, which has a major impact on how clothing and other materials are produced. A high-strength fiber, it's used in cords and textiles.

1992

The Board on Chemical Sciences and Technology (BCST) of the National Research Council (NRC) established a committee to rethink synthetic polymers and the harm they may cause the environment.

1994

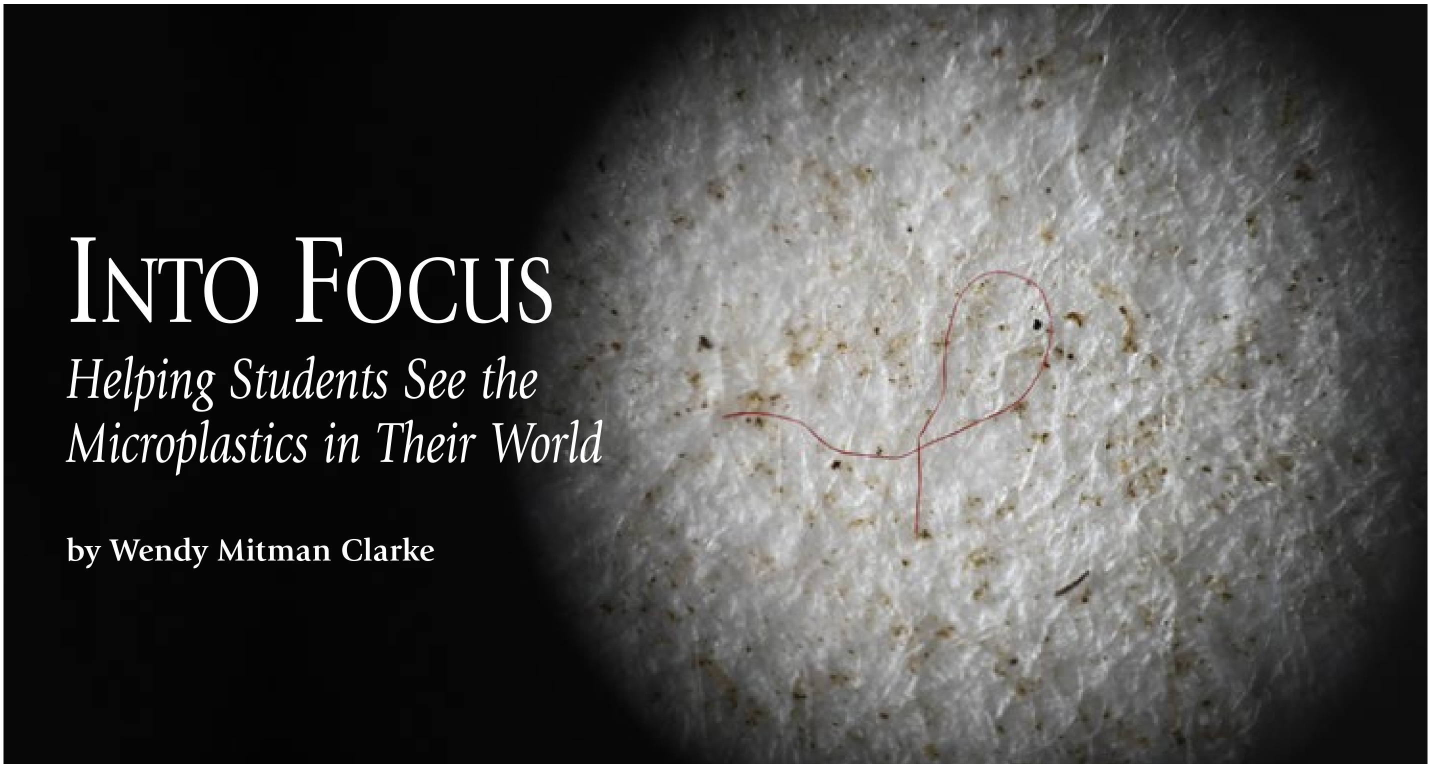
Recognizing the environmental hazards of plastic disposal and creation, a National Academies report outlines the need for an integrated approach to polymer research with hopes of achieving improvements in manufacturing, transportation, energy, housing, medicine, information and communications, and defense. It also calls for integrating polymer researchers into the broader faculty at universities and national laboratories. The report recommends appointing an independent national committee to analyze environmental issues in polymer production, including end-use disposal.

2015: Microbead-Free Waters Act

The US Congress passes the **Microbead-Free Waters Act** of 2015, which prohibits the delivery and introduction into interstate commerce of any rinse-off cosmetics containing added plastic microbeads. This federal law follows some state actions that banned microbeads—tiny plastic additives—in shampoos, body washes, and other cosmetics.

