AN INNOVATIVE, COLLABORATIVE APPROACH TO ADDRESSING THE SOURCES OF MARINE DEBRIS IN NORTH CAROLINA

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I. INTRODUCTION

The volume of plastics and other non-biodegradable litter in the marine environment has emerged as one of the most tangible and damaging of humanity's impacts on the natural world. As of 2017, plastics have been found in each of the major gyres in the world's oceans,[1] and in some of the world's most remote locations, including Henderson Island in the South Pacific[2] and the Mariana Trench.[3] Scientists have found plastics in the stomachs of seabirds, whales, sea turtles, and fish.[4] In addition to ingestion, marine animals suffer from entanglement in plastic debris.[5] Because plastic production, use, and

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1. Oliver Milman, *Full Scale of Plastic in the World's Oceans Revealed for First Time,* THE GUARDIAN (Dec. 10, 2014), https://www.theguardian.com/environment/2014/dec/10/full-scale-plastic-worlds-oceans-revealed-first-time-pollution.

2. Ed Yong, *A Remote Paradise Island is Now a Plastic Junkyard*, THE ATLANTIC (May 15, 2017), https://www .theatlantic.com/science/archive/2017/05/a-remote-paradise-island-is-now-a-plastic-junkyard/526743/.

3. *Pollution Found in the Most Remote Park of the World Ocean*, PLASTIC POLLUTION COALITION (Feb. 15, 2017), http://www.plasticpollutioncoalition.org/pft/2017/2/15/pollution-found-in-the-most-remote-part-of-the-world-ocean.

4. Chris Wilcox, Erik Van Sebille & Britta Denise Hardesty, *Threat of Plastic Pollution to Seabirds is Global, Pervasive, and Increasing*, 112 PNAS 11899, 11899 (2015); Charles James Moore, *Synthetic Polymers in the Marine Environment: A Rapidly Increasing, Long-Term Threat*, 180 ENVTL. RES. 131–39 (2008); Rita Mascarenhas, Robson Santos & Douglas Zeppelini, *Plastic Debris Ingestion by Sea Turtle in Paraíba, Brazil,* MARINE POLLUTION BULL. 49: 354–55 (2004); Christinana M. Boerger, Gwendolyn L. Lattin, Shelly L. Moore & Charles J. Moore, *Plastic Ingestion by Planktivorous Fishes in the North Pacific Central Gyre*, MARINE POLLUTION BULL. 60: 2275–78 (2010).

5. S.B. Sheavly & K.M. Register, *Marine Debris & Plastics: Environmental Concerns, Sources, Impacts, and Solutions*, 15 J. OF POLYMERS AND THE ENV'T 301, 302–03 (2007).

dumping continues unabated, at least one study estimates that the amount of plastic in the world's oceans will outweigh fish by 2050.[6]

The chronic and ubiquitous nature of litter poses a direct threat to water quality in both freshwater and marine environments. Much litter, including plastics, is not biodegradable. It persists and accumulates in the environment, thereby degrading water quality, harming aquatic animals, and marring the aesthetic nature of these environments. The extent of plastic contamination in the world's oceans has only recently been documented, and evidence of plastic pollution in freshwater streams and rivers is also emerging. In fact, an estimated 80% of all marine debris originates on land,[7] and up to 2.4 million metric tons of plastic waste enters the marine environment from rivers every year.[8]

In freshwater systems, the physical presence of litter in waterways can disrupt habitats and alter natural processes such as the flow of rivers, with recent studies showing evidence of plastic contamination in freshwater organisms[9] as well as the presence of microplastics in drinking water.[10] Once in the environment, plastics break down by physical weathering and photo-degradation into smaller and smaller pieces called microplastics or nanoplastics depending on their size (<5mm and <50μm, respectively).[11] Because of their small size, microplastics are accessible and readily ingested by low-trophic organisms,[12] which may in fact mistake small plastic pieces for food.[13]

6. *The New Plastics Economy Rethinking the Future of Plastics*, WORLD ECON. F., http://www3.weforum.org/docs/WEF_The_New_Plastics_Economy.pdf (last visited Feb. 13, 2018); *see also* Jenna Jambeck, *et al.*, *Plastic Waste Inputs from Land into the Ocean*, 347 SCI. 768, 768–71 (Feb. 13, 2015), http://www3.weforum.org/docs/ WEF_The_New_Plastics_Economy.pdf.

