Characterizing Macro and Microplastic Pollution in the Neuse River Basin

J. Jack Kurki-Fox[a,*], Barbara A. Doll[a,b], Bonnie Monteleone[c], Kayla West[c], Gloria Putnam[b], Liam Kelleher[d], Stefan Krause[d, e], and Uwe Schneidewind[d]

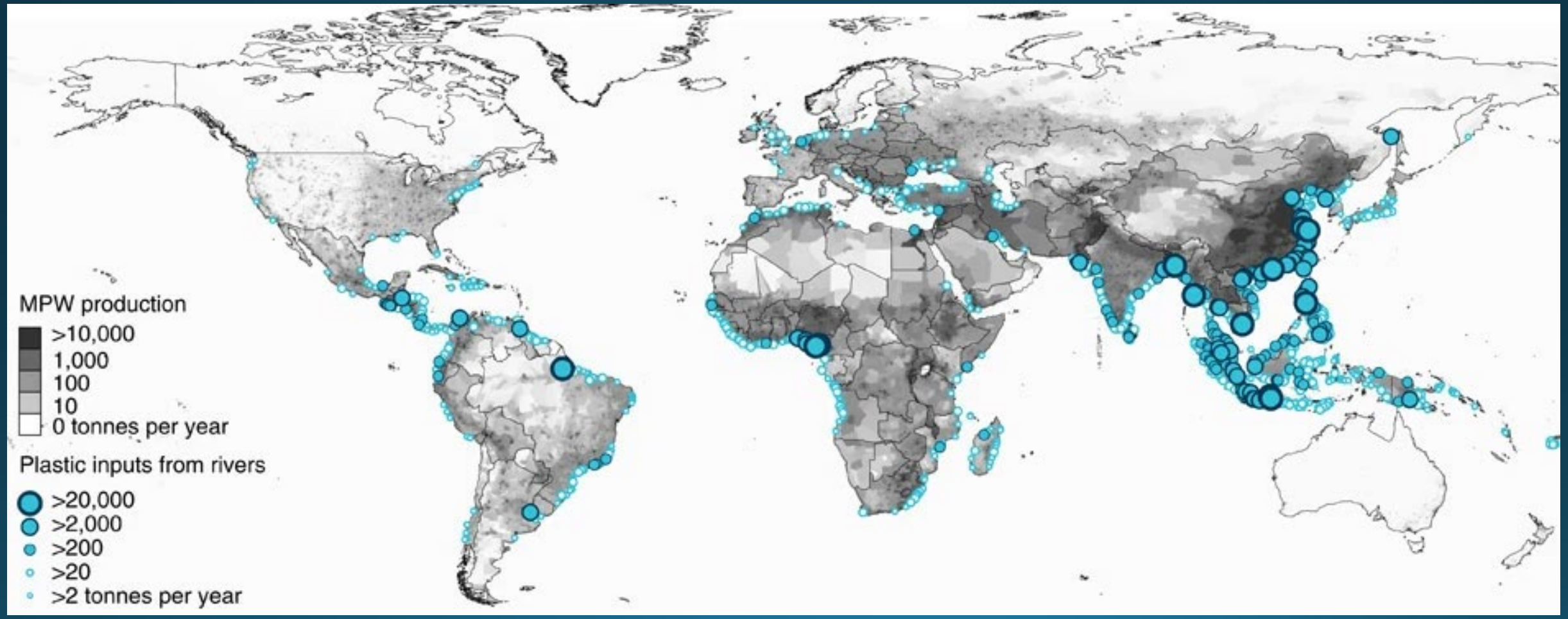
a Biological and Agricultural Engineering, North Carolina State University,
b North Carolina Sea Grant, NC State University, Raleigh, NC, USA
c Plastic Ocean Project, Wilmington, NC, USA
d School of Geography, Earth and Environmental Sciences, University of Birmingham,
e LEHNA - Laboratoire d'ecologie des hydrosystemes naturels et anthropises, University of Lyon, Villeurbanne, France.

8 million tons/year of plastic waste escapes into the oceans from coastal nations

InterAction Council, https://www.interactioncouncil.org/

World Wildlife Fund

- 1.15 and 2.41 million tons (≈30%) of plastic waste currently enters the ocean every year from rivers
- 10 Rivers contribute to the bulk of the plastic loading – 8 in Asia and 2 in Africa



Leberton, Laurent C.M., J. van der Zwet, J. Damsteeg, B. Slat, A. Andrady & J Reisser, 2017, Nature Communications

Microplastics

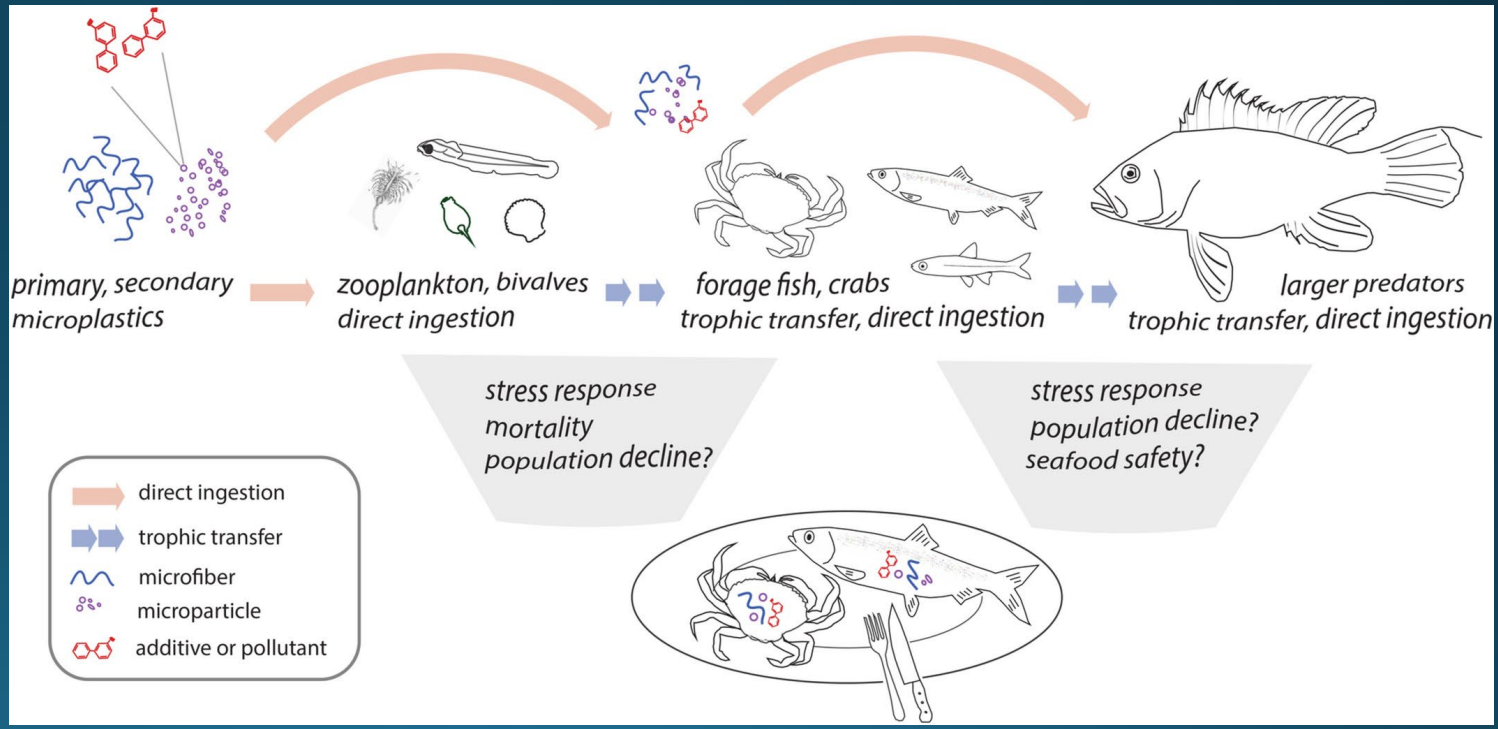
- Microplastics (MP) (<5 mm) - ubiquitous in aquatic environments

- Breakdown of mismanaged plastic trash, wastewater, agriculture, tire wear, manufacturing, breakdown/ degradation of 1000's of products

- Very slow degradation

Fate of microplastics

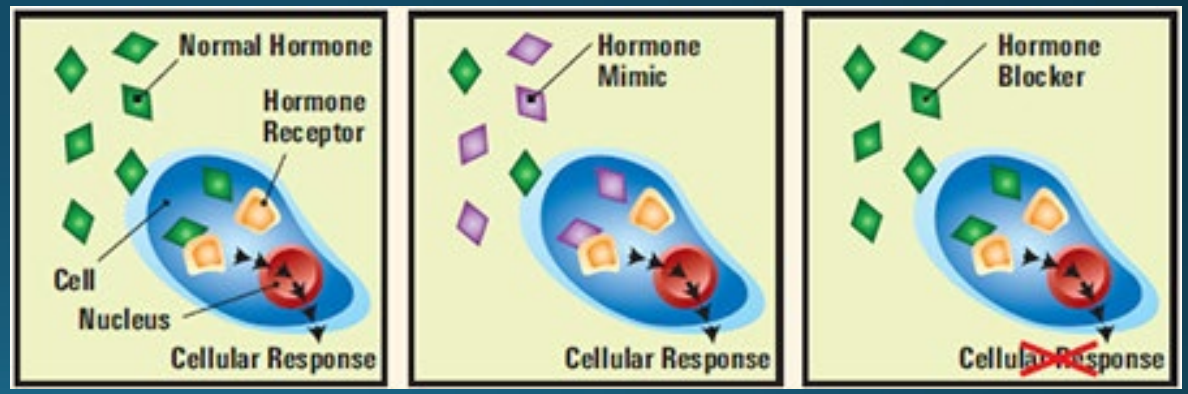
- Oregon – average of 11 microplastic pieces per oyster and 9 per clam (mostly microfibers).
- Texas gulf coast- microplastics found in 46.5% of pinfish
- Saskatchewan, Canada - Microplastics found in 83% of northern Pike.
- Mosquito Lagoon, FL - 16.5 microplastic pieces per oyster; Crabs had higher microplastic concentrations per gram of tissue than oysters (fibers most common).



B.R. Baechler et al., 2019. Microplastic occurrence and effects in commercially harvested North American finfish and shellfish: Current knowledge and future directions, *Limnology & Oceanography Letters.*

Potential Effects on Human Health

- Vector for toxic metals and persistent organic pollutants
- Chemicals (e.g. phthalates and BPA) used in the manufacture of plastics pose adverse health effects
- Hormone production (Endocrine Disrupters)
- Reproductive abnormalities
- Cardiovascular disease
- Insulin secretion



Source-
https://www.niehs.nih.gov/health/topics/agents/endocrine/index.cfm

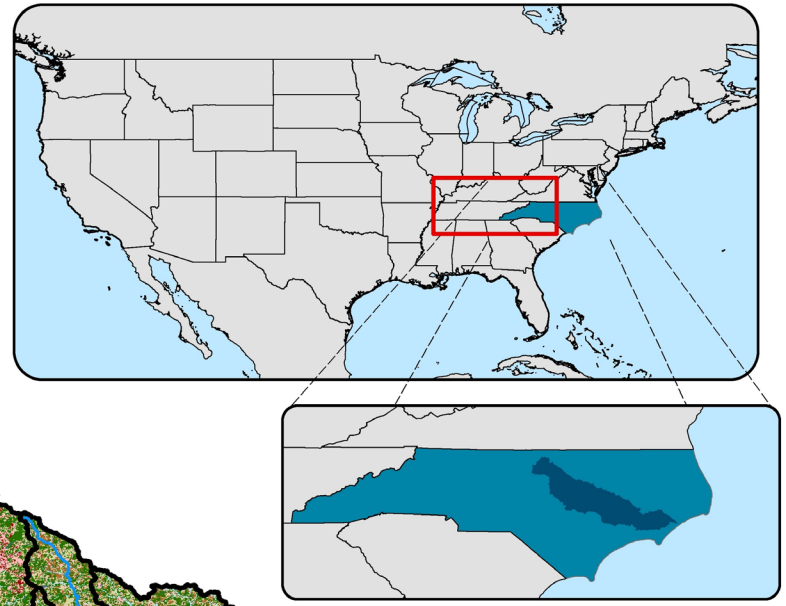
Thompson, R.C., C.J. Moore, F.S. vom Saal & S.H. Swan. 2009. Plastics, the environment and human health: current consensus and future trends. Philos Trans R Soc Lond B Biol Sci. 2009 Jul 27; 364(1526): 2153–2166.

