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Reducing Microplastics in the Delaware River Estuary

Technical Report No. 2022-1

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Introduction

Plastic is the most prevalent type of marine debris found in our oceans and Great Lakes (NOAA 2016). Plastic debris can come in all shapes and sizes, but those that are less than five millimeters in length (or about the size of a sesame seed) are called microplastics. Plastics in the aquatic environment are of increasing concern because of their persistence and effect on the environment, wildlife, and human health (Baldwin et al., 2016; Browne et al., 2008; Eerkes-Medrano et al., 2015 and Wagner and Lambert, 2017). A recent study in the Susquehanna River found 87.5% of the diet of smallmouth bass showed the presence of a variety of microplastics (Parks et al., 2019).

To date, little is known about microplastics in the upper Delaware estuary and their effects on fish and wildlife. The first step in understanding these potential effects is to understand the distribution and concentration of microplastics within the estuary. Few microplastics studies have been conducted in the Delaware watershed. Projects have been completed in the Delaware Bay (Cohen et al., 2019) and non-tidal Delaware (USGS, 2021), but these studies leave the upper portion of the Delaware estuary (DRBC Water Quality Management Zones 2-5) understudied. This reach of the river is largely urbanized and is likely a major contributor to microplastic loading in the Delaware estuary. Understanding the inputs from major tributaries into the estuary and quantification of microplastics in the river is a vital first step towards understanding the potential problems posed by this contaminant of emerging concern.

Data on microplastic concentrations can be used to target cleanup efforts in high plastic loading watersheds. Cleanups like these have positive benefits on fish and wildlife populations and our waterways in general. On a coarse scale, removing these debris prevents fish and wildlife species from becoming entangled in objects like cords, nets, and beverage containers. On a finer scale, removing these debris before they have a chance to break down in the estuary will prevent microplastics and other harmful chemicals from entering the waterways and public water supplies and help maintain water quality for fish and wildlife.

This project aimed to increase the understanding of the distribution of microplastics in the Delaware estuary through monitoring and modeling and help reduce plastic loading and increase public awareness of the issues associated with microplastics.

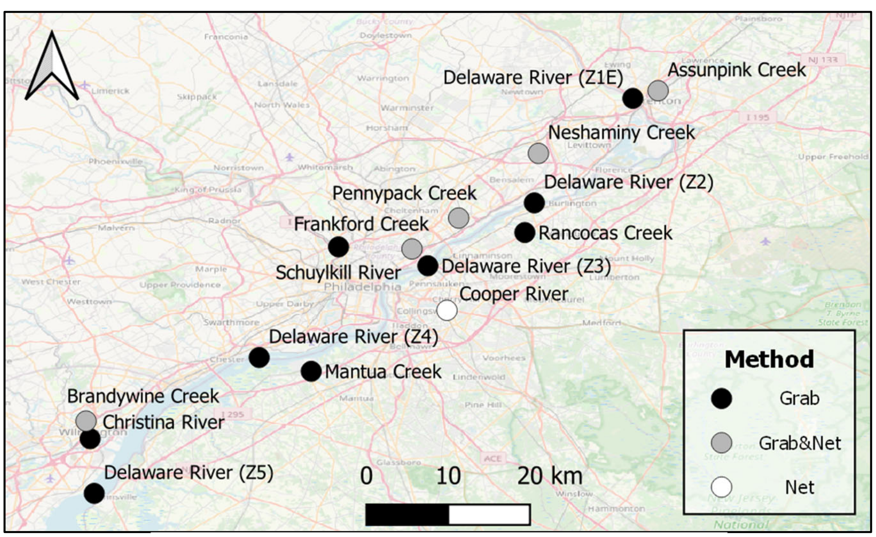

Figure 1. Map of DRBC microplastic sampling locations

Methods

Grab Samples

Ten-liter grab samples were collected at nine tributary locations and five mainstem locations throughout the basin in August 2019 (Figure 1). Flows at the Delaware River at Trenton ranged from 6420 - 6640 cfs and were rising during sampling. Tributary samples and the mainstem Zone 1E (Z1E) samples were collected at bridges directly into amber glass sampling jars using a weighted sampler. Mainstem samples in Zones 2 – 5 (Z2-Z5) were collected via boat in the main channel of the river. A Niskin sampler was used to collect boat samples near surface and near bottom. The Niskin sampler was rinsed between sites to avoid contamination. Deionized (DI)-water blank sample was collected for each of the two methodologies.

Net Samples

In addition to grab samples, net samples were collected over a period of 3 weeks in March 2021 at a subset of stations as a methodological comparison (Figure 1). Flows at the Delaware River at Trenton ranged from 18,500 – 23,700 and were generally declining during sampling. Net samples were collected by deploying two 153-µm, Nylon mesh plankton nets at each site. Nets were anchored to weights and floats were affixed to nets to keep them on the surface (Figure 2). Nets were deployed for approximately 4-5 hrs at each site and stream flow was estimated before and after the deployment to calculate the volume of water that passed through each net. Total volume of water sampled at each site ranged from 600 – 18,000 ft^3. Due to the logistics of the net sampling setup, net samples could only be collected at sites that were wadable and had little tidal influence. A net sample blank was collected by rinsing tap water through the net for several minutes.

Figure 2. DRBC staff member records flow measurements between two microplastic sampling nets at Neshaminy Creek

Lab Analysis

Lab analysis of microplastic samples was completed by Temple University Water and Environmental Technology (WET) Center. The analytical process generally followed procedures outlined in Masura et al. 2015 with some modification. Data collected for each sample included total particle count, particle size, particle shape, particle color, and particle composition via FTIR spectroscopy (Figure 3).

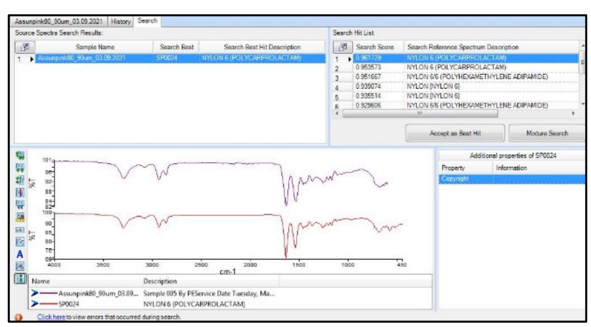

Figure 3. FTIR analysis of sample composition

Modeling

DRBC staff have developed a 3-Dimensional hydrodynamics model for the Delaware Estuary using the USEPA supported Environmental Fluid Dynamics Code (EFDC). The 3-D hydrodynamics model simulates hydrodynamic and transport information (e.g., tides, water depth, current velocity, salinity, water temperature) over a range of hydrologic and meteorologic conditions with the degree of accuracy and confidence needed to support modeling objectives. The model was calibrated and validated based on existing data. In this study, this hydrodynamics model is considered as a tool that can be used to inform and estimate the trajectory of any microplastics being released into the Delaware Estuary.

A conservative tracer simulation was utilized to predict likely areas where microplastics can travel to and accumulate from key tributary sources. Because the density, shape and formulation, and particle size distributions of MP are complex and challenging to interpret in a numerical model, for the purpose of this study, MP was treated as conservative tracer for simplicity. A more accurate approach could be to constrain the transport of MP as "surface-trapped" particles presented by Cohen et al. (2019). Release locations and scenarios are summarized in Table 1.

Table 1. Summary of modeling simulations

No.	Run ID	Release Location	EFDC Cell ID	Flow Condition	Monthly Mean Flow at Trenton
1	EFDC_HYDRO_G72_MP_2021-10-07a	Neshaminy	(31, 199)	May 2019 release	27,300 cfs
2	EFDC_HYDRO_G72_MP_2021-10-08a	Pennypack	(29, 182)		
3	EFDC_HYDRO_G72_MP_2021-10-09a	Frankford	(31, 167)		
4	EFDC_HYDRO_G72_MP_2021-10-10a	Pennsauken	(37, 170)		
5	EFDC_HYDRO_G72_MP_2021-10-11a	Schuylkill	(27, 138)		
6	EFDC_HYDRO_G72_MP_2021-10-12a	Mantua	(36, 131)		
7	EFDC_HYDRO_G72_MP_2021-10-13a	Christina	(30, 90)		
8	EFDC_HYDRO_G72_MP_2021-10-07b	Neshaminy	(31, 199)	October 2019 release	3,510 cfs
9	EFDC_HYDRO_G72_MP_2021-10-08b	Pennypack	(29, 182)		
10	EFDC_HYDRO_G72_MP_2021-10-09b	Frankford	(31, 167)		
11	EFDC_HYDRO_G72_MP_2021-10-10b	Pennsauken	(37, 170)		
12	EFDC_HYDRO_G72_MP_2021-10-11b	Schuylkill	(27, 138)		
13	EFDC_HYDRO_G72_MP_2021-10-12b	Mantua	(36, 131)		
14	EFDC_HYDRO_G72_MP_2021-10-13b	Christina	(30, 90)		

The output of these modeling exercises are series of maps of relative concentrations and animations at a given time interval from individual tributary sources. Not all results are presented in this report, and the results and animations are available if interested.

Results

DRBC has developed an interactive web-app for viewing the results of this study that can be viewed at this link. Users can toggle between grab samples and net samples and click on points to reveal information about each site including plastic size, shape, color, and composition. For additional discussion of the results, see sections below.