2020: Save Our Seas 2.0

President Trump signed the **Save Our Seas 2.0 Act** to address marine debris, and in particular, plastic waste.



Into Focus

Helping Students See the Microplastics in Their World

by Wendy Mitman Clarke

A microfiber *(above top) from the Baltimore Harbor. Photographed at IMET. J. Adam Frederick (above bottom) presents high school science faculty with upgrades to the microplastics protocol.* PHOTO TOP, NICOLE LEHMING / MDSG; PHOTO BOTTOM, WENDY MITMAN CLARKE / MDSG

In January, in a lab at South Carroll High School's Career and Technology Building, a handful of high school science teachers are eating pizza and studying a photo that Maryland Sea Grant Assistant Director for Education J. Adam Frederick has projected on a computer monitor. It looks like a thin, dark river winding across a field of dirty snow. But it is actually a sample of microplastics—in this case, a microfiber—tiny fragments from everyday products that can harm the environment.

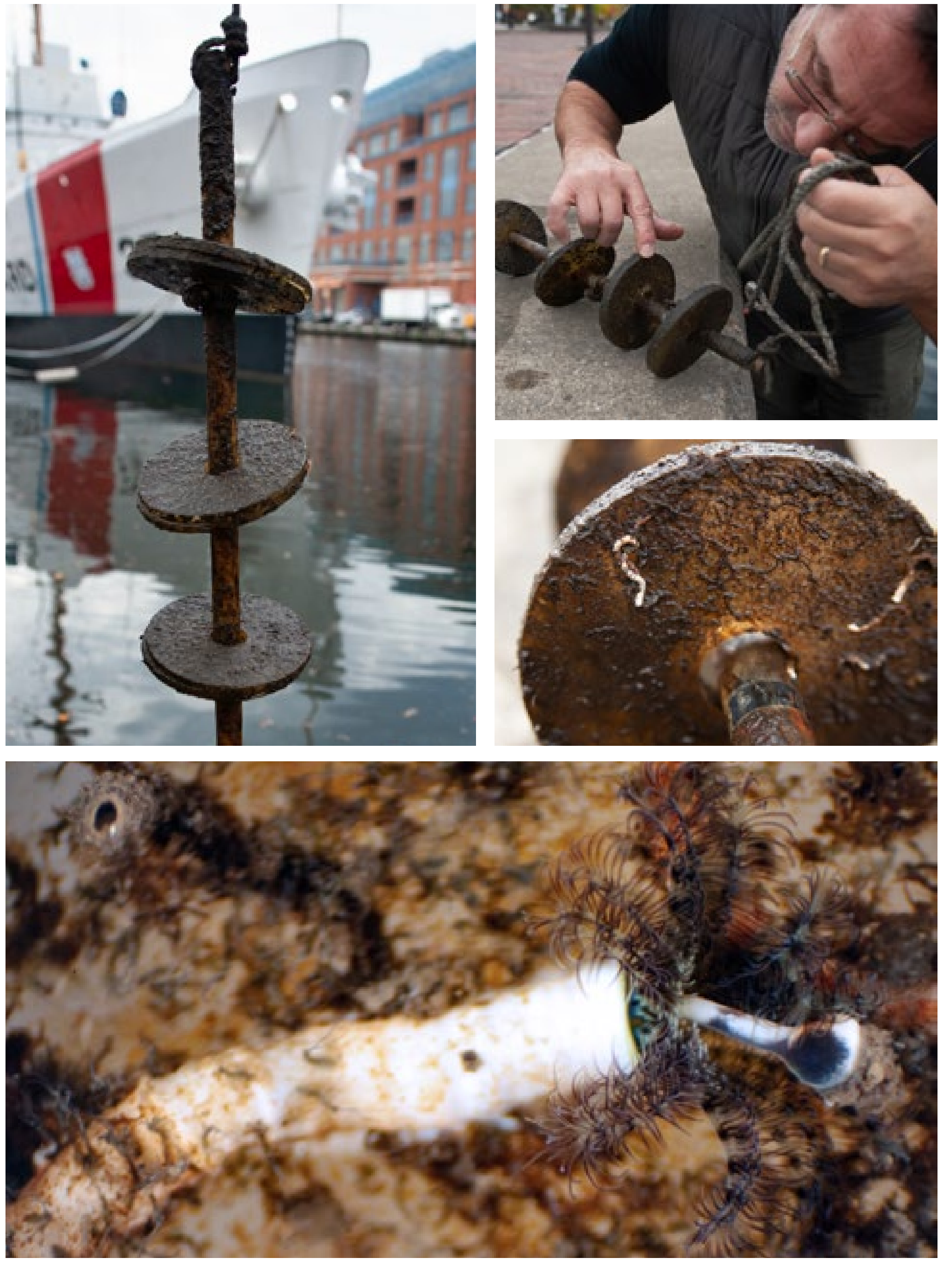
"See all the fiber in the back?" Frederick asks the group. "It's kind of distracting."