7. Dr. Chris Sherrington, *Plastics in the Marine Environment*, EUNOMIA (June 2016), http://www.eunomia.co.uk/reports-tools/plastics-in-the-marine-environment/.

8. Laurent C.M. Lebreton, Joost van der Zwet, Jan-Willem Damsteeg, *et al.*, *River Plastic Emissions to the World's Oceans*, NATURE COMM. DOI:10.1038/ncomms15611 (2017).

9. Ellen Besseling, Bo Wang, Miquel Lürling *et al., Nanoplastic Affects Growth of* S. obliquus *and Reproduction of* D. magna, 48 ENVTL SCI. & TECH. 12336, 12336 (2014); Courtney Humphries, *Freshwater's Macro Microplastic Problem*, PBS (May 11, 2017), http://www.pbs.org/wgbh/nova/next/earth/freshwater-microplastics/.

10. Damian Carrington, *Plastic Fibres Found in Tap Water Around the World, Study Reveals*, THE GUARDIAN (Sept. 5, 2017), https://www.theguardian.com/environment/2017/sep/06/plastic-fibres-found-tap-water-around-world-study-reveals.

11. Olubukola S. Alimi, Jeffrey Farner Budarz, Laura Elena Muñoz, & Nathalie Tufenkji, *Micoplastics and Nanoplastics in Aquatic Environments: Aggregation, Deposition, and Enhanced Contaminant Transport,* 52 ENVTL. SCI & TECH. 1704, 1704 (2018).

12. *See* Nadia von Moos, Patricia Burkhardt-Holm, & Angela Köhler, *Uptake and Effects of Mircoplastics on Cells and Tissue of the Blue Mussel* Mytilus edulis *L. after an Experimental Exposure,* 46 ENVTL. SCI. & TECH. 11327, 11327 (2012).

13. Austin S. Allen, Alexander C. Seymour & Daniel Rittschof, *Chemoreception Drives Plastic Consumption in a Hard Coral,* MARINE PLASTIC BULL. 124: 198–205 (2017).

In addition, their high surface area-to-volume ratio means that microplastics adsorb and concentrate persistent organic pollutants (POPs) that may be present in water, including polychlorinated biphyenls (PCBs), polycyclic aromatic hydrocarbons (PAHs), flame-retardants, and pesticides.[14]

Because of its ubiquity, there is no one simple solution to the problem of marine debris. For example, because illegal dumping is not the main source of marine debris,[15] traditional legal approaches such as enforcement of anti-dumping laws may be largely ineffective at curtailing the amount of debris that makes its way into the oceans. Instead, a multifaceted approach is needed, using a combination of physical, regulatory, legal, and scientific interventions – in addition to removing the litter already present in the marine environment and increasing public awareness and education on related matters.

The Duke Environmental Law and Policy Clinic ("the Clinic") has adopted a multifaceted approach to this challenge by investigating the sources of litter in North Carolina's marine environment; working with scientists to understand and document its impact on the environment, water quality, and human health; and exploring effective methods to engage the public and improve public education about the impacts and possible approaches for mitigation. The Clinic's work focuses on stormwater as a primary source of debris in aquatic environments and involves collaboration with local nonprofits, environmental advocates, state and local regulatory agencies, and scientists. This work is a prime example of "thinking globally and acting locally."

II. REGULATING STORMWATER SOURCES OF MARINE DEBRIS

More than 80% of marine debris comes from improperly disposed solid waste from land-based sources.[16] Rivers transport litter into coastal and near-shore ocean areas, which also receive debris from stormwater point sources as well as from wind and direct dumping.[17] Studies conducted in California suggest that stormwater runoff is the main source of litter into local waterways and have demonstrated clear relationships between storm events and debris collection at storm

14. Almira Van *et al.*, *Persistent Organic Pollutants in Plastic Marine Debris Found on Beaches in San Diego*, CHEMOSPHERE 86: 258–63 (2012).

15. *See* Sherrington, *supra* note 7.

16. *Sources of Aquatic Trash*, EPA, https://www.epa.gov/trash-free-waters/sources-aquatic-trash (last visited Mar. 29, 2018).