Microplastic Concentrations

Microplastic particles were found in each sample. A large discrepancy was seen in plastic concentrations depending on collection method (Figure 4). Grab samples showed higher concentrations of plastics than net samples. Grab sample concentrations ranged from 8.5-250.0 particles/ft^3 with the highest concentrations occurring in Rancocas Creek. Mainstem Delaware River grab samples generally showed mid-high concentrations of microplastics with similar concentrations being found at both surface and bottom collections.

Net samples displayed drastically lower microplastic concentrations than grab samples. Net samples ranged from 0.0021-0.0947 particles/ft^3 with the highest concentrations occurring in the Cooper River. The Cooper River was not sampled by grab sampler, so a direct methodological comparison was not possible at this site.

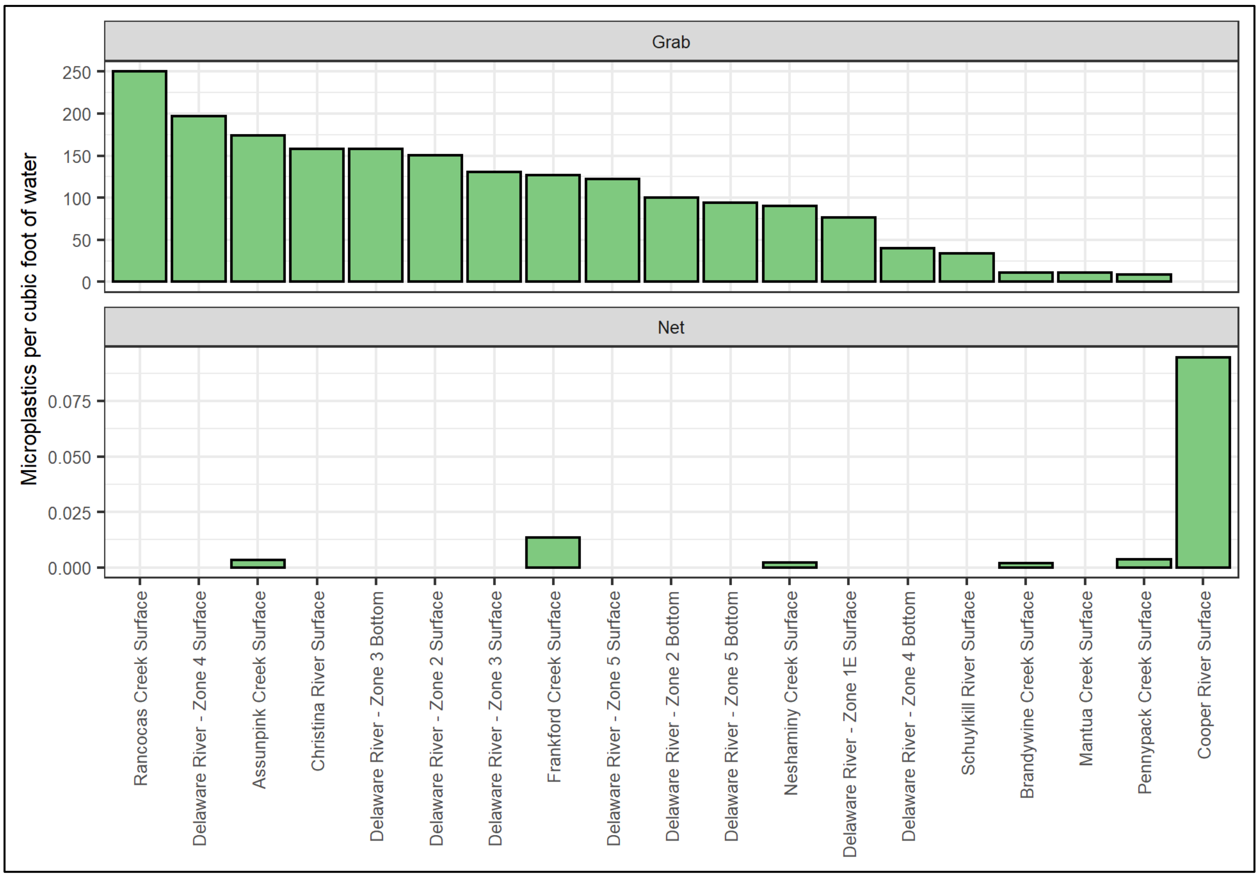

Figure 4. Microplastic concentrations (per ft^3 at sampling locations in the Delaware Estuary and selected tributaries.

Microplastic Shapes

A variety of shapes of plastics were captured during sampling including fibers, fiber bundles, films, fragments, and spheres (Figures 5 and 6). Grab samples were dominated by fibers which comprised 90% of the total particles found in grab samples. Fibers were the most abundant shape at all sites and levels of the water column. Net samples showed a more even distribution of shapes with fragments being the second most abundant behind fibers.

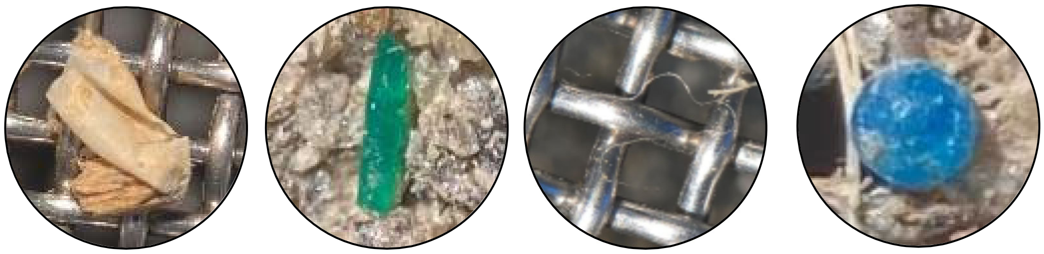

Figure 5. Images of various shapes of microplastic particles found in DRBC samples

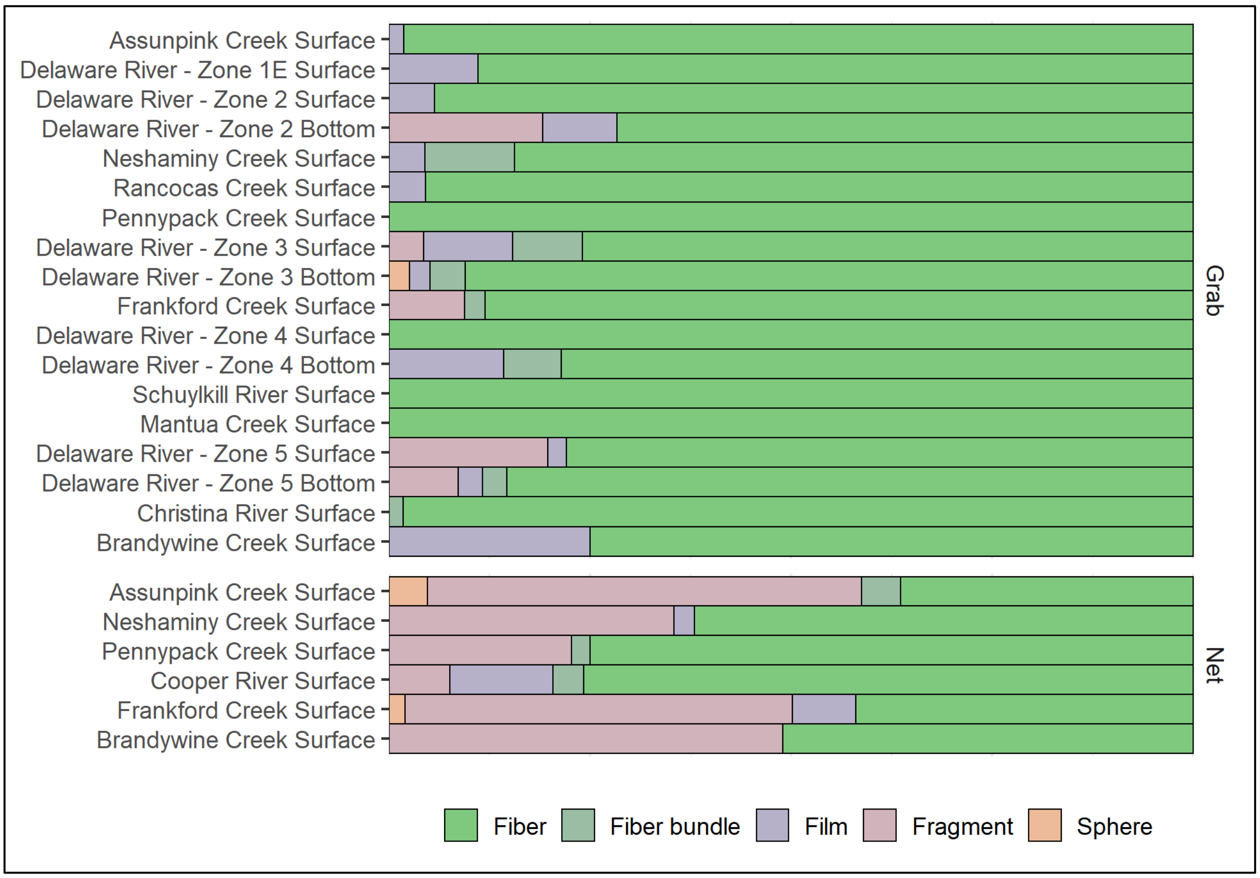

Figure 6. Shapes of microplastics collected at sampling locations in the Delaware Estuary and selected tributaries.

