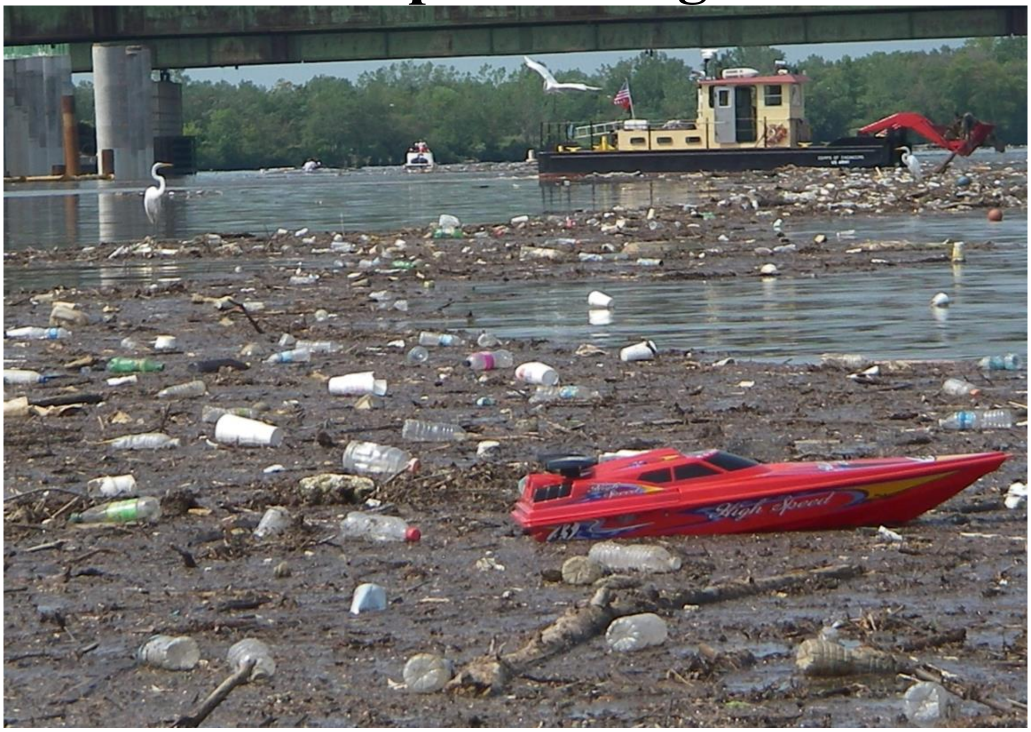
Microplastics in the Chesapeake Bay and its Watershed: State of the Knowledge, Data Gaps, and Relationship to Management Goals



STAC Workshop Report
April 24-25, 2019
Woodbridge, VA

STAC Publication 19-006

About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay Watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Watershed. For additional information about STAC, please visit the STAC website at http://www.chesapeake.org/stac.

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Executive summary

Over the past ten years there has been an exponential rise in the number of technical publications regarding microplastics in the environment. At first, the literature was primarily concerned with characterizing the presence of microplastics in the environment. This research lead to questions about impacts on organisms, with much of the research conducted in Europe. In 2018, the Toxic Contaminants Workgroup of the Chesapeake Bay Program (CBP) Water Quality Goal Implementation Team (GIT) identified microplastics in the bay as an emerging issue of concern in their most recent management strategy. This urgency was largely prompted by findings featured in the 2016 STAC Technical Review of Microbeads/Microplastics in the Chesapeake Bay (Wardrop et al., 2016). A pilot study conducted by Tetra Tech, Metropolitan Washington Council of Governments (MWCOG), and DC Department of Energy and Environment found microplastic in submerged aquatic vegetation (SAV) habitat in the Tidal Potomac River. This prompted the SAV Workgroup to submit a proposal to STAC to support a two-day workshop to identify current knowledge of microplastic pollution in the Chesapeake Bay and potential policy implications.

A two-day STAC workshop entitled Microplastics in the Chesapeake Bay and its Watershed: State of the Knowledge, Data Gaps, and Relationship to Management Goals, was convened April 24th – 25th, 2019 at the George Mason University Potomac Science Center in Woodbridge, VA. Over 50 participants from government, academia, consulting, and non-governmental organizations met to present current research and policy initiatives, followed by facilitated discussion on data gaps and needs. The workshop was designed within the framework of an ecological risk assessment (ERA), treating microplastics in the environment similarly to other pollutants. Participants noted that while our understanding has progressed in recent years, we still have little idea of the magnitude and distribution of microplastics within the watershed, much less the potential impact microplastic pollution may be having on living resources. Workshop participants concluded that microplastics pose a potential serious risk to successful restoration of the Chesapeake Bay watershed. As a result, the following recommendations are being presented to the Chesapeake Bay Program (CBP) as ***urgent*** and ***immediate*** needs:

1. ***The CBP should create a cross-GIT Plastic Pollution Action Team to address the growing threat of plastic pollution to the bay and watershed.***

2. ***The Scientific, Technical Assessment and Reporting Team should incorporate development of ERAs of microplastics into the CBP strategic science and research framework, and the Plastic Pollution Action Team should oversee the development of the Ecological Risk Assessments (ERAs) focused on assessment of microplastic pollution on multiple living resource endpoints.***

3. ***STAC should undertake a technical review of terminology used in microplastic research, specifically size classification and concentration units, and recommend uniform terminology for the CBP partners to utilize in monitoring and studies focused on plastic pollution in the bay and watershed.***

4. ***The CBP should develop a source reduction strategy to assess and address plastic pollution emanating from point sources, non-point sources, and human behavior.***

5. ***The CBP should direct the Plastic Pollution Action Team and STAR Team to collaborate on utilizing the existing bay and watershed monitoring networks to monitor for microplastic pollution***.

1. Introduction

The global production and disposal of plastics has increased by orders of magnitude over the past 60 years (Li et al. 2016; Rochman and Browne 2013) and a large proportion of plastic waste makes its way into waterways and coastal systems (Andrady 2011). Aside from the deleterious impacts on the aesthetics of the environment, there are concerns about the ecological harm posed by plastics. It is well-documented that larger plastic debris has significant and negative impacts on a variety of wildlife (Li et al. 2016), ranging from entanglement to increased mortality through ingestion (Davison and Asch 2011). An emerging concern, however, has shifted focus from large, visible plastic debris to the largely unseen microplastic contamination of the aquatic environment.

Recent research has shown microplastics to be ubiquitous in habitats around the world (Anderson et al. 2016; Castaneda et al. 2014; Jabeen et al. 2016), posing an emerging concern for aquatic life, and potentially, human health (Barboza et al. 2018). Despite filtration methods, wastewater effluent is estimated to release, on average, 4 million microparticles per facility per day (Sun et al. 2019). With 516 major wastewater treatment plants (WWTP) discharging wastewater effluent into its own watershed, this is a significant concern for the Chesapeake Bay ecosystem. Additionally, the Chesapeake Bay watershed contains numerous urban and suburban areas that, via storm drains, are sources of plastic waste to the bay (Peters and Bratton 2016). These larger, visible plastic items fragment into smaller microplastics over time and are hypothesized to affect the bay in a variety of ways, both at the organismal and ecosystem level. First, while microplastics themselves could be directly harming bay species physically and chemically, recent research has also shown that organic toxic contaminants (e.g. PAHs, PCBs), already known to pollute the bay, adsorb to microplastic particles. Once consumed by bay species, these compounds may have physiological and neurological effects, and may be magnified up the food chain (Batel et al. 2016; Windsor et al. 2019). De Frond et al., 2019 estimate that 190 tons of chemical additives are introduced to the ocean annually because of plastic materials.

As will be shown later in this report, microplastics are ubiquitous in the Chesapeake Bay and its watershed. A 2014 survey showed microplastics to be present in four tidal tributaries to the bay, with 59 of the 60 samples collected showing presence of particles (Yonkos et al. 2014). This study also found concentrations of microplastics to be highly correlated with population density and presence of suburban and urban development (Peters and Bratton 2016; Yonkos et al. 2014). A 2015 bay-wide survey conducted by Trash Free Maryland and the University of Maryland found microplastics in every sample collected (n=30). A 2017 study conducted by Tetra Tech, the Metropolitan Washington Council of Governments (MWCOG), and the DC Department of Energy & Environment (DOEE) found that microplastics accumulate in submerged aquatic vegetation (SAV) beds in the tidal Potomac River. SAV is one of the bay's most important habitats and provides food and refuge for some of the region's most commercially and ecologically significant fisheries. Lastly, recent research has shown that potential human pathogens, such as *Vibrio* spp., have also been found to colonize microplastics providing evidence that particles could help disperse disease (Kirstein et al. 2016).

As the evidence in this report will show, microplastic pollution in the bay and watershed is a urgent issue that may affect restoration success, warranting immediate action by the CBP partnership. The CBP Toxic Contaminants Workgroup to the Water Quality GIT identified microplastics as an emerging issue in their most recent management strategy. Their management strategy included a recommendation to propose a workshop to the CBP Scientific and Technical Advisory Committee (STAC) on this issue. Findings from the workshop illustrate potential effects microplastics have on management priorities set by other GITs such as Sustainable Fisheries (e.g. physiological effects on bay species) and Habitat (e.g. accumulation in important habitat types).

In 2016, STAC published a *Technical Review of Microbeads/Microplastics in the Chesapeake Bay* (Wardrop et al., 2016). This report made three major conclusions:

1) There were significant research gaps in the Chesapeake Bay region in terms of collection of data, analysis, and transferability of results gathered in studies on microplastics.
2) Additional monitoring is needed to determine sources, fate and transport, and potential toxicity of microplastics and constituent chemicals.
3) There is potential for innovation in the areas of initiating long-term study; education and outreach programs; further legislation; development of sustainable products that are benign by design; and better best management practices for waste management.

Since the publication of that report, there has been additional, albeit a modest amount of, research conducted across the bay and its watershed on microplastic pollution. The 2019 workshop strived to create a forum in which this research was presented and discussed, allowing the region's understanding of this issue to evolve.

1.1 Objectives and Workshop Format

On April 24th and 25th, 2019, a 2-day workshop with over 50 research, management, and policy experts was held at the George Mason University Potomac Science Center in Woodbridge, VA, USA. Participants were identified by the workshop co-chairs and steering committee based on technical background, policy or management experience, and geographic representation (i.e. representation from each of the bay watershed jurisdictions).

The steering committee anticipated a large interest in this emerging issue from a variety of scientific disciplines, as well as from the management community given the large increase in research worldwide, stories in the media, and recent efforts that have been undertaken by Chesapeake Bay watershed jurisdictions to reduce trash and marine debris. Examples include total maximum daily loads (TMDLs) for trash in the Patapsco and Anacostia Rivers, and the Virginia Marine Debris Reduction Plan. Specific goals for the workshop were:

1) Assess the state of the knowledge of microplastic pollution in the Chesapeake Bay and its watershed;

2) Assess possible effects of microplastics on various habitats and associated living resources;

3) Identify existing policy and management tools being used to address plastic pollution in the watershed and beyond, and their effectiveness;

4) Identify research gaps moving forward and develop recommendations for further studies or new tools.

Early in the planning process, the steering committee decided to structure the workshop within the framework of an ecological risk assessment (ERA). As will be discussed later in this report, ERAs are a very effective way of visualizing and communication potential ecological risks, especially risks associated with emerging issues. As such, the steering committee recognized the potential impacts microplastic pollution has on living resources in the bay and watershed based on research conducted elsewhere. Figure 1 below displays the EPA ERA framework logic model. The three main components to an ERA are:

1) Problem Formulation: Determine assessment endpoints and measurement endpoints.

2) Risk Analysis: Identify testable linkages between sources, stressors and assessment endpoints.

3) Risk Characterization: What are the risks and effects? For example, the lethal concentration to kill 50% of a population (LC50).

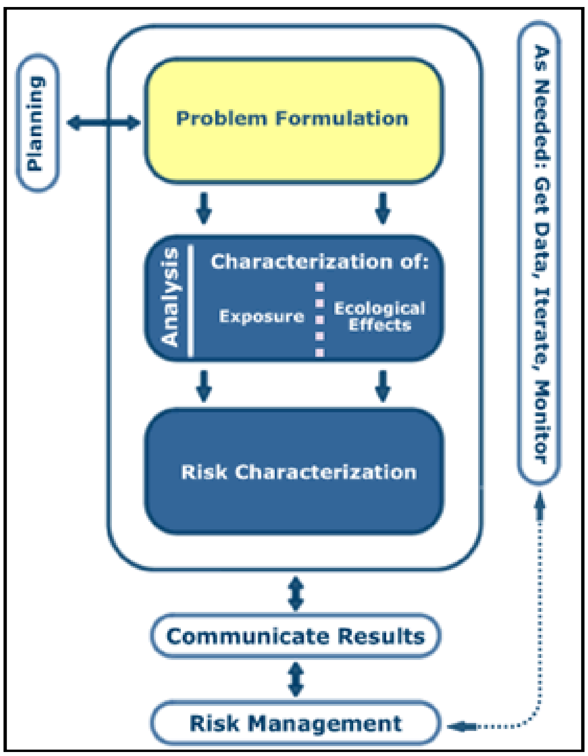

Figure 1. Ecological risk assessment framework logic model (U.S. EPA 1992)

In order to address the three major components of the ERA framework, the steering committee formulated the following questions to answer during the workshop:

1) What are the sources of microplastics to the bay and its tributaries?
2) How common are microplastics in the Chesapeake Bay and its tributaries?
3) What additional information do we need to gauge distribution?
4) What are the possible effects of microplastics on habitat and living resources?
5) Are there any policy and management tools being used to address plastic pollution in the bay (e.g., Anacostia River Trash TMDL)? How effective have they been?
6) Can we recommend pursuing future studies or new management and policy? Can we recommend more funding be made available for research at this time?

2. Workshop Summary

The workshop agenda was organized to address each of the questions listed above. A final session was held to discuss and compile all of the recommendations that emerged during the two-day workshop. With the exception of the final session, each session began with two talks on the subject matter, followed by a facilitated discussion. Speakers were recruited regionally and nationally to present on the various topics. A pre-workshop questionnaire was sent out prior to the workshop and the responses were used to help guide the in-person discussion. Below is a summary of talks given during each session.

2.1 Brief Summary of Presentations

2.1.1 Introductory Talks

The first session of the workshop included introductory talks designed to provide background on the concept of conducting an ERA, background on the 2016 STAC technical report on microbeads/microplastics in the bay, and microplastics as global pollution issue of concern.