17. *The Clean Water Act and Trash Free Waters*, EPA, https://www.epa.gov/trash-free-waters/clean-water-act-and-trash-free-waters (last visited Mar. 29, 2018).

drains.[18] While comparable studies in North Carolina are lacking, stormwater systems are likely responsible for transporting a substantial amount of litter into local rivers, reservoirs and, ultimately, the ocean.

In addition to causing harm in the oceans, litter harms freshwater systems, even those far inland. Litter loading from stormwater runoff impairs urban water quality, endangers public health, and mars the aesthetic appeal of city streams and creeks.[19] In the piedmont of North Carolina, the prevalence of urban debris in upstream waters likely contributes to the loading of microplastics and other litter in downstream local drinking water sources such as Falls Lake, Jordan Lake, and Lake Michie, as well as in marine and coastal environments.[20] Stormwater systems are intimately connected with the marine environment; stemming the tide of litter in urban stormwater is an essential upstream control for limiting marine debris.

Stormwater in urban areas is discharged through Municipal Separate Storm Sewer Systems ("MS4s"), which are regulated pursuant to the federal Clean Water Act.[21] The Clean Water Act prohibits the discharge of pollutants into waters of the United States, except in compliance with a National Pollutant Discharge Elimination System ("NPDES") permit.[22] MS4 stormwater is discharged from roads, parking lots, and roadside ditches directly into local waterways without treatment, often carrying litter. Once in the water, litter harms water quality; in large amounts, litter can smother aquatic vegetation and damage habitat quality, as well as injure or kill wildlife through

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18. *See Trash Total Maximum Daily Loads for the Los Angeles River Watershed*, CAL. REG'L WATER QUALITY CONTROL BOARD, LOS ANGELES REGION (Aug. 9, 2007), http://www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/2007-012/09_0723/L.%20A.%20River%20Trash%20TMDL_Final%20%20Staff%20Report_August%209,%202007.pdf.

19. *See generally Preliminary Data Summary of Urban Storm Water Best Management Practices*, EPA-821-R-99-012 (Aug. 1999), https://www.epa.gov/sites/production/files/2015-11/documents/urban-stormwater-bmps_preliminary-study_1999.pdf.

20. Chris Tyree & Dan Morrison, *Invisibles: The Plastic Inside Us*, ORB MEDIA (2017), https://orbmedia.org/stories/Invisibles_plastics; *Seven Reforms to Address Marine Plastic Pollution*, U. OF VICTORIA ENVTL. L. CENTRE, 4, fn. 2 (Aug. 2017), http://www.elc.uvic.ca/wordpress/wp-content/uploads /2017/08/2017-01-11-MarinePlastics_Final-WEB.pdf (noting that plastic makes it way to the ocean via "run-off, stormwater systems, rivers, etc. Sewage effluent also delivers a vast amount of microplastic fibers to the environment from laundering of clothes and textiles.").

21. 33 U.S.C. § 1342(p).

22. *See* 33 U.S.C. §§ 1311(a), 1342(a); *Stormwater Discharges from Municipal Sources*, U.S. Envtl. Prot. Agency, www.epa.gov/npdes/stormwater-discharges-municipal-sources (last visited Mar. 29, 2018).

ingestion and entanglement.[23] Settleable materials, such as glass and cigarette butts, harm bottom feeders and contaminate sediment, while other debris (e.g., diapers, medical waste, paint cans) are sources of bacteria and toxic substances. Floating debris, such as plastic bags or Styrofoam, which quickly degrade into small particles, has the greatest potential to be transported downstream into the ocean.