He advances to another image projecting a similar piece of plastic fiber, but on a cleaner background marked with thick, clear lines. It's gridded paper with no texture. "The optics are so much better because there's not the fiber background," Frederick says. "And, at low power on the stereoscope, you get one grid."

A different type of paper might seem a small victory, but in the effort to help students discern a fragment of microplastic in a perplexing world of natural and manmade bits and pieces, it's a big leap forward. And that's what this program is about: giving teachers tools to hook their students into project-based learning to study microplastics in the Chesapeake Bay.

Frederick has been guiding this project since 2017. It began in Carroll County, where about 250 juniors and seniors in seven public high schools were participating as of early 2020. Until COVID-19 disrupted classrooms across the country, it had been slated to expand into three schools in Baltimore City, three in Baltimore County, and possibly three in Washington, DC; those plans will likely remain in limbo into 2021.

It has expanded internationally, though, to Barcelona, Spain, via an online collaboration called VIRTUE Project that includes Maryland Sea Grant, the University of Gothenburg in Sweden, and partners in Spain and



The biofilm project *begins with a series of plastic or aluminum discs that are attached to a central pole and lowered into Baltimore's Inner Harbor (top left), where they are left for several weeks. During that time, organisms grow on the discs in what's called a biofilm; then, they can be retrieved for examination (top right). Students examine the biofilm and any large organisms—like these polychaete worms (middle right)—then scrape the film off and process it to look more closely at what's living there. Examining the biofilms under a microscope, students can see and learn how an array of species—from barnacles and whip worms to this polychaete worm—grow and interact (bottom).*
PHOTOS, NICOLE LEHMING / MDSG

Germany. Responding to the pandemic disruptions, VIRTUE Project has developed two online courses on the curriculum, one for teachers and another for students from partner schools in each country.

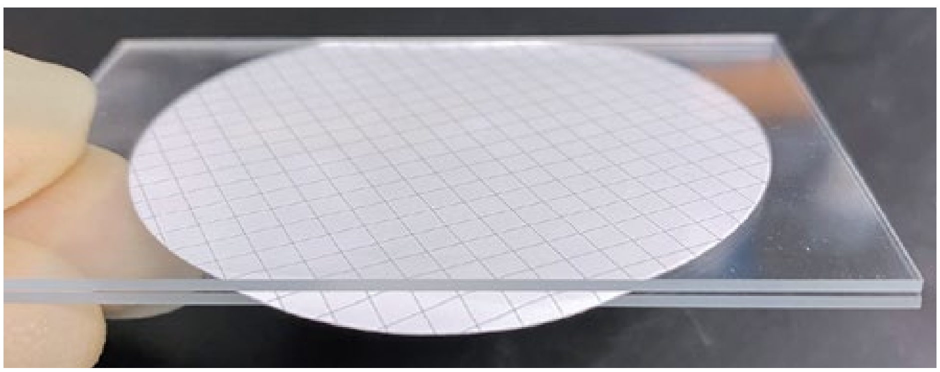
Looking for microplastics is a natural progression of Maryland Sea Grant's Biofilms and Biodiversity Project, which started about 23 years ago to help teachers and students understand local biodiversity and the challenges facing an urban aquatic ecosystem. Students examine a series of aluminum or acrylic discs that hang for several weeks in Baltimore's Inner Harbor to document the organisms growing on the discs in what's called a biofilm. Looking under a microscope, students learn how an array of species—from barnacles to whip mud worms—grow and interact.

Thinking about whether those same biofilms could provide insight into microplastics in the Inner Harbor was a logical next step, Frederick says.

Millions of tons of plastics enter the marine ecosystem every year, most transported from land through stormwater runoff, wind, and illegal dumping. The smallest pieces of these are called microplastics, a broad category of five types that can harm our ecosystems. The most common of these are microfibers, which are tiny, non-biodegradable parts of synthetic clothing. Microbeads are small plastic particles in facial cleansers and shampoos. Nurdles are tiny plastic pellets melted to make resealable containers and similar products; finally, there are fragments of plastic, and styrofoam. (See "Plastics in the Environment," page 5.)