Determining ecological risks of microplastics: current challenges and paths forward
Jerry Diamond, Tetra Tech

The first talk was given by Dr. Jerry Diamond of Tetra Tech, an internationally recognized expert on conducting ERAs. Dr. Diamond highlighted that interest and research on plastic consumption and pollution have exploded in recent decades, but the impacts of microplastics on the aquatic environment are poorly understood. In order to improve our understanding of their effects, conducting an ERA using the EPA framework may be appropriate (see Figure 1).
As discussed in Section 1.1, Dr. Diamond explained the steps to conducting an ERA. The first step is problem formulation which calls for identifying endpoints. There are two types of endpoints:

1) Assessment Endpoints – These endpoints should have value. The more explicit the endpoint, the more helpful risk analyses are likely to be useful (e.g., the abundance and distribution of American Shad) (*Alosa sapidissima*).

2) Measurement Endpoints – These endpoints show how the assessment will be quantified. Measurement endpoints don't always need to be complex to be effective (e.g., number of juvenile American Shad with microplastics in their guts).

Once the endpoints are determined, a conceptual model illustrating the ecological risk can be formulated. This model should describe pathways between human activities, which would be the source of a stress (e.g. source of microplastics); the stressors (e.g. effects of microplastics on fish physiology); and the assessment endpoint (e.g. abundance and distribution of fish). However, it is important to note that the initial conceptual model is not definitive, and it will most likely be based on the best available science and professional judgement. Nevertheless, such a model can be an effective communication tool, especially for non-scientists. Figure 2 displays an example ERA conceptual model included in Dr. Diamond's presentation.

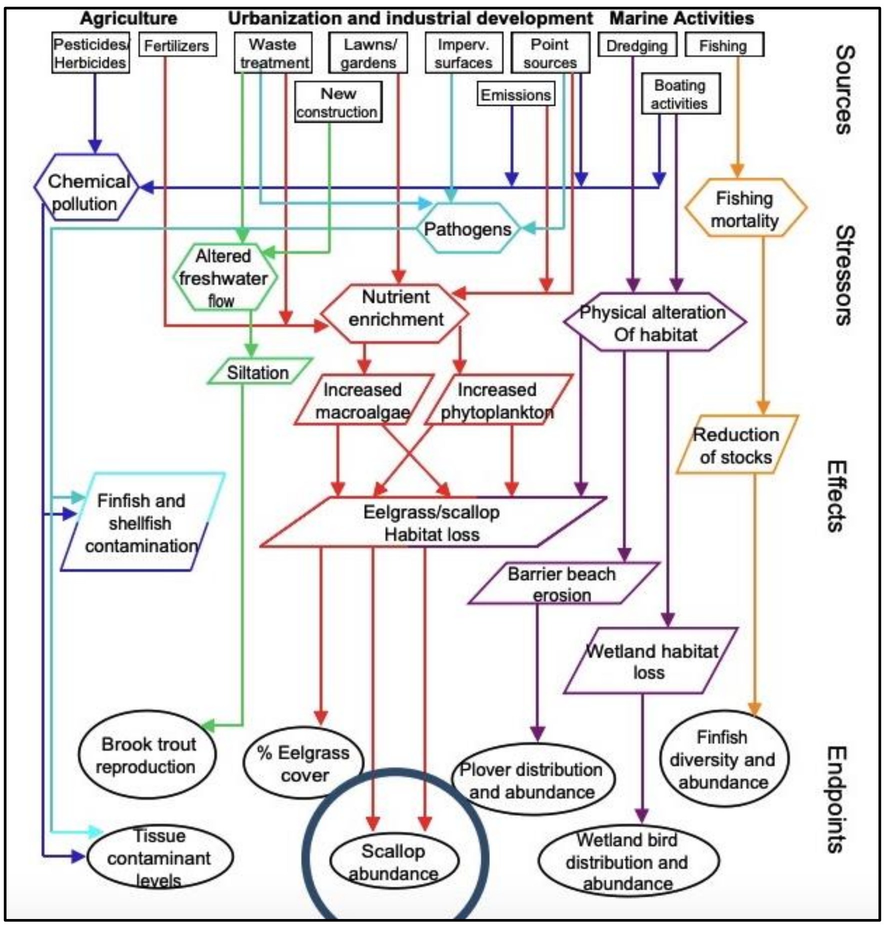

Figure 2. Example ecological risk assessment conceptual model looking at the effects of human activity on scallop abundance in Waquoit Bay, MA, USA

Following formulation of the conceptual model, it is time to fill in the gaps. The next step focuses on identifying risk hypotheses or testable linkages between sources, stressors, and assessment endpoints. This part of the process may be iterative; as more research is conducted in the lab and field, several refinements of the conceptual model may be necessary.

The final step of the ERA is the risk characterization which strives to integrate exposure and effects. The risk is articulated as effect thresholds such as lethal concentration to kill 50% of a population (LC50), species sensitivity distributions, and minimum levels for sustained population survival and reproduction. The risk analyses phase of the ERA informs this step. Uncertainties, data gaps, and confounding factors may also be identified.

Dr. Diamond next highlighted potential challenges of a microplastics ERA, arising from the characteristics of the microplastic itself (a wide range of sizes), as well as its ability to be both a chemical source as well as a carrier of other contaminants. Microplastics present a unique challenge in that there is a wide size range and a variety of polymers that could pose ecological risks. In addition, sources may be diffuse and widespread. Lastly, laboratory experiments are typically used to test effects of a pollutant on an endpoint, but this may not be the case since effects may need to be specified to an environment (e.g. saltwater vs freshwater) or microplastic size.

Looking forward, Dr. Diamond posed several questions that would need to be addressed before an ERA on microplastics can be conducted in the Chesapeake Bay and watershed:

1) What are the spatial/geographic boundaries for the ERA (e.g. Chesapeake Bay and/or bay watershed)?
2) What assessment endpoints are most important (e.g. fishery species populations, human health)?
3) Which measures of microplastic exposure and effects can be compiled and analyzed based on existing monitoring information for desired assessment endpoints?
4) How well do the data and measures reflect the assessment endpoints?
5) What resources are needed (e.g. new studies, funding) to obtain desired measures of exposure and effect?

How did we get here? Summary of the 2016 STAC Review on Microplastics
Denice Wardrop, Penn State

Dr. Denice Wardrop, Chair of the 2016 STAC Technical Review on microbeads and microplastics in the Chesapeake Bay, summarized the inspiration for conducting that review and the results. There were four main steps that led to the review:

1) News on the increasing prevalence of microplastics in the oceans and Chesapeake Bay. Dr. Wardrop specifically pointed to the work conducted by Yonkos et al. (2014) showing the presence of microplastics in four tidal tributaries to the Chesapeake Bay.
2) Increasing interest in state initiatives to ban personal hygiene products containing microplastic beads (microbeads), beginning with the State of Illinois (2015).
3) Emergence of new partnerships in the Chesapeake Bay region with the implementation of a microplastics survey in the Chesapeake Bay conducted by Julie Lawson of Trash Free Maryland and Chelsea Rochman of the University of Toronto.

4) Introduction of proposed legislation by the Virginia and Maryland legislatures banning the manufacturing and sale of a limited number of cosmetic products containing microbeads.

One of the questions posed during the hearing on the Virginia legislation asked what the potential environmental effects of microbead pollution could be to the region. This led to the Chesapeake Bay Commission requesting a STAC workshop to address this question; STAC ultimately decided to hold a technical review conducted by a panel of regional and national experts on this issue. This technical review consisted of four components, each covering a set of specific questions:

1) *Fate and transport* – This component addressed questions of degradability of plastics in the aquatic environment; potential for other contaminants to adhere to plastics; and geographic range of impact.
2) *Impact* – This component addressed questions concerning physical impact of plastic on aquatic organisms; plastics serving as a vector for aquatic organisms; bioaccumulation of plastics and organic contaminants adsorbed to plastics; potential risks that plastics with adsorbed chemicals could pose a human health risk; and a review of any research conducted in the Chesapeake Bay.
3) *Treatment* – This component addressed questions concerning the ability of current waste water treatment plant technologies to remove microplastics and emerging technologies that could enhance removal; and the potential of other point sources to introduce microplastics to the bay.
4) *Urgency of intervention* – This component addressed whether there is any evidence that microplastics are being seen in increasing quantities at the regional scale and an assessment of whether this problem is severe enough to warrant individual state action.

During the technical review, the Federal Microbead Waters Act of 2015 was introduced and passed, superseding all other state laws that had already been passed or under consideration. The technical review panel had the opportunity to comment on the legislation. The panel found that while the legislation was somewhat beneficial in highlighting the issue of microbeads, it only addressed a small subset of the overall problem of microplastic pollution. In addition, the specific wording of the ruling would prevent current and future innovative solutions that utilize plastics that may be safe and truly degradable (e.g. research into biodegradable plastics).

In conclusion, Dr. Wardrop noted that this exercise revealed that we don’t need to be 100% certain about an issue before informing policy. As outlined in Section 1.0, the technical review workgroup offered the following recommendations in their report:

1) Significant research and development in analytical techniques, methods, and sampling approaches to microplastics;
2) Initiation of long-term monitoring to determine sources, composition, fate and transport, and potential toxicity of microplastics in Chesapeake Bay;
3) Adoption of management actions such as education and outreach programs; further legislation; development of sustainable products that are benign by design; and better best management practices for waste management.

Microplastics - An Emerging Global Issue
Fred Dobbs, Old Dominion University

The final talk of session one was given by Dr. Fred Dobbs of Old Dominion University on microplastics as an emerging global issue. Dr. Dobbs provided an overview of global plastic production, consumption, and pollution. Using a brief Google Scholar analysis, Dr. Dobbs illustrated the exponential increase in microplastics research since the year 2000, spiking from less than 500 publications per year to over 3,000 publications per year in 2018. This reflects consumption trends that sky rocketed from 0 tons per year in the 1950's, to over 299 million tons per year in 2010 (American Chemistry Council 2013; Figure 3). Geyer et al. (2017) conducted a life-cycle analysis of plastic produced since the 1950s. Since that time, they estimated that 6,300 metric tons of plastic has been produced, with estimates showing 12,000 metric tons of plastic waste ending up in landfills or the environment by 2050. This means the world could be facing a major future waste disposal problem. Nearly all plastics are non-biodegradable and may persist for thousands of years. As mentioned earlier in the report, plastic materials, including microplastics, may absorb other chemicals in the environment (e.g. persistent organic chemicals), leading to additional concerns about organismal consumption and biomagnification. These materials may also serve as vectors for macro- and micro-organisms.

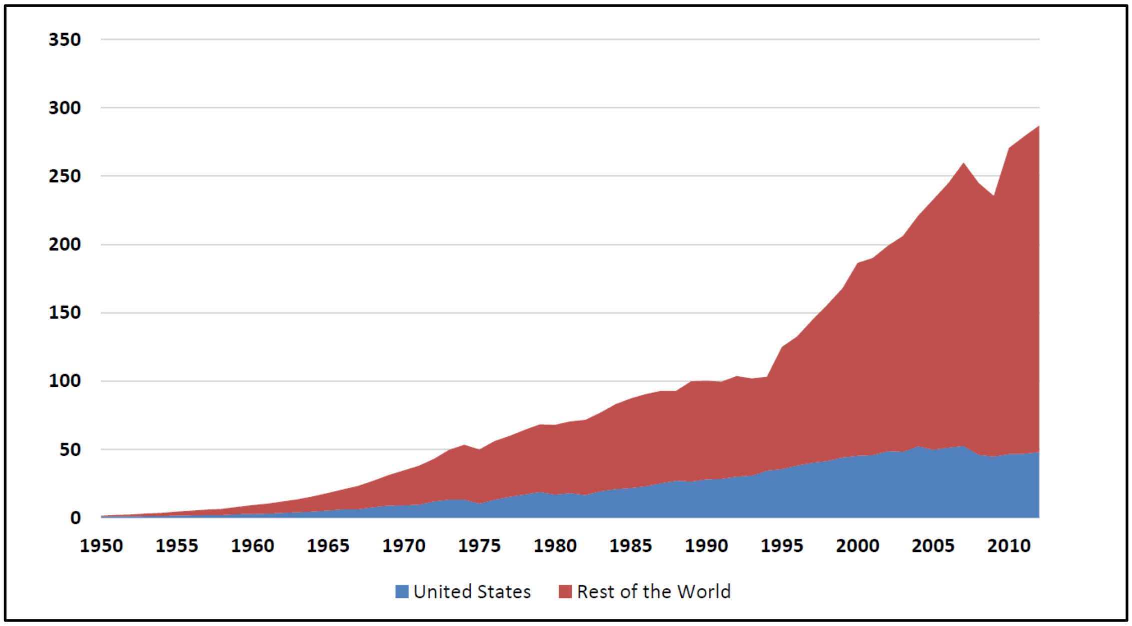

Figure 3. Analysis from the American Chemistry Council illustrating plastic production in the US vs. the rest of the world, 1950 – 2013 (American Chemistry Council 2013)

Dr. Dobbs discussed the current classification schemes for microplastics. There are currently two widely accepted types:

1) Primary microplastics – This type consists of pre-production plastic pellets, or "nurdles", and the microbeads used in personal hygiene products.
2) Secondary microplastics – This type consists of the particles which breakdown from large plastic products.

Another challenge with microplastic classification concerns size. Dr. Dobbs highlighted that particles ranging from 0.1 µm to 5 mm have been classified as microplastics, with different size classification schemes adopted worldwide.

Dr. Dobbs highlighted some of the recent environmental research on plastics. First, the literature has shown plastic pollution is ubiquitous world-wide. For example, studies have shown plastic presence in the Sargasso Sea, deep ocean environments, and in remote mountain ranges such as the Pyrenes (Carpenter et al., 1972; Chiba et al., 2018; Allen et al., 2019). Second, Dr. Dobbs touched on presence of microplastics in the aquatic food chain. Wilcox et al. (2016) estimated that 60% of all seabirds have ingested plastic, and by 2050, that number is expected to rise to 99%. Davison et al. (2011) estimated that mesopelagic fish (i.e. species inhabiting 200 – 800 m depths) in the North Pacific consumed 12,000 to 24,000 tons of plastic per year. Dr. Dobbs also presented an adverse outcome pathway scheme developed by Galloway & Lewis (2016) showing potential effects of microplastics on growth and reproduction (Figure 4). This model highlights one point discussed later in this report which is the concern over nanoplastics, or plastic particles smaller than 1µm. Lab studies have shown particles of this size do cross cellular membranes which means they could affect intracellular processes such as respiration and gene expression. Studies have shown that the presence of nanoplastics may be greatly underestimated given that most microplastic surveys in aquatic environments have not focused on particles smaller than 300µm.

