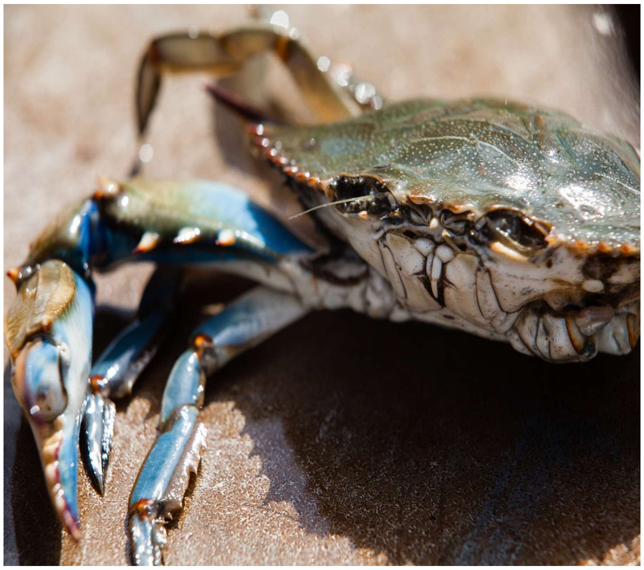
Potential Linkages between Microplastics and 2014 Chesapeake Bay Watershed Agreement Outcomes



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August 1, 2022

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Introduction

Ecological risk of microplastics to wildlife is an ongoing area of research and the Plastic Pollution Action Team (PPAT) recommends that future research should focus on trophic linkages, mortality rates, and other biological effects of microplastics on Chesapeake Bay wildlife. Furthermore, microplastic pollution has the potential to adversely affect efforts at meeting goals and outcomes outlined in the 2014 Chesapeake Bay Agreement. Here we present potential impacts, some speculative and without data to support it, to outcomes for the Agreement.

Abundant Life

1. Sustainable Fisheries Goal

1.1. Blue Crab Abundance Outcome

Maintain a sustainable blue crab population based on a target of 196 million adult females. Refine population targets through 2025 based on best available science.

1.1.1. Microplastic Impacts and Opportunities

Microplastic ingestion in larval and juvenile blue crabs may result in loss of fitness, subjecting them to a potential increase in predation (Cohen 2020). In adult blue crabs, microplastic consumption may cause acute or sub-acute physiological effects, resulting in increased mortality which may have population-level impacts. Additionally, microplastics are known to adsorb and leach chemical pollutants and potentially toxic elements (e.g., PAHs, PCBs) that could result in negative physiological and neurological effects in blue crabs (Hartmann et al. 2017; Wright et al. 2013). Microplastic pollution may make efforts to maintain a sustainable blue crab population more difficult.

1.2. Blue Crab Management Outcome

Manage for a stable and productive crab fishery including working with the industry and other stakeholders to improve commercial and recreational harvest accountability. By 2018, evaluate the establishment of a Bay-wide, allocation-based management framework with annual levels set by the jurisdictions for the purpose of accounting for an adjusting harvest by each jurisdiction.

1.2.1. Microplastic Impacts and Opportunities

As noted above, setting management goals for a stable and productive crab fishery may include mortality estimates related to microplastics.

1.3. Fish Habitat Outcome

Continually improve effectiveness of fish habitat conservation and restoration efforts by characterizing critical spawning, nursery, and forage areas within the Bay and tributaries for important fish and shellfish and use existing and new tools to integrate information and conduct assessments to inform restoration and conservation efforts.

1.3.1. Microplastic Impacts and Opportunities

Microplastics accumulate on shorelines, wetlands, and on plant leaves in submerged aquatic vegetation (SAV) beds (Goss et al. 2018, Murphy 2019, Townsend et al. 2019, Jones et al. 2020) increasing the potential rate of exposure and uptake of microplastics by larval, juvenile, and adult fish and shellfish. Uptake of microplastics by fish and shellfish could result in direct physical damage and potential toxicity effects (due to the adsorption and leaching of chemical pollutants by microplastics) (Wright et al. 2013). Microplastic accumulation in these areas may impact the efficacy of fish habitat conservation and restoration efforts.

1.4. Forage Fish Outcome

Continually improve the Partnership's capacity to understand the role of forage fish populations in the Chesapeake Bay. By 2016, develop a strategy for assessing the forage fish base available as food for predatory species in the Chesapeake Bay.