Microplastic Colors

Microplastics were found in a variety of colors in Delaware Estuary samples including clear, pink, purple, red, orange, yellow, green, black, brown, gray, silver, and white (Figures 7 and 8). Grab samples were dominated by clear particles, most of which were fibers. Net samples showed a more even color distribution with many particles being green, blue, red, black, and clear.

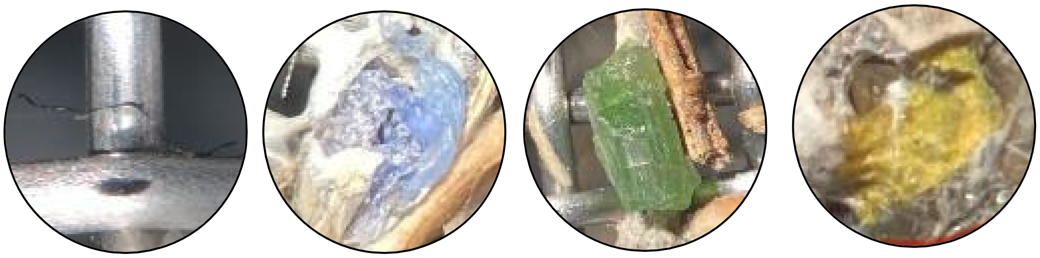

Figure 7. Images of various colors of microplastic particles found in DRBC samples

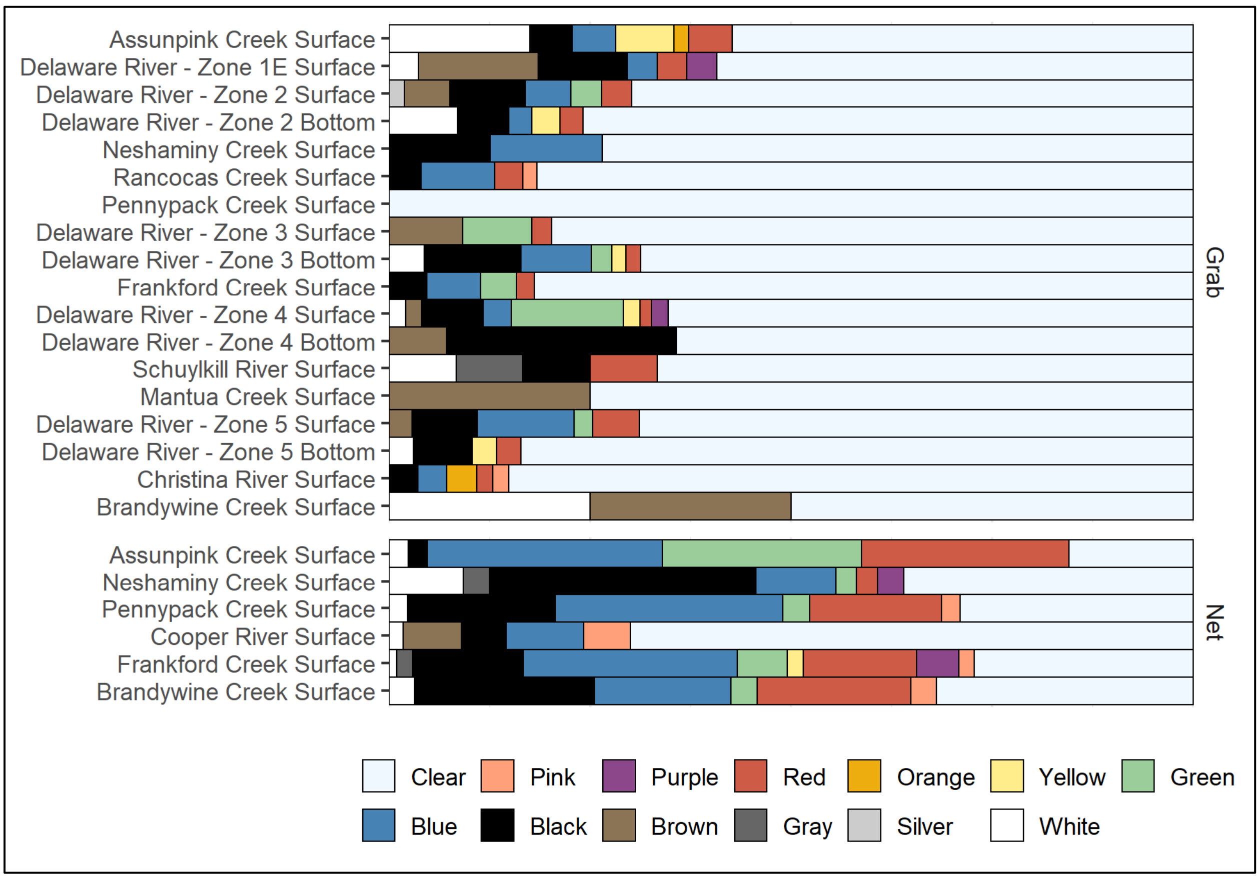

Figure 8. Color of microplastics collected at sampling locations in the Delaware Estuary and selected tributaries.

Microplastic Sizes

Microplastics were found in sizes ranging from 50 µm to 2000 µm (Figure 9). Grab samples generally had smaller particles with 75% of the particles being less than 500 µm. Net samples had larger particles with 53% of the particles being greater than 500 µm. This discrepancy was expected as the 153-µm mesh of the sampling net would allow smaller particles to pass through. Additionally, the samples were dominated by fibers, which may have also been able to pass through the mesh of the net.

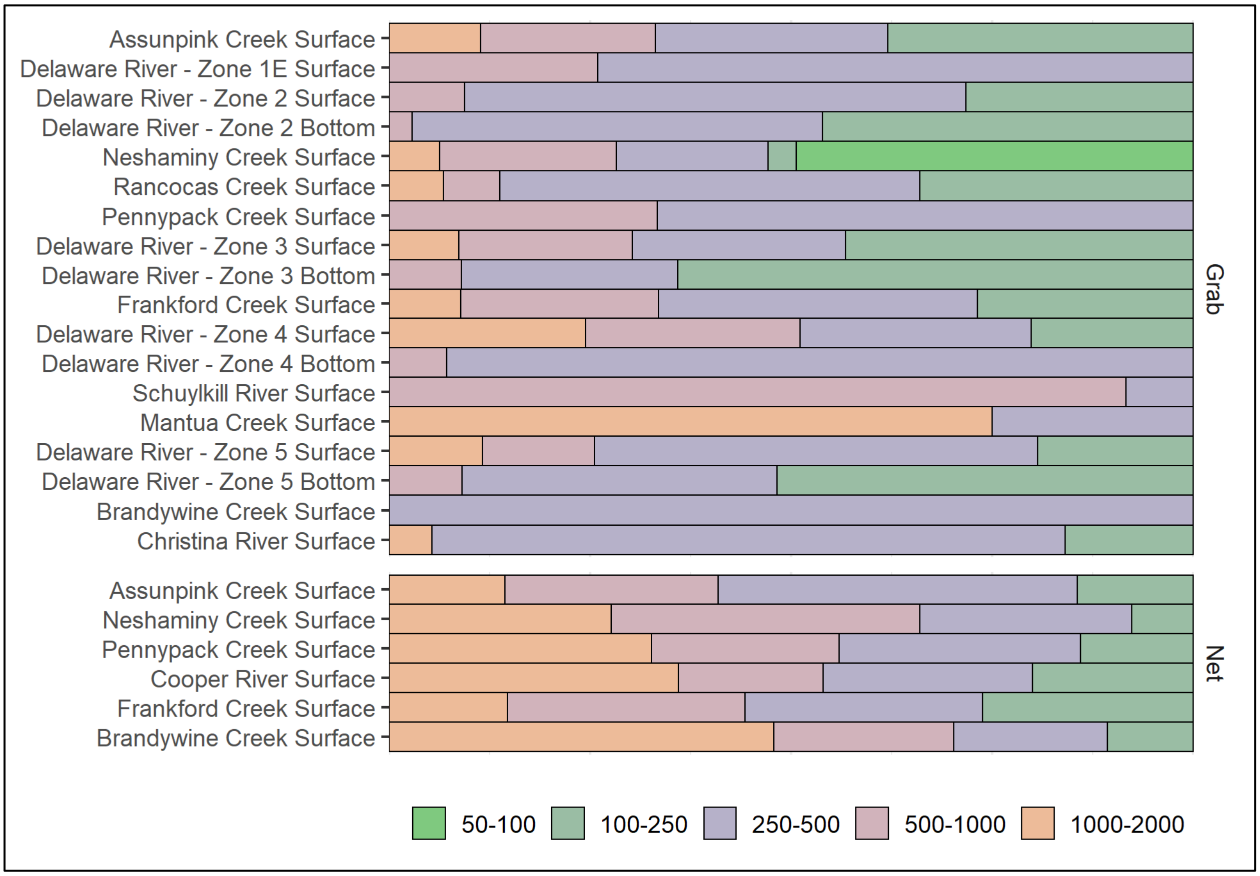

Figure 9. Size (µm) of microplastics collected at sampling locations in the Delaware Estuary and selected tributaries.

