Microplastic Monitoring & Science Strategy of Chesapeake Bay

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# Executive Summary

World production of plastic surpassed the 320 million tons mark in 2016, most of which is intended for packaging, i.e., for immediate disposal. Most plastic eventually breaks down into progressively smaller fragments that make their way into waterways. The occurrence of small plastic particles on beaches and in coastal waters was first reported in the 1970s although the term ‘microplastics’ was not used until relatively recently. Microplastics are currently defined as particles <5 mm (with the definition of nanoplastic still evolving, but generally <330 µm). It is likely that the amount of plastic waste in the ocean will continue to increase, driven primarily by the inexorable rise in plastics consumption and the continued inadequacy of re-use, recycling and waste management practices in many parts of the world. The Chesapeake Bay Program (CBP) Scientific & Technical Advisory Committee (STAC) sponsored a workshop to evaluate the state of the knowledge within the Chesapeake watershed, resulting in several action items including developing a science strategy on microplastics.

The Plastic Pollution Action Team (PPAT) was formed at the directive of the CBP Management Board and was charged to develop a preliminary ecological risk assessment model, in addition to a size classification document and this science strategy. Many of the topics from those first two documents are found in this document as we formulate a strategy to address microplastics baywide.

This strategy document provides an overview of management needs regarding implementing policies to reduce plastic pollution. Answering these knowledge gaps will provide a defensible position for policy development. To do this, we recommend implementing a monitoring program within the framework of the existing baywide monitoring programs. Additionally, data gaps important for basic research are noted as these can be filled by specific studies or within a monitoring program. This strategy is intended to be a starting point to develop research priorities, monitoring efforts, and policy development. It is expected to be amended in the future as more work is completed and new paradigms emerge.

# Introduction

The global production and disposal of plastics has increased by orders of magnitude over the past 60 years (Rochman and Browne 2013, Li et al. 2016) 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.

In 2019, the Chesapeake Bay Program’s Scientific & Technical Advisory Committee (STAC) convened a two-day workshop focused on sharing the current state of the science regarding microplastics in the Bay and its watershed (Murphy et al. 2019). Several recommendations emerged from the workshop, including:

* formation of a Plastic Pollution Action Team (PPAT);
* development of a preliminary ecological risk assessment model (eventually targeting Striped Bass);
* standardizing terminology;
* developing a source reduction strategy; and
* utilizing the existing monitoring networks to monitor for plastic pollution.

This document summarizes the state of the science of microplastics, both in a global context and within the Chesapeake Bay region. It also builds off the completed preliminary risk assessment model to identify data gaps that will aid our understanding of the trophic pathways, sinks and sources, of microplastics that potentially impact important Bay resources. The PPAT membership also identified management questions that helped identify additional data gaps that, once better understood, might lead to policy decisions. We also provide a framework to build microplastic monitoring into the existing monitoring efforts with regard to water quality, particle transport, and living resources. Lastly, using our current understanding of the magnitude of the issue, we also identify potential partnerships, technical, and financial resources. Our aim is to provide a path forward that ultimately informs management decisions.

# State of the Science

Recent research has shown microplastics to be ubiquitous in habitats around the world (Castaneda et al. 2014, Anderson et al. 2016, Jabeen et al. 2016), posing an emerging concern for aquatic life, and potentially, human health (Barboza et al. 2018). There has been a significant increase in the concentrations of microplastic particles in the surface waters of oceans within the last four decades and concern about the potential impact on the marine environment has increased during the past few years. Currently, plastic makes up about 80 to 85% of marine litter. Scientific investigations about the impact of microplastics on ecosystems have increased, along with public interest (GESAMP 2015). Plastics became the fastest growing segment of the municipal waste stream between 1950 and 2003, and its global production has increased significantly over the past decades (Auta et al. 2017). 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 and non-point source surface run-off, are sources of plastic waste to the bay (Peters and Bratton 2016). These larger, visible plastic items degrade 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.