In water, larger plastics break down through ultraviolet (UV) radiation exposure and wave action and become microplastics—polymer fragments that are smaller than 5 mm. Microfibers from synthetic clothing can enter the water system from washing machines, while microbeads and other small abrasive plastic particles used in cleaners and detergents flow down household drains. In the Chesapeake, where the study of microplastics is still evolving, the nonprofit Trash Free Maryland has documented these fragments in the Chester, Patuxent, Patapsco, West, Rhode, Severn, South, and Magothy rivers.

Frederick figured microplastics were on the biofilms, and educators could isolate them with students. He teamed up with Ana Sosa, a PhD microbiology student at the Institute of Marine and Environmental Technology (IMET) in Baltimore; and Jesse Meiller, director of undergraduate studies for the Department of Environmental Science at American University, who had been working with her students on finding microplastics in water and sediment samples around Washington, DC.



The microplastic protocol *begins by scraping the biofilm, which includes sediments and shells of living organisms, from the disc (top left). Next, students separate the material they've scraped off (top right). A saltwater solution of 70 parts per thousand (ppt) pushes denser materials down and allows less dense items—like microplastics—to float. Finally, they place the sample on gridded filter paper that's sandwiched between two glass slides (above). At this point—safe from external contamination between the slides—the sample is ready for examination under the microscope. Opposite page: A microscopic piece of foam or polymer is caught in the byssal threads of a mussel, found in a biofilm retrieved from Baltimore's Inner Harbor.* PHOTOS ABOVE, COURTESY OF J. ADAM FREDERICK; ABOVE RIGHT, WENDY MITMAN CLARKE / MDSG; PHOTO, OPPOSITE PAGE, NICOLE LEHMING / MDSG

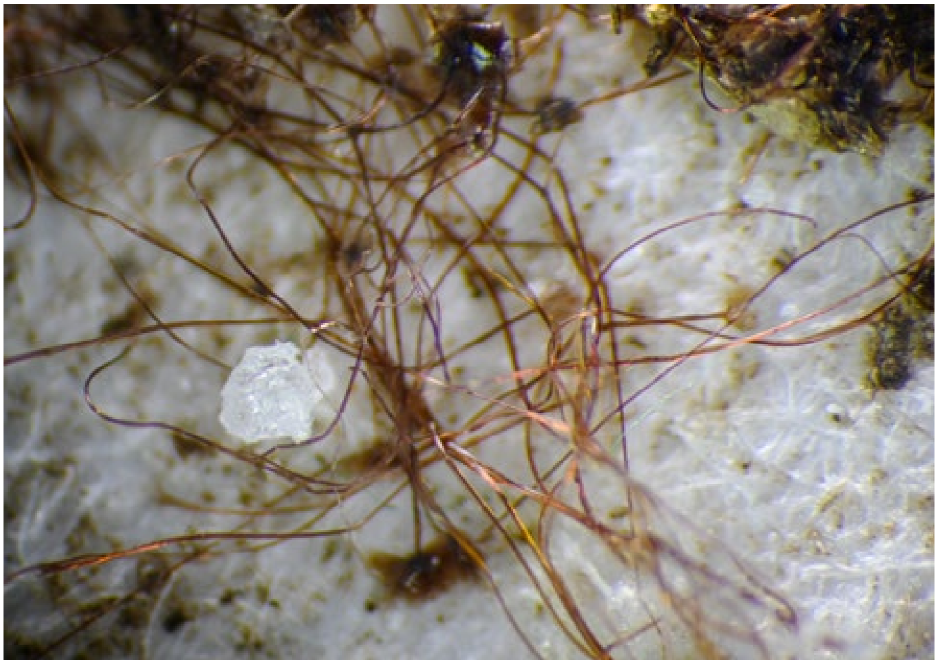
"I had done some separation before in sediment and in water, and I had also done work on fish guts on microplastics with a student here," Meiller says. "Adam and I had been working on taking parts of each of those methods and trying to figure how to separate the microplastics from the biological material and all the mud and shells" that accumulate on the discs.

That material, including sediments and shells of living organisms, make up the biofilm that students and teachers use a razor to scrape from the discs. Then, using a saltwater solution of 70 parts per thousand (ppt)—the heavier saltwater solution pushes denser materials down and allows less dense items to float—they filter the sample so that it can finally be placed on a specific filter paper that's sandwiched between two large glass slides. At that point, it's ready for examination under the microscope.