Microplastic Composition

Samples were composed of a variety of types of plastics. Polyester, Rayon, and man-made cellulosic fibers were the most common types seen in samples. Most sites contained a variety of plastics. Microplastic composition was similar between both net and grab sampling methods however a higher proportion of polyethylene particles were seen in the net samples (Figure 10).

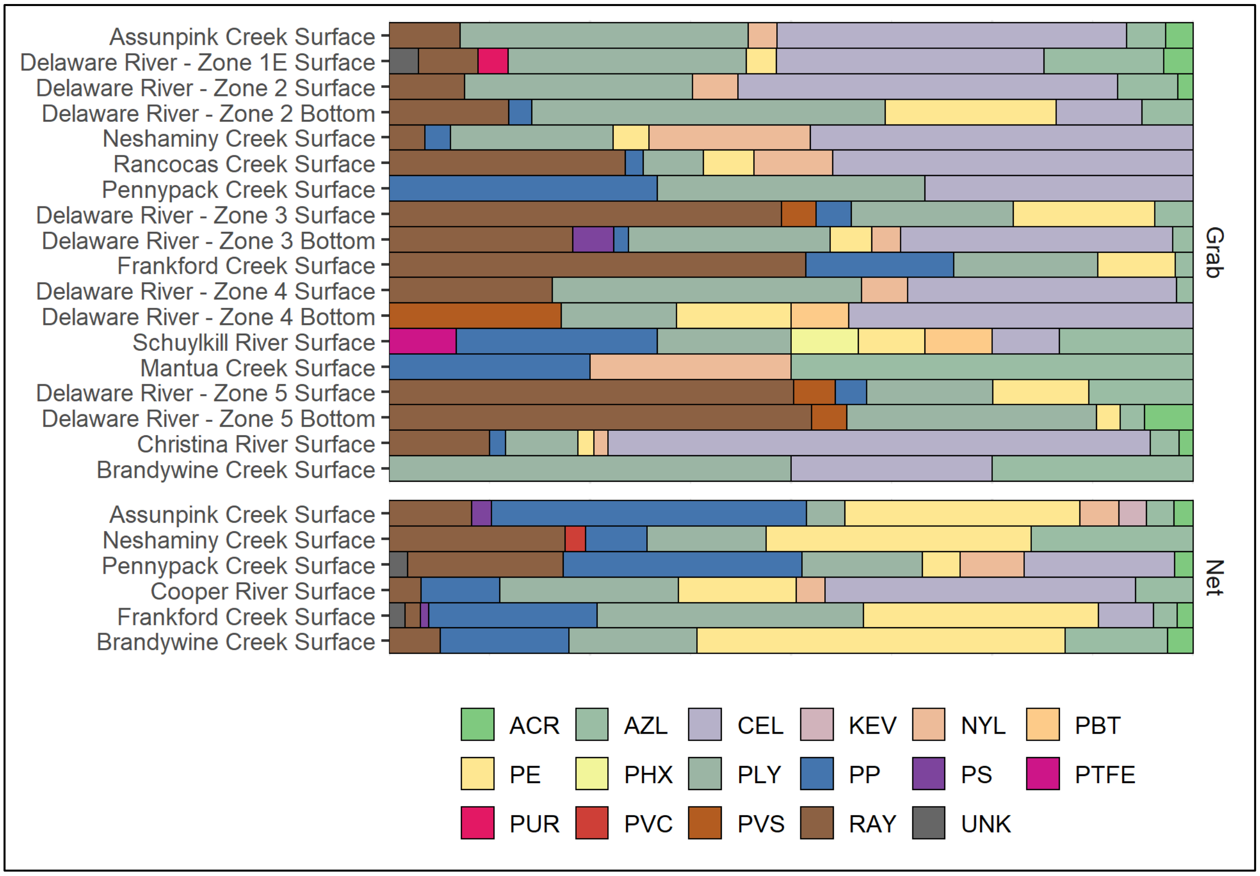

Figure 10. Composition of microplastics collected at sampling locations in the Delaware Estuary and selected tributaries. ACR = Acrylic, AZL = Azlon, CEL = Cellulosic, KEV = Kevlar, NYL = Nylon, PBT = Polybutylene Terephthalate, PE = Polyethylene, PHX = Polyhexamethylene, PLY = Polyester, PP = Polypropylene, PS = Polystyrene, PTFE = Polytetrafluoroethylene, PUR = Polyurethane, PVC = Polyvinyl Chloride, PVS = Polyvinyl Stearate, RAY = Rayon, UNK = Unknown.

Blank Analysis

Plastic particles were found in all blanks (Figure 11). Concentrations of microplastics in blanks were 33.98 particles per ft^3 in the bridge sampler and 42.07 particles per ft^3 in the Niskin sampler. Twenty-five plastic particles were found in the net blank as well although a concentration could not be calculated because the volume of water used to rinse the net was not available. While the exact volume is unknown, the volume of water used to rinse the nets was likely at least an order of magnitude larger than the 10L grab sample blank. Therefore concentrations in the net blank were likely much lower than in the grab blanks, similar to what was witnessed in the field samples. Most particles found in blanks were clear, Rayon fibers. This is suggestive of possible cross-contamination of samples from clothing or other sources. Other potential source of blank contamination were plastic components that were integral to the sampling design (DI water tank/system, Niskin bottle, tap water used to rinse net).

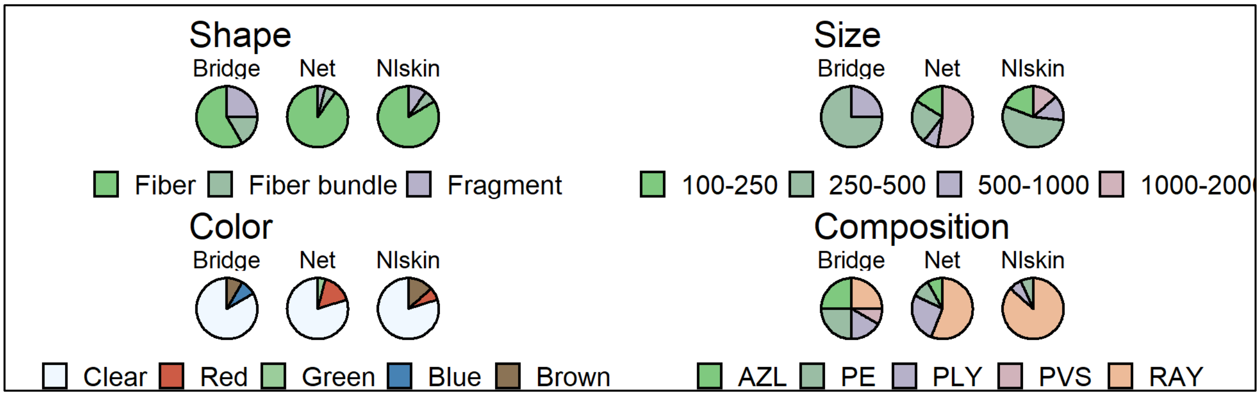

Figure 11. Shape, size, color, and composition of plastic particles found in blanks

Microplastic Modeling

In this study, quasi-instantaneous plastic release was simulated by mass release of 1 metric tons of conservative tracer over 24-hour period (Figure 12). The model results from 1 day and 5 days after the release under high-flow and low-flow conditions are presented in Appendix 1. Majority of the MP was transported in the system in the surface and near-surface layers, and simulated concentrations in the surface layer are higher. For given scenario simulation, simulated MP concentration at the water surface was normalized by the maximum concentration at the release location and presented as percent of the maximum concentration to inform the trajectories, the relative concentration pattern, and footprint extent of MP being release into the Delaware Estuary within a certain time window following the release (here a five-day window was used).

The logarithmic color scale was used, and red-to-pink color range presents a relative concentration equal to or greater than 0.1 percent of the maximum concentration being observed in the simulation at the release location. These simulations indicate a rapid dilution occurred during a very short period and concentration dropped by 2 to 4 orders of magnitudes near the release location. Despite a rapid dilution, MP concentration remained relatively noticeable (higher than 0.1 percent) for quite a long time (could be 10 to 20 days) depending on flow conditions. Under high flow condition, the concentration diluted much faster, and a faster travel time and larger footprint of MP were predicted. The simulation also showed some level of lateral variations, the MP plume tends to be moving along the west bank (or east bank) if it was being released from west bank (or east bank) in the vicinity of the release site.

Further study of the MP transport in the estuary may consider the MP as moving parcels with its own buoyancy and may also allow it to be landed to the riverbank or being trapped in the Estuary Turbidity Maximum (ETM) zone and settled to the sediment bed. More comprehensive study on MP transport with an enhanced modeling tool may be necessary in the future.