Numerous attempts have been made to assess their potential effects not only to the environment, but specifically to biota and, ultimately, to humans. Due to their small size, these particles can be ingested by numerous marine species, leading to direct physical damage and potential toxicity effects (Wright et al. 2013). Microplastics may also leach plastic additives, including persistent organic pollutants (POPs) and potentially toxic elements that are adsorbed in higher concentrations than those found in the surrounding environment. These pollutants may transfer and accumulate in different tissues of organisms, possibly undergoing biomagnification along the food chain (GESAMP 2015). Hence, consumption of contaminated seafood poses a route for human exposure to microplastics, POPs, and potentially toxic elements (GESAMP 2015). POPs including polychlorinated biphenyl (PCBs) and polycyclic aromatic hydrocarbon (PAHs) have also been shown to accumulate on microplastics, thus enhancing their potential toxic effect in the environment (Hartmann et al. 2017). Such dangers have been demonstrated for numerous organisms, such as blue mussels, in which von Moos et al. (von Moos et al. 2012) verified that microplastics, namely, high-density polyethylene (PE), ranging from 0 to 80 mm were ingested and taken up into the cells and tissues of these organisms. Microplastic particles were drawn into the gills, transported into the stomach and into the digestive gland, where they accumulated in the lysosomal system after 3 h of exposure (von Moos et al. 2012). Jovanovic (Jovanović 2017) reported potential negative effects of the ingestion of microplastics and nanoplastics by fish, including possible translocation of microplastics to the liver and intestinal blockage, yielding not only physical damage, but also histopathological alterations in the intestines and modification in lipid metabolism. It should be noted, however, that, despite demonstrating the potential fate and effects of microplastics on biota, these studies, as well as other numerous reports described in the scientific literature, focus on experiments on the use of polymeric particles at concentrations that far exceed those determined in the environment, thus not accurately simulating natural settings regarding composition, morphology, and concentration.

The state of the science of understanding microplastic distribution and potential harm is in its infancy in the Chesapeake Bay (Murphy et al. 2019). Recent studies have shown that microplastics are ubiquitous in the Chesapeake Bay and its watershed (Bikker et al. 2020b). 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 (Yonkos et al. 2014, Peters and Bratton 2016). 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).

The recent ecological risk assessment conceptual model developed by Tetra Tech and the University of Maryland examined potential impacts of microplastics on Striped Bass (*Morone saxatillis*) in the Potomac River. Overseen by the PPAT, this document evaluated a range of potential trophic pathways that microplastics may follow to reach Striped Bass, causing a potential ecological impact, as well as a potential risk to human health. This preliminary model demonstrated the paucity of the state of the science with regards to microplastics in the Bay and this document will build on that effort to describe data gaps and how the science may move forward.

# Management Questions

This document has been developed to provide guidance in support of the Chesapeake Bay Program’s PPAT. The PPAT recently completed a preliminary ecological risk assessment for microplastics and Striped Bass in the Potomac River, along with a companion document that recommended standardized terminology to be used for microplastics monitoring and research in the Chesapeake Bay. Furthermore, based on these two documents and interests from multiple agencies, the PPAT provided additional management questions and concerns that are addressed in this document.

1. *How can government and resource managers develop sound policies to reduce [micro]plastic pollution and assessing the economic impacts?*

To answer this question, data on the source and composition (i.e. polymer type) of plastic is required as limits on plastic availability or behavior change of a population are likely policy options. This document also recommends the establishment of a monitoring program to answer these questions in more detail, with particular emphases on hotspots and sources. Current modeling efforts of microplastic transport and fate baywide is also a valuable tool and it is recommended that this effort is expanded to include each of the tributaries and extend up into the watershed. It has been noted that stormwater control is one action that can reduce microplastic movement into waterways, provided the particles can be effectively removed from control structures. The economics of policy-making is somewhat beyond the scope of this document; however we do recommend that socio-economic studies be conducted simultaneously to determine cost-benefit models for plastic reduction. Coupling these models with source-transport-fate models can likely help policy-makers determine the impact of plastic reduction strategies. Similar approaches with nutrient reduction have proven successful, both economically and ecologically. Several PPAT members have recommended that a regional strategy will have greater impact over a broader area; this approach, using existing regional partnerships (such as CBP, Delaware National Estuary Program, river commissions, etc) will only strengthen the impacts of strong multi-jurisdictional policies. Initial programs, including best management practices, will provide a good starting point for full policy development.