Study Goals

Goals:

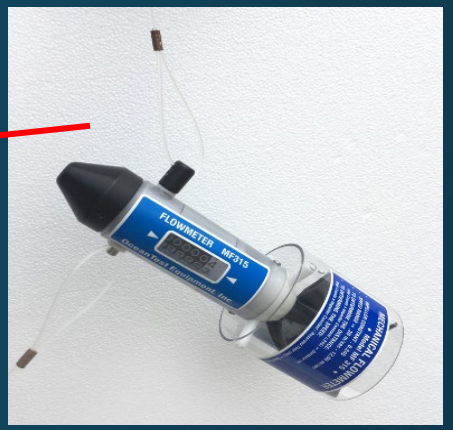
- Determine the concentration and loadings of plastics reaching the coastal waters from a large watershed
- Determine the relative contributions based on watershed scale and land-use characteristics

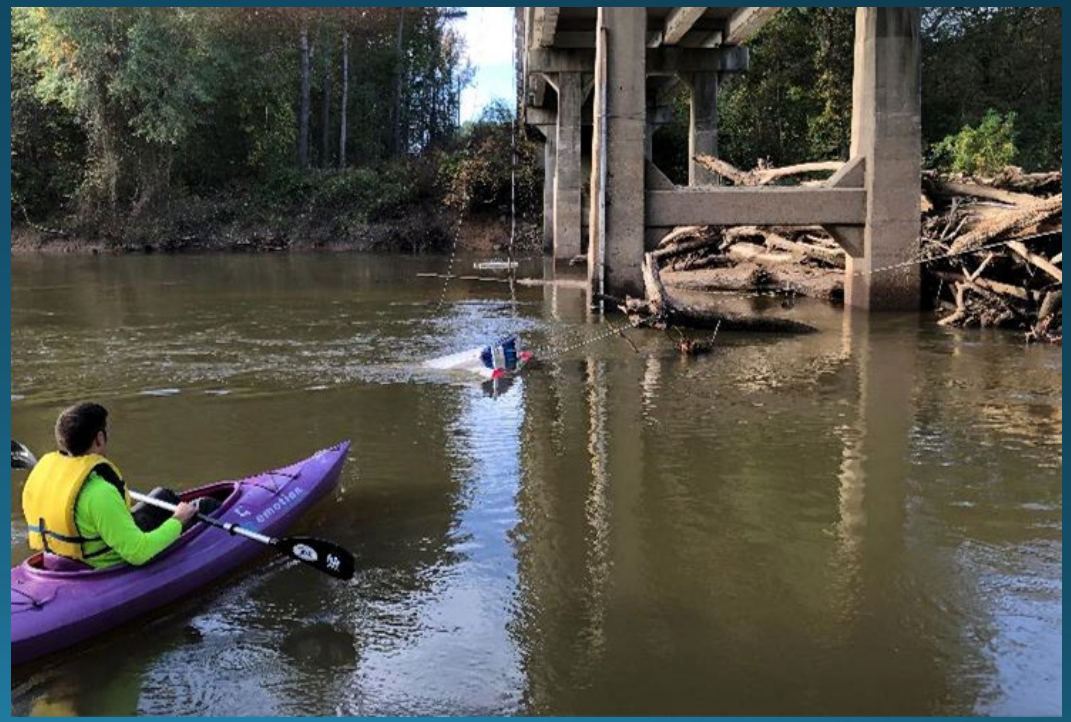
DRAINAGE AREA
= 14,000 sq. km



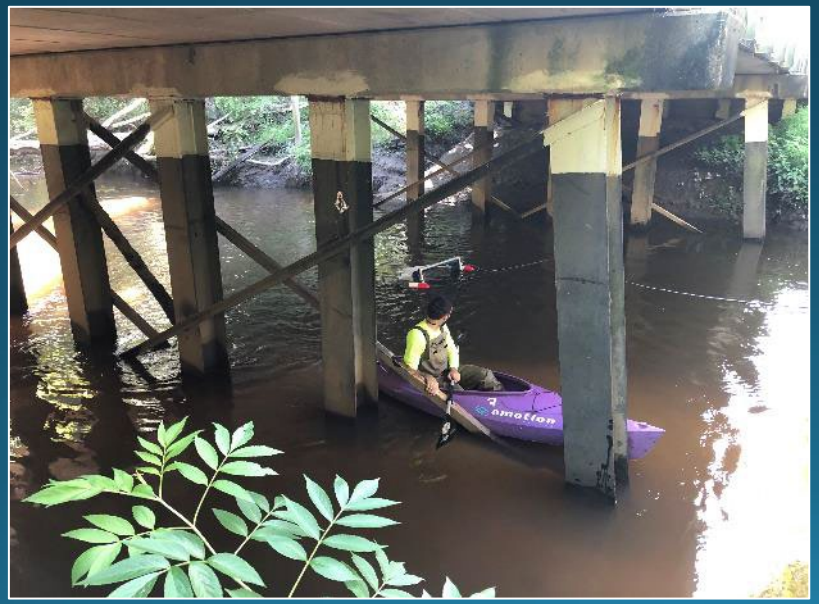
Microplastic Sample Collection - Trawl

- 335 micron net (1 m x 40 cm)
  - USGS methodology
- Measure velocity
- Trawl for ~5-15 minutes (depending on flow rate)

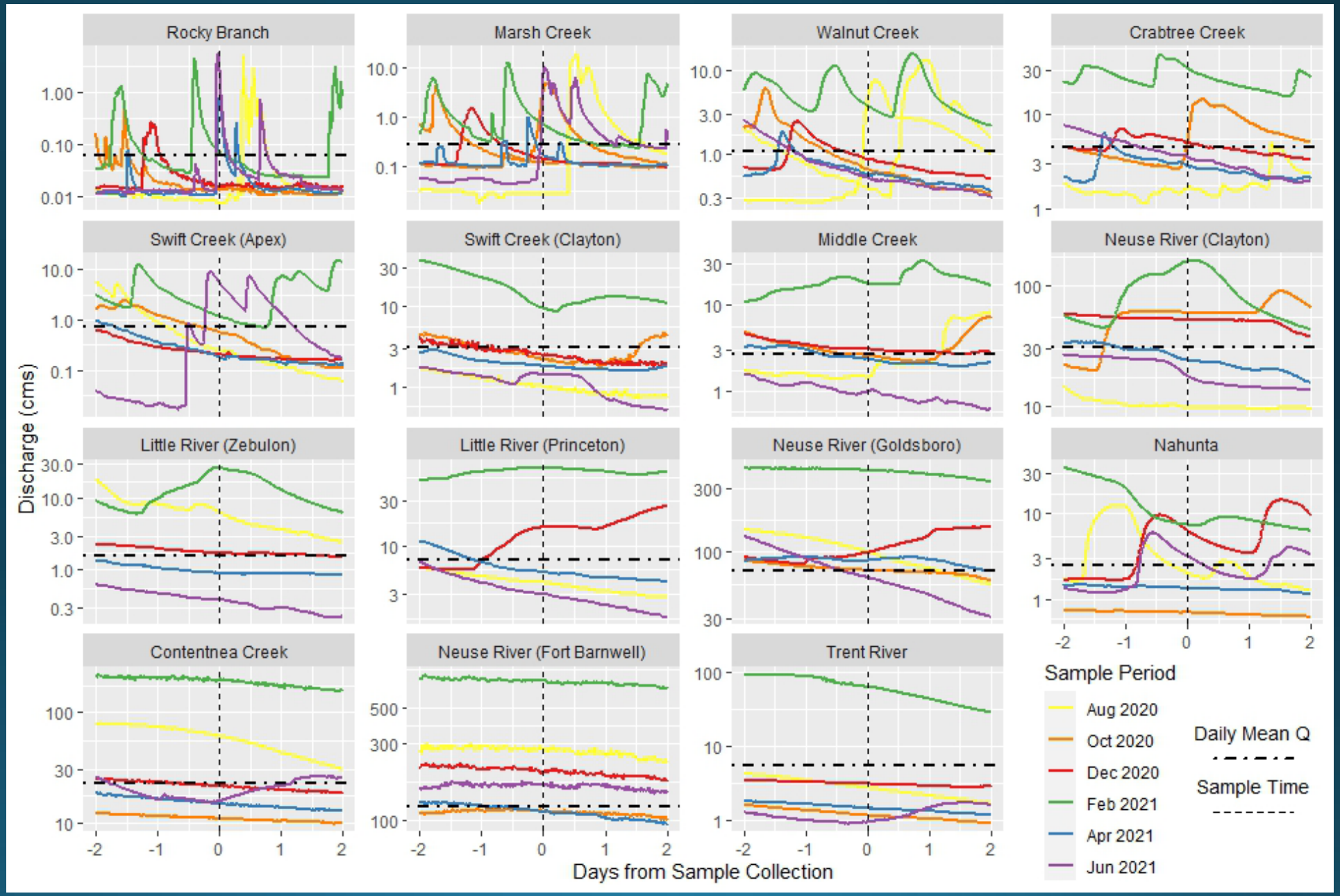




Microplastic Sample Collection - trawl



- Capture a range of flow at each location



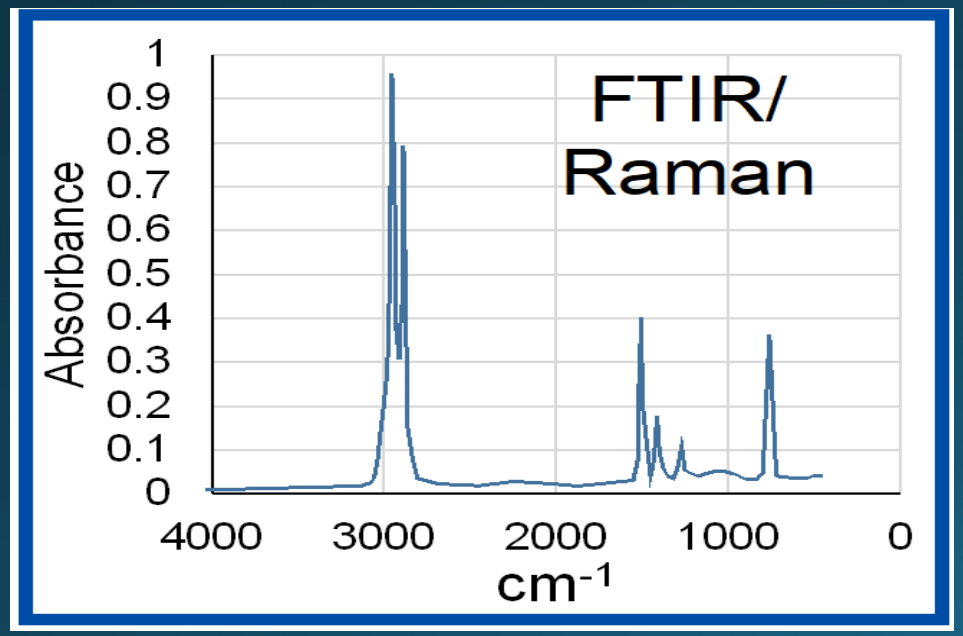
Microplastic Sample Collection - Bailing

- Smaller particles (>64 µm)
- Bail 100 L through 64 µm sieve

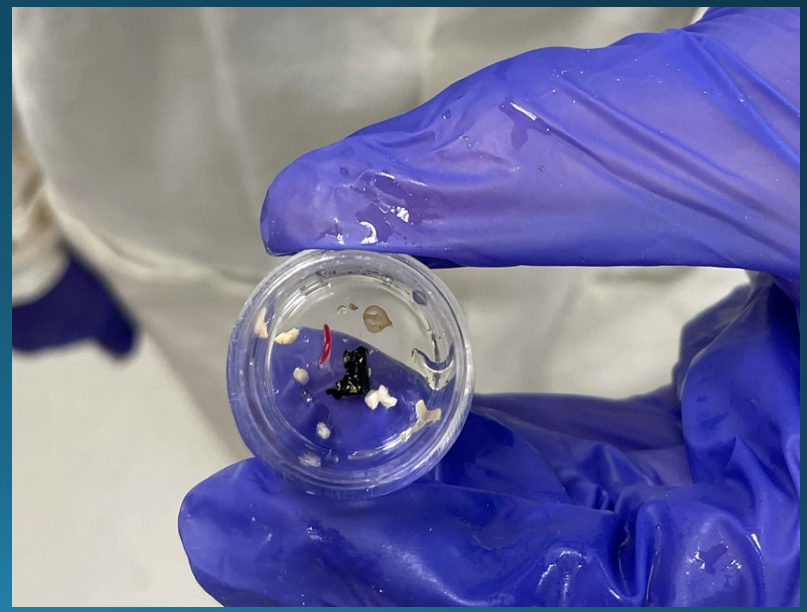
The Plastic Ocean Project

Sample Analysis

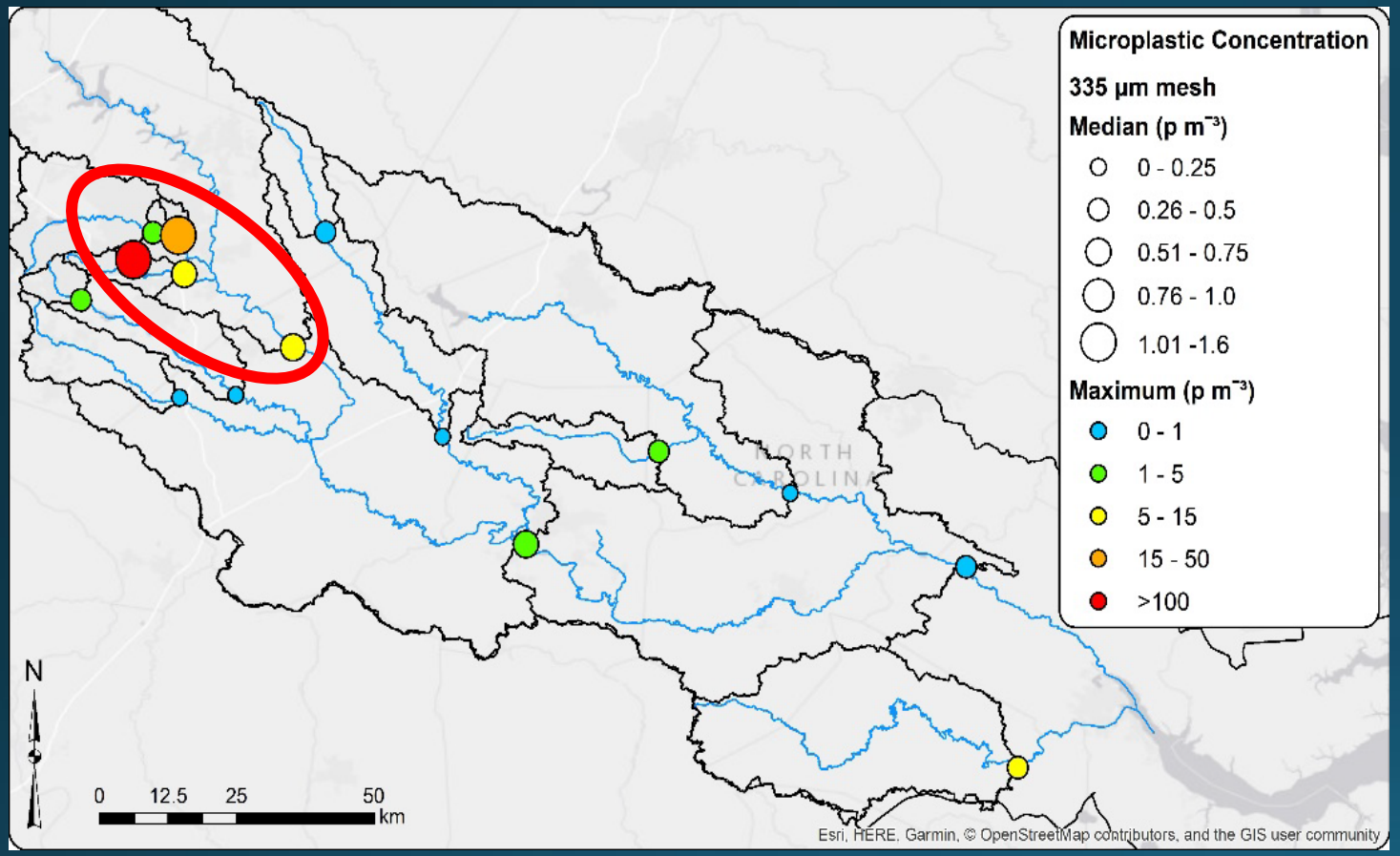
- Chemical digestion
- Density Separation
- FTIR / Raman