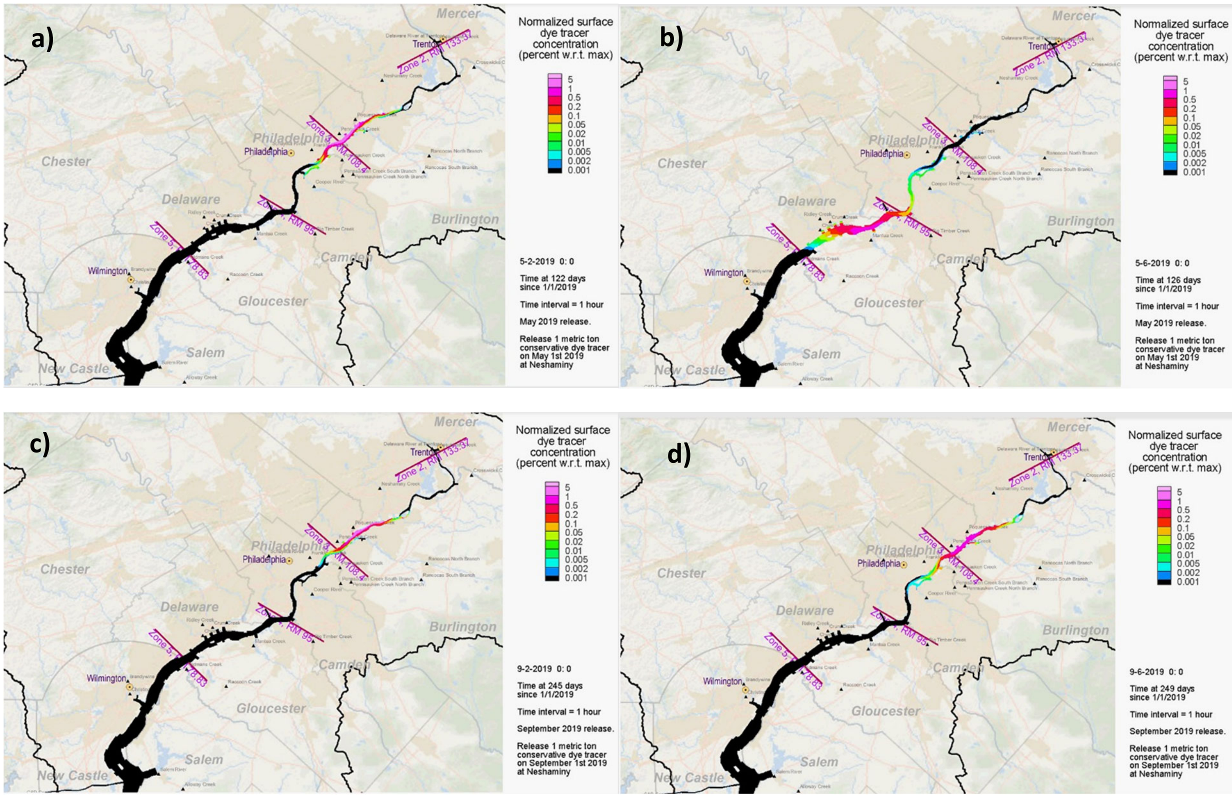

Figure 12. Modeled release at Neshaminy Creek at (a) high-flow, 1 day after; (b) high-flow, 5 days after; (c) low-flow, 1 day after; (d) low-flow, 5 days after

Plastic Cleanup Efforts

Due to timing constraints caused by the COVID-19 pandemic, microplastics cleanup efforts needed to be scheduled prior to the completion of sample analysis. Two sites were selected that were suspected to contain high levels of plastic pollution: Tookany/Tacony-Frankford (TTF) Creek and the mainstem Delaware River at Palmyra Cove. On October 13th, 2021, 12 DRBC staff members and several members of the general public met at the Rorer Street Gateway to Tacony Creek Park for a plastic cleanup event in cooperation with the TTF Watershed Partnership (Figure 13a). Approximately 20 contractor bags of trash along with several larger items were removed from the riparian area along Frankford creek during this event (Figure 13b). On October 27th, 2021, 13 DRBC staff members met at Palmyra Cove at the base of the Tacony-Palmyra Bridge for a second cleanup event in cooperation with Palmyra Cove Nature Center (Figure 13c,d). During this event, approximately 25-30 contractor bags of trash were removed from the riparian area along the tidal Delaware River. DRBC aquatic biologist Jake Bransky spoke to the groups at both events about the topic of microplastics in the Delaware River Basin.

Figure 13. Photographs of DRBC microplastic cleanup efforts: a) DRBC staff educate volunteers at TTF cleanup event, b) trash removed from riparian area along TTF creek, c) debris found along tidal Delaware River at Palmyra Cove, d) DRBC staff collecting trash at Palmyra Cove.

Discussion

Microplastics were prevalent at all locations and were found with all collection methods. We saw a large difference in concentrations between the grab and net methodologies. Grab samples displayed much higher concentrations than net samples. This discrepancy could have been driven by a variety of factors. First, the net methods sampled a much larger volume of water than the grab methods and likely allowed a portion of the smaller particles to pass through. Additionally, differences in flow regimes during the two sampling periods could have driven differences in microplastic concentrations. Flows during the grab sampling period in August 2019 were lower than flows during the net sampling period in March 2021 (Figure 14). On the surface, these flow patterns seem be contradictory to the patterns seen in plastic concentrations, however a closer look at the direction of the flow change (i.e., rising vs falling) may shed some insight on the discrepancies seen in plastic concentrations. Net samples, which had lower plastic concentrations, were collected on falling or stable hydrographs. Grab samples, which had higher plastic concentrations, happened to be collected on rising hydrographs. These spikes in flow, while not large in magnitude, could have been caused by summer storms which may have introduced pulses of plastic into the system via runoff.

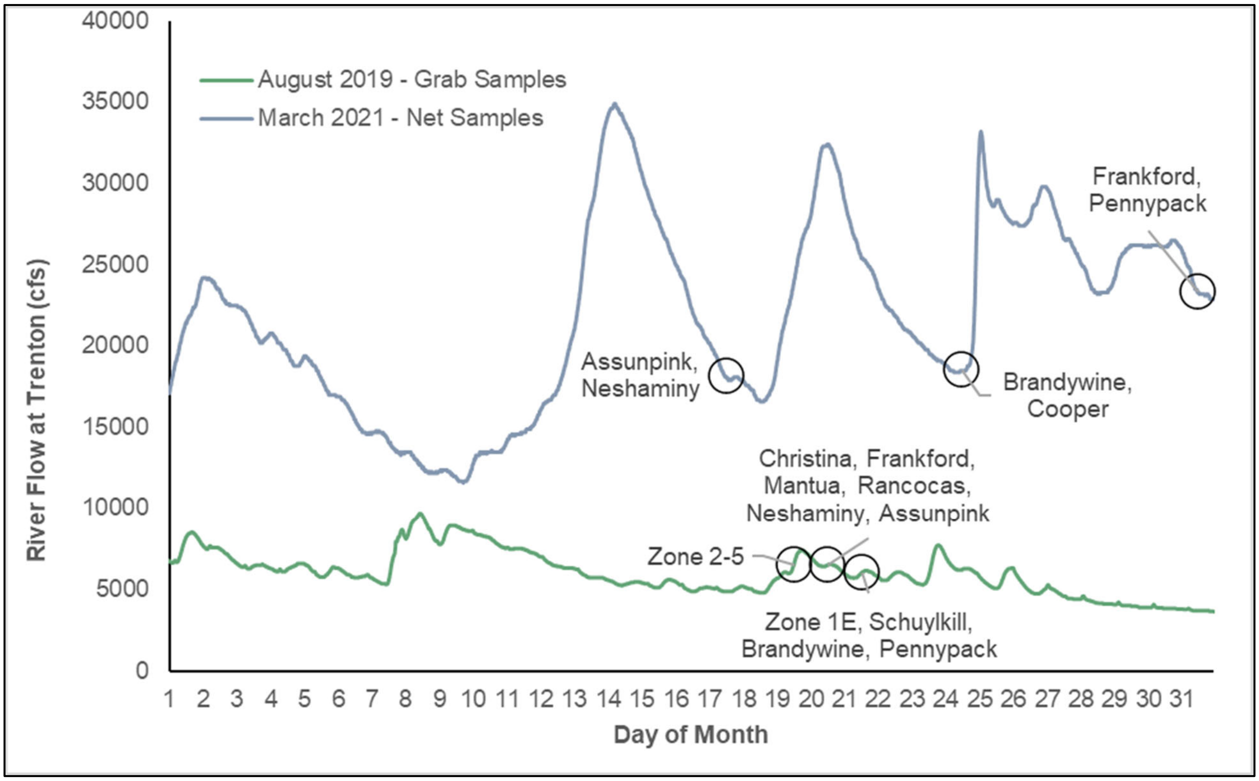

Figure 14. River flow at Trenton during microplastic sampling in August 2019 and March 2021. Lines represent river flows and circles represent when samples were collected.

While microplastics were found in all grab and net samples, they were also found in all blank samples. Concentrations of microplastics in blanks were comparable to some of the lower-end concentrations seen in field samples. High numbers of fibers (often commonly used materials in clothing like Rayon or Polyester) were found in the samples which suggests a possibility of contamination from human clothing during sampling or analysis. However, it is difficult to disentangle the source of these particles. For future studies, it will be important to understand these potential sources of cross contamination.

This study contributes valuable information about microplastics in the upper Delaware Estuary. However, even with this study and several others completed in the basin, the effects of microplastics are still understudied. It is feared that microplastics could have a negative impact on fish and wildlife populations as well as drinking water (Baldwin et al. 2016; Browne et al. 2008; Eerkes-Medrano et al. 2015 and Wagner and Lambert 2017). The Delaware estuary is an important habitat for many threatened and endangered species, as well as a source of drinking water for millions, so it is paramount that we develop a better understanding of microplastics in the watershed and begin efforts to reduce their levels. As research continues, data from a project like this will be useful. The findings from this study could lay the groundwork for future studies to help understand the effects of microplastics on the health of the Delaware estuary ecosystem.