1. *What health risks are posed by microplastics?*

The health effects of microplastics to humans is only recently being evaluated and better understood, although we are a long way from complete understanding of this highly variable impact. Ecological risk to wildlife is an ongoing area of research and we strongly recommend that research into trophic linkages, mortality rates, and other biological effects take place. As we have seen with Striped Bass, the unknowns are vast, but understanding the basics of transfer, or laboratory studies on mortality/reduced fitness will be especially valuable to fisheries managers. The link from Striped Bass (and other organisms harvested for consumption) to human health will be one component of this evolving question.

1. What are the sources, pathways, composition, and fate of microplastic loadings into the Chesapeake Bay?

This question addresses the crux of the issue in terms of our incomplete understanding the scale and nature of microplastic loadings within the watershed. This question drives the need to establish a monitoring program to answer these, as this data can be used to answer a host of other questions associated with understanding these processes. Current modeling of microplastic transport has provided excellent insight into general trends that we would expect in the mainstem of the Bay. However, model outputs are only as robust as the parameterized data that drive them. Understanding, through monitoring data, the sources, type, and abundance of microplastics will help refine models and increase spatial applicability to include the tributaries. Additional PPAT concerns centered mainly on the fate of microplastics and how physical properties (e.g. salinity, freshets, storms) impact microplastic distribution. Similar questions have been raised in terms of understanding impacts on benthic habitats (e.g. SAV beds, oyster reefs). Directed monitoring (addressed in a separate section) can potentially answer these questions, as can research on topics discussed under Data Gaps.

1. What management actions or policies may be effective in reducing microplastic pollution?

This question is shared by the PPAT and the group that drafted the science strategy for microplastics in San Francisco Bay. This is not surprising as it will take some form of intervention to reduce plastic loading throughout the watershed. Several ideas have been brought forth and many more are in development and should be evaluated. Foam food container bans, microbead bans, recycling efforts, and plastic bag bans have all been management strategies implemented to reduce plastic pollution. Additional ideas include engaging businesses that either produce or rely on plastic bottles to consider adopting alternate materials (e.g. glass) as these changes do not appear to create major economic hardship.

# Sampling and Analytical Methods

Quantification of microplastics is necessary to understand abundance in environmental matrices and develop a better correlation between exposure and effects including potential dose-response relationships in exposed organisms. Methods for sampling and analyzing microplastics across studies remain inconsistent. This is due to varying study goals, media, or plastic types/sizes considered; rapidly evolving technology; lack of standardized methodology; and reflective of the fact that the study of microplastics is relatively recent.

The 2019 *Microplastics in the Chesapeake Bay and its Watershed: State of the Knowledge, Data Gaps, and Relationship to Management Goals* workshop proceedings noted that inconsistencies such as the tendency to report mass/unit volume or particles/unit area in similar studies. Mixed unit estimates like these pose problems as number of particles m-3 cannot directly correspond to aquatic surface area since the volume of water in one area may be more or less than in another of the same area (Bikker et al. 2020a). Similarly, Burns and Boxall (2018) explain that because ecotoxicity tests are reported in measures of mass or number of particles per volume, measures reported in “items per square meter” are not as easily comparable. Consistency in estimation of particles per unit area or volume is critical since organisms respond differentially depending on the impact measured. For example, number of particles per unit area is appropriate when measuring impact on respiration since gill area is the determining factor for gas exchange. However, volumetric estimates are more appropriate for gastrointestinal studies since ingested “food” is more biologically relevant when measured by volume (although number of particles can also be relevant when assessing ingestion effects). Most microplastic analysis methods lack standardization and continue to update as new analytical technologies become available. Thus, the sampling, identification, and quantification of microplastics in different media remains inconsistent.