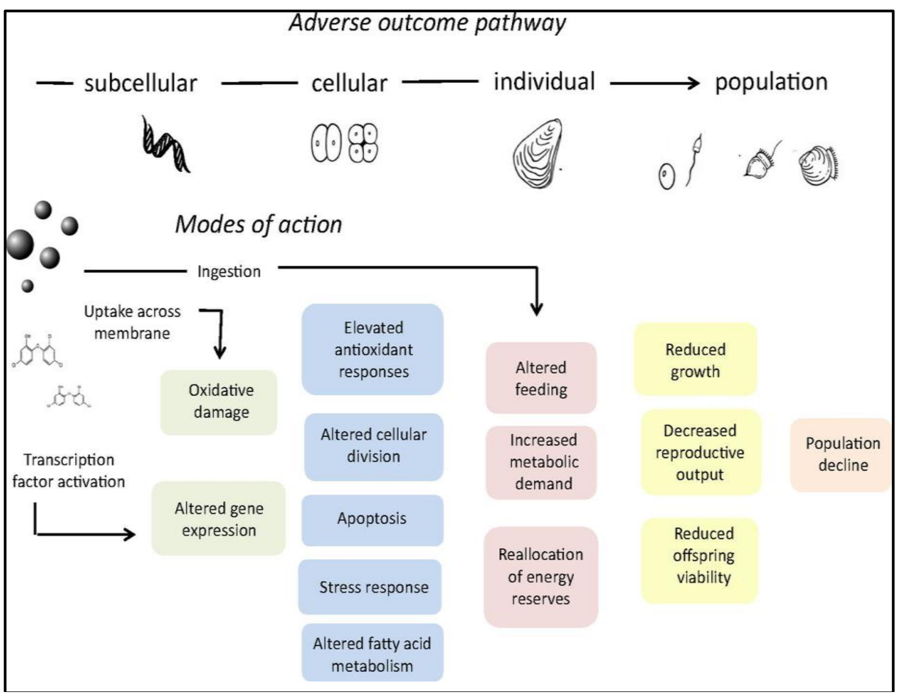

Figure 4. Adverse outcome pathway scheme from Galloway & Lewis (2016) showing physiological effects of microplastics following organismal consumption. This model also highlights potential organismal effects of nanoplastics (particles<1µm) such as oxidative damage and altered gene expression.

Finally, Dr. Dobbs highlighted research conducted in the Chesapeake Bay region on microplastic pollution. The Yonkos et al. (2014) study was highlighted since it is the only published study to date on microplastics in the Chesapeake Bay. Research conducted in the lab of Dr. Dobbs by Amanda Laverty (Old Dominion University) examined marine plastic pollution as a substrate for biofilms, with an emphasis on *Vibrio* spp. known to be human pathogens. Ms. Laverty collected microplastics in the marine environment and analyzed bacteria biofilms for antibiotic resistance, antibiotic resistant genes, community composition, and *Vibrio* spp. presence. The study has three important findings: 1) microplastics serve as substrates for all three species of Vibrio that cause disease in humans, *V. cholerae, V. vulnificus, and V. parahaemolyticus;* 2) this study extends the threats of plastic pollution serving as vectors for *Vibrio* spp. from the open ocean to coastal environments; and 3) marine plastics likely facilitate horizontal gene transfer and may disseminate antibiotic resistant genes.

In conclusion, Dr. Dobbs highlighted the ramifications of unbridled plastic production and the nearly endless supply of plastic waste. In 2017, China, the world's largest importer of plastic waste, passed the National Sword Policy banning the importation of plastic waste for recycling. Because of this, innovation within the United States to address this problem may be warranted. Examples include using economic concepts, such as closed loop systems or circular economies (see Figure 19, p. 32), and plastic waste disposal methods, such as the Yoshia et al. (2014) study which found a bacterium which consumes polyethylene terephthalate (PET), a polymer commonly used in the production of single-use plastic products.

2.1.2 Sources of Microplastics

This session focused on two sources of plastic pollution to the bay and watershed: waste water and stormwater. Both sources have been found to be common sources of microplastics and macroplastics (DOEE 2011; Wardrop et al., 2016; Sun et al., 2019). Recent research has been conducted in Washington, DC, Maryland, and Virginia on both source types.

Microplastics and Wastewater Treatment
Dr. Chris Burbage, Hampton Roads Sanitation District

The first talk was provided by Dr. Chris Burbage of the Hampton Roads Sanitation District (HRSD). Dr. Burbage presented results from HRSD's work with the Virginia Institute of Marine Science (VIMS) to study the effects of tertiary filtration at its Waste Water Treatment Plants (WWTPs) on microplastic concentrations in effluent. There are currently over 516 major WWTPs in the Chesapeake Bay watershed (Figure 5), collectively treating 1,600 million gallons per day (MGD) of sewage during dry weather conditions, and more than 3,500 MGD during wet weather conditions. HRSD manages 16 WWTPs in 18 counties and cities in Virginia. On average, these plants alone together treat 150 MGD. HRSD is currently undertaking a project called the Sustainable Water Initiative for Tomorrow (SWIFT) in which WWTP effluent is being treated through tertiary treatment. Through this additional treatment, HRSD is hoping to achieve a water quality level for treated water that will be pumped back into the local aquifer. The goals of this project are:

1. Provide regulatory stability for wastewater treatment;
2. Provide a sustainable supply of groundwater;
3. Reduce nutrient discharges to the bay; and
4. Reduce the rate of land subsidence.

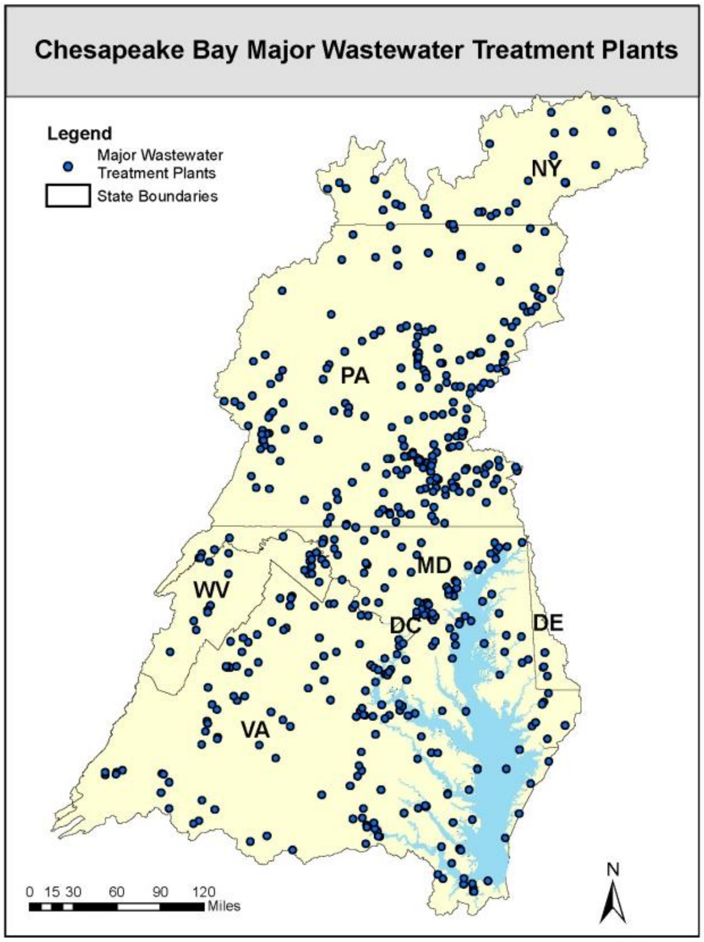

Figure 5. Map of current major waste water treatment plants (WWTPs) in the Chesapeake Bay watershed (Chesapeake Bay Program 2019).

Dr. Burbage presented a study conducted at the HRSD York River WWTP in Seaford, VA. This plant has already been outfitted with secondary treatment and enhanced nutrient removal technology. As part of the SWIFT project, HRSD is testing tertiary treatment on a portion of the effluent. Figure 6 below displays the current treatment train used at the York River facility. The tertiary treatment method that has been tested consists of several additional steps illustrated in Figure 7 below. Figure 7 also displays a picture of the tertiary treatment device currently being tested and how the different components make up the steps of the tertiary treatment train.

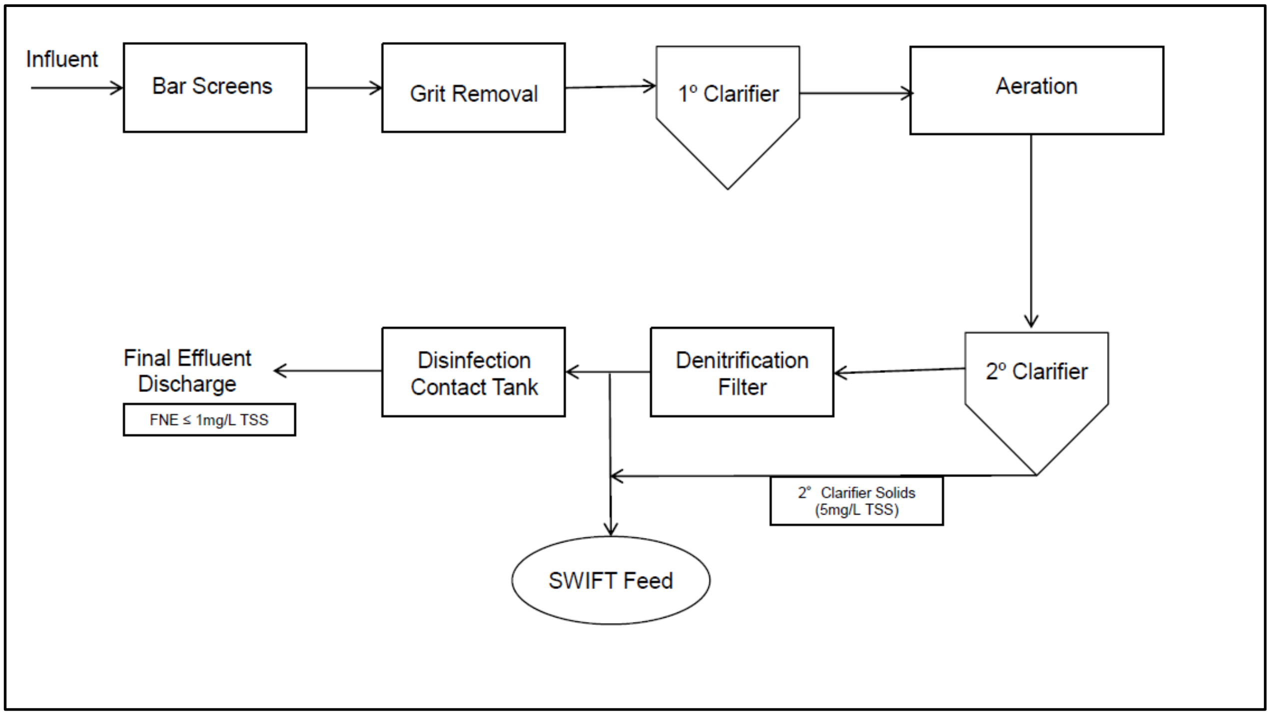

Figure 6. Diagram of treatment train currently being utilized at York River WWTP in Seaford, VA. A portion of sewage is being redirected to the Sustainable Water Initiative for Tomorrow (SWIFT) tertiary treatment device to test for reductions in microplastics (HRSD 2019).

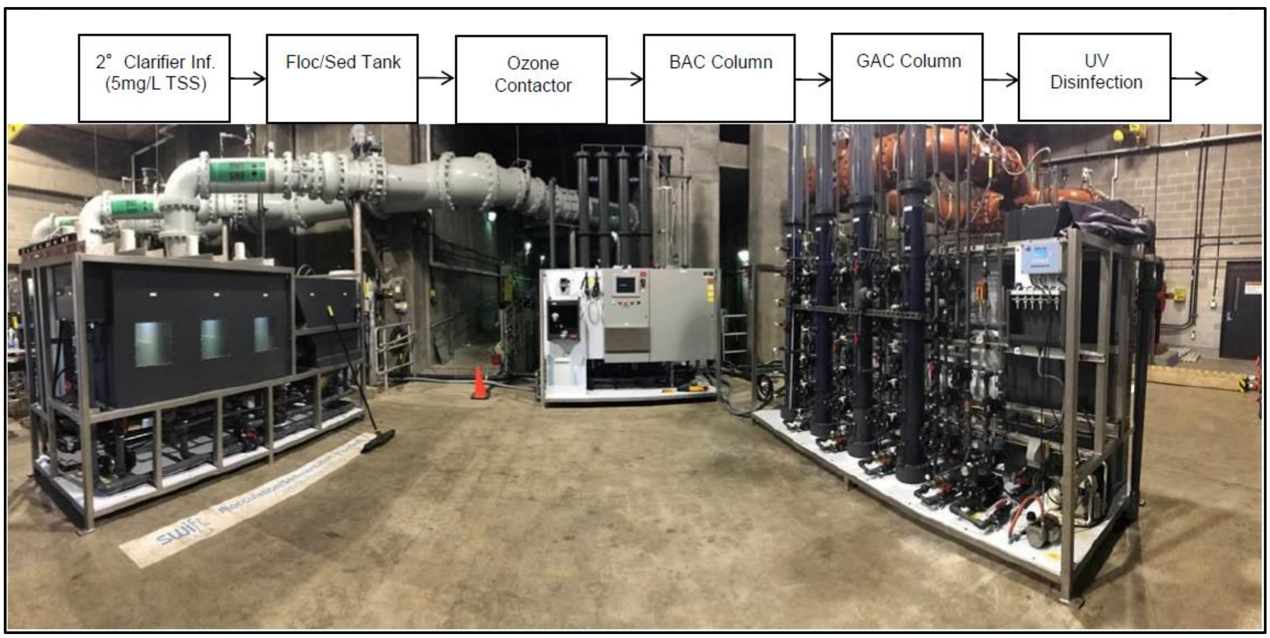

Figure 7. Diagram of HRSD Sustainable Water Initiative for Tomorrow (SWIFT) tertiary treatment train being utilized at the York River WWTP in Seaford, VA (HRSD 2019).

HRSD and VIMS have found that microplastic concentrations post-secondary treatment at the York River WWTP have been as high as 66,000 particles L^{-1}. Following treatment with the SWIFT device, particle concentrations typically drop to 500 particles L^{-1}. Using this information, HRSD has estimated dilution of microplastic concentrations in effluent post discharge into prohibited and restricted shellfish harvesting zones near the York River WWTP outfall at concentrations as low as 40 particles L^{-1} in the prohibited zone and 10 particles L^{-1} in the restricted zone. These calculations show that SWIFT tertiary treatment may significantly reduce microplastic concentrations, lessening the chance of ingestion by filter feeders like oysters.

Anacostia Watershed Trash and Litter Monitoring – The Macro Source
Phong Trieu, Metropolitan Washington Council of Governments

The second talk was given by Phong Trieu of the Metropolitan Washington Council of Governments (MWCOG). Mr. Trieu and colleagues at MWCOG have been studying trash in the Anacostia river and its watershed for almost 20 years. MWCOG conducts annual trash monitoring looking at count and weight of trash found along tributaries and river shorelines. The Anacostia river runs 8.4 miles from the mouth near Hains Point in Washington, DC (the District) up to Bladensburg, MD (Figure 8). The watershed is approximately 176 square miles in size and is highly urbanized with approximately 25% of the area covered in impervious surface. Over 6,000 stormwater outfalls discharge to the river and its tributaries, with stream flows characterized as flashy.