1.4.1. Microplastic Impacts and Opportunities

Uptake of microplastics by forage fish could result in direct physical harm and potential toxicity effects (due to the adsorption and leaching of chemical pollutants by microplastics) including potential loss of overall fitness and subjecting them to potential increase in predation (Wright et al. 2013). Trophic transfer is recognized as a major mechanism of microplastic exposure – predators could be impacted by the ingestion of microplastics by forage fish (Nelms et al. 2018). 2018). Additionally, toxicity effects could include the transfer and accumulation of chemical pollutants and contaminants in different tissues of forage fish, possibly undergoing biomagnification along the food chain (GESAMP 2015).

1.5. Oysters Outcome

Continually increase finfish and shellfish habitat and water quality benefits from restored oyster populations. Restore native oyster habitat and populations in 10 tributaries by 2025 and ensure their protection.

1.5.1. Microplastic Impacts and Opportunities

Uptake of microplastics by oysters could result in direct physical harm and potential toxicity effects (due to the adsorption and leaching of chemical pollutants by microplastics), including potential loss of overall fitness (Knauss 2021). Trophic transfer is recognized as a major mechanism of microplastic exposure – predators could be impacted by the ingestion of microplastics by oysters (Nelms et al. 2018). Additionally, toxicity effects could include the transfer and accumulation of chemical pollutants and contaminants in different tissues of oysters, possibly undergoing biomagnification along the food chain (GESAMP 2015). The effects of microplastics on oysters may make native oyster population restoration more difficult.

2. Vital Habitats Goal

2.1. Black Duck Outcome

By 2025, restore, enhance, and preserve wetland habitats that support a wintering population of black 100,000 ducks, a species representative of the health of tidal marshes across the watershed. Refine population targets through 2025 based on best available science.

2.1.1. Microplastic Impacts and Opportunities

Black ducks use tidal wetlands of the Chesapeake Bay for habitat – the seeds, bay grasses, aquatic plants, and small invertebrates of which make up their diet. Microplastics that accumulate within small invertebrates, on shorelines, wetlands, and on plant leaves in submerged aquatic vegetation (SAV) beds increase the potential rate of exposure and ingestion of microplastics by black ducks (Reynolds and Ryan 2018). Ingestion of microplastics could result in direct physical damage and potential toxicity effects (due to the adsorption and leaching of chemical pollutants by microplastics) in black duck populations (Wright et al. 2013). Additionally, research shows that microplastic pollution can negatively affect the growth of wetland plants (e.g., reduction in weight, height, and chlorophyll b synthesis) (Yu et al. 2018), potentially reducing food quality and availability for black ducks and habitat restoration and preservation efforts difficult.

2.2. Brook Trout Outcome

Restore and sustain naturally reproducing brook trout populations in Chesapeake Bay headwater streams, with an eight percent increase in occupied habitat by 2025.

2.2.1. Microplastic Impacts and Opportunities

While there are fewer data on impacts of microplastics in freshwater bodies, particularly on freshwater fish, Sanchez et al. (2014) confirmed that "continental fish" do ingest microplastics (Sanchez et al. 2014); additionally, microplastics have been found in brown trout (O'Connor et al. 2020). Microplastic ingestion in larval and juvenile brook trout may result in loss of fitness due to potential toxicity effects (adsorption and leaching of chemical pollutants by microplastics) and direct physical damage. These impacts could subject brook trout populations to increased predation, potentially making attaining the Brook Trout Outcome more difficult.

2.3. Fish Passage Outcome

Continually increase access to habitat to support sustainable migratory fish populations in the Chesapeake Bay watershed's freshwater rivers and streams. By 2025, restore historical fish migration routes by opening an additional 132 miles every two years to fish passage. Restoration success will be indicated by the consistent presence of alewife, blueback herring, American shad, hickory shad, American eel, and brook trout, to be monitored in accordance with available agency resources and collaboratively developed methods.

2.3.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Fish Passage Outcome.

2.4. Forest Buffers Outcome

Continually increase the capacity of forest buffers to provide water quality and habitat benefits throughout the Chesapeake Bay watershed. Restore 900 miles of riparian forest buffers per year and conserve existing buffers until at least 70 percent of riparian areas in the watershed are forested.