The protocol is more than two dozen precise steps, with specific equipment, that has taken a couple years to modify and improve, always with an eye toward making it more accessible and affordable for use in the classroom. Recently, Frederick honed the methods to make it easier for students to find and photograph the microplastics that they had removed from the discs.

"The protocols have changed every year, and from a science perspective, that's very important for students to understand," says Emily Fair, a Francis Scott Key High School teacher whose students have worked on the microplastics project for two years. "You have to continually go back to the drawing board and perfect the science, you have to go back and be flexible and reflect on your practices to make them better."

Along with weeklong teacher professional development workshops, Frederick sends updates when he finds new gear or refinements, as he did at the South Carroll High meeting in January 2020, before the pandemic. There, he presented not only the cleaner, gridded filter paper but also an adapter that can connect a smartphone directly to a microscope's eyepiece; an app called



Camera+ that can disable the autofocus feature so that smartphone cameras don't get overwhelmed by the multiple points of focus on a sample; a clip-on lens that instantly provides wide angle and macro; a new filtration setup that eliminates an earlier issue with sediment clogging the filters and slowing the separation process; and 70-by-50-mm glass slides that can perfectly sandwich the filter paper holding the sample, the better to avoid contamination. All of these are relatively inexpensive, ranging from about $200 for the eyepiece to 99 cents for the Camera+ app.

After photographing the samples with a variety of microscopes at IMET, Frederick showed the teachers a stereoscope with a zoom lens that works well for the small particles and costs $270, a much less expensive option when compared to other scopes.

Jim Peters, secondary science supervisor for Carroll County Schools, immediately ordered the scopes for his teachers. He also found enough in his budget to order the cell phone brackets, the clip-on lenses, and the gridded filter paper.

"Adam's always bringing fun new stuff, we just jump on it, and it drives our instruction," Peters says. "He and Sea Grant and IMET offer us that level of expertise that we want and that teachers desire, and we want to bring that to our kids."

For schools without such support, Frederick can help with funding from a $1.5 million National Science Foundation grant, led by Associate Professor Paul Leisnham at the University of Maryland's College of Agriculture and Natural Resources, that's part of the Coupled Natural and Human Systems (CNHS) projects. (Maryland Sea Grant Extension Specialist Amanda Rockler is also on that project. For more on her role, see "Meet the Extension Specialist" on page 16.) Frederick can access money for teacher professional development in Baltimore and DC with a focus on aquatic biodiversity and how pollutants like microplastics are present in their biofouling communities.

Erin Frye, a former Maryland Sea Grant intern who now teaches environmental science at Baltimore City College, hopes to add the program to her curriculum for about 130 students. Teaching students about a global problem like microplastics and then giving them a tangible connection in their own backyard is critical; this protocol helps that happen, she says.

"A lot of times there's a big disconnect between what you're talking about in school and how that actually applies to what's happening outside that classroom," Frye says. "For students to be able to learn about environmental issues and then actually understand, how do we quantify these issues and develop ways to solve those problems—this is a really big piece."

Judy Plaskowitz, who directs South Carroll High School's Science Research Lab and has been teaching the biofilms project since 2012, has her students apply the protocol to isolate microplastics in sediment samples from a local tributary of Piney Run, as well from beach sand gathered while on vacation. Seeing microplastics in Baltimore Harbor samples didn't surprise her students. But finding them on the beaches where they swim did.

"On our campus we have pretty much a headwater stream, it's spring-fed," she says. "My assumption is that the amount of microplastics in this particular area is going to be pretty low. But, as the students follow the stream down through its watershed, it does pass through developed areas, so I would assume that as the stream flows by populated areas it's going to pick up more microplastics, and we should be able to see that in the samples."

Following microplastics from a pristine local stream to the harbor compels students to consider how their actions affect interconnected ecosystems. By asking students to document each sample location using GPS, she hopes they can eventually map and correlate the increase in microplastic density with population in the sample's drainage area.

"Baltimore Harbor is the end of our drainage here at South Carroll," Plaskowitz says. "So I really feel it's important to show them that the harbor is a polluted mess, but it's the sum of its drainage. As they collect samples along the drainage, I'd like them to be cognizant of how we're contributing to what's going on in the harbor."

—wclarke@mdsg.umd.edu

For a multimedia-rich version of this story, visit: bit.ly/CQ-into-focus

Meet the Extension Specialist

Amanda Rockler

As a baby, Amanda Rockler's first word was "water." For the past couple of decades, it's also been her life.

Rockler is a watershed specialist with Maryland Sea Grant Extension, based in Montgomery County. The position covers the suburban areas around Washington, DC, and allows her to keep her focus on water—keeping it clean, finding ways to filter stormwater runoff and increase tree canopies, and preventing pollution from microplastics and other common household products that can disrupt Chesapeake Bay ecosystems.