FTIR = Fourier-transform infrared spectroscopy - produces an infrared adsorption spectrum



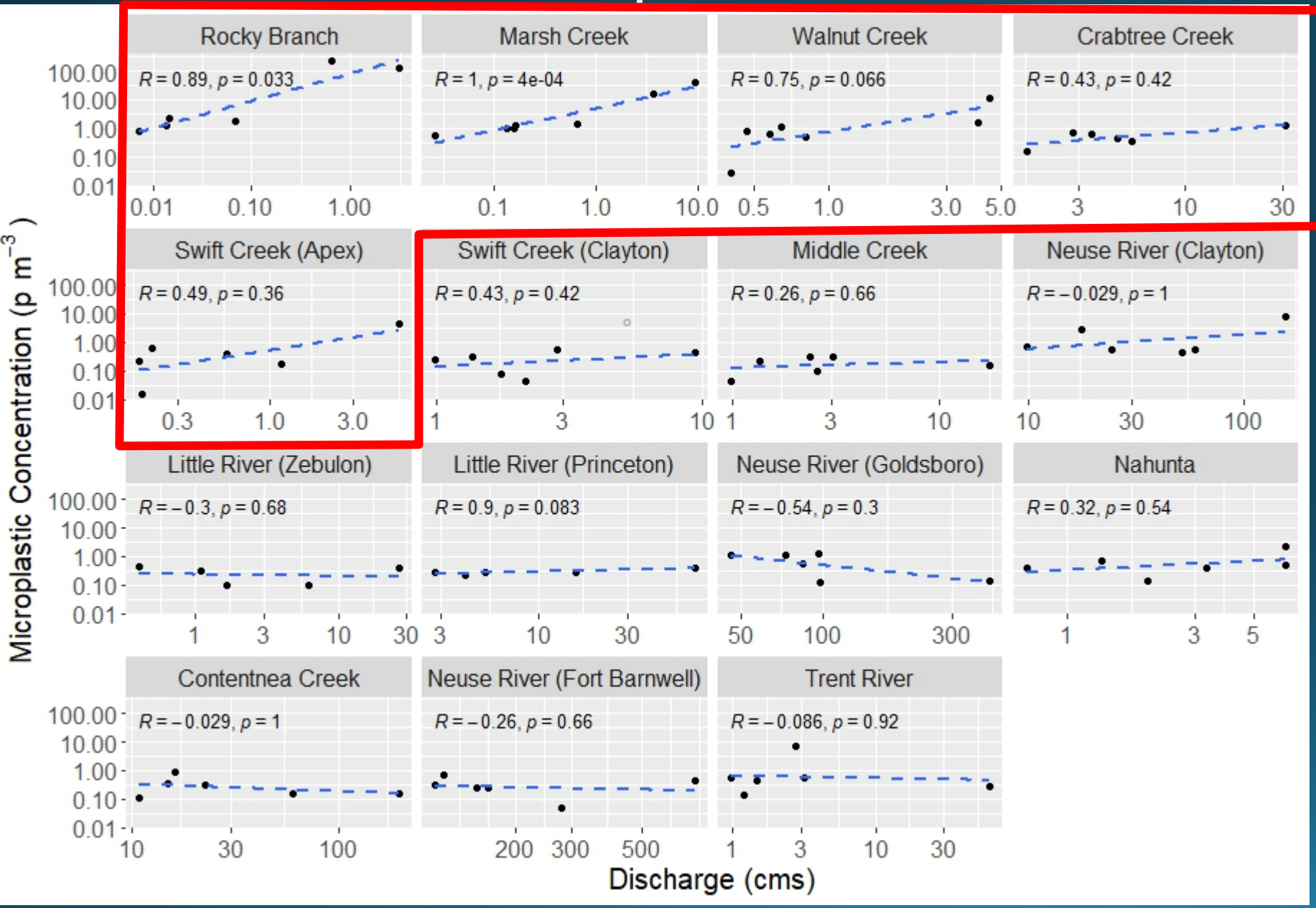
Results – Trawl samples



Type	Median	Range
Number of Particles/sample	66	2 - >2000
Concentration (particles/m^3)	**0.44**	**0.02 - 221**

- Baldwin et al. (2016) : Midwestern streams - median: 1.9 p/m^3, range: 0-32= p/m^3
- Dris et al. (2015): streams in Paris- range: 0.28–0.47 p/m^3
- Lechner et al. (2014): Danube River – median: 0.32 p/m^3

Results – trawl samples - concentration vs. discharge

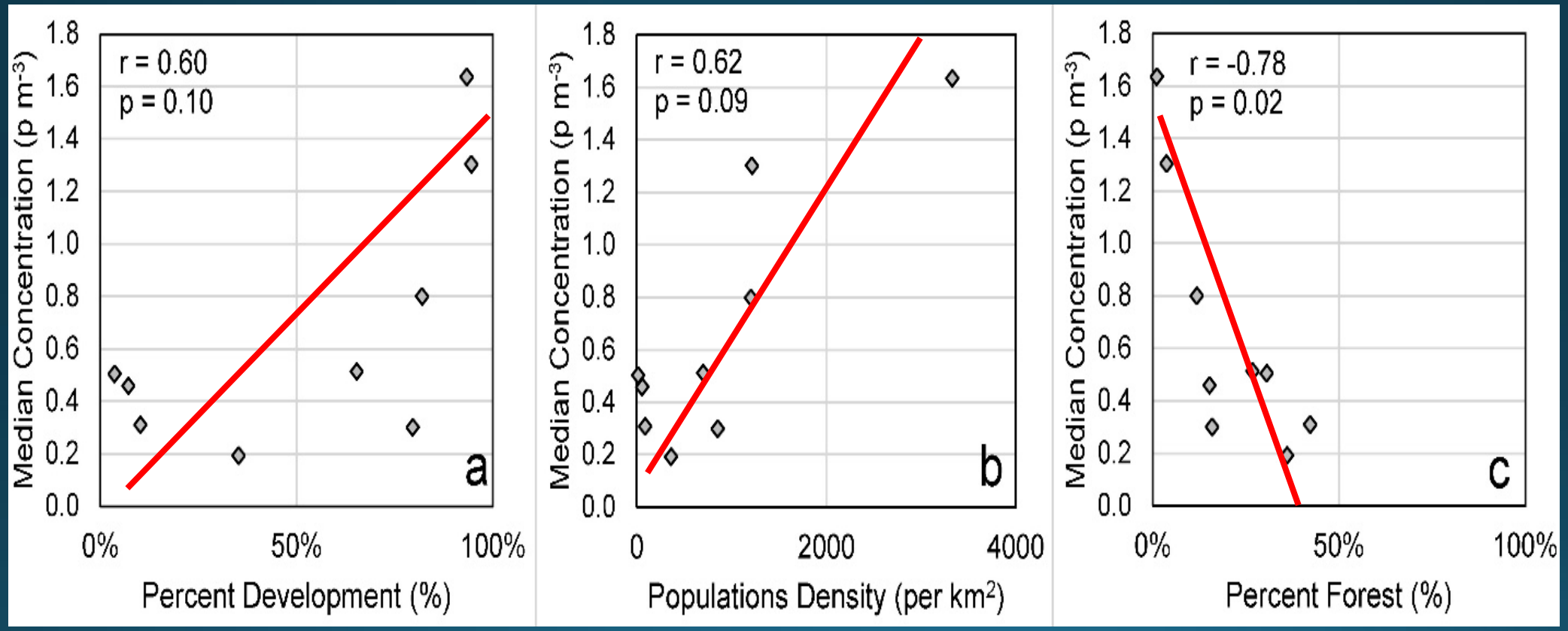


Urban Creeks

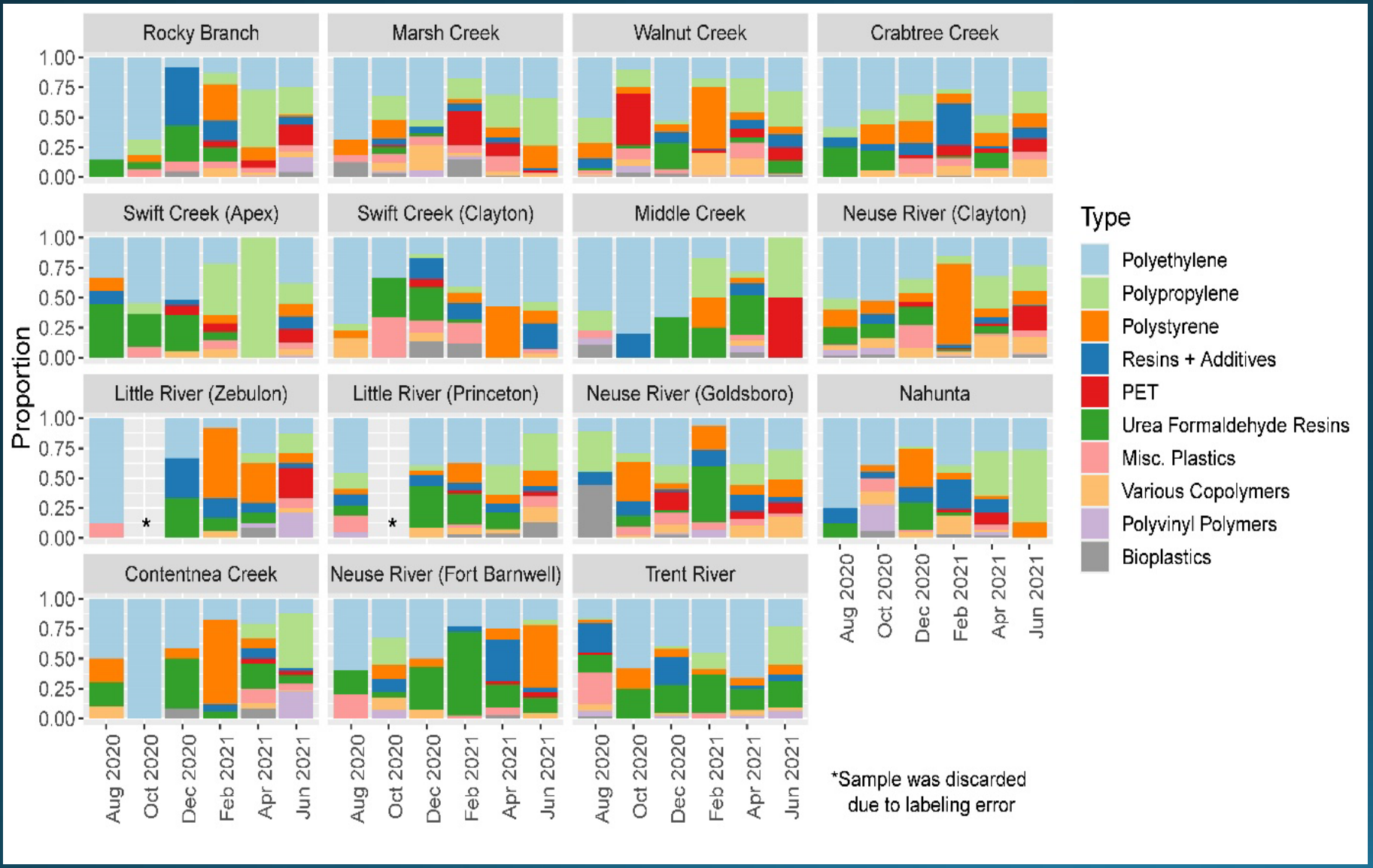
- Highest concentrations during stormflow
- 1-2 orders of magnitude greater than baseflow

Results – trawl samples – watershed attributes

Headwater catchments in upper watershed

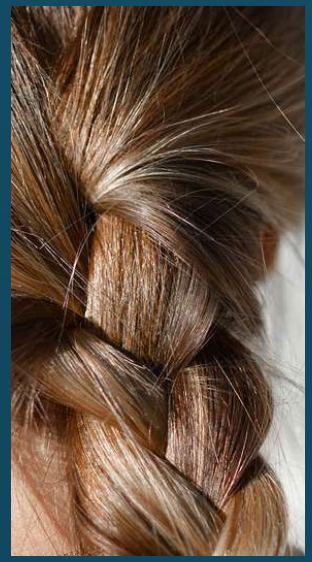


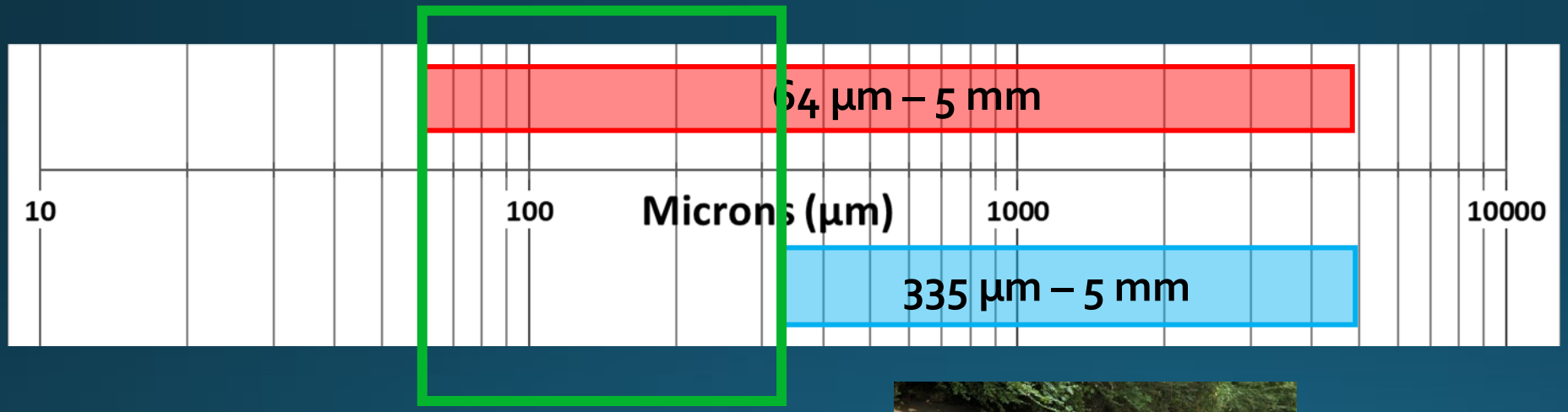
Results - Polymer Types – FTIR analysis



- Dozens of unique chemical compounds
- PE (30%) in 98%
- PP (18%) in 70%
- PS (15%) in 78%
- High site to site and sample to sample variability