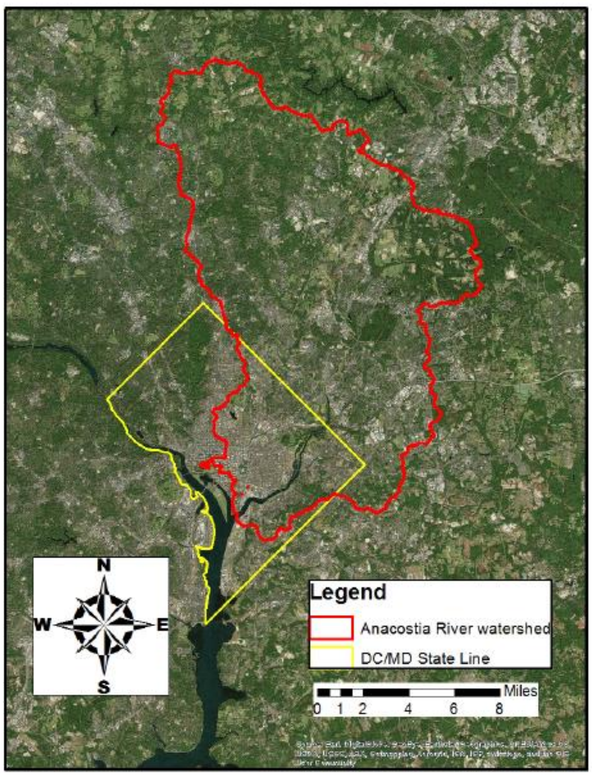

Figure 8. Map of the Anacostia River watershed (DOEE 2019)

Due to this intense urbanization, storm sewer systems are extremely efficient at conveying trash to the Anacostia River. Since 2010, the District and the State of Maryland have had a TMDL in place for trash for the Anacostia. Mr. Trieu used visuals in his presentation to show how trash enters the local storm sewer system and is eventually discharged by nearby outfalls into the Anacostia River or one of its tributaries.

MWCOG conducts annual trash counts along linear transects in Anacostia tributaries and the mainstem. For the purpose of MWCOG surveys, trash is defined as *"all improperly discarded waste material, including but not limited to, convenience food, beverage, and other project packages or containers constructed of steel, aluminum, glass, paper, plastic, and other natural and synthetic materials thrown or deposited on the land or water"* (in-text citation). As prescribed by the Anacostia River trash TMDL, all trash monitored is at least one inch in length or diameter. Based on litter counts along linear transects, MWCOG conducts ratings of stream cleanliness. They also have compiled the latest data watershed wide on the most common types of trash by count (Figure 9) noting that plastic bags, plastic bottles, food packaging and polystyrene foam are common trash items found. Such items break down into smaller plastic pieces in the stream channel network.

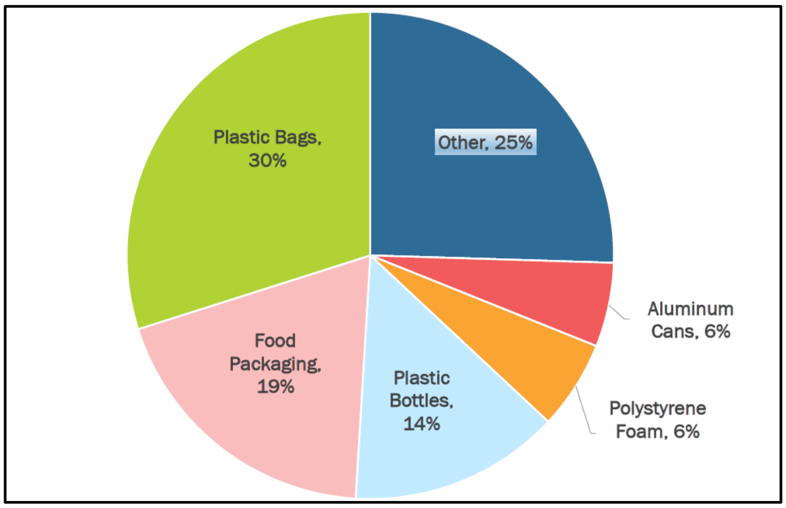

Figure 9. Most common types of trash counted during annual Metropolitan Washington Council of Governments trash surveys in the Anacostia tributaries (Metropolitan Washington Council of Governments 2019)

2.1.3 Distribution of Microplastics

This session focused on research examining the distribution of plastic pollution in tidal and non-tidal waters within the Chesapeake Bay region. Not surprisingly, microplastics have been found to be ubiquitous throughout the region.

Microplastics in the Chesapeake Bay
Dr. Lance Yonkos, University of Maryland, College Park
Department of Environmental Science & Technology

The first talk was given by Dr. Lance Yonkos of the University of Maryland, College Park Department of Environmental Science and Technology. In collaboration with the NOAA Marine Debris Program in 2011, Dr. Yonkos conducted a study on the presence and abundance of microplastics in four tidal tributaries to the northern Chesapeake: Patapsco River, Magothy River, Rhode River, and Corsica River. In addition to being the first study to sample microplastic pollution in the bay, this study also examined the relationship between microplastic abundance and land cover of contributing drainage areas to these tributaries (Yonkos et al. 2014).

Surface water samples using a manta trawl were collected between December 2010 and July 2011 in all four tributaries. The mesh of the trawl was able to capture sample sizes ranging from 0.3mm - 5mm. Samples were processed using density separation and hydrogen peroxide digestion to remove labile organic material. Fifty-nine of the 60 samples collected showed presence of microplastics. Microplastic abundance was found to be positively correlated with population density, urban/suburban development, and percent imperviousness. Inversely, the study showed a negative correlation between microplastic abundance and increasing presence of agriculture or forested land use (Figure 12; Yonkos et al., 2014).

Figure 10. Photo of sample collected by Yonkos et al. (2014) for their study of microplastic presence and abundance in four tidal tributaries to the northern Chesapeake Bay (Photo courtesy of Lance Yonkos, University of Maryland, and Will Parson, Chesapeake Bay Program Office).

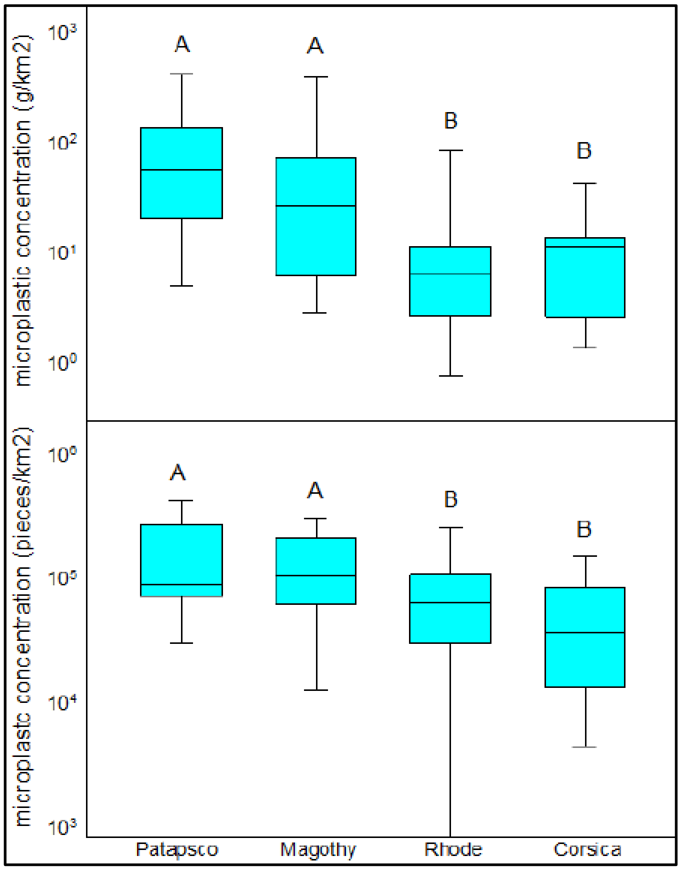

Figure 11. Box and whisker plots showing microplastic concentrations (both particles/km^2 and g/km^2) observed in all four tidal tributaries by Yonkos et al. (2014).

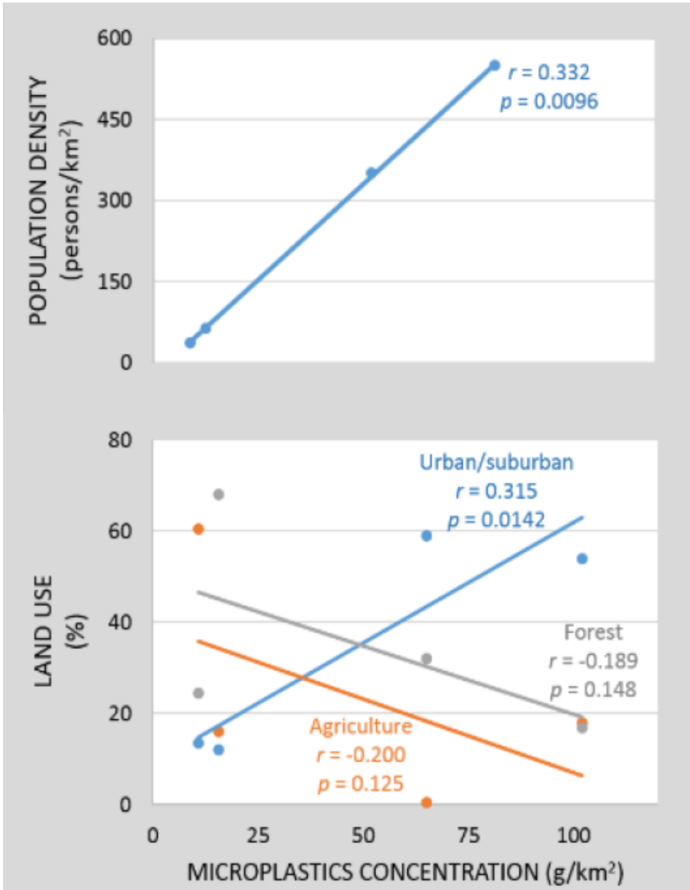

Figure 12. Linear regression analysis from Yonkos et al. (2014) showing positive and negative correlations between microplastic abundance and drainage area characteristics (e.g. population density and land use types).

Microplastics in Natural Waters of the Northeast
Dr. Shawn Fisher
USGS New York Science Center

The second talk was given by Dr. Shawn Fisher of the U.S. Geological Survey (USGS) New York Water Science Center. Dr. Fisher and his colleagues at USGS have been conducting surveys of microplastics across the northeast United States, from Virginia to Massachusetts. They have worked to leverage existing USGS water-quality monitoring programs to collect data on microplastics and have collected data at 20 urban stations to assess impacts of baseflow and stormflow on microplastic abundance. Dr. Fisher presented results from the following five of sites in the Chesapeake Bay watershed:

1) Susquehanna River mainstem, Harrisburg, PA
2) Rock Creek, Washington, DC
3) Watts Branch, Washington, DC
4) Lick Run, Roanoke, VA
5) Difficult Run, between Reston and Tysons, VA

Samples were collected with manta nets using several methods—wading, towed by boat, or deployed from bridges—depending on the depth and flowrate of the stream. Samples were processed at the Washington Water Science Center Microplastics Lab using sieves to separate two size class ranges: 0.355 – 0.999mm and 1.00 – 5.60mm. Samples were then placed through wet peroxide oxidation to dissolve organic materials, followed by density separation to further separate plastic particles.

To date, USGS has found microplastics in all samples taken at all five nontidal stations in the Chesapeake watershed. The majority of particles found have been microfibers. Figure 13 below displays the relative abundance of different types of plastic particles found during sampling and relative abundance varied between individual sites. For example, the Rock Creek, Washington, DC site was found to contain almost all fibers, with some other types during baseflow conditions; however, during stormflow conditions samples were found to contain all fibers. In contrast, the Watts Branch, Washington, DC site was found to contain almost equal proportions of microfibers and other types (e.g., foam, bead/pellet, fragments); however, during stormflow conditions the relative proportion of other types increased.

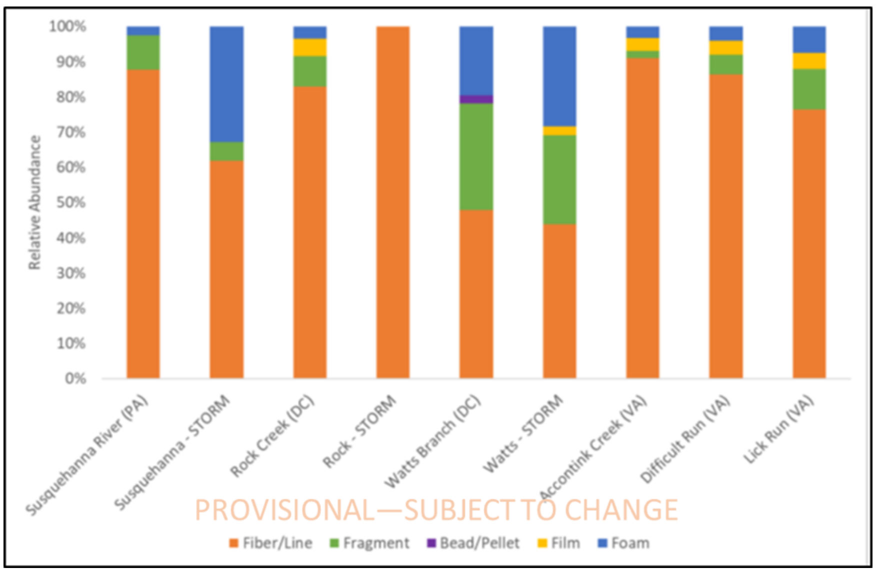

Figure 13. Relative abundance of different types of microplastic particles found by USGS from 2017 - 2018 at five nontidal sites in the Chesapeake Bay watershed (USGS 2019)

Analysis conducted at three sites examining the relationship between concentration (total particles m^{-3}), baseflow, and stormflow showed concentrations decreased during stormflow (Figure 14). However, in examining the relationship between different particle types and flow conditions, not all types displayed this same relationship.