Pursuant to the federal Clean Water Act, states must adopt Water Quality Standards ("WQS") to protect surface waters and their biota from pollution.[24] These state-adopted standards, which are set at levels designed to protect designated uses (such as fishing, swimming, and drinking water) of those surface waters,[25] are protected through the issuance and enforcement of NPDES permits.[26] WQS may be either numeric (e.g., "<10ug/L of arsenic") or narrative (e.g., "no visible oil deposits").[27] In areas where WQS are violated, the state is required to develop a Total Maximum Daily Load ("TMDL") for the parameter exceeded, and allocate an allowable level of that pollutant among permitted NPDES sources as well as non-point sources.[28]

Although litter may be considered a pollutant,[29] and the use of WQS can be an effective approach to stemming the flow of litter into local waterways, WQS for litter are not often well-defined.[30] North Carolina, like the majority of states, lacks a specific WQS for litter.[31] Consequently, the Clinic began exploring the possibility of implementing stormwater litter controls through amendments to local MS4 NPDES permits. Writing litter reduction provisions into stormwater permits may be more cost-effective and less time consuming than establishing a specific WQS for debris, as the process

23. *Id.*

24. *See* 33 U.S.C. §1313(a)(3); U.S. Envtl. Prot. Agency, https://www.epa.gov/wqs-tech/state-specific-water-quality-standards-effective-under-clean-water-act-cwa (last visited Mar. 29, 2018).

25. 40 C.F.R. §131.2 (2015).

26. 40 C.F.R. §131.14 (2015).

27. 40 CFR §131.3(b) (1983).

28. 33 U.S.C. §1313(d) (1997).

29. 33 U.S.C. § 1362(6) (1977).

30. For example, *see* 314 C.M.R. 4.05(3)(a)(5)(2004) ("Solids. These waters shall be free from floating, suspended and settleable solids in concentrations or combinations that would impair any use assigned to this class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom."). For an example of a stricter standard, *see* 6 NYCRR 701.3(b)(1991) ("These waters shall contain no floating solids, settleable solids, oil, sludge deposits, toxic wastes, deleterious substances, colored or other wastes or heated liquids attributable to sewage, industrial wastes or other wastes.").

31. *See* 15A N.C. Admin. Code 2B.0211(8) (1976). *Id.* at .0220(7); *Id.* at .0221(3)(a); *Id.* at .0222(3)(a); *Id.* at .0231(b)(2) (Wetlands).

for successfully petitioning the state water quality agency to develop WQS can take many years.

III. CASE STUDY: IDENTIFYING AND CONTROLLING STORMWATER SOURCES OF LITTER IN DURHAM, NC

The City of Durham, NC is currently renewing its MS4 NPDES permit and Stormwater Management Program Plan ("SWMP"),[32] which implements the general terms and conditions of the MS4 permit, providing a unique opportunity for Durham to address litter loading in its waterways. Over the course of 2017, the Clinic conducted legal, regulatory, and scientific research to develop a recommended approach to litter reduction for the City of Durham to adopt in its SWMP.

As a first step in this process, the Clinic conducted a pilot project during the summer of 2017 to quantify the amount of litter present in Durham's waterways. Determining the baseline load of litter in local waterways is a critical step in understanding the extent of the litter problem, both in terms of the spatial distribution of litter and litter volume. Measuring the baseline litter load can also aid in the identification of litter "hotspots" – areas where trash accumulates – which can then be targeted for more efficient, cost-effective cleanup actions. Finally, establishing a baseline litter load is necessary in order to develop targets for litter reduction. For example, if the goal of a litter reduction program is to reduce the litter load by 80% by 2020, knowing the current litter load will allow a municipality to track progress towards this goal and determine appropriate interim reduction targets.

The Clinic's pilot project served the dual-purpose of testing a standardized sampling methodology and providing a baseline indication of litter levels in a highly urbanized stream in Durham, the Ellerbe Creek. Ellerbe Creek was chosen for the pilot study because it is an accessible stream that runs through a populated region of central Durham and empties into Falls Lake, a drinking water reservoir that serves much of Wake County and the City of Raleigh.[33] The Clinic developed a protocol that is based on a simple, cost-effective methodology similar to those that have been implemented to assess baseline litter levels in the Anacostia, Maryland and throughout

32. *City of Durham Stormwater and GIS Services*, THE CITY OF DURHAM, https://durhamnc.gov/785/Technical-Reports (last visited Mar. 26, 2018).

33. *Drinking Water: Where Does it Come From?*, CITY OF RALEIGH, https://www.raleighnc.gov/services/content/PubUtilAdmin/Articles/WhereDoesMyDrinkingW.html (last visited Feb. 14, 2018).

California.[34] This protocol can be replicated easily in streams across Durham and other municipalities to generate precise and comparable estimates of baseline litter loading.