"As the extension agent, our name is not always in the forefront. We are the people who fill the gaps in the communities," Rockler said. "With us, it's always a team effort. We're always trying to partner with people to do the work and reduce duplications in effort."

Collaborating with a team of watershed specialists throughout the region, Rockler helps inform and encourage residents' efforts to clean their water, ranging from rain barrel workshops and rain garden plantings to larger-scale stormwater restoration projects. She was instrumental in expanding the Watershed Stewards Academy (WSA), which Maryland Sea Grant Extension specialists support in Howard, Cecil, St. Mary's, and Harford counties, and the metro DC region. It is among several such academies run by nonprofits, counties, and Extension; Anne Arundel's Department of Public Works started the first one in 2008 and continues to run it, while Extension's began in 2011. The Anacostia Watershed Society runs the DC one, with support from Rockler.

The WSA program lasts up to 18 months and includes more than 40 hours of classroom and field training and project implementation experience. Field training includes learning how to install best management practices, while classroom training includes lessons about stormwater flow, permitting, and project management. Participants also complete a capstone stormwater restoration project that includes a site assessment, community engagement, implementation activities, and a maintenance plan.

Rockler also collaborated with environmental groups and governmental organizations to create and expand a certification program for green landscaping, called the Chesapeake Bay Landscape Professional certification. The program, now in its fifth year, allows landscapers to become certified on proper installation, design, and maintenance of small-scale conservation landscape and stormwater practices.

Currently, she is working closely with an undergraduate student who is conducting a literature review of what's known about the tiny plastic particles that are getting into waterways. This microplastics work is just beginning, but Rockler said she's excited about the collaborative aspect of it.

Rockler enjoys working across disciplines with researchers on various projects. She is the co-principal investigator on a $1.5 million National Science Foundation grant that is part

***Amanda Rockler** at home with a rain barrel similar to the kinds she helps install.*
PHOTO COURTESY OF AMANDA ROCKLER

of the Coupled Natural and Human Systems (CNHS) Program and builds on previous Environmental Protection Agency funding her team received. (Maryland Sea Grant's Adam Frederick is also on the grant; see "Into Focus" on page 12) The work examines ways to fuse social and natural sciences, motivating people to implement stormwater management practices that will ultimately result in a cleaner environment.

It's work Rockler has been gravitating toward since she earned her undergraduate environmental science degree at the University of Colorado-Boulder and realized she "didn't want to be in someone's lab necessarily." After graduation, she moved to New York City to teach at an environmental education center. She then moved to the Washington, DC, area and did stormwater work for the City of Rockville.

In 2009, Rockler earned her master's degree in sustainable landscape design from the George Washington University, and in some ways, she's been furthering her education ever since.

She takes one class a semester within the University of Maryland System, ranging from research methodology to applied entomology—"I'm interested in ticks and mosquitoes"—and also earned a graduate certificate in sustainability and behavior change from the University of California San Diego. Rockler is now pursuing a doctorate through the University of Maryland's Marine Estuarine Environmental Sciences graduate program, studying environmental impacts through a social lens. Much of her focus will be looking at what motivates people to put certain practices in place to reduce pollution and clean local waterways.

"It's what I do every day anyway," she said. "I thought this was the time to incorporate school into that."

—*Rona Kobell*

Maryland Sea Grant Welcomes

Wendy Mitman Clarke

PHOTO, TAMZIN B. SMITH

Wendy Mitman Clarke's connection to the Chesapeake Bay began shortly after she was able to walk.

Her family trailered their 16-foot wooden boat from West Chester, Pennsylvania, to the rivers of Cecil and Kent counties in Maryland to play, swim, water-ski, and picnic. When she was about 8 years old, they bought a sailboat to keep on the Sassafras River in Georgetown on Maryland's Eastern Shore.

"Just about every weekend, I was down on the Sassafras, in my dinghy with my dog," she said. "I'd always feel sad about leaving when the weekend was over."

In 2008, Clarke and her husband, a lifelong sailor who works in the marine industry, fulfilled a dream of going sailing full-time and showing their young son and daughter a larger world. After four-and-a-half years, when their children were 16 and 13, they came back to land, settling just 28 miles from the Georgetown marina where she grew up sailing.

After a long career covering the Chesapeake Bay, both as a sailor and a chronicler of its environmental riches and challenges, Clarke has joined Maryland Sea Grant as a science writer and editor.