A companion document to the initial ecological risk assessment of microplastics in the Chesapeake Bay, *Uniform Size Classification and Concentration Unit Terminology for Broad Application in the Chesapeake Bay Watershed,* preliminarily provides recommendations and considerations for future research related to study design, analysis, and sampling. These considerations are as follows:

**General Considerations**

* Environmental plastics are complex because they encompass a diverse group of materials with different physical/chemical properties along with fate, transport, and bioavailability characteristics.
* A convention for grouping plastic debris based on size or other descriptors will improve communication, ability to compare the results of studies in a meaningful manner, and determine which plastics are potentially associated with risk.
* The lower size limit of microplastics reported by studies is often functionally constrained by limitations of sampling technology. In the case of Chesapeake Bay and tributary studies, researchers used manta trawl nets to capture and report microplastic fragments with a lower limit of 333 µm (Bikker et al. 2020, Yonkos et al. 2014). However, this means that microplastic particles smaller than 333 µm are not quantified but may still be harmful to aquatic and terrestrial organisms.
* The findings of some studies, especially field -based ecological studies where perhaps only visible plastics are currently quantified may underestimate true exposure because smaller microplastics or nanoplastics could contribute to biological effects observed in a study but are not measured.
* Microplastic and nanoplastic designations will be the most useful terminology to describe plastics that are potentially biologically relevant via ingestion or inhalation/gill uptake. However, for the purposes of sampling, monitoring, and prediction of plastic loading to a particular system, it will be informative to classify larger plastics that are easily visible to the naked eye (e.g., bottles, packaging materials, etc.), as these are the precursors to micro and nanoplastics, and are easily visible during shoreline or open water monitoring.

**Potential Units of Measurement for Focus in Future Studies**

Different characteristics of media or study objectives influence the decision of how environmental plastics are analyzed or reported. The following units were identified for consideration of inclusion in future research to ensure comparability:

* **Water:** Number of particles m-3 ; Number of particles l-1which quantifies number of plastic particles in water by volume is recommended for standardized monitoring strategies in the Chesapeake Bay and watershed. This unit of measurement potentially accounts for particles throughout the water column, including those at the surface.
* **Sediment:** The number of particles in sediment should be measured volumetrically since organisms exist in a three-dimensional environment within the sediment. The exception to this would be to assess abundances of microplastics on the sediment surface as this region is exploited by a variety of deposit-feeding polychaetes, bivalves, crustaceans, and benthic fish.
* **Organism:** The mass of particles per individual is a general measurement that does not discriminate between organ or tissue as site of accumulation and accounts for an organism’s total exposure to microplastics. This measurement may serve as an informative tool for monitoring the prevalence of microplastic accumulation in organisms. This approach has advantages from a toxicology/risk standpoint.
* **SAV:** Measuring microplastics within SAV beds mostly depends on the research objectives. The most common measurement would assess the area covered on blades of plants. Goss et al. (2018) reported # particles blade -1 which provides insight to loadings. However, area covered by microplastic particles is more biologically relevant because a) area of microplastics will block the surface of blades from sunlight, and b) larger particles can potentially be consumed by grazers, therefore area estimates can serve as a proxy for mass (as recommended above). One exception to this recommendation is in the case of studies that are comparing SAV bed metrics (e.g. canopy capture of microplastics) to similar conditions elsewhere, which would entail measuring # particles unit volume-1.
* **Shoreline:** Quantifying plastics debris on shorelines will depend on the research, policy, or monitoring objective of interest. Options may include number or mass of particles per unit volume or area of shoreline substrate, or number of items per unit length of shoreline.

# Data Gaps

The ecological effects of microplastics on living resources in Chesapeake Bay are relatively unknown. Much of this uncertainty arises from a lack of observational and experimental data on the types, sources, and fates of microplastics in the ecosystem. With few exceptions, a lack of studies on the size-distribution and associated contaminant characteristics of microplastics in Chesapeake Bay is another important knowledge gap that hinders our understanding of the toxicological effects of microplastics in Chesapeake Bay. In some instances, ecological data on individual species are either absent, incomplete, or dated, contributing to the uncertainty surrounding potential exposure to microplastics for these populations. For example, spatial, temporal, and ontogenetic patterns in diet, habitat use, and movements can all influence the relative exposure of individuals to microplastics in the environment. Highlighted below are several key data gaps facing the implementation of a robust microplastics ERA for the resident life-stages of Striped Bass in the Potomac River.