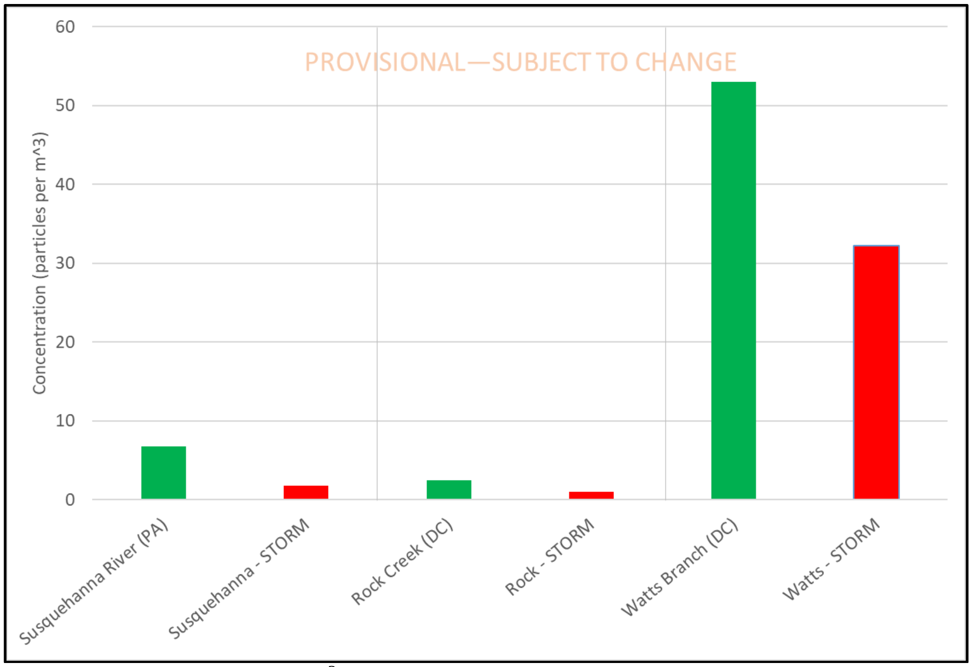

Figure 14. Relative concentrations (particles/m^3) of microplastics found at three nontidal sites in the Chesapeake Bay during baseflow and stormflow conditions (USGS 2019).

In conclusion, these results suggest that microplastics are ubiquitous throughout nontidal waters in the Chesapeake Bay watershed. Dr. Fisher recommended future study examining the relationship between different flow conditions and microplastic concentrations. Microfibers dominated most samples. While wastewater may be a major source for these particles, other sources such as atmospheric deposition and overland sludge application may also be contributing factors and warrant future examination.

2.1.4 Effects of Microplastics on Living Resources

This session focused on potential effects of microplastics on living resources in the Chesapeake Bay and watershed. Two speakers were identified who have conducted research on the effects of microplastics on the physiology of two species commonly found in tidal waters.

An assessment of microplastic impacts on the health of the black seabass (Centropristis striata) fishery
Dr. Susanne Brander, Oregon State University

The first talk was given by Dr. Susanne Brander of Oregon State University. Dr. Brander presented her research on the effects of microplastics on Black Seabass *(Centropristis striata)*, a temperate reef fish commonly found along the Mid-Atlantic coast, including the southern portion of Chesapeake Bay. Black seabass is an opportunistic feeder and grazes on a wide range of prey. Given its value as a commercial and recreational species, potential consumption of microplastics by seabass has human health implications.

The objective of Dr. Brander's research is to investigate microplastic ingestion, bioavailability, trophic transfer, effects and toxicokinetics in seabass in the laboratory and field. The data collected in Dr. Brander's studies will be used to formulate an ecological risk assessment to help visualize the effects of microplastics on seabass. Dr. Brander sampled adult wild seabass to survey consumption of microplastics. She also conducted studies in the lab looking at sub-lethal effects (i.e. respiration, immune response) of larval, juvenile, and adult seabass exposed to microplastics in the water column and through feeding.

Dr. Brander observed 60 particles in the 120 fish sampled in the field. Both microplastics and macroplastics (particles >5mm) were found present in guts. Classification of particles was based on color, shape, and morphological properties. 60% of the particles found were microfibers. Dr. Brander is working to identify all samples using Fourier-transform infrared spectroscopy (FTIR). Preliminary analysis of some samples revealed polymers such as polyethylene terephthalate (PET), which is commonly used in the manufacturing of single-use plastic bottles, and polyvinyl alcohol (PVA), which is used to make sportfishing products.

Dr. Brander's lab experiments revealed that juvenile seabass which consumed inland silverside (*Menidia beryllina*) fed with pre-cleaned microplastics displayed increased oxygen consumption. In addition, juveniles exposed to microfibers in the water column displayed increased oxygen consumption. This may be due to fibers getting caught in black seabass gills, but this warrants further investigation.

Impacts of microplastics on larvae of the Eastern oyster (*Crassostrea virginica*)
Christine Knauss, University of Maryland Center for Environmental Science
Horn Point Lab

The next presentation was given by Ms. Christine Knauss of University of Maryland. Ms. Kanuss has been conducting her graduate research on the effects of microplastics on the Eastern oyster (*Crassostrea virginica)*. Ms. Knauss highlighted that the larval stage of many bivalves is free swimming in the water column and considered to be the most vulnerable during their life cycle. It is believed that this is the stage most susceptible to pollutants. However, experiments looking at the effects of microplastic ingestion are lacking for this life stage. With restoration goals of creating self-sustaining oyster bars in the Chesapeake Bay, it is crucial to understand the impacts microplastics have on oyster larvae for this process.

Ms. Knauss presented results from her study investigating the physiological responses of *C. virginica* after exposure to microplastics. Polystyrene (PS), a polymer commonly found in the surface waters of coastal environments, was chosen for the microplastic exposure solutions. *C. virginica* larvae of various ages were allowed to feed on two sizes of polystyrene (PS) microbeads similar in size to their normal prey items and at concentrations near global estuarine concentrations. Larvae were exposed to PS microbeads over a 6-day period. Physiological parameters were measured throughout and showed that PS microbead ingestion caused a significant increase in algal clearance rates and carbon assimilation in a dose-dependent manner. However, growth was not affected.

Ms. Knauss plans on conducting future work investigating the physiological effects of different polymer microfibers on oyster larvae. Microfibers are more abundant than microbeads in the environment and could cause more significant effects because of their sharp edges and different shapes, as compared to round smooth beads.

2.1.5 Policy and Management

This session consisted of lunchtime presentations on current policy and management approaches being taken by jurisdictions in the Chesapeake Bay watershed. Even though microplastics have not been targeted by federal, state, or local authorities in the region as a pollutant of concern, other jurisdictions have taken efforts to address potential sources of microplastics by addressing aquatic trash and marine debris.

Tackling Marine Debris in Virginia and the Mid-Atlantic
Katie Register, Clean Virginia Waterways

The first talk was given by Katie Register, Executive Director of Clean Virginia Waterways. Clean Virginia Waterways, (CVA) through funding from the Virginia Coastal Zone Management Program (VA CZMP), drafted the Virginia Marine Debris Reduction Plan in 2014. The plan was designed to be implemented over a period of 10 years and foster collaboration. The plan is focused on implementing initiatives in the commonwealth that are politically, socially, and economically feasible.

Two major sources of debris are addressed by the plan: water-based sources and land-based sources. Examples of water-based sources include derelict fishing gear such as crab pots and clam nets. Examples of land-based sources include stormwater runoff. Through monitoring along Virginia's beaches, CVA has determined that 93% of items found are plastic. The number one item found during surveys is balloons, followed by single-use plastic beverage bottles (Figure 16).

CVA is working with the VA CZMP, other state agencies, local governments, and non-profit partners through prevention, innovation, interception, and cleanups. Examples of actions taken to date include convening two Virginia Marine Debris Summits and a broader mid-Atlantic summit. Stormwater and litter workshops have been held annually to update local governments on the role stormwater plays in Virginia's marine debris problem and what solutions are currently available to address the problem. In addition, CVA and VA CZMP have been collaborating with other mid-Atlantic state partners on a social marketing campaign to reduce the number of balloon releases in the mid-Atlantic.

Figure 15. Derelict plastic clam netting used in aquaculture operations being removed from the Mockhorn Island Wildlife Management Area on Virginia's barrier islands (VA CZMP 2014)

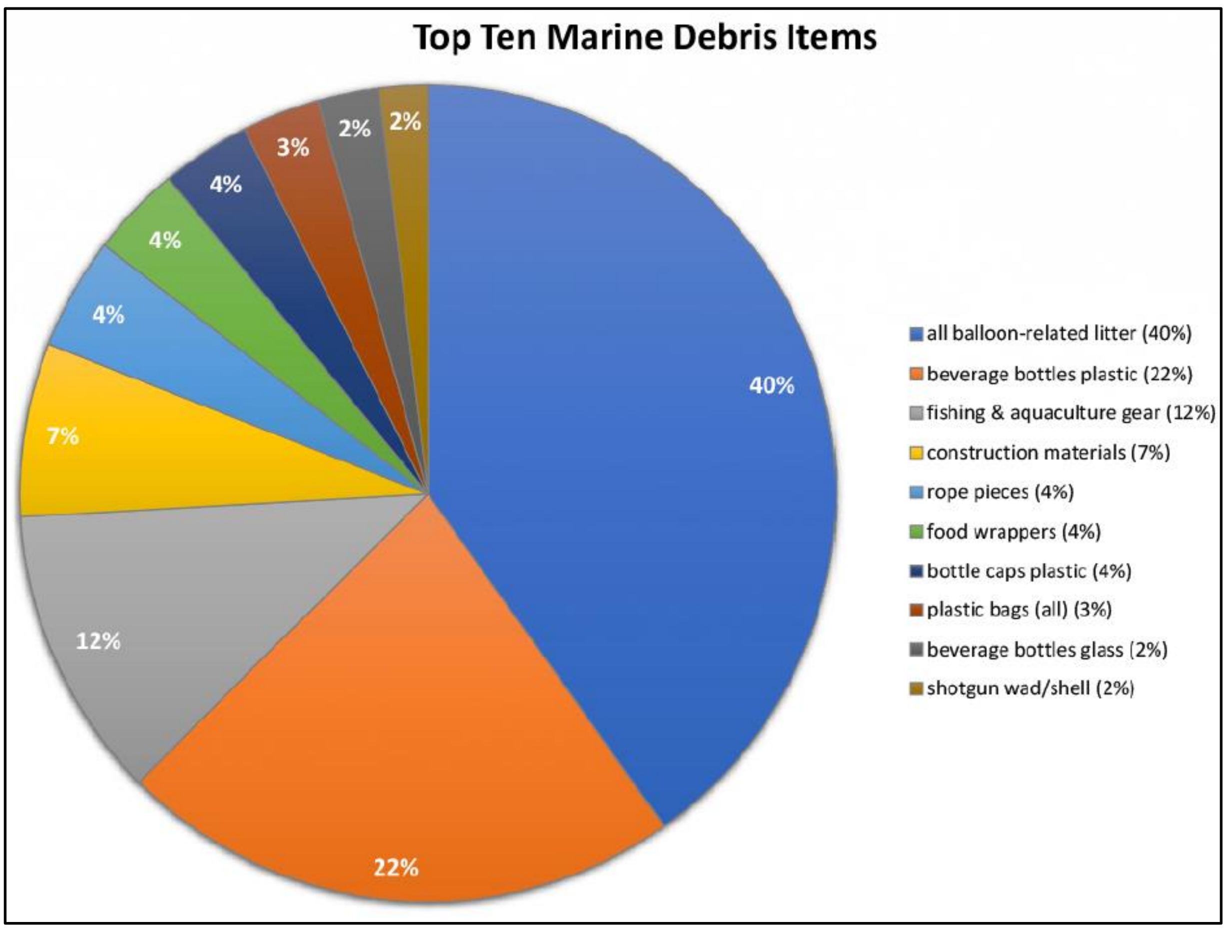

Figure 16. Top 10 marine debris items observed during beach surveys conducted by Clean Virginia Waterways, 2013-2017 (Clean Virginia Waterways 2018).

Implementing a Trash TMDL for the Anacostia River, Washington, DC
Matt Robinson, DC Department of Energy & Environment

The last talk was given by Matt Robinson of the DC Department of Energy Environment (DOEE) on implementing a total maximum daily load (TMDL) for the Anacostia River. The Anacostia River is a tidal, urban river that has been subjected to over 400 years of development. The watershed is approximately 45,580 hectares in size and is divided between the District and two counties in the state of Maryland: Montgomery County and Prince George's County (Figure 4).

DC first listed the Anacostia River for trash in 2006 on its 303(d) list, followed by Maryland in 2008. In 2010, a TMDL was completed in collaboration between DC, Maryland, both counties, and U.S. EPA Region III. The TMDL requires 1.2 million pounds of trash to be prevented from reaching, or removed from, the Anacostia River on an annual basis. The largest point source contributors include municipal separate storm sewer systems (MS4) and combined sewer systems (CSS). Non-point source loads are attributed to illegal dumping along the river and tributaries (DOEE, 2010).

The TMDL was developed based on monitoring of MS4 and CSS outfalls and conducting stream counts for illegally dumped debris along the river and tributaries. A total of 231,000 pounds of trash per year is estimated to come from point and non-point sources in the District alone. Beginning in 2012, the District's national pollutant discharge elimination system (NPDES) permit for the city's MS4 required 103,188 pounds to be prevented from reaching, or removed, from the Anacostia River. This number is equivalent to the load attributed to the MS4 under the TMDL (EPA Region III, 2012).

Mr. Robinson's presentation focused on efforts the District is undertaking to comply with the TMDL and MS4 permit. DOEE has been working with District sister agencies, Federal agencies, and non-profits to implement a variety of trash reduction practices. Examples include the District's trash traps. Figure 17 shows an example trash trap installed at an MS4 outfall in the Anacostia watershed. The District has also established policies, such as the $0.05 fee on single-use plastic bags, a ban on expanded polystyrene foam food containers, and a ban on single-use plastic straws. All of these materials have been found to be common in the Anacostia River. Finally, the District sponsors a variety of watershed cleanup programs, included the DC Department of Small and Local Business Development Clean Teams Program. This program provides grants to local non-profits to hire unemployed residents to help with maintenance of business corridors in the District, which includes trash removal. In 2017 alone, this program was responsible for the removal of over 9 million pounds of trash and debris city-wide (DSLBD, 2019).

Figure 17. A Bandalong litter trap installed at the beginning of Nash Run, one of the District's tributaries to the upper Anacostia River (DC Department of Energy and Environment 2019).

With these controls in place, the District first came into compliance with its MS4 permit requirements in 2015. To address trash emanating from the District's CSS, the DC Water and Sewer Authority (DC Water) has been constructing a large combined sewer overflow containment project known as the Clean Rivers Project. Obligated by their own NPDES permit, DC Water's approach includes constructing large underground tunnels to capture combined sewer overflow, detain it, and pump it to the Blue Plains wastewater treatment plan in the District for treatment. The first of two planned tunnels was completed in 2018. DC Water reports that over 400 tons of trash and debris was captured since the first tunnel was completed.

3. Key Discussion Points

As discussed earlier, the discussion periods focused on questions that could help to inform an ecological risk assessment looking at effects of microplastics on the Chesapeake Bay and watershed. Examples of discussion points included sources of microplastics, distribution of microplastics in the bay and watershed, and potential effects on living resources, specifically species that could serve as assessment endpoints. In addition, discussions were held around other challenges on conducting microplastic research in the bay and watershed, such as establishing universal terminology for microplastic size classes and concentration units, and the types and availability of analytical techniques. This section summarizes these discussions in detail.