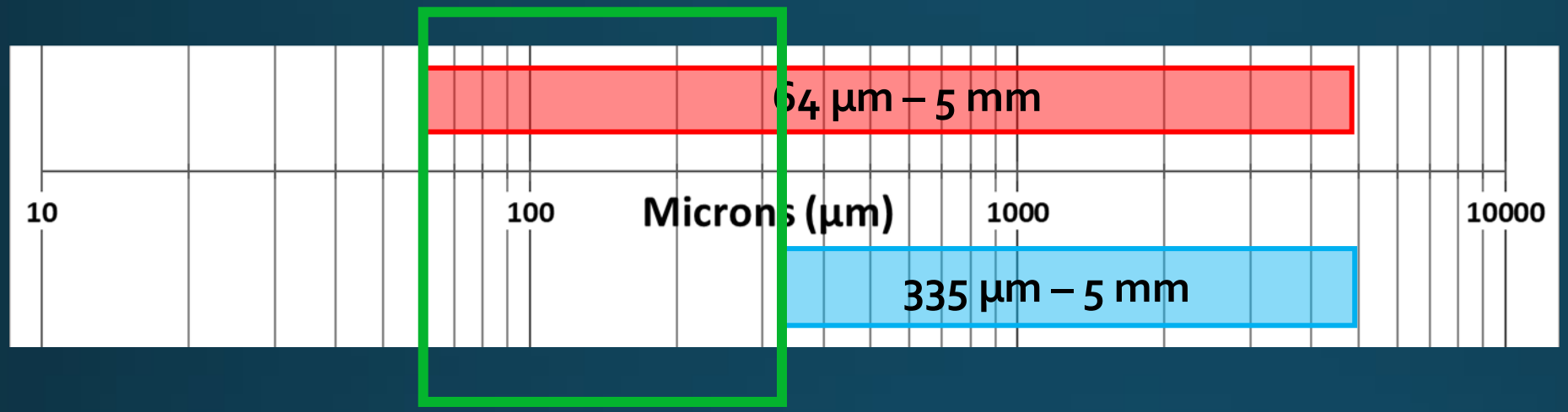
Results - Bailing samples

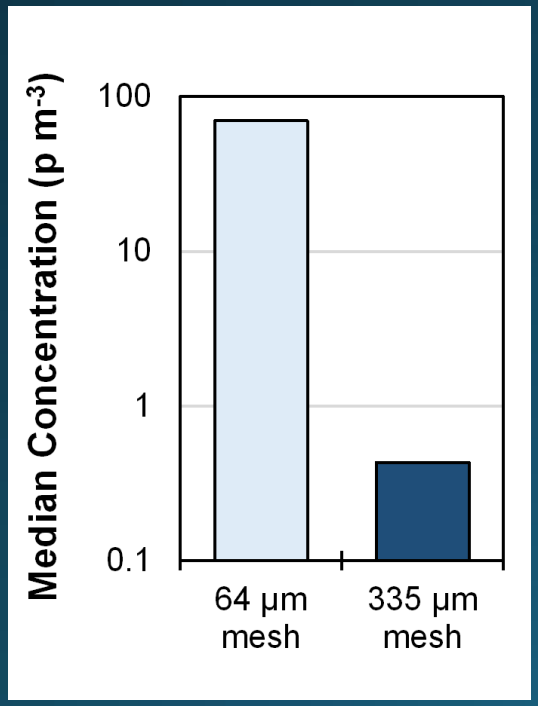




Mesh Size: 335 µm
~ ½ diameter of standard mechanical pencil lead

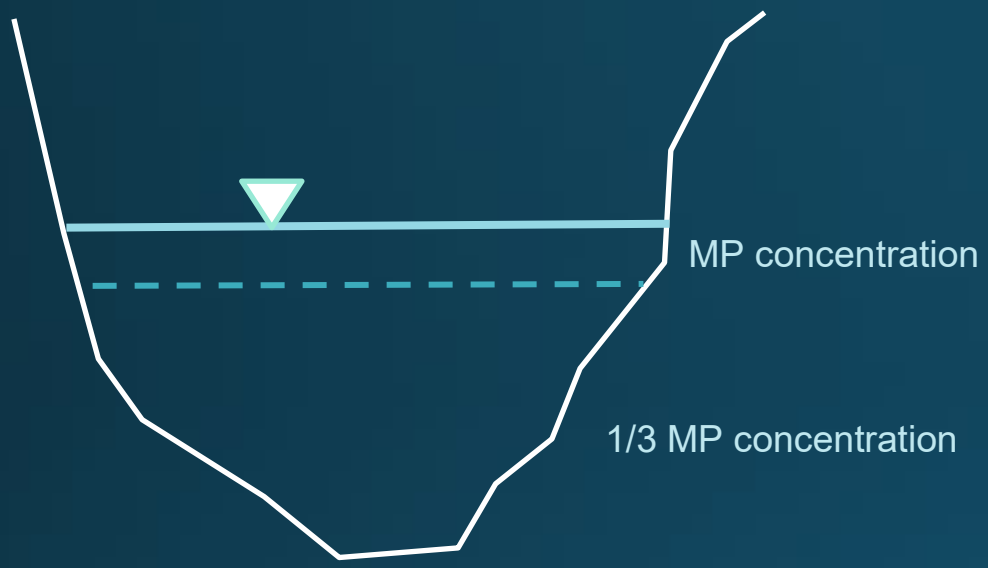
Results - Bailing samples





- 64 µm concentration ~**170** greater than 335 µm results
- >90% of particles less then 335 µm

Microplastic Loading



- Method developed by Eo et al. (2019)

$$MP\ Load = \int Daily\ Mean\ Q \times Average\ MP\ Concentration$$

Total MP loading to coastal waters

Microplastics > 335 µm

- 670 million MPs / year

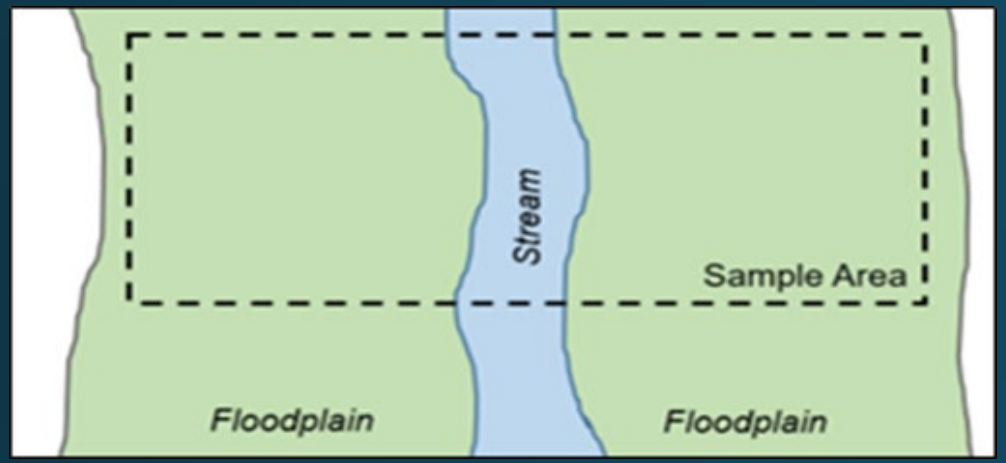
Microplastics > 64 µm

- 230 billion MPs / year
- 110,000 MPs/ person/ year

Could be a *substantial underestimate* relative to other studies of similar sized watersheds (Eo et al., 2019).