Ecological niche: There is an incomplete understanding of the diet of juvenile and resident sub-adult Striped Bass in the Potomac River. Previously published studies of young-of-the-year Striped Bass diet from the Potomac (e.g., Beaven and Mihursky 1980, Boynton et al. 1981) provide useful insight into ontogenetic and spatial patterns in diet. Specific to juvenile diet, results from the Boynton et al. (1981) study and those from other systems suggest this life-stage is highly opportunistic and suggests local prey availability will have a strong effect on local diet composition. It also suggests that any ecosystem-scale changes in the availability of prey in recent decades is likely to alter the realized diet of juvenile Striped Bass. Further, there is very little information available on diet of yearling and age-2 Striped Bass in the Potomac River although data from the adjacent mainstem of Chesapeake Bay suggests these age-classes are also quite opportunistic in their prey choice (Ihde et al. 2015). This generalist feeding behavior underscores the need for a contemporary and robust spatiotemporal assessment of resident Striped Bass diet composition along the Potomac River estuary in order to accurately quantify the trophic niche, and by extension the potential for trophic transfer of microplastics, of Striped Bass in this system.

Microplastics in the Potomac River food web: In order to link Striped Bass feeding to microplastics exposure, an understanding of in situ microplastics contamination in key trophic resources is needed. Previous studies have identified microplastics associated with basal trophic resources such as macrophytes and associated epiphytes, benthic organic matter, and suspended particulate organic matter (Table 1). While not intentionally consumed by Striped Bass, these basal resources represent sources of microplastics at the base of the Potomac River food web. Direct trophic transfer of microplastics from prey to fish consumers has been verified in numerous laboratory studies and recent evidence suggests that the trophic transfer of microplastics can be more important than passive uptake through non-trophic mechanisms in some situations (e.g., Hasegawa et al. 2021). Therefore, empirical measurements of microplastics loadings in dominant prey taxa are needed in order to track routes of microplastics exposure through trophic transfers to Potomac River Striped Bass.

A broad range of prey have been identified for Striped Bass in the Potomac River (Table 1). These prey all represent potential pathways for microplastics exposure for Striped Bass; however, those prey that contribute most to diet are considered the most critical data gaps regarding trophic exposure to microplastics. During exogenous feeding larval stages, spanning yolk-sac to post-finfold stages, *Bosmina longirostris* (Cladocera), *Eurytemora affinis* (Copepoda), and unidentified cyclopoid copepods were the dominant prey identified in a study by Mihursky and Beaven (1980). Young-of-the-year juveniles and resident subadults feed heavily on *Neomysis americana* (Mysida), polychaetes, and amphipods. Piscivory increases during this period, with Bay Anchovy (*Anchoa mitchilli*) and Atlantic Menhaden (*Brevoortia tyrannus*) contributing substantially to diets as well. These prey represent the most important knowledge gaps in our understanding of the potential for trophic transfer of microplastics to resident Striped Bass in the Potomac River.

| **Table 1.** Primary prey taxa, type of study verifying ingestion of microplastics by prey, and critical prey status (Juvenile/resident sub-adult Striped Bass: 1 = low priority, 2 = moderate priority, 3 = high priority; Lx = larval-stage Striped Bass with values matching the juvenile priority levels). Table modified from Tables 2-4 of the Preliminary Conceptual Model for an Ecological Risk Assessment for Microplastics on Striped Bass in the Potomac River Estuary). | | |
| --- | --- | --- |
| **Major Taxa** | **Type of study** | **Critical Prey status** |
| Habitat | | |
| Macrophytes | Field |  |
| Epiphytes | Field |  |
| Benthic organic matter | Field |  |
| Phytoplankton | Laboratory |  |
| Invertebrate Prey | | |
| Insects | Field | 2 |
| Crustacean larvae | Laboratory | 1 |
| Cladocerans | Laboratory | 2 |
| *Bosmina longirostris* |  | L3 |
| Copepods | Laboratory; Field | 2 |
| *Acartia tonsa* |  | L1 |
| Cyclopoid |  | L3 |
| *Eurytemora affinis* |  | L3 |
| Amphipods | Laboratory | 3 |
| Mysids | Laboratory | 3 |
| Polychaetes | Laboratory; Field | 3 |
| Blue crab | Field | 1 |
| Crustacea (other) | Field | 1 |
| Mollusks | Laboratory | 1 |
| Fish | | |
| Bay anchovy | Field | 2 |
| Atlantic menhaden | Field | 2 |
| Fish larvae | Laboratory; Field | 2 |

Field studies that verify the presence of microplastics in the stomachs and guts of Striped Bass and their dominant prey should be considered the highest priority data gaps needed to be addressed through field studies. In order to be most effective, field collections should span the range of life-stages of resident Striped Bass and the habitats occupied by these life-stages throughout the year. Establishing spatiotemporal ‘hotspots’ of microplastics contamination of prey taxa would provide the information needed for resolving potential exposure of Striped Bass through trophic transfer.