2.4.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Forest Buffers Outcome.

2.5. Stream Health Outcome

Continually improve stream health and function throughout the watershed. Improve health and function of ten percent of stream miles above the 2008 baseline for the watershed.

2.5.1. Microplastic Impacts and Opportunities

A study by the Federal Institute of Hydrology and Goethe University in Germany found microplastics in freshwater streams in amounts high enough to potentially, pending further investigation, consider them plastic pollution sinks (Wagner et al. 2014). Exposure of benthic stream organisms to microplastics (Ehlers et al. 2019) may result in loss of fitness due to potential toxicity effects (adsorption and leaching of chemical pollutants by microplastics) and direct physical damage (Wright et al. 2013). Changes in benthic organism fitness may impact overall stream health and function, potentially making achieving this outcome more difficult.

2.6. Submerged Aquatic Vegetation (SAV) Outcome

Sustain and increase the habitat benefits of submerged aquatic vegetation (SAV) in the Chesapeake Bay. Achieve and sustain the ultimate outcome of 185,000 acres of SAV Bay-wide necessary for a restored Bay. Progress toward this ultimate outcome will be measured against a target of 90,000 acres by 2017 and 130,000 acres by 2025.

2.6.1. Microplastic Impacts and Opportunities

Recent studies by Murphy (2019, 2020) have confirmed the presence of microplastics in Chesapeake Bay SAV beds. Often accumulating on the leaves of SAV, microplastic presence increases the potential rate of exposure and ingestion by the wildlife including fish, shellfish, and ducks that use this important habitat for food and refuge. Ingestion of microplastics could result in direct physical damage and potential toxicity effects (due to the adsorption and leaching of chemical pollutants by microplastics) in wildlife populations (Wright et al. 2013). Additionally, recent studies found that large numbers of microplastics accumulate on SAV, which can block the surface of vegetation from sunlight, inhibiting growth (Goss et al. 2018, Jones et al. 2020). These impacts could affect efforts to sustain and increase the habitat benefits of SAV in the Chesapeake Bay.

2.7. Tree Canopy Outcome

Continually increase urban tree canopy capacity to provide for air quality, water quality, and habitat benefits throughout the watershed. Expand urban tree canopy by 2,400 acres by 2025.

2.7.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on Tree Canopy Outcome.

2.8. Wetlands Outcome

Continually increase the capacity of wetlands to provide water quality and habitat benefits throughout the watershed. Create or reestablish 85,000 acres of tidal and non-tidal wetlands and enhance function of an additional 150,00 acres of degraded wetlands by 2025. These activities may occur in any land use (including urban), but primarily occur in agricultural or natural landscapes.

2.8.1. Microplastic Impacts and Opportunities

Vegetated wetlands are likely to act as microplastic sinks which appear to cause a reduction in wetland vegetation density. (Helcoski et al. 2020, Rasta et al. 2020) The presence of microplastics in wetlands increases the likelihood of ingestion by the wildlife that use such wetlands for food and refuge. Ingestion of microplastics could result in direct physical damage and potential toxicity effects (due to the adsorption and leaching of chemical pollutants by microplastics) in wildlife populations (Wright et al. 2013). Additionally, there is evidence that microplastic accumulation in wetlands may disturb nitrogen removal capacity (Seeley et al. 2020, Yang et al. 2020), may change the germination strategies of seeds, reduce weight, height, and chlorophyll b synthesis in wetland plants, and may negatively alter the structure of soil microbial communities (Yu et al. 2021). Together, these microplastic impacts may hinder efforts to increase the capacity of wetlands to provide water quality and habitat benefits throughout the watershed.

Clean Water

3. Water Quality Goal

3.1. 2017 Watershed Implementation Plans (WIPs) Outcome

By 2017, have practices and controls in place that are expected to achieve 60 percent of the nutrient and sediment load reductions necessary to achieve applicable water quality standards compared to 2009 levels.

3.1.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on 2017 Watershed Implementation Plans (WIPs) Outcome.

3.2. 2025 Watershed Implementation Plans (WIPs) Outcome

By 2025, have all practices and controls in place to achieve applicable water quality (i.e., dissolved oxygen, water clarity/submerged aquatic vegetation and chlorophyll a) standards as articulated in the Chesapeake Bay Total Maximum Daily Load.