Macroplastics

- Floodplain Grids

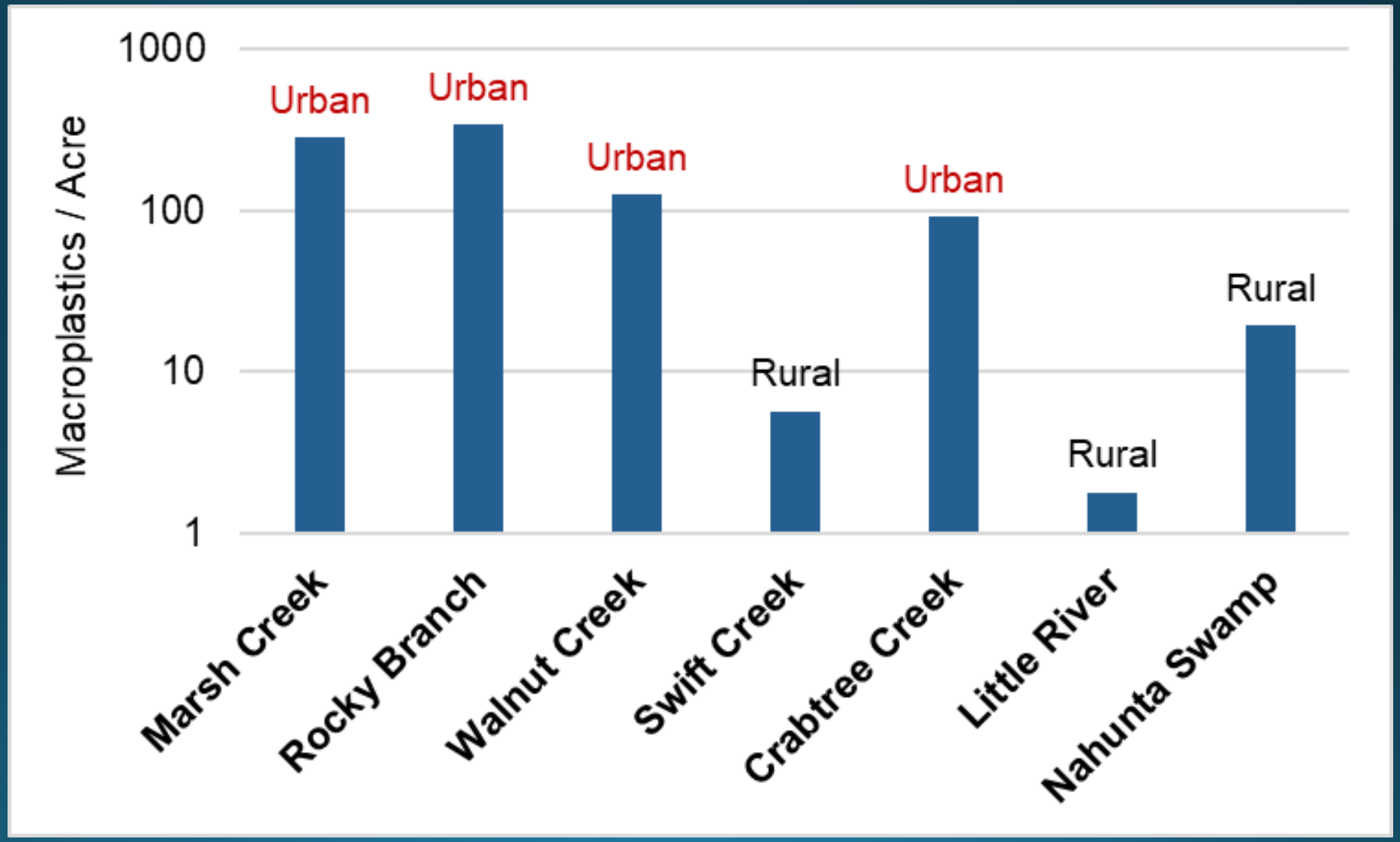


- Visual Counts

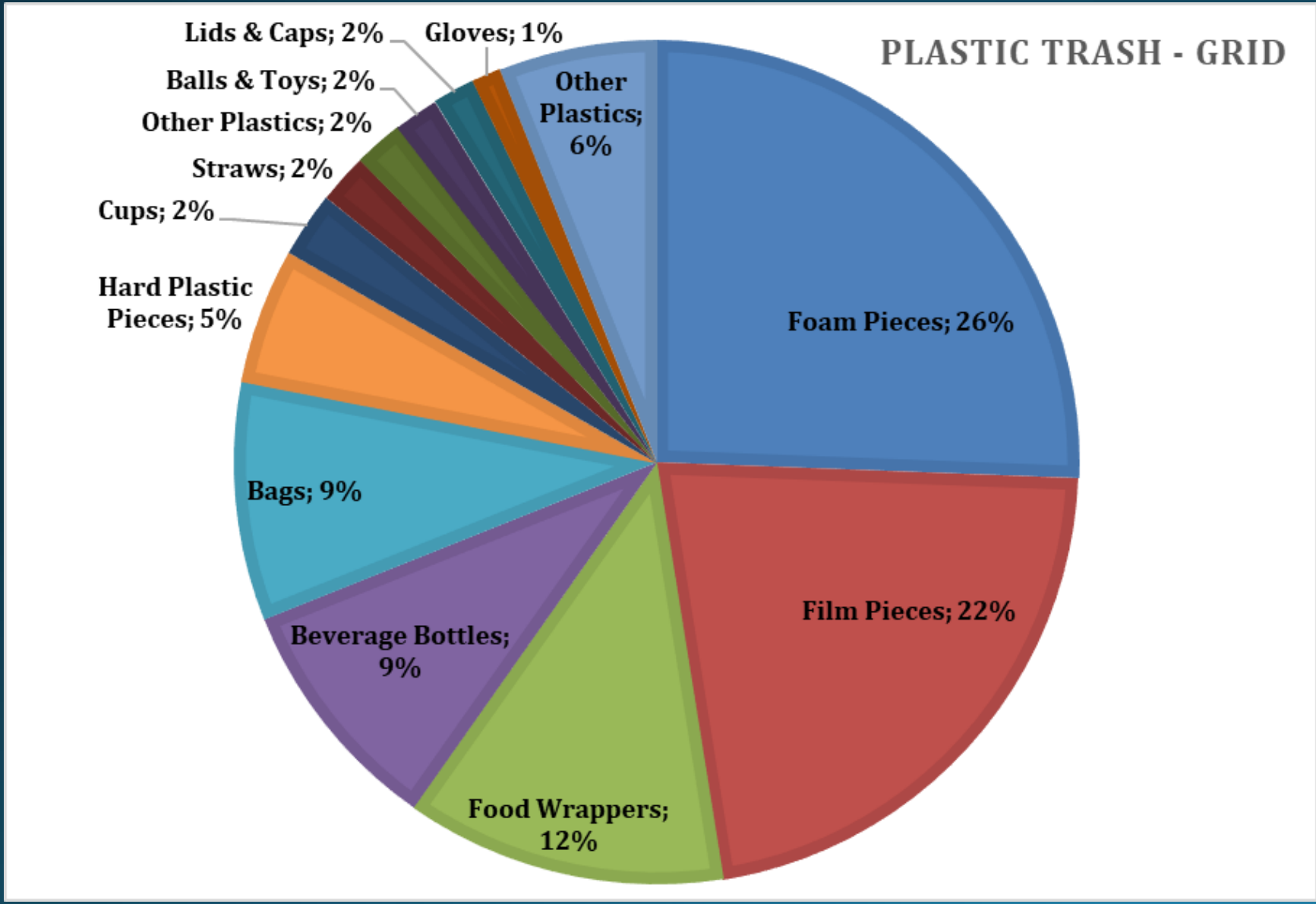
- In-stream capture

Macroplastics

- >90% of collected trash were plastics

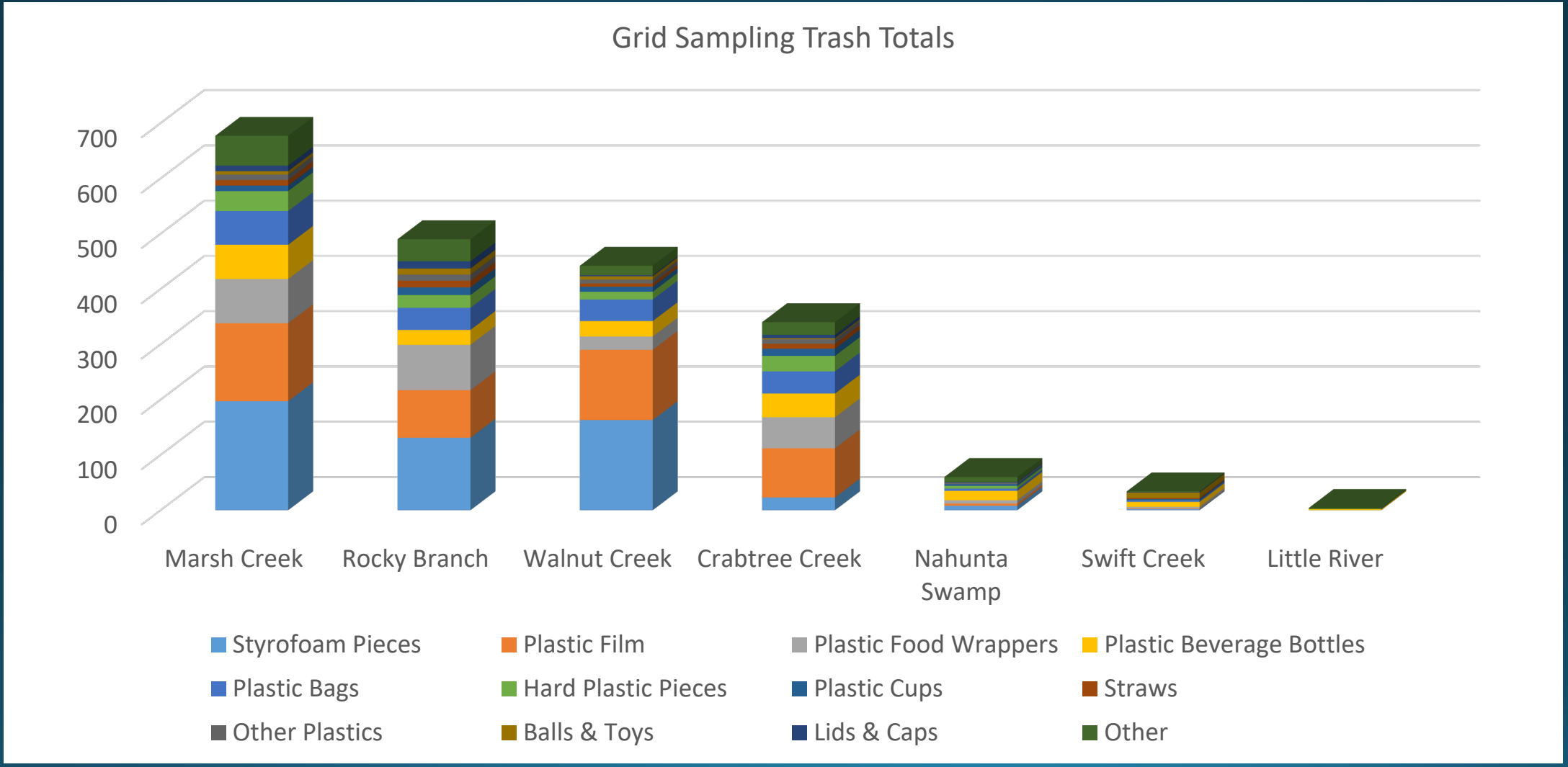


Macroplastics – Grid Samples

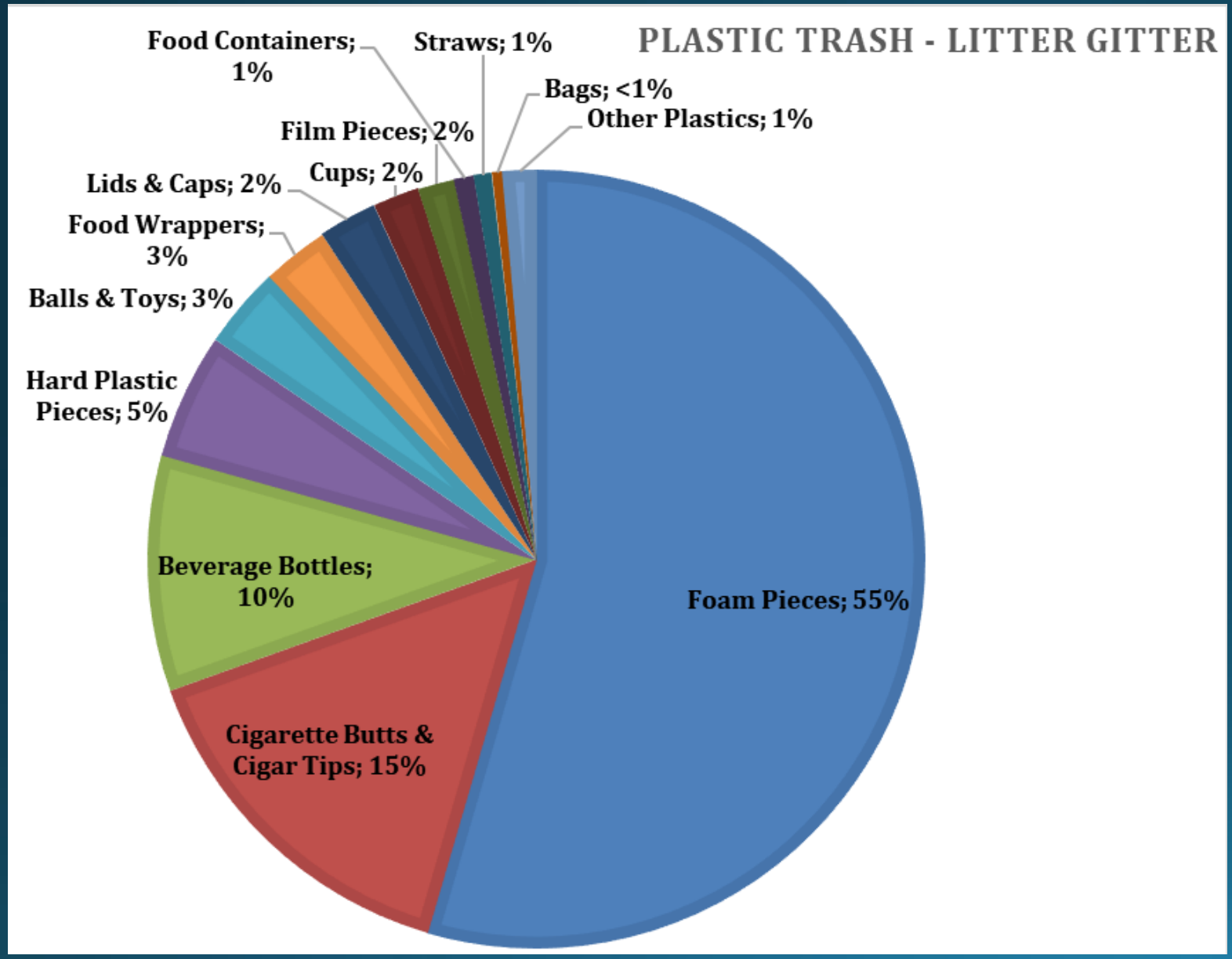


- Polyethylene
  Polypropylene
  Polystyrene
  PET
- Contributes to MP over time

Macroplastics – Grid Sampling

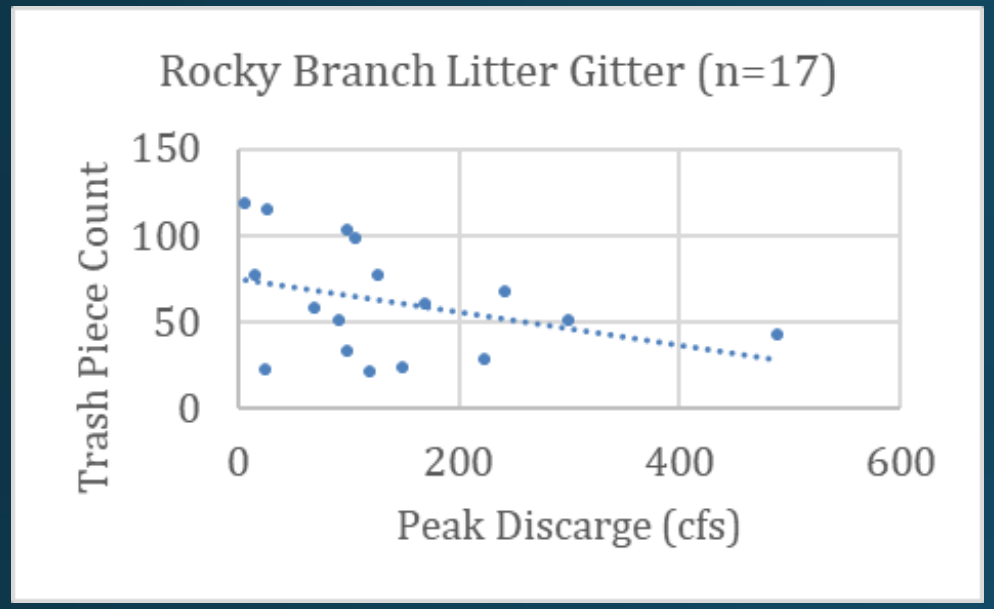


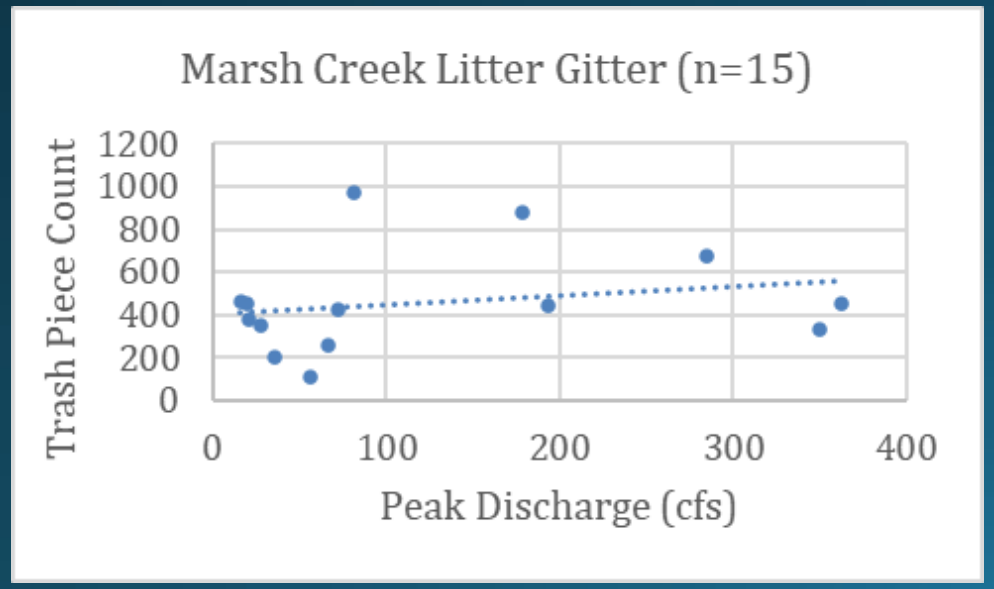
Macroplastics – Litter Gitter Samples



- Captured lots of Polystyrene & PET Bottles
- Not successful at capturing Plastic Bags & Food Wrappers (Polyethylene)