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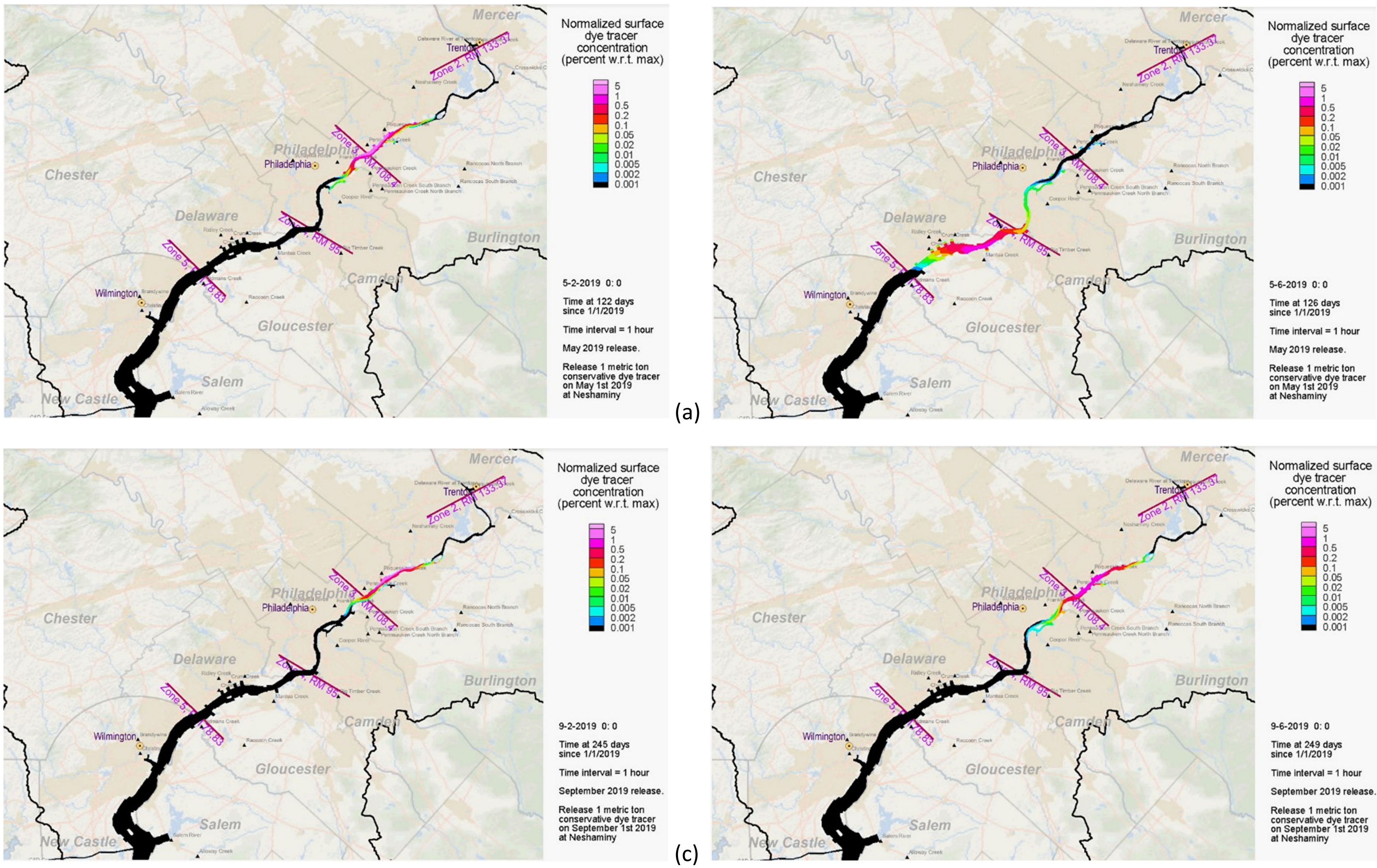
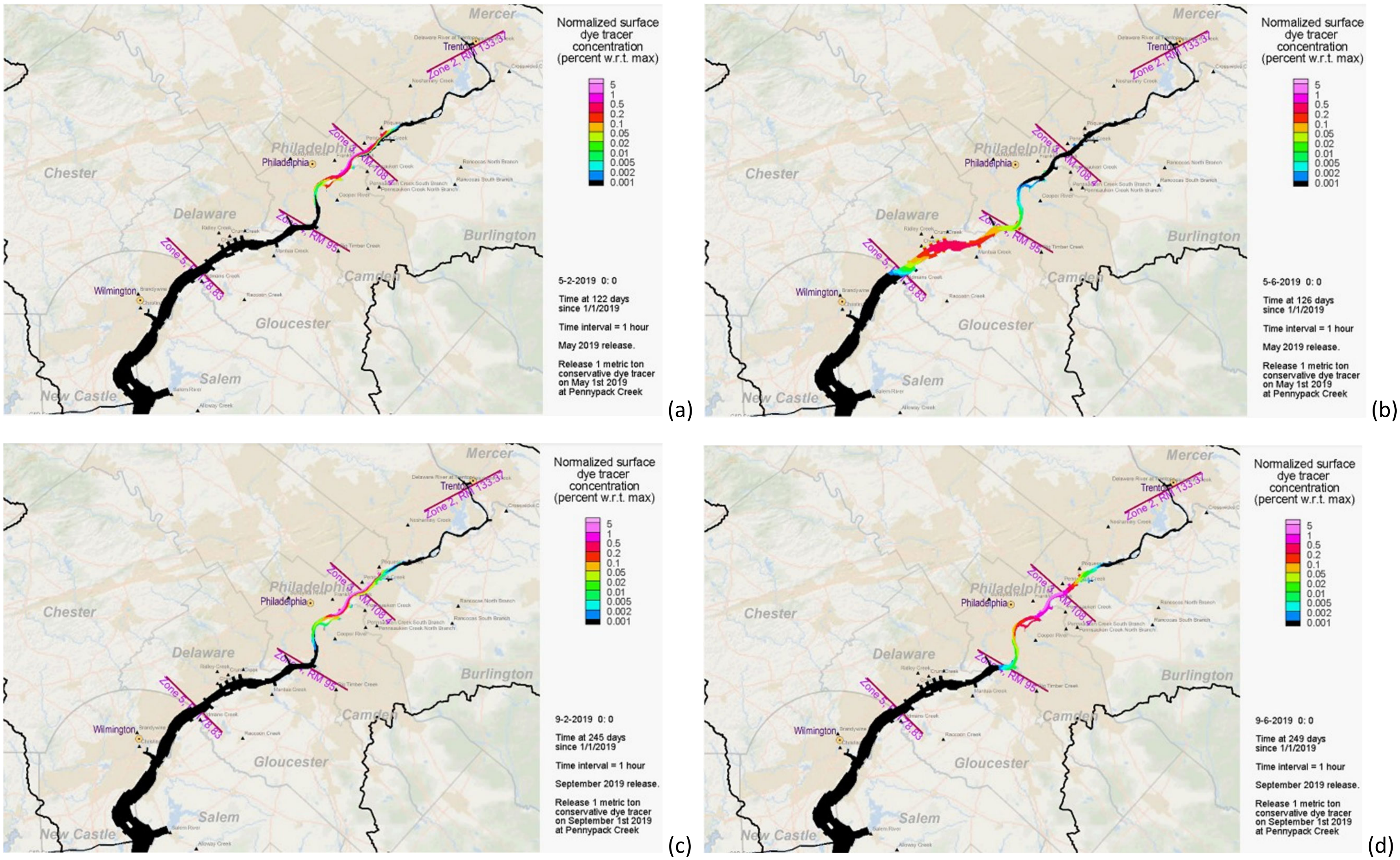
Appendix 1. Modeling Results

***Neshaminy Creek Release** (a) high-flow, 1 day after release; (b) high-flow, 5 days after release; (c) low-flow, 1 day after release; (d) low-flow, 5 days after release*