3.1 Technical Terminology

The first major discussion during the workshop focused on adopting uniform terminology for size classification and concentration units of microplastics. As highlighted in the presentation given by Dr. Fred Dobbs of Old Dominion University, different size classification schemes have been adopted worldwide. The term microplastic has been applied to particle sizes ranging from 1 nm to 5mm in length or diameter. The current methodologies available to test for the presence of microplastics vary significantly in their rigor and cost depending on the size of the microplastic particle one is searching for. Therefore, recognizing a need to monitor for microplastics in an affordable and technically feasible way, most workshop participants felt that a standardized size range classification scheme should be adopted for the Chesapeake Bay region for all future monitoring studies to follow. The following two classification schemes were discussed during the workshop:

1) The UN Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) system classifies microplastics as particles ranging from 1nm to 5mm in length or diameter.
2) Seiburth (1978) classification system for plankton assigns size classification for different types of plankton, such as virioplankton (0.02 nm) to megaplankton (200 cm).

Workshop participants emphasized that the size classification system should take into consideration practical approaches for sampling microplastics, as well as the different media that need to be sampled in the bay and watershed (e.g. water, sediment, tissue). For example, several of the surveys conducted in the Bay and other waterbodies all over the world use manta trawls and nets which typically use a mesh size of 300 µm. (300000 nm or 0.3 mm). Using a smaller mesh size would be infeasible due to clogging.

Workshop participants also discussed the need for adopting uniform units of concentration used in different types of monitoring. Microplastic studies conducted in the same media elsewhere will express microplastic abundance in the form of mass/unit volume or particles/unit area. Workshop participants expressed that inconsistencies in units can result in incorrect inferences being drawn and the magnitude of the problem can be over or under-represented. Uniformity is needed in order for results to be compared across studies conducted throughout the Bay and its watershed.

Workshop participants recommended that STAC undertake a technical review of terminology used in microplastic research, specifically size classification and concentration units, and recommend uniform terminology for the Chesapeake Bay Program partners to utilize in monitoring and studies focused on plastic pollution in the bay and watershed.

3.2 Sources

The first facilitated discussion focused on the question: *What types of sources for microplastics in the Chesapeake Bay and its watershed should we focus on*? The pre-workshop questionnaire included a question asking participants what they think the largest sources of microplastics to the bay and watershed are. Four different types of responses were provided:

1) Point and non-point sources (e.g. wastewater, stormwater, air)
2) Microplastic type (e.g. primary vs. secondary)
3) Product source (e.g. plastic bags, Styrofoam products)
4) Polymer type (e.g. polyethylene, polystyrene)

Based on the variety of responses, participants at the workshop were asked: *What is the most important question in terms of source? Can we answer that question today? If not, what additional information do we need?*

Wardrop et al. (2016) stated in their technical review for STAC that sources are primarily divided between the two types of microplastics: primary and secondary. They state that primary sources include products such as microbeads from personal hygiene products and "nurdles" or pre-production plastic pellets. Secondary sources are particles from macroplastics which may come from point and non-point sources. Given the variety of answers, it seemed prudent to discuss what types of sources should be addressed based on potential management implications. Jambeck et al. (2015) showed that in 2010 an average of 8 million metric tons of trash entered the world's oceans from land-based sources. In the U.S., this could include point sources such as municipal separate stormwater sewer systems (MS4s) or non-point source littering and illegal dumping. It is believed that a majority of the microplastics in the oceans are secondary microplastics (Moore 2008).

There was debate during this session on how to define "origin" for plastic pollution. Some workshop participants emphasized people as the source. This includes manufacturers of plastic products and the improper disposal (e.g. littering) of those products throughout the bay watershed. Many of the workshop participants were familiar with the regulatory framework of the Federal Clean Water Act which assigns pollutant loads to point and non-point sources, so an emphasis was also made that we should focus on those sources. There was concern that if the focus is put on a conveyance system, such as point sources, then those responsible for those systems would carry the weight of the burden. However, others argued that if management approaches start with the conveyance system, then the burden may move back "upstream" to those responsible for allowing plastic to enter the system in the first place. For example, as shown in Mr. Trieu's presentation on monitoring trash and litter in the Anacostia River watershed, macroplastics littered on the street will eventually enter a storm sewer system and will be discharged to a local stream or river via a stormwater outfall. Recognizing that in their strategy for implementing the trash TMDL for the Anacostia River, DOEE includes enforcement of the DC 5-cent fee on single-use plastic bags as a best management practice for meeting its TMDL obligations (Robinson pers. comm.). This illustrates the effectiveness of the burden placed on consumers and manufacturers to reduce plastic pollution through the establishment of controls on point sources.

The workshop participants highlighted several questions that should be answered before a source reduction approach is adopted for the bay and watershed:

1) Which sources (e.g. point and non-point sources) are delivering the most plastic to the bay and watershed?
2) What are the most common products (e.g. plastic bags, Styrofoam) in terms of sources to the Chesapeake Bay?
3) Should stakeholders focus on addressing macroplastics, microplastics, or both?
4) What solutions to the problem are actionable?
5) Can we push for more closed loop systems for plastic products?
6) Are there viable alternatives to creating closed loop systems (e.g. more biodegradable plastics)?

Closed loop systems emphasize management approaches that tend to capture single-use plastic products and reuse them to make new ones. A common term to describe this is the "circular economy." Figure 19 displays a conceptual model for a circular economy that emphasizes components such as using fewer raw materials; designing longer lasting, more durable products; engaging retailers to offer products that can be easily reused and refurbished; making producers fully responsible for recovering material; and utilization of improved, more cost-efficient recycling (UNEP 2018). Other alternatives include policies that focus on banning or reducing use of single-use plastic products. Examples include the DC 5-cent fee on single-use plastic bags, foam ban, and single-use plastic straw ban. In 2019, the State of Maryland also passed a state-wide foam ban. VIMS has been experimenting with plastic biopolymers to use in the manufacturing of single-use products such as escape hatches on fishing gear (Bilkovic et al., 2012). Examples of these polymers include polyhydroxyalkanoates (PHAs) and poly-ß-hydroxybutyrate (PHBs). Both polymers are produced naturally by microorganisms, are biodegradable, and have been shown to enhance growth and disease resistance in aquatic organisms because of their conversion into short chain fatty acids during digestion. It has been shown that Chinese mitten crab larvae (*Eriocheir sinensis)* fed with PHB showed greater resistance to infection with *Vibrio anguillarum* (Sui et al., 2012). De Schryver et al. (2010) showed that European seabass (*Dicentrarchus labrax*) larvae partially fed with PHB displayed increased growth.

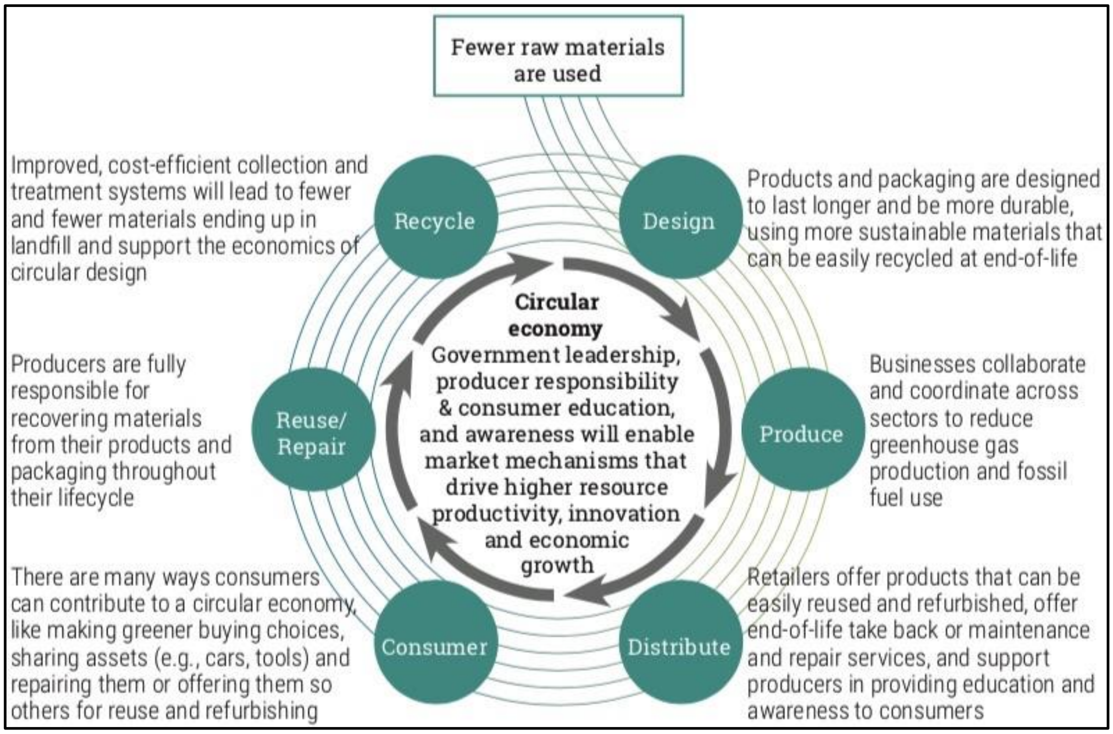

Figure 15. Conceptual model of a circular economy (UNEP, 2018).

3.3 Analytical Methods

The workshop steering committee anticipated that in order to properly determine sources of microplastic pollution, questions concerning analytical methods needed to be discussed. Microplastic research requires access to sophisticated analytical equipment that can be used to analyze sample polymer types. Two of the most common types are Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy. Put simply, both types of instrumentation assess the interaction of polymer molecules with light, with different polymers giving back unique signals. Signals can then be compared to a spectrograph library to help determine the polymer type.

Steering committee members highlighted that this instrumentation is not easily accessible for conducting microplastics research so a discussion during the second part of the first session focused on the following questions: *Who has these types of instruments? What is the preferred type of instrumentation? Are there other analytical methods that are better, cheaper, or both? What is the barrier for obtaining these instruments?*

Who has these types of instruments?

Six entities represented at the workshop responded that they have access to these instruments. The point was raised by one participant that the assumption should be made that every single research institution in the region has access to at least one of these instrumentation types. However, in response other workshop participants commented that while that may be true, utilizing this instrumentation for microplastics research may not be a priority. Participants commented that with the exception of one or two service providers, commercial labs do not currently seem interested yet in conducting these types of analyses.

What is the preferred type of instrumentation?

In response to this, the point was made that it depends on what you are trying to do. While FTIR is commonly used for microplastic analysis, Kappler et.al (2016) showed it only works for particles greater than 400 microns in size. Raman spectroscopy is more effective at analyzing smaller particles but is more time-consuming.

Are there other analytical methods that are better, cheaper, or both?

The workshop participants did not seem to know of more effective or cheaper types of instrumentation that can be used to analyze microplastics. One participant brought up the potential use of mass spectrometry for analyzing samples, however, others felt that instrumentation could greatly damage samples.

What is the barrier for obtaining this type of instrumentation?

Workshop participants stated overwhelmingly that funding is by far the biggest challenge to obtaining these types of instrumentation. Whether it is purchasing instrumentation or paying an existing lab which already possesses it to conduct the analysis, this is a significant barrier that should be overcome in order to analyze samples.

In conclusion, there are institutions in the bay watershed that possess the necessary type of instrumentation and the science behind this technology is evolving all of the time. The primary barrier is finding funding to either purchase new instruments or to fund use of existing instrumentation for analyzing microplastics. Regardless, use of sophisticated analytical methods will be necessary in order to determine the origin of microplastics found in the bay and watershed.

3.4 Distribution of Microplastics

Two questions concerning distribution were included in the pre-workshop questionnaire: *Where are microplastics most common?* Most respondents replied that microplastics are most common in urban areas with high population density. Other responses included:

- River sediments;
- Surficial waters;
- Along the eastern shore of the Chesapeake Bay due to the Coriolis effect;
- Areas with WWTPs;
- Areas with non-hardened shorelines; and

- Areas of the bay with dead zones.

Using these results, the steering committee began discussion with the question: *Can we decide on where hotspots for microplastics are across multiple geospatial scales, including landscape and habitat?*

Workshop participants responded that a focus should be placed on areas of concern rather than the location of microplastic hotspots. For example, are there important habitat types, such as submerged aquatic vegetation (SAV) beds, that accumulate microplastics leading to a greater risk of exposure for aquatic organisms? Workshop participants commented that this will shift the focus to effects on living resources which resonates more with people.

A recent study examining microplastic abundance in SAV beds in the tidal Potomac River, Washington, DC, revealed a significant difference between microplastic concentrations within SAV beds versus the adjacent open water column (Murphy, personal communication). Figure 19 shows trash accumulating in a large SAV bed south of Reagan National Airport on the Potomac River, Washington, DC. Goss et al. (2018) observed microplastics encrusted within epiphytes on 75% of blades of turtle grass (*Thalassia testudinum*) sampled on Turneffe Atoll, Belize. They also observed the greatest amount of grazer activity on blades with epiphytes which suggests seagrasses could act as a vector for microplastics to enter benthic food webs. During his presentation earlier in the session, Dr. Yonkos announced current projects are underway to survey abundance of microplastics found in surface waters and sediment near oyster beds in the Chesapeake Bay, as well as in oysters themselves.

Figure 16. Trash accumulating in a submerged aquatic vegetation (SAV) bed in the tidal Potomac River, Washington, DC, summer 2017 (Photo courtesy of Damien Ossi, DOEE).

Dr. Jesse Meiller of American University has observed biofouling communities incorporate microplastic particles into their matrix. Biofouling experiments conducted in Baltimore Harbor found microfibers were utilized by organisms, such as polychaetes, in constructing structures such as tubes. Presence of microplastics in these structures could serve as vectors for grazers (Meiller, personal communication).

Two additional important points were made by workshop participants. First, it is important to address both presence and abundance. While ubiquity does tell an important story about the extent of microplastic pollution, determining areas of high abundance may help with strategic use of resources to address the issue. Second, it is important to also assess the presence and abundance of smaller plastic particles, such as nanoplastics and picoplastics (i.e. particles < 1 micron in length or diameter).

In conclusion, the workshop participants recommended a series of research questions to help gauge distribution throughout the bay and its watershed:

1) Standard methods for collection and processing need to be developed;
2) Decide on the definition of source;
3) Determine degradation rates for different plastic products;
4) Assess presence and abundance at different depths;
5) Assess presence and abundance in different habitats;
6) Research and establish the most efficient detection methods;

7) Analyze samples for polymer types; and
8) Assess seasonality of microplastic concentrations in tidal and non-tidal waters.