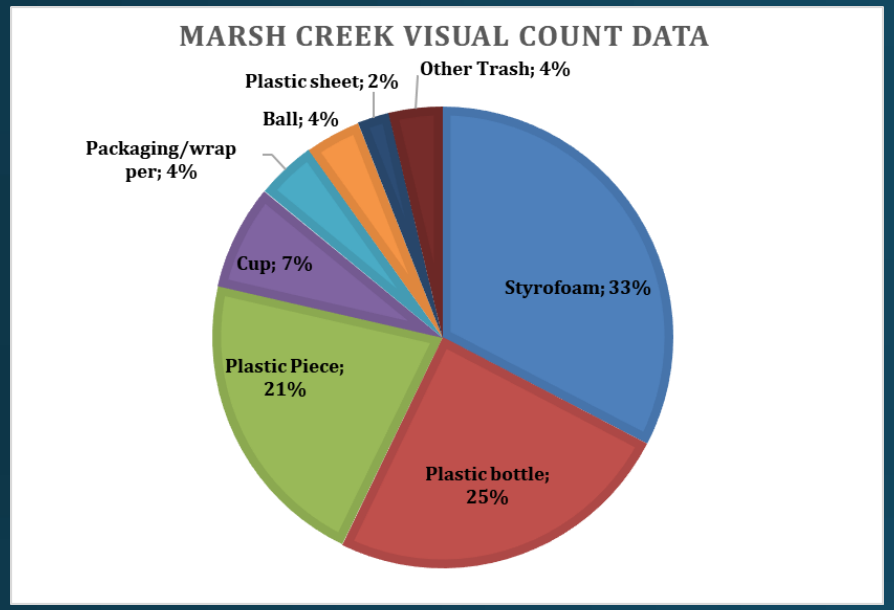
Litter Gitter Capture

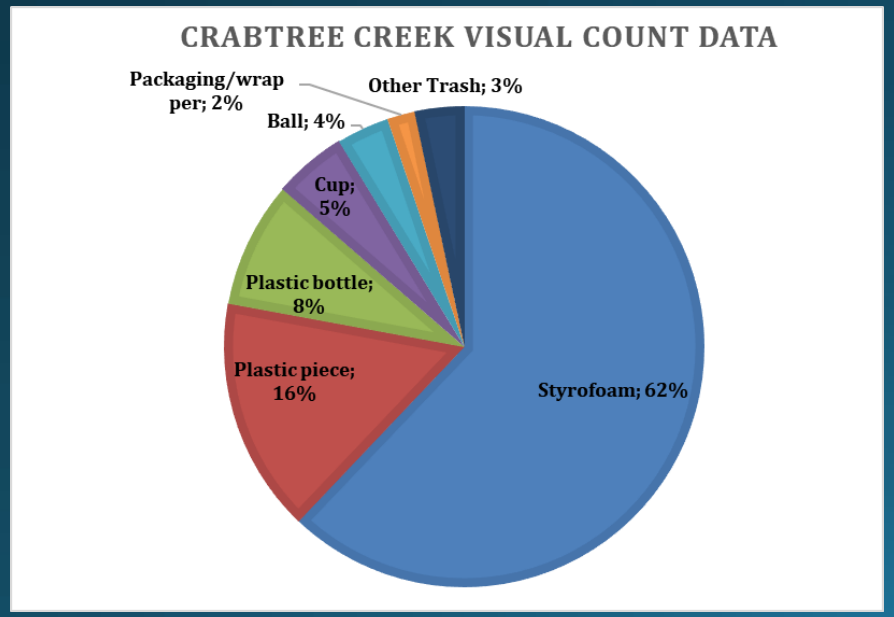




- Larger basket at Marsh Creek basket more effective than smaller basket at Rocky Branch
- Data indicates that litter capture devices are more effective at low to moderate flows

Macroplastics – Visual Samples

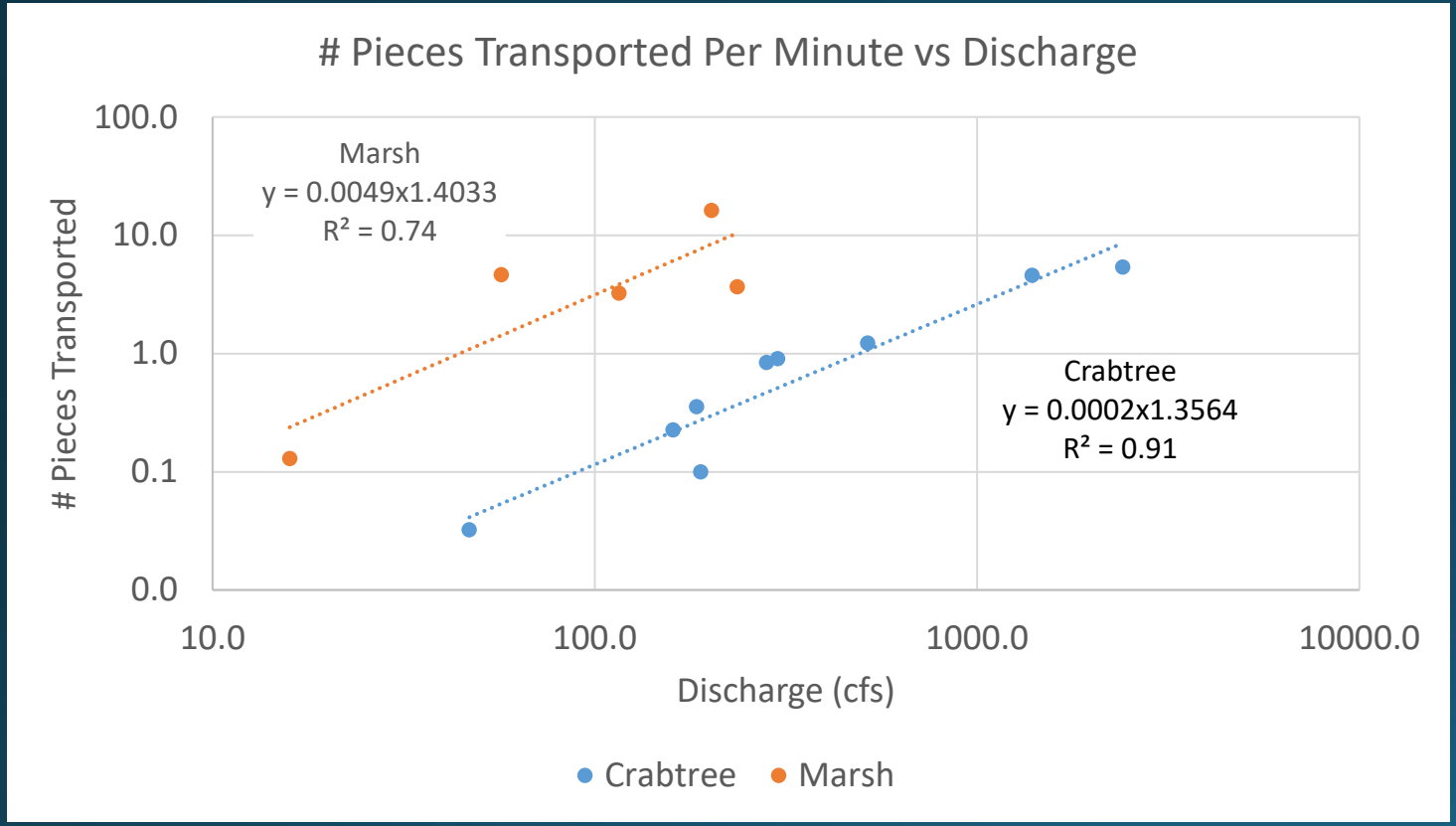




- Observed lots of Polystyrene & PET Bottles
- Very few observations of Plastic Bags & Food Wrappers (Polyethylene)

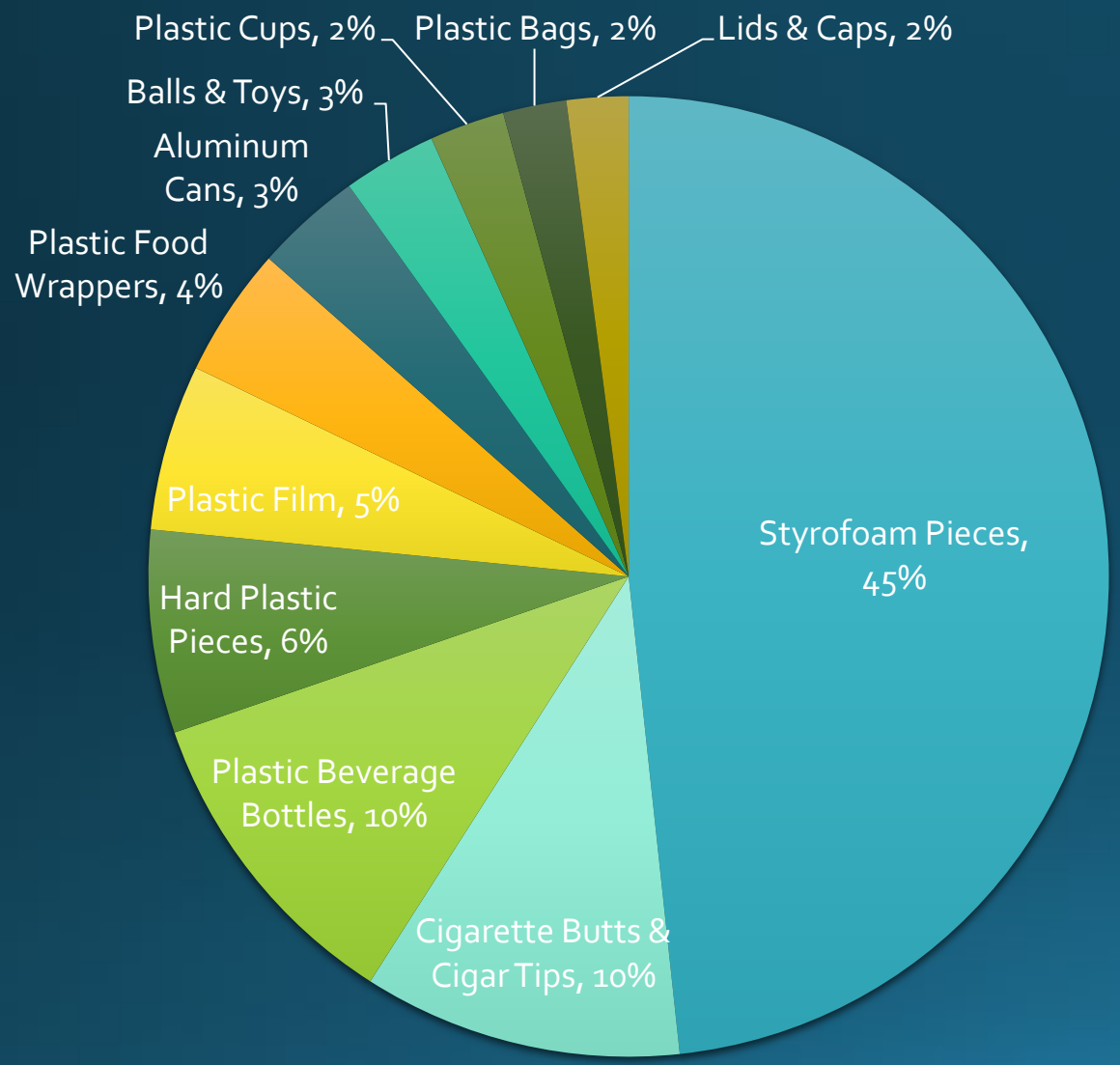
Macroplastics – Visual Counts

- Antecedent period
- Watershed land use



- Marsh Creek - 120,250 pieces of floating trash annually (styrofoam and plastic bottles)

Macroplastics – All Sampling Methods Combined



- 92% of 11,246 pieces of trash collected and observed were plastic

A River of Plastics

North Carolina Neuse River Basin

Rivers supply the majority of plastics that reach our coastal waters. Wildlife and aquatic animals can ingest plastic debris or become entangled. Litter on streets, sidewalks, and ditches washes through storm drains into our waterways when it rains. Plastic litter breaks down into smaller and smaller components--**microplastics**--which accumulate in fish, crabs, and oysters. Preventing and removing litter helps keep plastic out of our rivers, sounds, and food.

Microplastics

- Small particles less than 5 millimeters
- Pervasive in our streams, rivers, estuaries and the ocean

Most common microplastic types found in the Neuse River Basin:

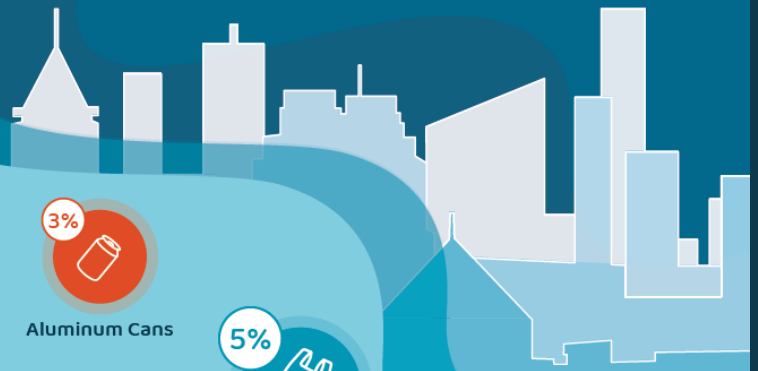
- **Polyethylenes (PE)** — Plastic bags, films, containers — 30%
- **Polypropylenes (PP)** — Fabrics, bottle caps, carpet, food containers — 18%
- **Polystyrenes (PS)** — Styrofoam packaging and food containers, plastic ware — 15%
- **Resins** — Paints, adhesives, sealants — 7.5%
- **Polyethylene terephthalate (PET)** — Bottles, containers, polyester fabrics — 6.5%
- **Other Plastics** — Electronics, car parts, toys, etc. — 23%

"Findings are based on a 2020-2021 NC Sea Grant led study. For more information go.ncsu.edu/plastics."

Macroplastics

- Plastic particles larger than 5 millimeters

Approximately 92% of the litter that washes into the creeks that drain into the Neuse River is plastic.



- 2% Plastic Lids & Caps
- 2% Plastic Cups
- 3% Balls & Toys
- 4% Plastic Food Wrappers
- 3% Aluminum Cans
- 5% Plastic Bags
- 8% Other Trash
- 6% Hard Plastic Pieces
- 10% Plastic Beverage Bottles
- 5% Plastic Film
- 10% Cigarette Butts & Cigar Tips
- 45% Styrofoam

Summary

- Plastics are everywhere! – found in every single sample collected
- Highest concentrations in urban areas during stormflow
  - Flush of microplastics moving downstream
- MP concentrations identified with a 64 µm mesh were on average ~170 times larger than with a 335 µm trawl net
  - Degrade into smaller and smaller pieces
- Further highlights the challenges posed by plastic pollution
  - Cannot be removed from the environment
  - Half of all plastics ever manufactured have been made in the last 20 years.
  - <10% recycled

Kurki-Fox, J.J., Doll, B.A., Monteleone, B., West, K., Putnam, G., Kelleher, L., Krause, S. and Schneidewind, U., 2023. Microplastic distribution and characteristics across a large river basin: Insights from the Neuse River in North Carolina, USA. *Science of the Total Environment*, *878*, p.162940.