The findings from the Clinic's pilot project, which focused on five different sections, totaling approximately 1/3 mile of the Ellerbe Creek, indicated that the baseline load of litter into this waterway was very high. On average, the Clinic found 183 items per 30-meter section of the Creek, and half of the sampled segments contained more than 295 items on average per 30m transect (Fig. 1).

The majority of litter collected was plastic film, including plastic bags, candy wrappers, chip bags, and other film fragments (over 1,000 items collected; Fig. 2). Glass was the second-most common item (722 items collected) and most of these items were found concentrated at a few sites, where fragmented glass was integrated into "sediment islands" in the middle of the stream (Fig. 2). Styrofoam and other foams (513 items), hard plastics (337 items), and aluminum (190 items) were also frequently recorded and commonly found accumulated at log booms (Fig. 2).

34. John Galli & Kathy Corish, *Anacostia Stream Trash Surveying Methodology and Indexing System,* ANACOSTIA TRASH WORKGROUP (May 19, 1998), https://www.anacostia.net/Archives/download/ TrashSurveyProtocol.pdf; Geoff Brossau, *Tracking CA's Trash: On-land Visual Assessments*, BAY AREA STORMWATER MANAGEMENT AGENCIES ASSOCIATION (March 21, 2017), http://basmaa.org/Announcements/tracking-cas-trash-on-land-visual-assessments.

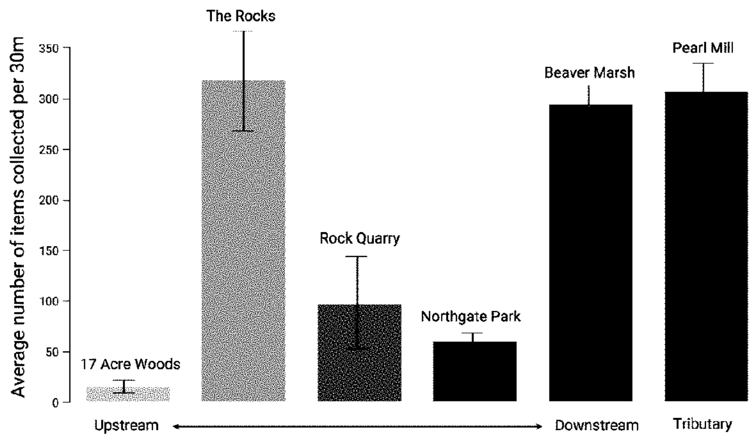

Figure 1. Average number of litter items collected per 30m transect at each site along the Ellerbe Creek in Durham, NC. Error bars represent standard error.