3.5 Effects of Microplastics on Living Resources

In the pre-workshop questionnaire participants were asked the following questions: *Are there studies which show specifically that microplastics are, or could be, impacting living resources in the bay and its tributaries? Has anyone observed species in the bay consuming microplastics? What are the possible effects to the food chain, especially humans?*

As presented during her talk at the workshop, Christine Knauss of the University of Maryland showed that plastic microbeads impact oyster larvae respiration. Dr. Susanne Brander of Oregon State University displayed evidence her during her talk that adult black seabass (a species common to the lower Chesapeake Bay) consume microplastics in the wild, and that exposure to microplastics in the lab affects different life stages. More recently, researchers in the lab of Dr. Jon Niles at Susquehanna University have found microplastics in up to 95% of Smallmouth Bass (*Micropterus dolomieu*) sampled in the central Susquehanna River (Parks 2019).

Other respondents offered anecdotal evidence of microplastics affecting living resources. For example, Dr. Jesse Meiller of American University has observed microplastics in the guts of brown bullhead catfish (*Ameiurus nebulosus*) in the Anacostia River. Researchers at George Mason University Department of Environmental Science and Policy have observed microplastics in the guts of Blue Catfish (*Ictalurus furcatus*) collected from the Potomac River. In addition, Dr. Meiller at American University has also observed microplastics being incorporated into the community matrix of tube worms and mussels in biofouling experiments conducted in Baltimore Harbor.

During the workshop, the group discussed potential effects microplastics have on the food chain, including any potential threats to human health. First, a question was asked whether the research conducted by Christine Knauss at University of Maryland and Dr. Brander at Oregon State University offers evidence that microplastics could serve as an additional environmental pressure that affects recruitment of important commercial species. Workshop participants agreed that this is something very difficult to test, however it is possible that microplastics could compound the effects of different pressures on larval fish survival.

Another major issue brought up during the discussion on food chain effects concerned chemical leachates (e.g. phthalate) from microplastics and chemical constituents (e.g. PCBs) that bind to microplastics in the water. Once microplastics are consumed by an organism, these other compounds may have additional physiological effects beyond the direct effects from microplastics (Ziccardi et al. 2016).

Several of the workshop participants emphasized the need to focus on the presence, abundance, and effects of nanoplastics. It has been shown, using Zebrafish (*Danio rerio*) embryos in the lab, that polystyrene nanoparticles crossed the outermost membrane of an embryo, the chorion, and accumulated throughout the entire developing embryo (Lee et al. 2019). However, this research only observed marginal effects on survival, development, hatching rates, and cellular death. Furthermore, Mediterranean mussels (*Mytilus galloprovincialis*) exposed to polystyrene nanoparticles displayed various physiological effects in the digestive glands and neurological effects such as a decrease in cholinesterase activity in the haemolymph (Brandts et al. 2018). One additional effect of microplastic pollution on living resources concerns the indirect effects through possible disruption of the nitrogen cycle. VIMS researchers have found that polyvinyl chloride (PVC) particles possess antibacterial properties. They have conducted experiments in the lab showing these particles cause a die-off of nitrifying bacteria. This may potentially affect the benthic nitrogen cycle of the Chesapeake Bay and its tidal tributaries (Seeley, personal communication).

One major conclusion from this discussion is that there is a real lack of information specifically on the effects of microplastics on living resources of the Chesapeake Bay and watershed. The workshop participants reverted back to the ecological risk framework to think about potential studies focused on this area. For example, suggestions were made concerning assessment endpoints. Specific species and organismal responses were highlighted as potential endpoints. However, it was suggested the workshop participants should not be too prescriptive. The Chesapeake Bay Program partners should decide what species are most important to them. For example, there are no current restoration goals for Black Seabass. However, there are goals for other species such as oysters, Striped Bass, American Shad, and blue crabs.

3.6 Monitoring

Early into the workshop, it became evident that data gaps were pervasive and the distribution of microplastics within the bay was not well understood. Although it was recognized as somewhat intuitive that urban areas are likely hotspots of plastic *sources*, the limited data suggests that other regions may serve as origins of ecosystem plastic particles. Furthermore, workshop participants struggled to define source, with the understanding that microplastic objects used by consumers was the ultimate source, while storm drains, waste water treatment facilities, streams and rivers served as conduits. But each of these conduits operates differently and are in unique geographic settings, therefore it is incumbent upon natural resource management agencies to assess the relative microplastic burden for these pathways.

The workshop led to a discussion about establishing a monitoring program to assess microplastic distribution throughout the bay that would effectively address pathway and loading issues. Several workshop participants commented on how a broad monitoring program may not be technically useful without being designed to answer specific questions and hypotheses. For example, participants acknowledged that standardized sampling protocols are necessary to develop a cohesive, meaningful data set. This will be partly driven by how microplastics are defined, as size fractions will dictate several steps in sampling, processing, and analysis. Also, questions arose with some specifics of regular sampling. Are commonly used protocols (e.g. manta nets) capable of providing a representative sample? Sampling protocols that are biased towards near-surface waters may potentially miss significant microplastic pools or fractions or may overestimate microplastic concentrations if this layer is relatively enriched in microplastics. Accurate and representative measurements is critical to understanding transport, loading, and potential ecological effects of microplastics.

3.7 Ecological Risk Assessment

The workshop was designed to follow the framework of an ecological risk assessment, despite some deviation during the discussions. The introductory talk given by Dr. Jerry Diamond of Tetra Tech outlined the process of problem formulation in order to carry out an appropriate ecological risk assessment. In addition, it was noted that ecological risk assessments use organisms (usually commercially or recreationally valuable) as endpoints (Figure 20), with the understanding that there is ultimately a potential human health risk.

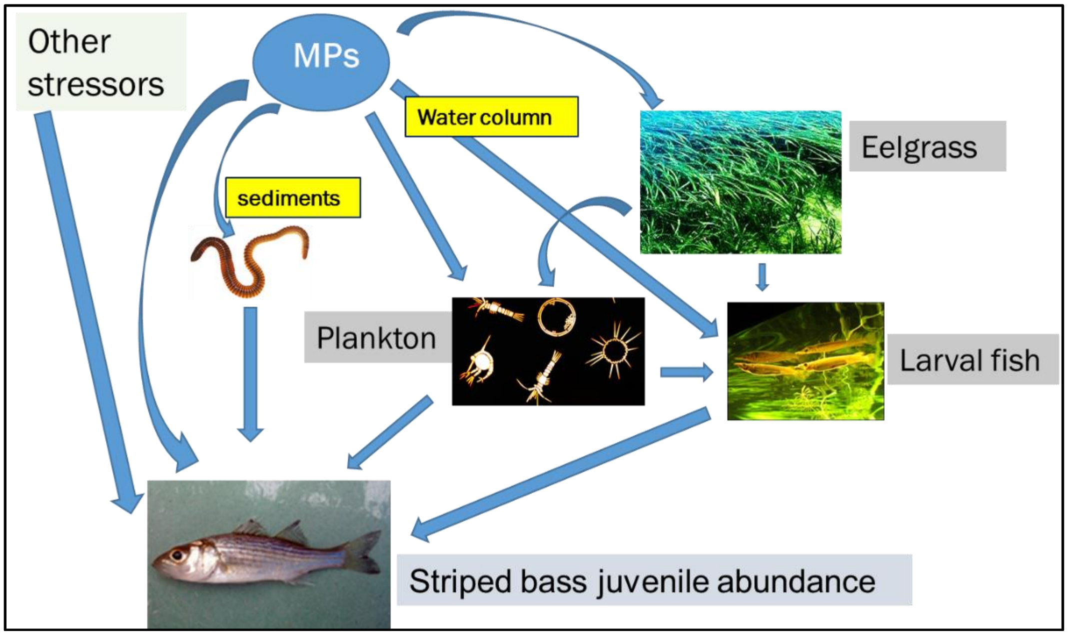

Figure 20. Conceptual model of potential ecological risk assessment for Chesapeake Bay with striped bass as endpoint (image courtesy J. Diamond, Tetra Tech)

In addition to the risk assessment endpoint, we discussed the secondary aspect that may be investigated regarding potential impacts to fitness and/or mortality as these parameters affect stock biomass. Dr. Brander's work suggested a potential mechanism that impacts Black Seabass (*Centropristis striata*) fitness.

Furthermore, discussion also included the toxic attributes of fish consumption since microplastics potentially behave as vectors for adhered chemicals of concern (Batel et al. 2016; de Sa et al. 2018). Emerging research is demonstrating that this can have ecological as well as human health consequences (Batel et al. 2016; Rochman et al. 2013). Participants were vocal about the connection between microplastics, disease, contaminants, living resources, and ultimately human health as strong reasons for the Chesapeake Bay Program to take quick action.

Recognizing that an ecological risk conceptual model can be an effective communication tool, the workshop participants attempted to compile information on the sources of microplastics to the bay and watershed. First, the group used fish health as the assessment endpoint. There is evidence to suggest that when fish consume microplastics this leads to effects on the digestive system, growth, and respiration. Next, group discussed the following elements that will potentially inform an ERA:

1) What is the risk? How likely is it that fish will be exposed to microplastics? Workshop participants decided that based on research presented at the workshop, as well as work performed elsewhere, that microplastic pollution is ubiquitous. Therefore, there is a possibility that there will be uptake through ingestion or through gill action.
2) What are the pathways of exposure? Based on research discussed at the workshop and work conducted elsewhere, microplastics can be found in water, sediment, and food.
3) What are the sources? How do plastics end up in these places? Based on discussions held during the workshop and research conducted elsewhere the group felt it was reasonable to focus on four main sources: stormwater, wastewater, air, and non-point sources.

This is summarized in Figure 21 below.

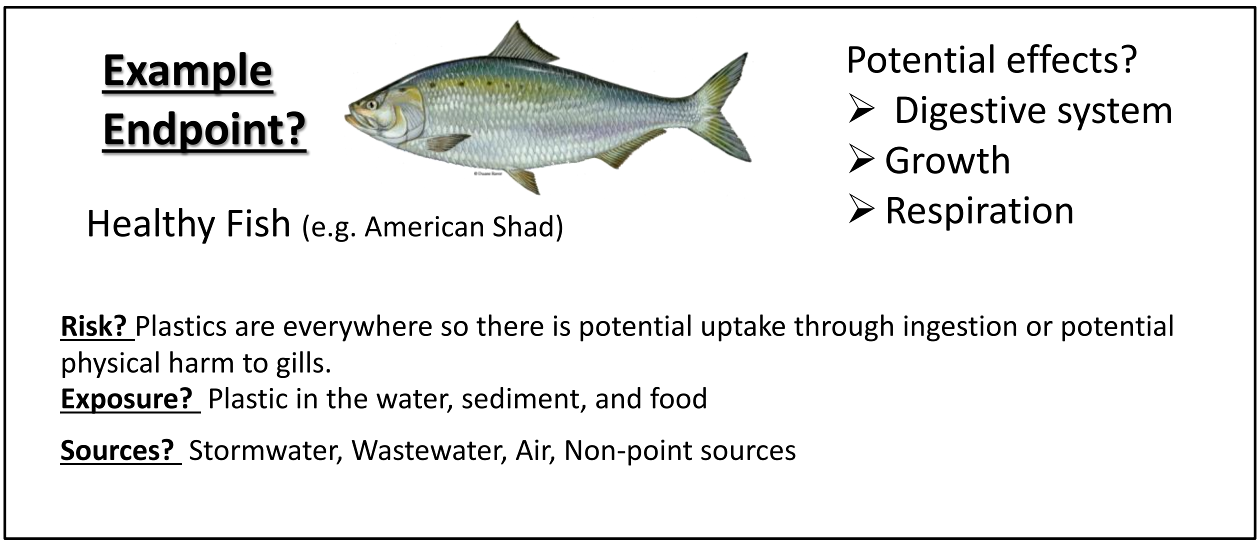

Figure 21. Summary of workshop discussion on hypothetical ecological risk assessment endpoint for microplastics in the bay and watershed, including answers to questions concerning risk, exposure, and sources.

Workshop participants then attempted to answer the following four questions about the four main sources:

1) Do we know the size and type of plastics coming from each source?
2) Do we know if this is a source for macroplastics, microplastics, nanoplastics, or all three?
3) Do we know what human behaviors (e.g. improper disposal) lead to each of these being a source?
4) Do we know of any source management controls?

Table 1 below illustrates the results of the discussion. Workshop participants acknowledged the two sources we know the most are stormwater and wastewater. However, there are still a considerable number of information gaps that need to be addressed before a comprehensive assessment of plastic pollution sources can be completed.

	Source Type			
What info do we have on the following questions?	**Stormwater**	**Wastewater**	**Air**	**Non-Point Sources**
Do we know the size and type of plastics coming from each source?	There is some information on size but more is needed. More information is needed on type.	There is plenty of information on size. More information is needed on type.	There is some information on size, but more is needed. There is very little information, if any, on type.	There is some information on both size and type, but more is needed.
Do we know if this is a source for macroplastics, microplastics, nanoplastics, or all three?	This is a source on macroplastics. More information is needed on whether it is a source for microplastics and nanoplastics.	This is a source for microplastics. More information is needed concerning nanoplastics. It is not a source for macroplastics.	More information is needed on whether this is a significant source for microplastics and nanoplastics. This is not a source for macroplastics.	There is some information on whether this is a source for microplastics and macroplastics, but more is needed. More information is needed concerning nanoplastics
Do we know which human behaviors lead to these being a source?	Improper dispoal (e.g. littering and illegal dumping)	Washing clothes, personal care products, and dish washing	Washing clothes and plastic products degrading	Plastic products degrading
Do we know of any source management controls?	Best management practices that address trash (e.g. trash traps, volunteer cleanups)	Enhanced filtration (e.g. HRSD SWIFT project) and policies (e.g. Federal microbeads ban)	Unknown	Enforcement, reduction in application of biosolids from WWTPs, consumer behavior change, and best management practices designed to capture nutrients and sediment.

Table 1. Results of workshop discussion focused on answering questions about potential sources of plastic pollution to the bay and watershed.

4. Recommendations

Following the ecological risk framework discussion exercise on the second day of the workshop, participants attempted to compile a list of recommendations from the workshop to the Chesapeake Bay Program. Based on the talks and discussions held throughout the two days of the workshop, the abundance of plastics in waterbodies worldwide, and projected rates of plastic production in coming years, the steering committee would like to emphasize that addressing plastic pollution in the Chesapeake Bay is an extremely **URGENT** issue that the CBP should take action to address. Below are the recommendations in order of importance.

4.1 Recommendation #1: Establish a Plastic Pollution Action at Team at the CBP

The CBP should create a cross-GIT Plastic Pollution Action Team to address the growing threat of plastic pollution to the bay and watershed.