Individual and population-level effects: Laboratory studies on the toxicological effects of microplastics on Striped Bass (and other Bay species) are needed to place the exposure of Striped Bass into a risk context. Studies of acute and chronic exposure of different types and concentrations of microplastics are necessary to determine individual-level effects on Striped Bass. Endpoints that span ecological (e.g., slower growth, smaller size at age) and behavioral consequences, as well as more traditional morbidity and mortality estimates need to be established although care should be taken when extrapolating laboratory studies to field conditions. Population-level effects of microplastics exposure, such as changes in natural mortality rates, are difficult to test but represent key data gaps that are ultimately of greatest potential benefit to natural resource managers seeking to model the effect of microplastics on Potomac River Striped Bass population dynamics

# Monitoring Strategy

The 2019 STAC workshop (Murphy et al. 2019) participants identified microplastic monitoring throughout the Chesapeake Bay watershed as a primary need for several reasons. At present, the Bay community recognizes that baseline data showing the abundance and distribution of microplastic occurrence baywide is data poor (although, see (Yonkos et al. 2014, Bikker et al. 2020b), while only few studies have focused on tributaries or very localized assessments (Murphy 2020). For the management community, understanding baseline conditions of distribution and composition of microplastics will serve as a starting point for policy development and implementation. The monitoring strategy outlined here represents a starting point for this effort, although it is understood that monitoring programs may evolve as more data is collected, understanding of the conditions change, or resources to conduct such a program fluctuate. Members of the PPAT offered multiple ideas and endpoints that would be useful for both the scientific understanding and the data needs for managers.

***Framework***

The Chesapeake Bay Program, in partnership with the member states and Washington, DC, federal agencies, and several academic institutions, maintains a water quality monitoring program that assesses current status of potential pollutants (e.g, nutrients), harmful algal blooms, sediment loads, dissolved oxygen, and numerous biological indicators. Because the nature of existing monitoring programs includes probable pathways or sinks for microplastics, working within the existing monitoring framework would be the most effective approach. In addition, as many PPAT members have indicated, the CBP is the logical home for driving multi-jurisdictional programs that address the shared resources of the watershed. Not only should a robust monitoring effort be addressed by CBP, it is also would serve (as it currently does) as a repository for microplastic monitoring data that would available for analyses and potentially for policy development. Similar to previous bay agreements that set goals to be met, microplastic data collection can be a goal in itself, i.e. having a spatially explicit map of microplastic distribution within 5 years of monitoring commencement.

***Water quality***

PPAT members frequently noted that monitoring the waters of the Chesapeake watershed is a top priority. This will address specific questions, including source identification (point source and non-point source), hotspots and ‘hot moments’ (temporal events associated with high concentrations), and polymer type within the water column. It was also noted that water monitoring include the non-tidal portions of the watershed as this will aid in identifying sources and potential impacts on living resources not addressed in the initial ecological risk assessment model. Given the numerous monitoring stations around the bay and tributaries, spatial resolution of suspended microplastics can be better understood following this network. This may also assist with refining existing models on microplastic movement within the estuary.

***Benthos***

The CBPO currently supports a long-term benthic monitoring program of the tidal portion of the Chesapeake Bay and tributaries. Benthos monitoring is designed to give comprehensive spatial and temporal information on benthic conditions in the Bay and tributaries and includes taking a sample of sediment to be analyzed for organismal composition and sediment characteristics. This is an ideal sampling design whereby microplastic occurrence and quantity can potentially be quantified within the existing program. This data would provide excellent spatial information and be critical for identifying hotspots and sinks.