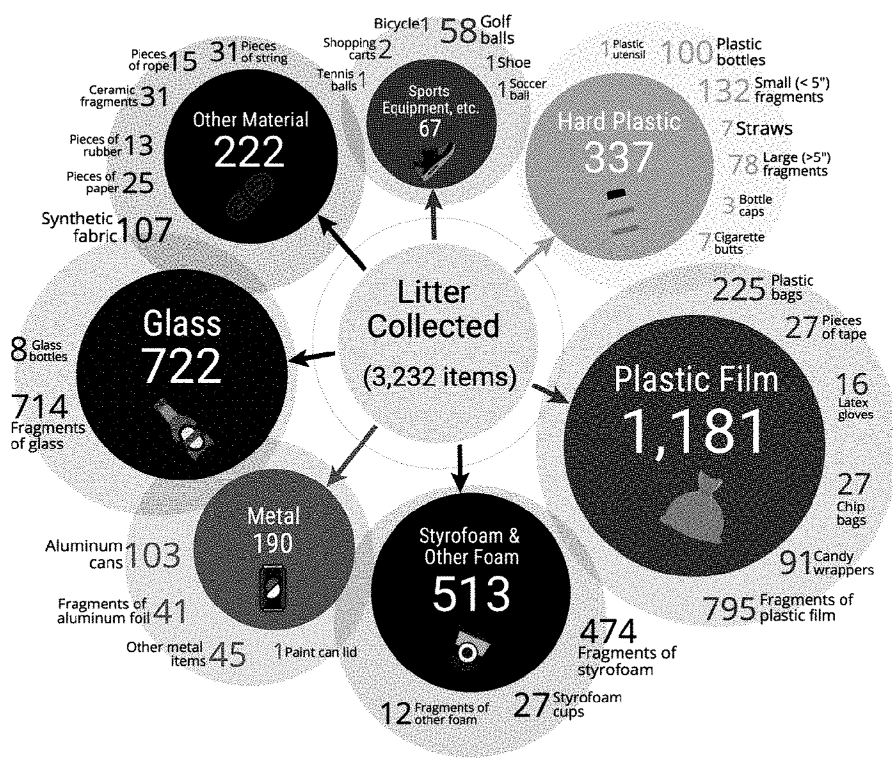

Figure 2. Summary of types of litter collected from transects along the Ellerbe Creek in Durham, NC.

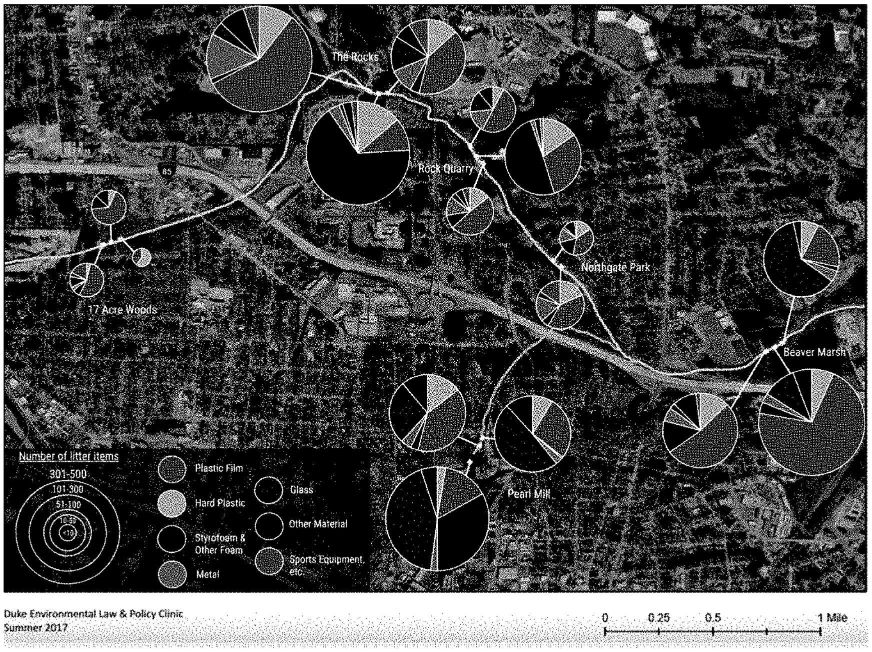

Figure 3. Sampled portions of the Ellerbe Creek, showing location of sampling transects, amount of litter collected, and types of litter present.

Although the scope of the pilot project conducted by the Clinic was not intended to be a comprehensive assessment of the Creek, its results nonetheless provide insight into the location of potential litter "hotspots" (Fig. 3). For example, the highest number of items found along a single 30m segment was 499. In this area, a natural boom composed of branches and larger logs had formed and accumulated a large amount of Styrofoam and plastic items. In general, the formation of litter "hotspots" is likely caused by hydrogeological and physical features present at various locations along the Ellerbe. Therefore, determining the factors that result in litter accumulation makes it easier to target specific areas with tailored control methods.

Based on the findings of this pilot project, the Clinic compiled a set of recommendations for the City of Durham as it renews its NPDES permit and revises its SWMP.[35] The Clinic submitted these comments to the City in February 2018, and met with members of the Stormwater Services Office and the City/County Environmental Affairs Board

35. Duke Environmental Law and Policy Clinic, *Proposal to Amend Durham's Stormwater Management Program Plan to Address Litter Loading in Urban Waterways*, (submitted Feb. 5, 2018).

shortly thereafter. Specifically, the Clinic recommends that the City conduct a Special Study under the City's Water Quality Assessment & Monitoring Plan to comprehensively assess the sources, transport, and fate of litter in Durham's streams, expanding on the pilot sampling that the Clinic conducted during 2017. Additionally, the Clinic recommends that the City expand its current stormwater Public Education and Participation program to include additional non-structural litter control methods, including developing point-of-purchase education materials to inform consumers about the lifecycle of packaging, and expanding the reach of Durham's Stormwater "STAR" Business Recognition Program, which rewards stormwater-friendly business practices such as proper litter disposal.