Jack Kurki-Fox - jjkurkif@ncsu.edu
Barbara Doll - bdoll@ncsu.edu

@NCState_Streams

Funding:

NOAA MARINE DEBRIS PROGRAM

Sea Grant North Carolina

Keep America Beautiful

2020 NATIONAL LITTER STUDY

Summary Report: May 2021

Lead Research Partner:

BURNS McDONNELL

- 25.9 billion pieces of trash along waterways
- 2411 pieces per mile
- 152 litter items per person (road & waterway litter)
- 90% of population says litter is a problem

Litter Capture at Stormwater Outfall Design – Senior Design Team

Existing Technologies

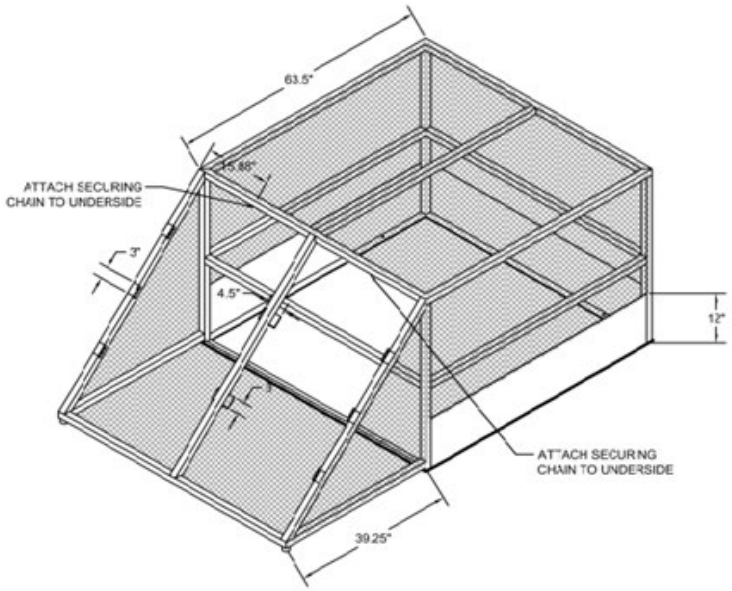
In-Stream

Inlet

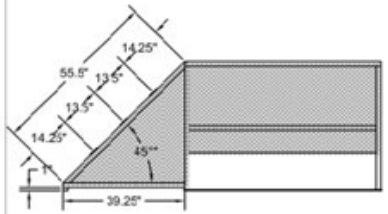
In-Line

Outlet

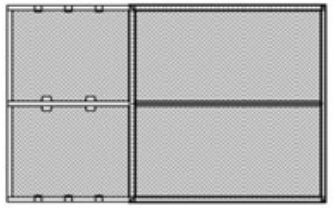
Location	Advantages	Drawbacks
In-Stream	Relatively Cheap 'Last Line of Defense'	Trash Already Mobilized Maintenance Heavy
In-Line	Very High Capture Efficiency Trash is Hidden	Expensive Requires Substantial Effort to Install
Inlet	Cheap Moderate Capture Efficiency	Covers Small Area Requires Frequent Maintenance
Outlet	Covers Large Area Moderate/Good Cost Effectiveness and Capture Efficiency	Existing Catchers Difficult to Remove Unsightly



SCALE: 30:1



SCALE: 40:1

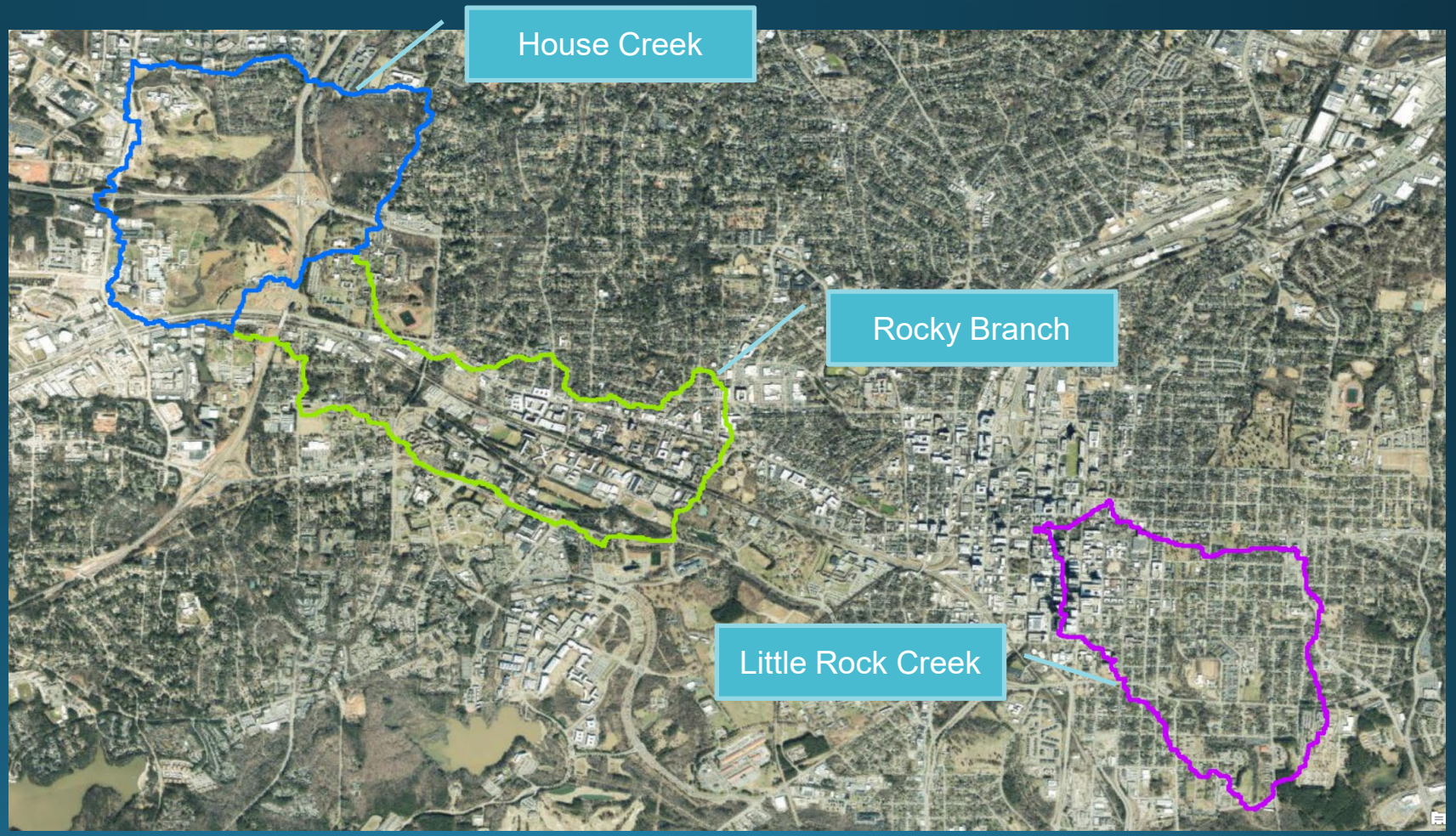


SCALE: 40:1

SHEET TITLE	PROJECT/TEAM NAME			
OUTLET CATCHER MK II	TEAM 3 LITTER CATCHER	BAE SENIOR DESIGN Class of 2023		
SITE NAME	DATE			SHEET 6 / 7
UPWELL OUTLET	4/18/2023			

Identifying Macroplastics Source Factors and Reduction Measures in Urban Streams – Ilene Doyle, M.S. Student

Tributary to Swift Creek, MacGregor Downs, Cary, NC



Approach

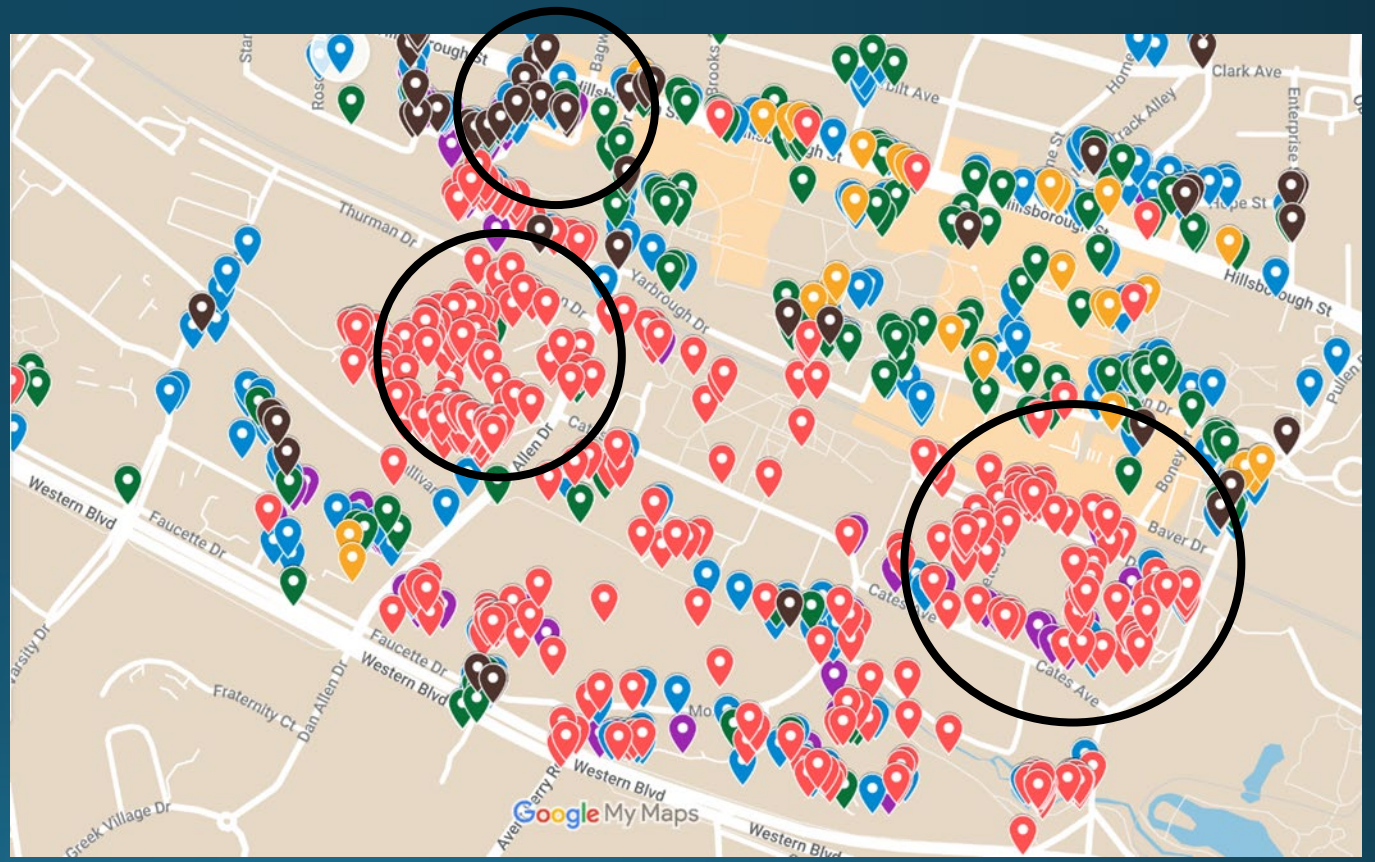
- Grid Sampling at all 4 streams
- Litter Capture at Rocky Branch and Little Rock
- Test Litter Reduction Measures at Little Rock Creek

Potential Predictors of Plastic Loading

- Land use
- Population demographics
- Stormwater Control Measures
- Road Lengths
- Density of Restaurants with To-Go Food

Test Litter Prevention Measures

- Watershed Clean Up
- Identify Litter Hotspots
- Add trash cans



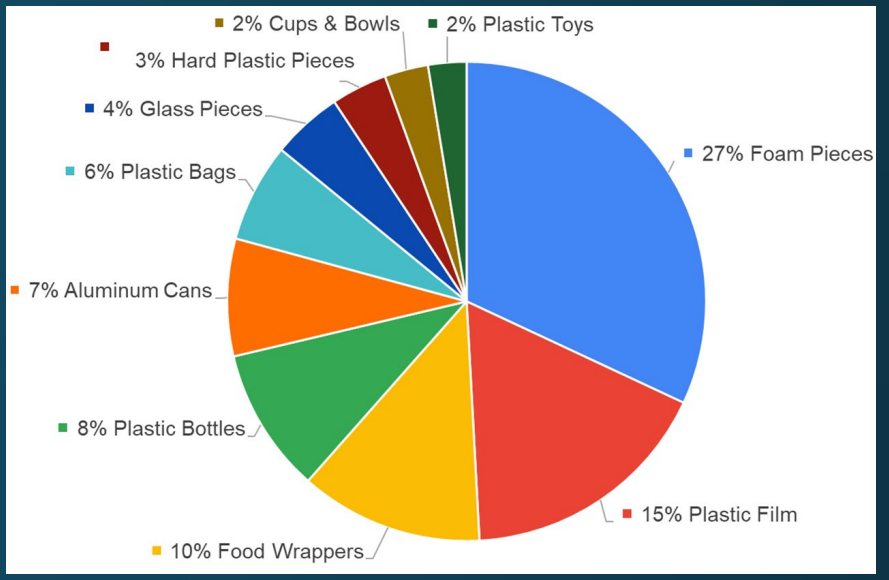
Anti-Litter Campaign

- Educational Signage
- Chalk Messages on Sidewalks
- Work with Local Schools in the Watershed

Ideas to Reduce Litter

- Education
- Incentive Programs to Improve Recycling and Reuse
- Regulatory Programs