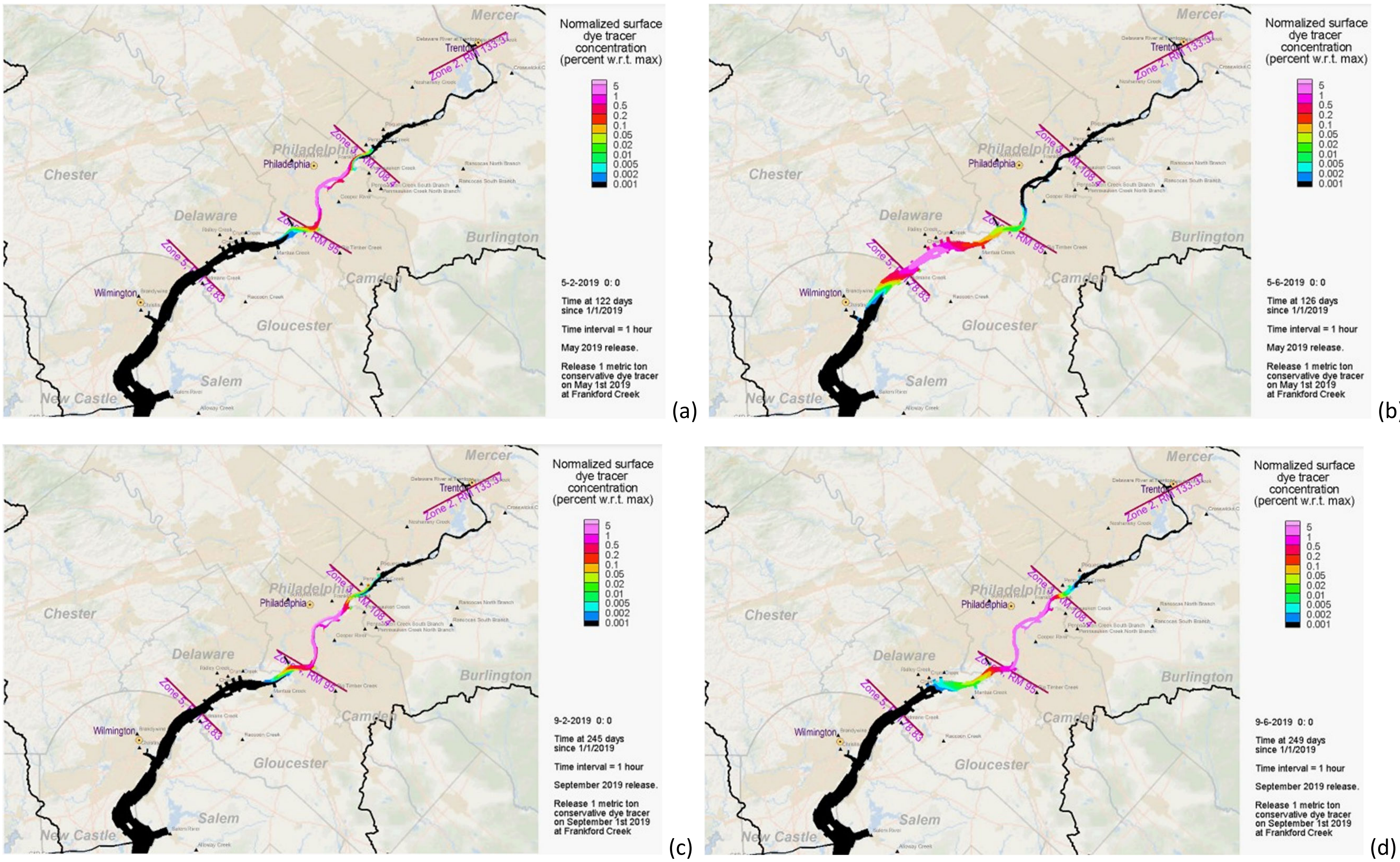


(a) (b) (c) (d)

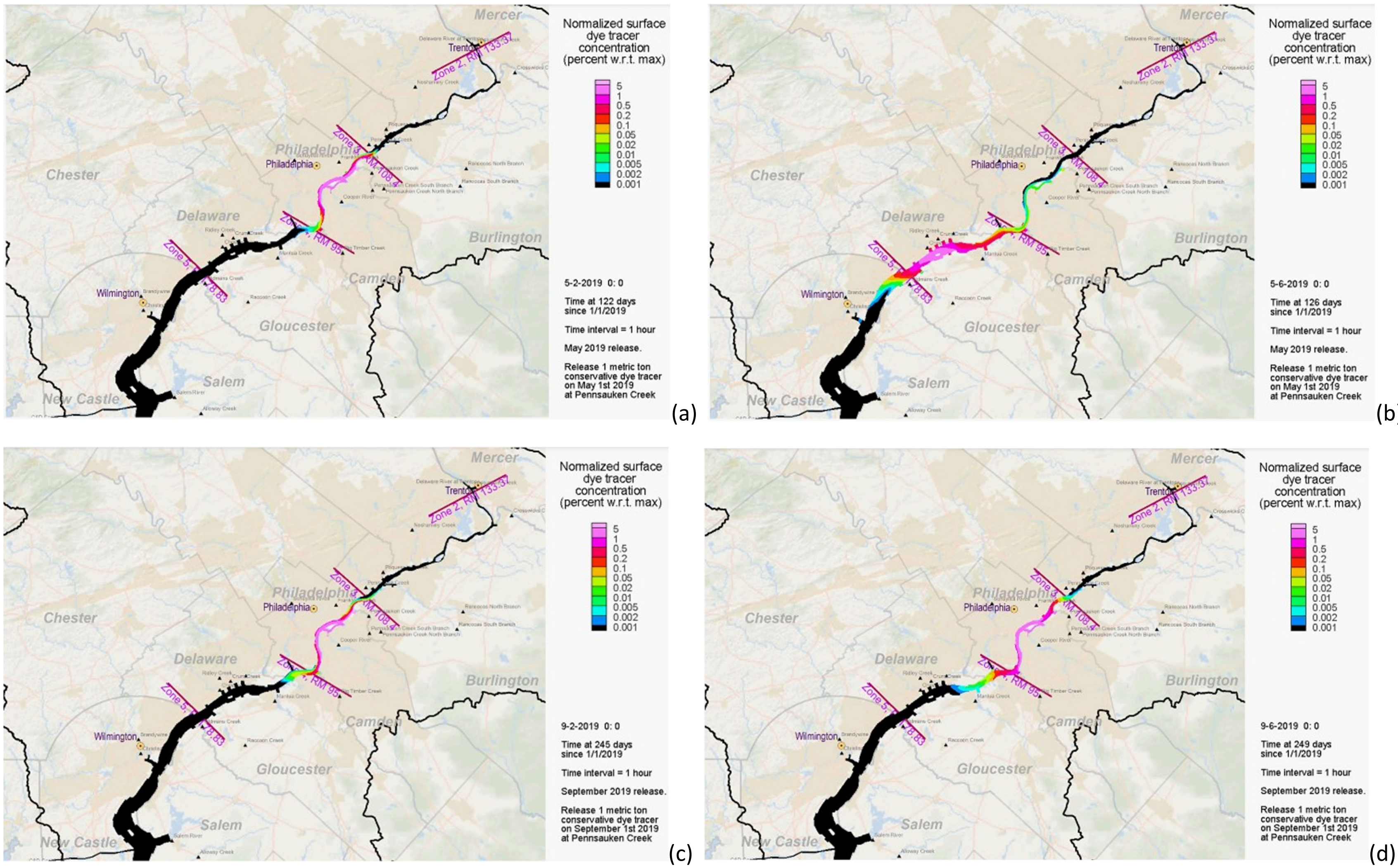
Pennypack Creek Release *(a) high-flow, 1 day after release; (b) high-flow, 5 days after release; (c) low-flow, 1 day after release; (d) low-flow, 5 days after release*



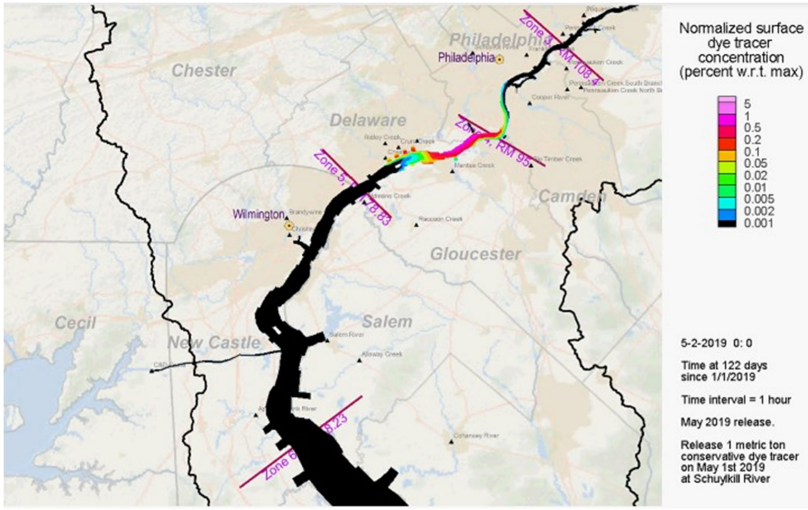
Frankford Creek Release *(a) high-flow, 1 day after release; (b) high-flow, 5 days after release; (c) low-flow, 1 day after release; (d) low-flow, 5 days after release*



Pennsauken Creek Release *(a) high-flow, 1 day after release; (b) high-flow, 5 days after release; (c) low-flow, 1 day after release; (d) low-flow, 5 days after release*



Schuylkill River Release *(a) high-flow, 1 day after release; (b) high-flow, 5 days after release; (c) low-flow, 1 day after release; (d) low-flow, 5 days after release*



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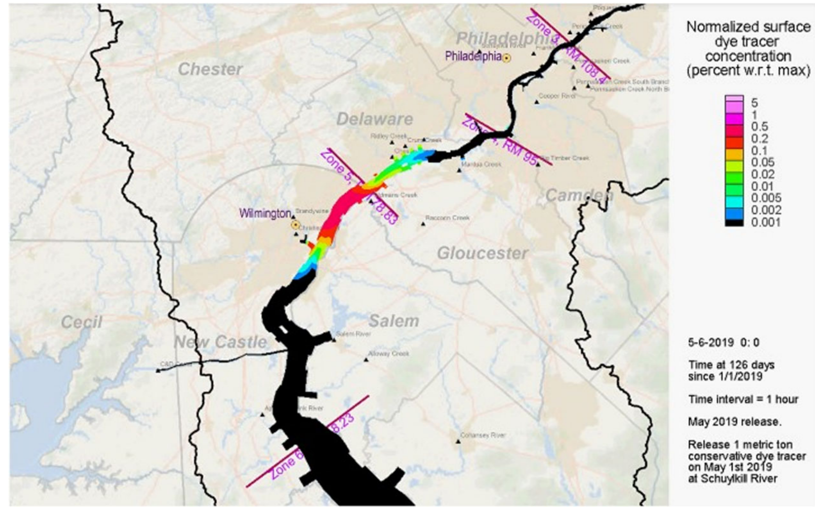