Workshop participants recommended that a cross-GIT Plastic Pollution Action Team be immediately convened by the CBP. This team would report directly to the Management Board and would be charged with addressing all of the remaining recommendations included in this report. Ideally, membership of this action team would include representation from all GITs whose goals may be impacted by plastic pollution in the bay and watershed, including, but not limited to, the Habitat GIT, Sustainable Fisheries GIT, Water Quality GIT, Fostering Chesapeake Stewardship GIT, and the Scientific, Technical Assessment and Reporting (STAR) team. Membership from the Advisory Committees should also be encouraged.

4.2 Recommendation #2: Researching Effects on Living Resources

The Scientific, Technical Assessment and Reporting Team should immediately incorporate development of ERAs of microplastics into the CBP strategic science and research framework, and the Plastic Pollution Action Team should oversee the development of the ERAs focused on assessment of microplastic pollution on multiple living resource endpoints.

Workshop participants were unanimous in their recommendation for one or more ecological risk assessments to be funded in the bay. Understanding plastic pollution from a systems perspective requires a way of conceptualizing sources, distribution and dynamics in the environment; identifying or quantifying impacts on wildlife, humans and other assets; and identifying and evaluating potential management responses. The uncertainties in our knowledge and the difficulty in resolving them satisfactorily can be challenging, given that we are confined to working with largely observational data because experiments at scale are difficult or impossible. To advance our understanding of the risk posed by anthropogenic debris, we suggest applying a conceptual framework that allows us to break the components into smaller parts that not only integrates uncertainty but also connects variables of interest to outcomes in which we are focused. The power of the risk assessment is in its ability to fully explore and quantify the pathways of microplastic impact on living resources and how any one of those might be suitable for management or policy decisions. In a regulatory context, risk assessments are often the first step in developing pollutant regulations, improved resource management, and policies to protect ecological and human health. Given the exponential growth of research and monitoring in marine debris and the potential for toxicological or other adverse impacts, approaches to assess ecological, economic, biodiversity and public health risk are needed to encourage science that can underpin sound policy decision making, as well as to identify critical areas for restoration and research.

Discussions centered on iconic Bay species frequently drive Chesapeake Bay Program goals and resonate with the citizenry. Examples of such species include blue crabs, striped bass, American shad, oysters, and others. Due to the nature of the problem and the largely unknown mechanisms by which microplastics might be affecting these species, a sense of urgency must be conveyed so that funding can be made available to begin research within the framework of a risk assessment. This funding can be found via multiple mechanisms, either through a competitive request for proposals, direct funding, or a combination. Funding should be provided by both the Chesapeake Bay Program and NOAA's Chesapeake Bay Office (NCBO). Both entities have equal roles to play in that the EPA (via CBPO) typically assesses water quality issues that deal with contaminants, TMDL development, and risk assessments, while NOAA typically manages coastal fishery resources and supports fisheries research within the Chesapeake.

Ecological risk assessment for microplastics is not entirely new (Everaert et al. 2018), although fully completed studies are very uncommon. Workshop participants noted the CBP ought to consider, when funding risk assessments, an analysis of constituent polymers as part of the risk assessment. Technological capabilities (e.g. laboratory spectroscopic microscopes such as Fourier-Transform Infrared) were recognized as a potential bottleneck in such applications, although multiple regional universities now have advanced instrumentation to conduct these analyses. Because risk assessments also rely upon high-quality concentration data, both in the environment and for confirmation of exposure levels in toxicity testing, the paramount importance of monitoring and laboratory analytical needs (i.e., reproducible, representative, accurate, precise methods for microplastics analysis) is clear. Understanding microplastics sources, distribution and fate is key to understanding ecological exposure and potential impacts.

4.3 Recommendation #3: Complete a Technical Review of Terminology

STAC should undertake a technical review of terminology used in microplastic research, specifically size classification and concentration units, and recommend uniform terminology for the CBP partners to utilize in monitoring and studies focused on plastic pollution in the bay and watershed.

Two size classification systems were discussed at the workshop:

1) The UN Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection System (GESAMP) – 1nm to 5 mm
2) Seiburth (1978) classification system for plankton – This system classifies virioplankton (0.02 nm) to megaplankton (200cm)

The classification system recommended should take into consideration practical approaches for sampling microplastics, as well as the different media that need to be sampled in the bay (e.g. water, sediment, tissue).

Concentration units vary across multiple studies. Some studies conducted in the same media will express microplastic abundance in the form of mass/unit volume or number of particles/unit area. STAC should recommend units of concentration for different sample media, specifically water, sediment, and tissue.

4.4 Recommendation #4: Address Sources

The CBP should develop a source reduction strategy to assess and address plastic pollution emanating from point sources, non-point sources, and human behavior.

As shown during the workshop there is a lot of information, and some major data gaps, about the sources of microplastics to the Chesapeake Bay and watershed. Regardless of the ultimate ecological effects on the bay and watershed, there is sufficient information to show that plastic pollution harms ecosystem health and aesthetics. While ERAs should be developed to help understand the effects of plastic pollution on the ecosystem, this should not preclude the Plastic Pollution Action Team from leading an effort to develop a source reduction strategy for the bay and watershed. That strategy should be informed by addressing the questions below:

1) Which sources (e.g. point and non-point sources) are delivering the most plastic to the bay and watershed?
2) What are the most common products (e.g. plastic bags, Styrofoam) in terms of sources to the Chesapeake Bay?
3) Should stakeholders focus on addressing macroplastics, microplastics, nanoplastics, or all three?
4) Which solutions to the problem are actionable?
5) Can we push for more closed loop systems for plastic products?
6) Are there other viable alternatives to creating closed loop systems (e.g. more biodegradable plastics)?

4.5 Recommendation #5: Monitoring

The CBP should direct the Plastic Pollution Action Team and STAR Team to collaborate on utilizing the existing bay and watershed monitoring networks to monitor for microplastic pollution.

Workshop participants concluded that information on the distribution of microplastics throughout the bay watershed was poorly known and largely unquantified. The Chesapeake Bay benefits from regular monitoring of water quality (e.g. nutrient enrichment, sediment loadings, etc.) from which management decisions can be made. These monitoring programs have been invaluable for resource managers to gauge source and fate of water quality stressors. Effective water quality monitoring programs identify goals prior to design, which may include:

- To assess use support status;
- To identify water quality problems, use impairments, causes, and pollutant sources;
- To respond to emergencies;
- To develop TMDLs and load/wasteload allocations;
- To track trends;
- To track management measure implementation; and
- To assess the effectiveness of best management practices and watershed restoration projects.

The CBP supports a comprehensive monitoring network throughout the bay, which addresses many of the goals listed above. Since microplastics are of serious concern, yet poorly understood, adapting the existing monitoring programs would be the most cost-effective means of collecting data on microplastic distribution. We recommend that the Plastic Pollution Action Team and STAR team, and/or other technical experts, collaborate on the development of a monitoring design to identify and answer the distribution of microplastics. This group should consider the most recently adopted sampling protocols for microplastics in aquatic systems and how these methods can be incorporated into current programs. In addition, temporal factors should be considered since sampling may not be necessary during each event, rather, it may be sufficient to sample less often than for nutrients, for example.

A good watershed monitoring program must be based on a thorough understanding of the system(s) being monitored. Collecting and evaluating all available information and data from other monitoring efforts lays an important foundation for such an understanding. Exploratory analysis of existing data might yield information that can help locate hot spots or critical areas, identify important covariates, or account for such characteristics as seasonality in the design of the monitoring program. Knowledge of the variability (i.e., “noise”) of the systems being monitored is very important because variability has a profound effect on the design and cost of the monitoring program the program’s ability to detect change reliably. As part of the design of a monitoring program, the group should factor in estimated costs and which might be borne by the states, municipalities and/or federal agencies. Lastly, the group should consider the duration of the proposed monitoring program and decide on if it has a finite lifespan or whether, since the production of plastic has no end in sight, may continue in perpetuity.

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Appendix A: Workshop Agenda

Microplastics in the Chesapeake Bay and its Watershed
A Scientific and Technical Advisory Committee (STAC) Workshop
Dates: April 24-25, 2019
Location: Potomac Science Center, George Mason University
650 Mason Ferry Avenue, Woodbridge, VA 22191
Workshop Webpage

The Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) is sponsoring this two-day workshop to determine the state of the research, data needs, field and laboratory research methodologies, and associated policy and management needs in regard to microplastics. The prevalence of microplastics in the Chesapeake Bay, its watershed, and their potential effects on the entire ecosystem make this a highly urgent issue. While the extent of plastic pollution and its ecological consequences have not been comprehensively assessed by the Chesapeake Bay Program partnership, research to date suggests microplastics pose an acute ecological risk. This workshop will provide a forum to discuss ongoing research and pose new questions to foster collaboration and advance understanding of this issue.

The goals of this workshop are to:

- Assess the state of the knowledge on microplastic pollution in the Chesapeake Bay and its tributaries
- Assess possible effects of microplastics on various habitats and associated living resources
- Identify existing policy and management tools being used to address plastic pollution in the watershed and beyond, and their effectiveness
- Identify research gaps moving forward, and develop recommendations for further studies or new tools

To accomplish these goals, the workshop will seek to answer the following key questions:

1. What are the sources of microplastics to the bay and its tributaries?
2. How common are microplastics in the Chesapeake Bay and its tributaries?
3. What additional information do we need to gauge the ubiquity of microplastics in the bay and its tributaries?
4. What are the possible effects of microplastics on the habitats in the bay and watershed (e.g. SAV beds, wetlands) and living resources (e.g., oysters, fish)? Are there any studies specific to the Chesapeake to confirm that microplastics are impacting these resources? What are the data gaps?
5. Are there any policy and management tools being used to address plastic pollution in the bay (e.g., Anacostia River Trash TMDL)? How effective have they been? Could these tools be emulated elsewhere? Are there additional tools we can recommend?
6. Can we recommend pursuing further studies or new management and policy tools at this time? Can we recommend that funding be made more available for this research?

Wednesday, April 24

9:30 am **Check-In, Coffee and Continental Breakfast (provided)**

10:00 am **Welcome and Introductions – Bob Murphy, Tetra Tech, and Chris Jones, George Mason University**
Workshop Co-Chair Bob Murphy will provide background on the workshop and outline goals of the next two days.

Morning Introductory Talks

Moderator: Bob Murphy, Tetra Tech

10:15 am **Introduction on Ecological Risk Frameworks – Jerry Diamond, Tetra Tech**

10:35 am **Summary of the 2016 STAC Review on Microplastics in the Chesapeake Bay – Denice Wardrop, Penn State**

10:55 am **An Introduction to Microplastics, an Emerging Global Issue – Fred Dobbs, Old Dominion University**

Q&A (10 mins)

11:25 am **Break (15 min)**

Session I

Key Questions:
1. What are the sources of microplastics to the bay and its tributaries?

11:40 am **Sources of Microplastics to the Chesapeake Bay and Watershed**
Moderator: Matt Robinson, DC Department of Energy & Environment (DOEE)
- Chris Burbage, Hampton Roads Sanitation District - Microplastics and Wastewater Treatment
- Phong Trieu, Metropolitan Washington Council of Governments - Litter surveys in the Anacostia and Potomac River watersheds

Q&A (10-15 min)

12:35 pm **Working Lunch (Provided)**
Facilitated Discussion on Session I – Brooke Landry (MD Department of Natural Resources)

Session II

Key Questions:
2. How common are microplastics in the Chesapeake Bay and the watershed (including habitat)?
3. What additional information do we need to gauge the ubiquity of microplastics in the bay and tributaries?

2:15 pm **Presence of Microplastics in Chesapeake Bay and the Watershed**
Moderator: Matt Robinson, DOEE
- Lance Yonkos, University of Maryland - Survey of Microplastics in Chesapeake Bay Tidal Tributaries

- Shawn Fisher, USGS – Microplastics in Freshwater Systems

Q&A (10 min)

3:05 pm **Break (25 mins)**

3:30 pm **Facilitated Discussion on Session II – Kelly Somers (EPA) & Matt Robinson (DOEE)**

5:00 pm **Adjourn Day 1**

Thursday, April 25

8:30 am **Coffee and Continental Breakfast (provided)**

9:00 am **Introduce Day 2; Reflections from Day 1 – Matt Robinson, DOEE and Bob Murphy, Tetra Tech**

Session III

Key Questions:

4. What are the possible effects of microplastics on living resources in the bay and watershed (e.g., oysters, fish, freshwater mussels)? Are there any studies specific to the Chesapeake to confirm that microplastics are impacting these resources? What are the data gaps?

9:30 am **Effects of microplastics on living resources in the bay and its watershed**

Moderator: Bob Murphy, Tetra Tech

- Susanne Brander – Oregon State University (Remote) – Consumption of microplastics in black sea bass *Centropristis striata*
- Christine Knauss, University of Maryland – Effects of microplastics on oysters

Q&A (10 -15 min)

10:20 am **Break (15 mins)**

10:35 am **Facilitated Discussion on Session III – Jason Rolfe, NOAA Marine Debris Program**

11:30 pm **Lunchtime presentations on policy and management tools (Lunch provided. Participants will have 30 min to get food)**

Moderator: Matt Robinson, DOEE

- Katie Register, Clean Virginia Waterways - Virginia Marine Debris Plan
- Matt Robinson, DC Department of Energy & Environment - Anacostia River Trash Total Maximum Daily Load

Session IV

Key Questions:

5. What are the major data gaps?

6. Can we recommend pursuing further studies or new management and policy tools at this time? Can we recommend that funding be made more available for this research?

1:00 pm Facilitated Discussion on Session IV – Denice Wardrop (PSU/STAC)

2:00 pm Final discussion on recommendations concerning management, policy tools, and recommendations for funding – Bob Murphy, Tetra Tech

2:30 pm Adjourn

Appendix B: Workshop Participants

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Appendix C: Acronyms

Chesapeake Bay Program	CBP
Clean Virginia Waterways	CVA
Coastal Zone Management Program	CZMP
D.C. Department of Environment and Energy	DOEE
Ecological Risk Assessment	ERA
Environmental Protection Agency	EPA
Fourier-Transform Infrared	FTIR
Goal Implementation Team	GIT
Hampton Roads Sanitation District	HRSD
Maryland Department of Natural Resources	MD DNR
Metropolitan Washington Council of Governments	MWCOG
Millions Gallons per Day	MGD
Municipal Separate Stormwater Sewer System	MS4
National Estuarine Research Reserve	NERR
National Oceanographic & Atmospheric Administration	NOAA
NOAA Chesapeake Bay Office	NCBO
Polycyclic aromatic hydrocarbons	PAHs
Polychloride biphenyls	PCBs
Scientific and Technical Advisory Committee	STAC
Submerged aquatic vegetation	SAV
Sustainable Water Initiative for Tomorrow	SWIFT
Total Maximum Daily Load	TMDL
United States Geological Survey	USGS
Virginia Institute of Marine Science	VIMS
Wastewater Treatment Plant	WWTP

Appendix D: List of Figures

Appendix E: List of Tables