Regulatory Programs

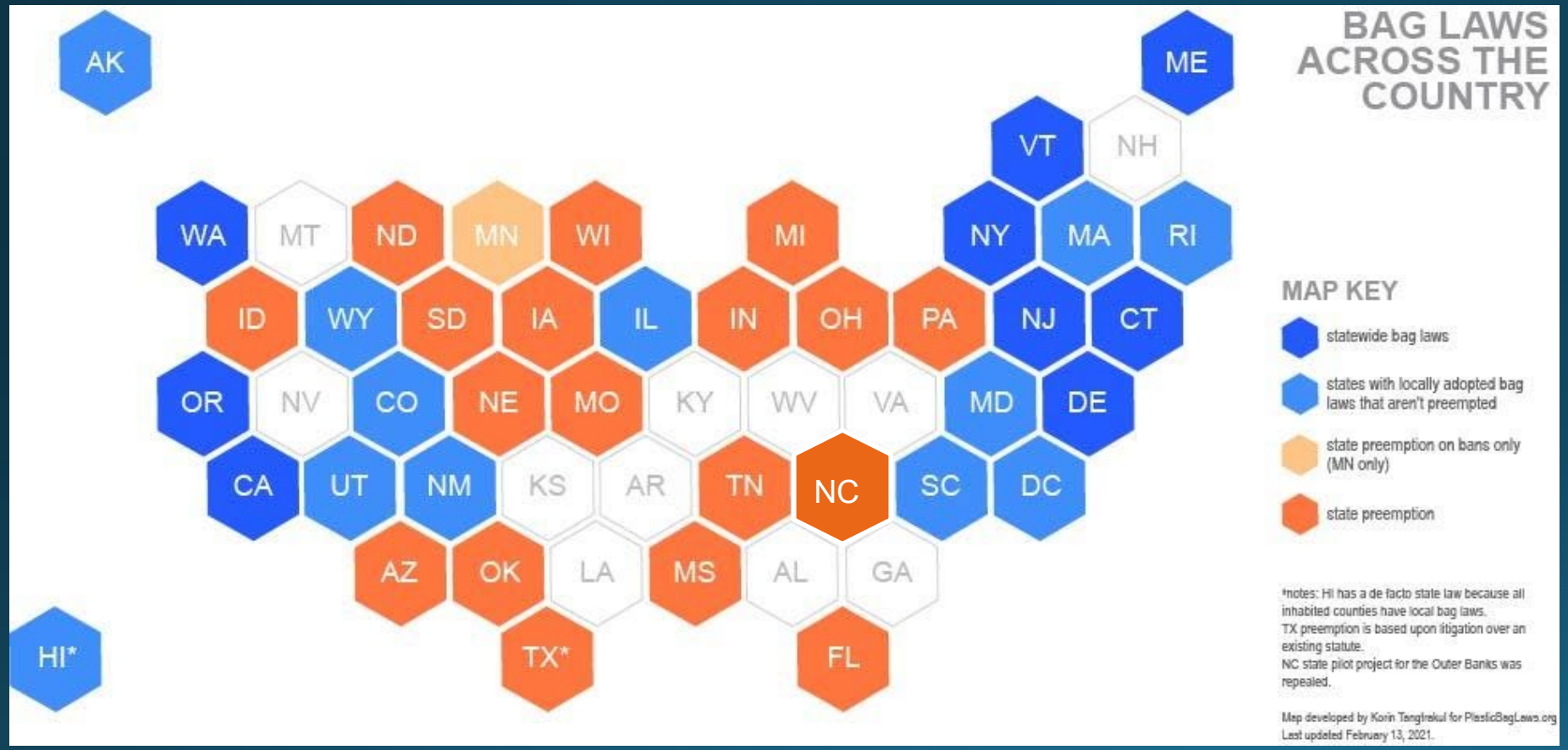


- Adopt packaging restrictions (e.g. Styrofoam)
- Plastic Bag Ban
- Bottle Deposit
- Expand NPDES Stormwater Permits to better address trash and microplastics
- Expand water quality standards for trash and microplastics
- Enforce Littering Laws

Biodegradable Substitutes for Styrofoam

- Paper
- Cornstarch
- Mushroom
- Palm Leaf
- Bamboo

Plastic Bag Bans and Preemption Laws



- NC Legislature Repealed 8-year plastic bag ban for OBX in 2017 (3 counties).
- OBX Chamber of Commerce Survey (1,100 members) all but two of about 500 responses opposed the repeal.

Source: Virginian Pilot 9-1-2017.

Bottle-Deposit

Studies Show Reductions in Litter:

- Beverage container reductions of 70 to 84%; Total litter Reduction of 34 to 47% (HI, IA, ME, MI, MA, NY, OR, VT) Source: BottleBill.org
- Significant decrease in returnable litter - NY compared to NJ (Levitt & Leventhal, 1986)
- Per capita fewer deposit and non-deposit materials found as litter in bottle bill states than in states without (Keep America Beautiful, 2020)

Waste =Valuable Resource

- Aluminum beverage cans are the most recycled container in the world
  - Global average recycling rate of 60% and a rate of over 90% in some countries
  - Bicycles, airplane parts, new cans, building facades
- Plastic bottle recycling creates jobs in N.C.
  - 1,700 direct employees in North and South Carolina
  - e.g. - Clear Path Recycling in Fayetteville and Envision Plastics in Reidsville
- Recycled plastic bottles become new products
  - t-shirts, sweaters, fleece jackets, insulation for jackets and sleeping bags, carpeting and more bottles
- Recycled plastic bags become new products
  - plastic lumber that is used to make park benches, backyard decks and fences – even playground equipment

Clean Water Act – NPDES Program

- NPDES = National Pollutant Discharge Elimination System (NPDES) permits
- Nationwide - 855 Phase I MS4s covered by 250 Individual Permits.

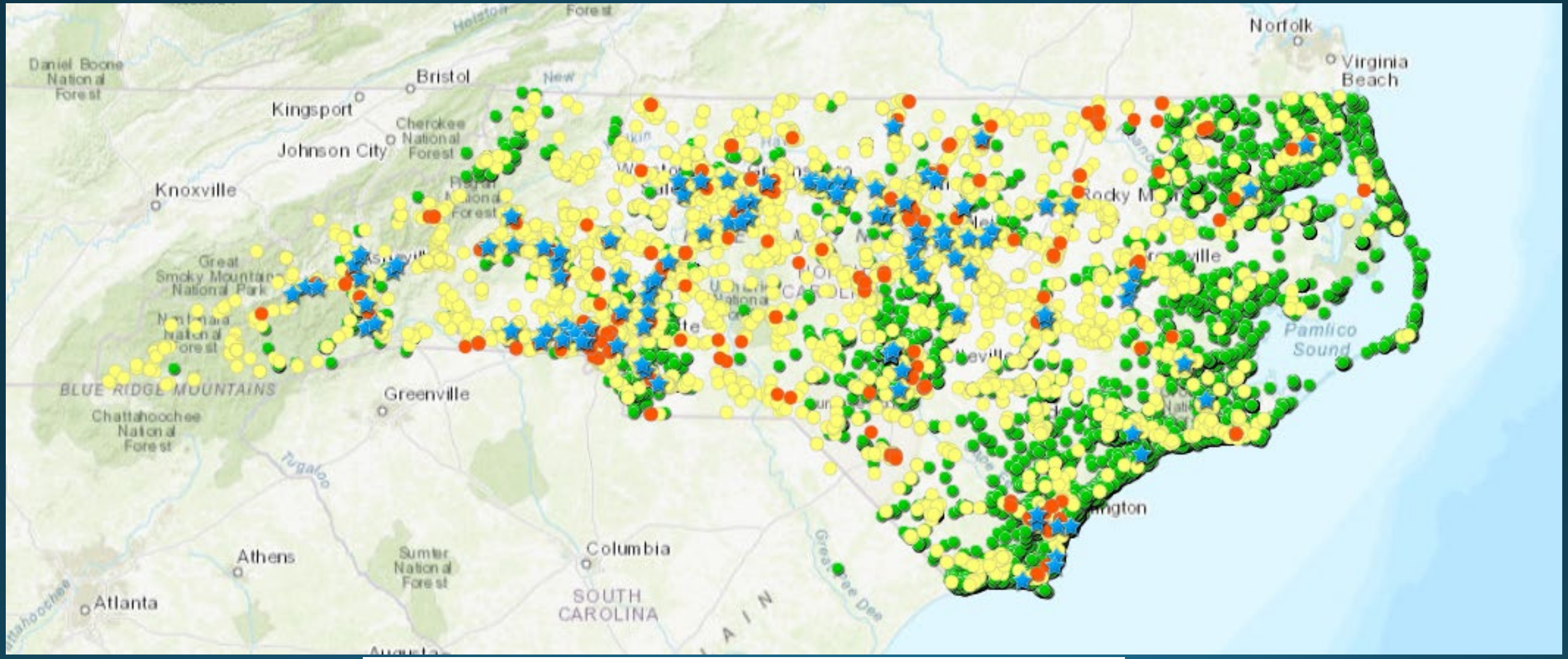
Recommendation: Expand NPDES Stormwater Program to address litter & microplastics

80% of trash is generated on land and then transported to a receiving water body

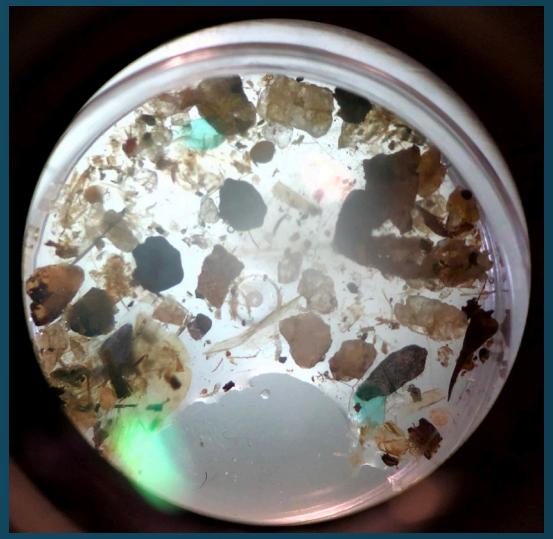
Point Source = Pipe Discharge from Industry or WWTP

Nonpoint Source = Diffuse Pollution from Stormwater Runoff

NC NPDES Stormwater Permits



Clean Water Act

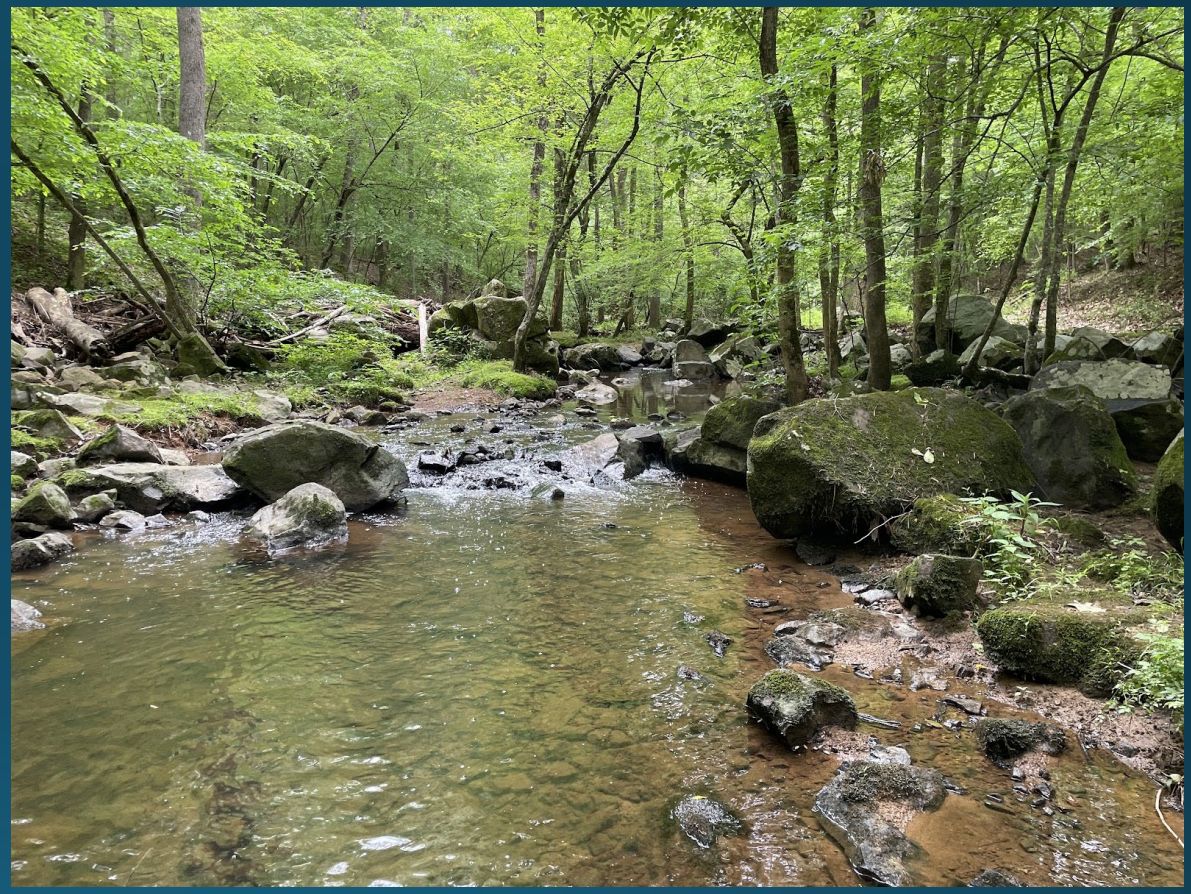


- Establish water quality criteria (micro & macro plastics)
- Develop approved field & lab testing methodologies
- Impaired waterways (303d List) - Sections of more than 200 waterbodies in 7 states have been listed for trash, debris or floatables since 1996 (AK, CA, CT, D.C., HI, MD & NY)

Enforce Littering Laws

- Identify litter dumping locations through a citizen reporting program
- Install signs and cameras
- Issue warning tickets (first offenders) followed by fines (repeat offenders)

Questions?



Barbara Doll - bdoll@ncsu.edu

@NCState_Streams

NC STATE UNIVERSITY Bio&Ag ENGINEERING

NC STATE UNIVERSITY

Sea Grant North Carolina