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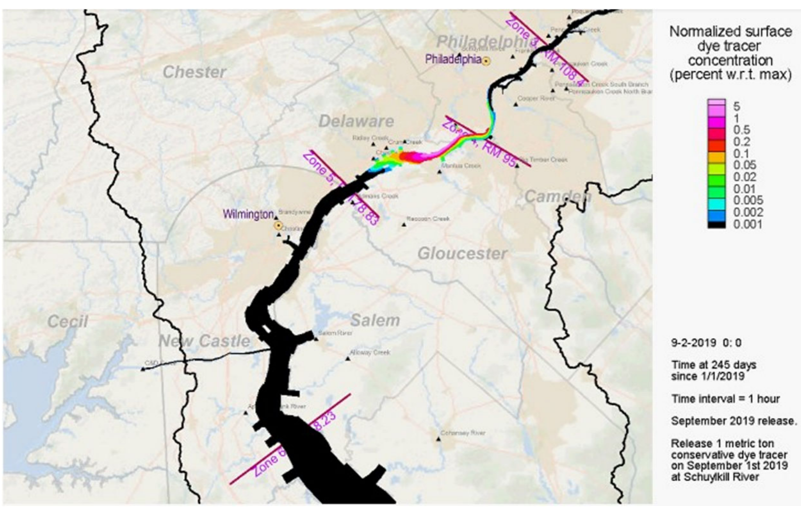

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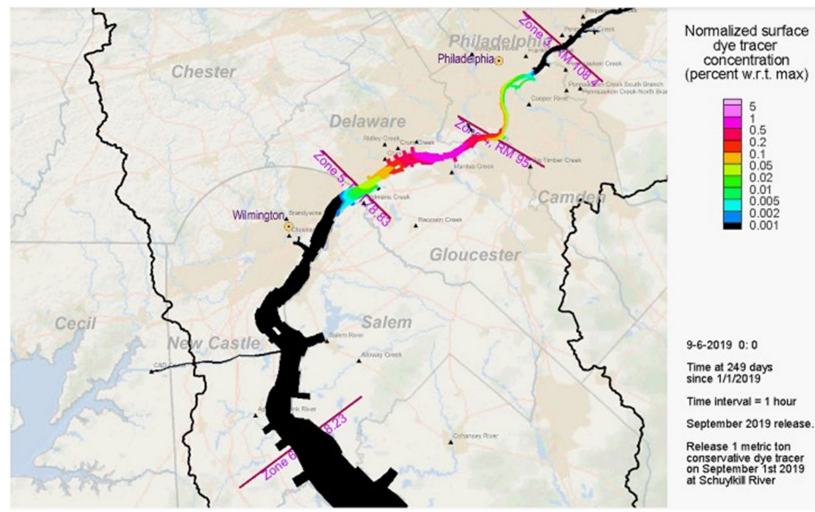
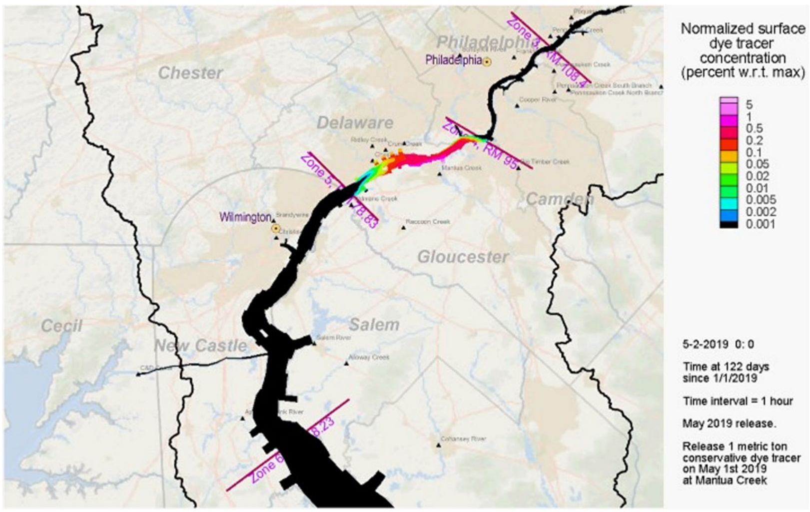


(d)

Mantua Creek Release *(a) high-flow, 1 day after release; (b) high-flow, 5 days after release; (c) low-flow, 1 day after release; (d) low-flow, 5 days after release*



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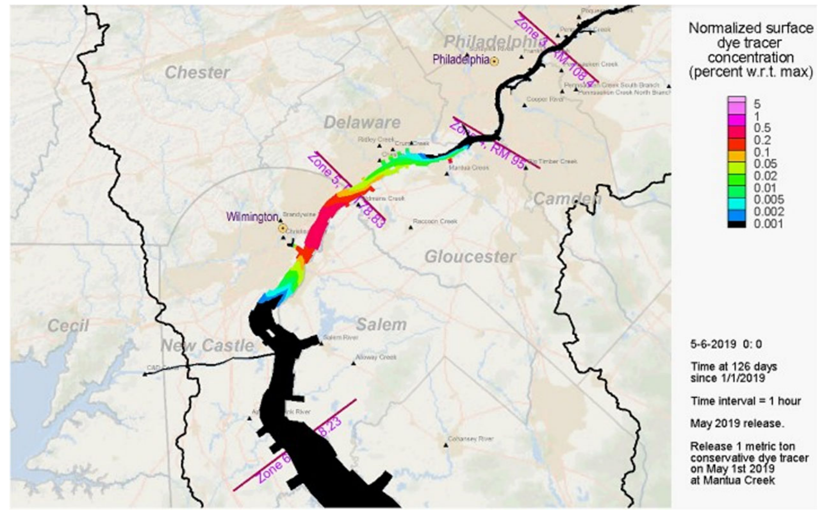

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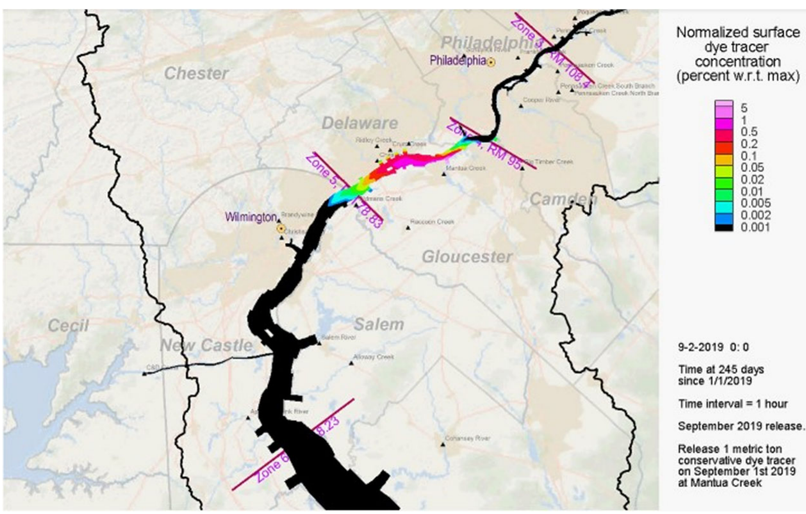
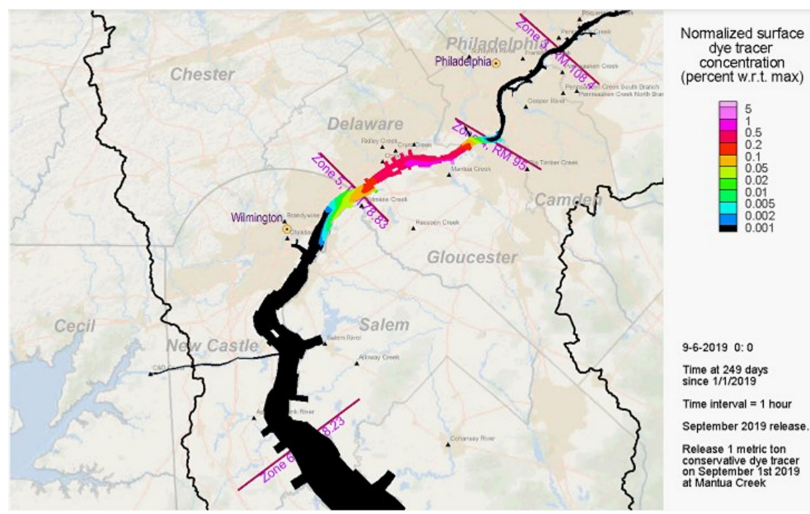


(c)



(d)

***Christina River Release** (a) high-flow, 1 day after release; (b) high-flow, 5 days after release; (c) low-flow, 1 day after release; (d) low-flow, 5 days after release*