3.2.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the 2025 Watershed Implementation Plans (WIPs) Outcome.

3.3. Water Quality Standards Attainment and Monitoring Outcome

Continually improve the capacity to monitor and assess the effects of management actions being undertaken to implement the Chesapeake Bay Total Maximum Daily Load (TMDL) and improve water quality. Use monitoring results to report annually to the public on progress made in attaining established Bay water-quality standards and trends in reducing nutrients and sediment in the watershed.

3.3.1. Microplastic Impacts and Opportunities

Seeley et al. (2020) demonstrated that microplastics disrupt the nitrogen cycle in estuarine sediments, the effects of which may impact nitrogen dynamics throughout the estuary. These impacts may hinder efforts to improve the capacity to monitor and assess the effects of TMDL related management actions.

4. Toxic Contaminants Goal

4.1. Toxic Contaminants Research Outcome

Continually increase our understanding of the impacts and mitigation options for toxic contaminants. Develop a research agenda and further characterize the occurrence, concentrations, sources, and effects of mercury, polychlorinated biphenyls (PCBs), and other contaminants of emerging and widespread concern. In addition, identify which best management practices might provide multiple benefits of reducing nutrients and sediment pollution as well as toxic contaminants in waterways.

4.1.1. Microplastic Impacts and Opportunities

Microplastics leach chemical additives and contaminants (including PCBs and polycyclic aromatic hydrocarbons [PAHs]) absorbed on their surfaces into the surrounding environment, potentially harming aquatic systems (GESAMP 2015, Hartmann et al. 2017). Human pathogens (including *Vibrio* spp.) have also been found to colonize microplastics in the Chesapeake Bay (Kirstein et al. 2016). These pollutants may transfer and accumulate in different tissues of organisms, possibly undergoing biomagnification along the food chain. This process could not only affect marine species but could make the consumption of contaminated seafood a possible route for human exposure to microplastics and potentially toxic contaminants (GESAMP 2015). Additional research on microplastic adsorption of toxic contaminants in the Chesapeake Bay could aid efforts to identify BMPs that could reduce toxic contaminants in waterways.

4.2. Toxic Contaminants Policy and Prevention Outcome

Continually improve practices and controls that reduce and prevent the effects of toxic contaminants below levels that harm aquatic systems and humans. Build on existing programs to reduce the amount and effects of polychlorinated biphenyls (PCBs) in the Bay and watershed. Use research findings to evaluate the implementation of additional policies, programs, and practices for other contaminants that need to be further reduced or eliminated.

4.2.1. Microplastic Impacts and Opportunities

As noted in section 4.1.1, microplastics leach chemical additives and contaminants (including PCBs and polycyclic aromatic hydrocarbons [PAHs]) absorbed on their surfaces into the surrounding environment, potentially harming aquatic systems (Hartmann et al. 2017; GESAMP 2015). Human pathogens (including *Vibrio* spp.) have also been found to colonize microplastics in the Chesapeake Bay (Kirstein et al. 2016). These pollutants may transfer and accumulate in different tissues of organisms, possibly undergoing biomagnification along the food chain. This process could not only affect marine species but could make the consumption of contaminated seafood a possible route for human exposure to microplastics and potentially toxic contaminants (GESAMP 2015). These impacts may hinder efforts to continually improve practices and controls that reduce and prevent the effects of toxic contaminants that harm aquatic systems and humans.

5. Healthy Watersheds Goal

5.1. Healthy Watersheds Outcome

100 percent of state-identified currently healthy waters and watersheds remain healthy.

5.1.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Healthy Watersheds Outcome.

Conserved Lands

6. Land Conservation Goal

6.1. Land Use Methods and Metrics Development Outcome

Continually improve our knowledge of land conversion and the associated impacts throughout the watershed. By December 2021, develop a watershed-wide methodology and local-level metrics for characterizing the rate of farmland, forest, and wetland conversion, measuring the extent and rate of change in impervious surface coverage, and quantifying the potential impacts of land conversion to water quality, healthy watersheds, and communities. Launch a public awareness campaign to share this information with local governments, elected officials, and stakeholders.

6.1.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Land Use Methods and Metrics Development Outcome.