***Fish***

The ERA conceptual model development for Striped Bass in the Potomac River identified major data gaps in the understanding of microplastic ingestion and trophic transfer in finfish (as noted elsewhere in this document). Most fish monitoring programs run by the states focus on population estimates, biodiversity, spatial distributions, stock assessments, and long-term changes in fish community structure. A subset of programs (e.g. VIMS’ ChesMMAP) collects biological data on fish populations that include trophic information (stomach content analyses). Within the framework of existing programs, these collections might be exploited to garner microplastic ingestion data across the tidal portion of the Chesapeake Bay.

***Non-Tidal***

Sampling in the non-tidal portions of the watershed is critical to understanding the sources and loadings of microplastics reaching the estuary. Several ongoing programs throughout the states actively collect water samples in streams and rivers which could theoretically be used for microplastic analyses. However, most preferred methods for sampling streams for microplastics include deployment of nets so the number of particles captured can be related to volume. Although not noted under fish above, several jurisdictions routinely sample non-tidal streams to assess fish and macroinvertebrate populations (e.g. Maryland Biological Stream Survey—MBSS). It could be feasible to include subsampling of fish and stream benthos for microplastic accumulation via these programs.

**Methodology**

Over the past decade, the science of microplastic collection, separation, and analysis has improved dramatically and has become more standardized in an effort to allow results from multiple studies to be compared equitably. NOAA and EPA have published microplastic extraction methodology documents suitable for fish, water, sediments, and other media. Furthermore, the recent PPAT report (*Standardization of Terminology Recommendations for Microplastic Ecological Risk Assessments in the Chesapeake Bay and its Watershed*) was developed for application to the development of monitoring programs. The terminology document goes into detail about optimal and (ecologically) relevant measurement units for various locations and habitat types and we emphasize their utilization as a monitoring program is developed. Lastly, a looming bottleneck is the availability of analytical techniques to determine polymer composition of plastic particles, or whether any given particle is indeed a plastic polymer. Laboratory spectroscopic analysis of a multitude of samples can increase the price of a monitoring program significantly, so it is a valuable exercise to consider when and where this data is most relevant and useful. For further discussion on monitoring methods, see the previous section Sampling & Analytical Methods.

# Current and Potential Future Management Actions

Many plastic particles are already found in the environment and range from undegraded macroplastics, primary microplastics that were intentionally created as small pieces, and secondary microplastics (and smaller) that have been degraded by natural processes. The study of their effects is ongoing. Reduction of potential ecological exposure can be achieved by control measures that address sources and pathways to local waterbodies.

Addressing the source of plastics is one method to control their abundance in the environment, and these measures can occur through national or local legislative actions. For example

* Microbead-Free Waters Act of 2015 was passed by congress in December 2015 and prohibits the manufacture, packaging, and distribution of over the counter products including cosmetics, medicines, and toothpaste that contain plastic microbeads ([The Microbead-Free Waters Act: FAQs | FDA](https://www.fda.gov/cosmetics/cosmetics-laws-regulations/microbead-free-waters-act-faqs)).
* The Anacostia River Clean Up and Protection Act of 2009 in Washington DC requires all businesses selling food or alcohol to charge a five cent fee if a disposable bag is provided with any purchase ([Anacostia River Clean Up and Protection Act of 2009 | ddoe (dc.gov)](https://doee.dc.gov/publication/anacostia-river-clean-and-protection-act-2009). The goal of this act is to reduce plastic waste in the Anacostia and other local water ways, and the fee is distributed to the Anacostia River Clean Up and Protection Fund, which provides education along with trash capture and stream restoration projects.
* Other counties or municipalities in Maryland including Mongomery County, Howard County, Baltimore City, Takoma Park, Chestertown, and Westminster also have legislation that limits usage of plastic bags.
* In January 2016, Washington DC enacted a Foam Ban that banned the use of disposable polystyrene food or beverage containers ([Foam Free DC | ddoe](https://doee.dc.gov/foam)). The act was amended in 2021 to include an additional ban of retail sale of foam food service ware, foam storage containers like coolers and ice chests, and loose-fill packing materials such as packing peanuts. The purpose of the act was to control the source of foam and plastic items that are wind blown or carried by storm water to rivers and streams. DOEE reports that since the Foam Ban was enacted in 2016, less foam trash has entered Nash Run, a tributary of the Anacostia. Specifically, foam trash dropped from 15% to 7% in 2016. Additionally, only 3% of trash consisted of foam in 2020, while 10 years earlier, up to 24% of captured trash was foam.
* On July 1, 2020, Prince George’s County, Maryland, banned straws and stirrers that are not reusable or meet home compostable standards. This ban applies to food service and retail businesses from providing or selling these items ([Plastic Straw Ban | Prince George's County, MD](https://www.princegeorgescountymd.gov/3524/Plastic-Straw-Ban)).
* The State of Maryland is considering a bill that would ban plastic bags statewide by 2022.
* Virginia State Code 29.1-556.1 bans the release of 50 or more balloons within a one hour period if they are made of “a nonbiodegradable or nonphotodegradable material or any material which requires more than five minutes' contact with air or water to degrade.” ([§ 29.1-556.1. Release of certain balloons prohibited; civil penalty (virginia.gov)](https://law.lis.virginia.gov/vacode/title29.1/chapter5/section29.1-556.1/)
* Executive Order No. 77- Virginia Leading by Example to Reduce Plastic Pollution and Solid Waste calls for the cessation of use of plastic bags, single use foam food containers, plastic straws and cutlery, and plastic bottles by the Virginia State Government. In addition, purchase and use of single use plastics and foam containers is being phased out with a goal of 25% reduction in 2022 and 100% by 2025.