Clarke began her writing career at a daily newspaper in West Chester, Pennsylvania, and then at The Associated Press in northern New England. Most recently, she was director of communications for Washington College in Chestertown. She became familiar with Maryland Sea Grant's work while working at the boating magazine *Soundings,* and then at *Chesapeake Bay Magazine.*

While at Washington College, Clarke began focusing her freelance writing on science because "it felt like the only way I could contribute to what I felt was the necessary education to people about climate change."

She added: "We are a maritime nation, even though nobody remembers that. I feel that the Sea Grant College network is a connection to that history."

In addition to her Sea Grant work, she is senior editor for *Good Old Boat,* a bi-monthly magazine. She's also a published poet, and in 2017 her Bay-based novel *Still Water Bending* was published. Being on the Chesapeake—and writing about it—brings her full circle in her journey as a journalist, sailor, and mother.

"The Bay and the ocean are not separate. We are not our own entity. We are connected," she said. "To me, the Bay has always been a doorway."

—*Rona Kobell*

Knauss Fellowship
Not (Remotely) Going as Planned
But Fellows Adapting to New Circumstances

Each year, Maryland Sea Grant welcomes its new class of Knauss fellows—graduate students in science fields who want deep experience in how to shape federal policy. The fellows spend a year in Washington, DC, working for federal agencies or congressional representatives who focus on ocean and Great Lakes issues.

Named for former National Oceanic and Atmospheric Administration (NOAA) Administrator John A. Knauss, the fellowship celebrated its 40th anniversary last year. Many Knauss fellows continue their careers in marine science policy after their fellowship year, and some currently work at Sea Grant.

This year's Knauss fellows are all diligently teleworking, said Hallee Meltzer, a communications specialist with NOAA's National Sea Grant Office. Because the fellowship relies on a lot of in-person networking opportunities, and those have been cancelled, Meltzer said the Knauss fellowship team has played a more active role in organizing events than they have in the past. Virtual events include professional development panels to learn about offices within NOAA and ask the leadership questions; the fellows will even have a chance to meet with NOAA Acting Chief Scientist Craig McLean. The virtual setting has fostered some creative ways of staying connected, Meltzer said. Past fellows are mentoring current ones. Fellows are also hosting virtual social events, like online movie-watching parties and "The Great Knauss Bake-Off," a virtual cooking competition with weekly challenges.

OUR 2020 KNAUSS FELLOWS

COURTESY OF LAURA ALMODÓVAR-ACEVEDO

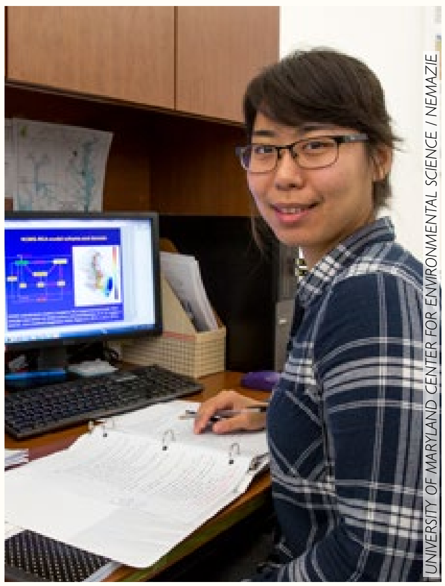
Laura Almodóvar-Acevedo is serving as a legislative fellow for the office of U.S. Rep. Alan Lowenthal of California's 47th District. For her doctorate, she is also researching habitat use of juvenile black sea bass in the Chesapeake Bay. Studying at the University of Maryland, Eastern Shore, she is specializing in ecology as part of the Marine Estuarine Environmental Sciences (MEES) graduate program at the University of Maryland. Her research includes a habitat survey to study black sea bass' temporal distribution and habitat preferences, the effect of temperature on their respiration rates, and a model to explore their available sustainable habitat in the Bay. Laura is from Puerto Rico and earned her bachelor's degree in biology from the University of Puerto Rico Mayagüez. She is also an alumna of the Maryland Sea Grant Research Experiences for Undergraduates, an immersive summer research program focused on the Chesapeake Bay. In her free time, she enjoys reading, traveling, and playing guitar.

UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE / NEMAZIE

Katie Hornick is working as a habitat restoration specialist in the NOAA National Marine Fisheries Service's Office of Habitat Conservation. She works on a range of topics related to developing monitoring and evaluation approaches for restoration efforts related to the Deepwater Horizon oil spill. Katie earned her bachelor's degree in natural science from Loyola Marymount University in Los Angeles. After graduating, Katie spent a year and a half in Puerto Montt, Chile, studying the effect of salmon aquaculture on microbial diversity and community composition of sediments. She then pursued a PhD at University of Maryland Center for Environmental Science (UMCES), where she worked at the Horn Point Laboratory under the direction of Louis Plough. Her dissertation research focused on Harris Creek, the largest oyster sanctuary restoration project in the world. She used molecular tools to compare genetic diversity of restored and wild oysters and built a computer model that integrated oyster genetics and biology with real-world restoration scenarios. In her spare time, Katie enjoys making jewelry, kayaking, hiking, and exploring new places with her pug, Oliver.

UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE

Amanda Lawrence is working with the U.S. Fish & Wildlife Service in the National Wildlife Refuge System for the Coastal and Marine Program to support coastal watersheds and their surrounding communities through conservation and restoration projects. Amanda grew up outside of Annapolis, just a short bike ride away from the shores of the Chesapeake Bay. She completed a dual-degree program, receiving bachelor's degrees in environmental marine science and biology from the University of Maryland Eastern Shore and Salisbury University, respectively. She is completing a master's degree in the MEES graduate program. Her thesis involves studying male sex hormones to understand the size at which the male Jonah crab, a commercially important species, reaches maturity. She hopes this research can be used to support the fishery. During graduate school, Amanda was awarded the National Institute of Standards and Technology Fellowship. She was also a NOAA Living Marine Resources Cooperative Science Center fellow and an intern with NOAA's Northwest Fisheries Science Center in Mukilteo, Washington, where she studied the effects of ocean acidification on Dungeness crab larval development. She loves being near the water in any capacity, be it researching, kayaking, or diving.



UNIVERSITY OF MARYLAND CENTER FOR ENVIRONMENTAL SCIENCE / NEMAZIE

Wenfei Ni works at NOAA Research's Climate Program Office, focusing on climate science, adaptation, and resilience issues. She earned her bachelor's degree in marine science from Nanjing University, China. She continued her graduate study on sediment dynamics of underwater sand ridge systems in the East China Sea. After bearing witness to a massive macroalgae bloom while working on a research vessel, Wenfei decided to change her research topic to environmental issues in the ocean and continued her doctorate work at UMCES. Her thesis used numerical models to study the impacts of regional climate change and watershed nutrient management on the Chesapeake Bay's oxygen depletion zone. She hopes the work can provide climate adaptation strategies for water quality restoration in the Bay. She is part of the tour guide team at the Horn Point Laboratory and a volunteer water quality monitor for ShoreRivers, a regional nonprofit organization.

COURTESY OF CAROLINE WIERNICKI

Caroline Wiernicki works in the Office of the Oceanographer of the Navy. During her fellowship she is working on interagency policy in topics relating to oceanography, meteorology, precise time, and astrometry. Caroline earned her bachelor's degrees in environmental science and English from Duke University. While at Duke, she worked on research projects including the spread of invasive seagrass in the U.S. Virgin Islands, competing population dynamics of seals in the western Atlantic Ocean, and community-based conservation practices in small-scale fisheries in the Gulf of California. After completing her undergraduate study, she returned home to Maryland, earning her master's degree from UMCES' Chesapeake Biological Laboratory. Her master's work focused on the disturbance ecology of black sea bass off Maryland's coast, using acoustic telemetry coupled with an oceanographic model to track changes in black sea bass movement in response to summer storms. In her free time, Caroline enjoys running, reading, and any activity that gets her on the water.

—Rona Kobell

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Over the past ten months, our communications team has been working virtually, over Zoom and other platforms, and conducting our reporting for *Chesapeake Quarterly* over the phone and via email instead of meeting in person or going out in the field.

We released our last issue of our award-winning magazine, which focused on groundwater and how it can impact the Chesapeake Bay, in an online format using ArcGIS StoryMaps. The StoryMap platform enables us to include more photos and graphics, as well as add videos, to highlight key projects and concepts in each story.

We'd really like to hear from you, our readers. What kinds of stories, graphics, and imagery do you look for in *Chesapeake Quarterly?* How do you like to read us—in print, on your computer, on a smartphone or tablet, or in a combination of those? What topics that we have explored in the past would you like us to revisit? And if you read our groundwater issue using the StoryMaps format, we'd love to hear what you thought of it.

Please take our survey. It's just a few questions and it will really help us better serve you, our readers. Feel free to add any additional comments in the space for them. We would all love to know your thoughts on how we can improve.

Thanks for reading!

—*communications@mdsg.umd.edu*

TELL US WHAT YOU THINK!
bit.ly/CQ-2020-reader-survey

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