6.2. Land Use Options Evaluation Outcome

By the end of 2017, with the direct involvement of local governments or their representatives, evaluate policy options, incentives, and planning tools that could assist them in continually improving their capacity to reduce the rate of conversion of agricultural lands, forests, and wetlands as well as the rate of changing landscapes from more natural lands that soak up pollutants to those that are paved over, hardscaped, or otherwise impervious. Strategies should be developed for supporting local governments' and others' effort in reducing these rates by 2025 and beyond.

6.2.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Land Use Options Evaluation Outcome.

6.3. Protected Lands Outcome

By 2025, protect an additional two million acres of lands throughout the watershed – currently identified as high-conservation priorities at the federal, state, or local level – including 225,000 acres of wetlands and 695,000 acres of forest land of highest value for maintaining water quality.

6.3.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Protected Lands Outcome.

Engaged Communities

7. Public Access Goal

7.1. Public Access Site Development Outcome

By 2025, add 300 new public access sites, with a strong emphasis on providing opportunities for boating, swimming, and fishing, where feasible.

7.1.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Public Access Site Development Outcome.

8. Environmental Literacy Goal

8.1. Environmental Literacy Planning Outcome

Each participating Bay jurisdiction should develop a comprehensive and systemic approach to environmental literacy for all students in the region that includes policies, practices, and voluntary metrics that support the environmental literacy Goals and Outcomes of this Agreement.

8.1.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Environmental Literacy Planning Outcome. Plastic pollution is considered a contaminant of emerging concern in the Chesapeake Bay watershed (Murphy et al. 2021); environmental literacy goals and outcomes could be amended to include education on the interaction of microplastics with human and environmental health.

8.2. Student Outcome

Continually increase students' age-appropriate understanding of the watershed through participation in teacher-supported meaningful watershed experiences and rigorous, inquiry-based instruction, with a target of at least one meaningful watershed educational experience in elementary, middle, and high school depending on available resources.

8.2.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Student Outcome. Plastic pollution is considered a contaminant of emerging concern in the Chesapeake Bay watershed (Murphy et al. 2021); meaningful watershed educational experiences could be amended to include instruction on the interaction of microplastics with human and environmental health.

8.3. Sustainable Schools Outcome

Continually increase the number of schools in the region that reduce the impact of their buildings and grounds on their local watershed, environment, and human health through best practices, including student-led protection and restoration projects.

8.3.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Sustainable Schools Outcome.

9. Stewardship Goal

9.1. Citizen Stewardship Outcome

Increase the number and diversity of trained and mobilized citizen volunteers who have the knowledge and skills needed to enhance the health of their local watersheds.

9.1.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Citizen Stewardship Outcome, though, efforts to integrate plastic pollution monitoring into established Chesapeake Bay citizen monitoring programs (e.g., Chesapeake Bay SAV Watchers) could potentially support Citizen Stewardship Outcome achievement and future Bay microplastic research efforts.

9.2. Diversity Outcome

Identify stakeholder groups not currently represented in the leadership, decision-making, or implementation of current conservation and restoration activities and create meaningful opportunities and programs to recruit and engage these groups in the Partnership's efforts.

9.2.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Diversity Outcome.

9.3. Local Leadership Outcome

Continually increase the knowledge and capacity of local officials on issues related to water resources and in the implementation of economic and policy incentives that will support local conservation actions.

9.3.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Local Leadership Outcome, but the integration of plastic pollution education into existing training materials for local officials could potentially influence plastic pollution related conservation actions and policy in local jurisdictions.

Climate Change

10. Climate Resiliency Goal

10.1. Climate Adaptation Outcome

Continually peruse, design, and construct restoration and protection projects to enhance the resiliency of Bay and aquatic ecosystems from the impacts of coastal erosion, coastal flooding, more intense and more frequent storms, and sea level rise.

10.1.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Climate Adaptation Outcome.

10.2. Climate Monitoring and Assessment Outcome

Continually monitor and assess the trends and likely impacts of changing climatic and sea level conditions on the Chesapeake Bay ecosystem, including the effectiveness of restoration and protection policies, programs, and projects.

10.2.1. Microplastic Impacts and Opportunities

There are no immediately identifiable microplastic impacts on the Climate Monitoring and Assessment Outcome.

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