Controlling the pathways that link trash to waterbodies is another method for reducing plastic in aquatic ecosystems. For example:

* Skimmer boats on the Anacostia river remove floating plastic trash.
* Street Sweeping programs target high-trash urban areas.
* Clean teams program in Washington DC collects plastic, recyclables, and other trash from public spaces and gutters to prevent it from washing into storm drains or streams.
* Trash traps, including one on Nash Run—a tributary of the Anacostia River, remove trash runoff from urban areas before entering larger waterways, such as the Anacostia River.

Future efforts to reduce the source of environmental plastics could follow the examples provided above, with similar efforts expanding to other cities, municipalities, and states. Bans on single use plastic in retail and food service sectors show promise for reducing the load of trash that is a parent material for some environmentally bound microplastics. Also, polymers like synthetic fibers from clothing materials are prevalent in wastewater or effluent, which may serve as another source of microplastics. Improved fabric technologies and upgrades to wastewater treatment facilities may be necessary to further address this potential point-source. Because of the vast and variable nature of microplastics, additional sources may eventually be correlated with specific industries, processes, products, or activities. Additionally, very little is currently known regarding fate and transport of microplastics in the Potomac River and larger Chesapeake Bay although ongoing hydrodynamic modelling efforts appear well-suited to begin addressing this knowledge gap. Management decisions should be informed by the most up-to-date science in order to ensure that policies and laws target those materials that are most likely to result in environmental and ecological degradation.

# Partnerships and Resources

As noted earlier, the scope of plastic pollution is only growing, with annual increases in plastic production and the ubiquity plastic pollution in all parts of the Bay. Microplastic persistence in the environment is a fact that managers must contend with, in addition to all other anthropogenic stressors currently being addressed. And these efforts must be undertaken with constrained resources and available technology.

The Chesapeake Bay watershed is fortunate in that it is home to the seat of the federal government in Washington, DC. This allows lawmakers to easily experience firsthand the issues surrounding Bay pollution and restoration efforts. The 2019 STAC workshop brought together experts from the Bay states in addition to federal representatives from NOAA (Marine Debris Program), US EPA, and USGS. Each of these federal agencies is actively involved in conducting or funding research into basic science of understanding aspects of microplastics in the environment. These funding sources are crucial to leveraging state and municipal resources to study microplastic distribution; this is particularly important within the existing monitoring framework, to which microplastic monitoring may be added. The watershed is also home to a range of academic institutions, consulting companies, and non-government organizations that have the technical resources to address many of the issues outlined in this document. These groups also have relationships with private foundation funding sources that are keen to support research into emerging contaminants. Adequate funding resources, in addition to technical capabilities (e.g. specialized instrumentation) will allow the CBP and its partners to address microplastic pollution on the same scale it did in the 1970s and 80s with regard to eutrophication. We must understand the current (baseline) conditions, better understand linkages to living resources (e.g. as described for Striped Bass), understand source, fate, and transport through robust modeling (ongoing), and answer the critical questions management needs to effect sound, defensible policy.

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