The Clinic also recommends that the City implement structural control best management practices under the Pollution Prevention section of its SWMP, including increasing the frequency of street sweeping and installing structural control pilot projects such as curb inlet screens, catch basin inserts, and in-stream booms to assess their efficacy, costs and benefits. Finally, the Clinic recommends that the City regulate point-sources of litter as illicit discharges under the Illicit Discharge Detection and Elimination section of its SWMP. Since illicit discharges are already regulated under the City's SWMP, treating point-sources of litter as illicit discharges would provide the City with a clear legal avenue by which polluters could be penalized. The Clinic will continue to work together with the City to refine and implement these recommendations for controlling litter in Durham's stormwater. Taken together, these changes will improve the City's ability to track and prevent stormwater litter from entering local waterways, enforce penalties against point-sources of littering, and engage the public on issues related to stormwater sources of litter in Durham.

IV. EXAMINING THE PRESENCE AND IMPACT OF MICROPLASTICS IN NORTH CAROLINA'S STREAMS AND RIVERS

Plastic does not biodegrade; instead, physical, chemical, and UV weathering cause plastics to break down into smaller and smaller pieces, generally called microplastics.[36] Recent research has begun to paint an alarming picture of the ubiquity and danger of this emerging contaminant in marine and freshwater environments. For example,

36. Olubukola S. Alimi, Jeffrey Farner Budarz, Laura Elena Muñoz, & Nathalie Tufenkji, *Micoplastics and Nanoplastics in Aquatic Environments: Aggregation, Deposition, and Enhanced Contaminant Transport,* 52 ENVTL. SCI & TECH. 1704, 1704 (2018).

although the human health implications of microplastics have not yet been extensively studied, a recent report indicates that drinking water around the globe is polluted with microplastics, with 94% of drinking water samples in the U.S. found to contain microplastics, mostly in the form of "microfibers" - microscopic plastic fibers that shed from synthetic fabrics during washing and from everyday abrasion of clothing, carpets, and upholstery.[37] Given the uncertain – yet potentially dangerous – human health impacts of microplastics and associated chemicals, plastic pollution in freshwater streams and drinking water sources must be examined and remediated.

There are two main concerns associated with microplastics that warrant a proactive approach to reducing plastic pollution. First, microplastics can accumulate within organisms, causing physical damage to internal organs or blocking digestive tracts.[38] Second, additives that adsorb onto microplastics become concentrated and bioaccumulate within organisms once ingested, with worrying implications for human and ecosystem health. For example, some common persistent organic pollutants (POPs) are known carcinogens and endocrine disruptors, including polycyclic aromatic hydrocarbons (PAHs), which are frequently used during the manufacture of plastics.[39] Other dangerous POPs, including polycholinated biphynels (PCBs) and dichlorodiphenyltricholorethane (DDT), are present in the environment in small amounts, and become locally concentrated when they adsorb onto plastics.[40] Preliminary studies of the effects of plastic byproducts on bivalves, barnacles, and crustaceans, including recent research from Duke, indicate that these contaminants can cause oxidative stress, negatively affect growth and reproduction, and alter feeding behavior of these organisms.[41] In fact, a recent study suggests that the chemicals leaching from microplastics may attract some organisms to them, as they misidentify the chemicals as food sources.[42]

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37. Tyree & Morrison, *supra* note 20.

38. Stephanie L. Wright, Richard C. Thompson, & Tamara S. Galloway, *The Physical Impacts of Microplastics on Marine Organisms: A Review*, 178 ENVTL. POLLUTION 483, 483 (2013).

39. *Id.*

40. *Id.*

41. *See* Tamara S. Galloway & Ceri N. Lewis, *Marine Microplastics Spell Big Problems For Future Generations*, 113 PNAS 2331, 2331 (2016).

42. Matthew S. Savoca, Chris W. Tyson, Michael McGill, & Christina J. Slager, *Ordours from marine Plastic Debris Induce Food Search Behaviours in a Forage Fish*, 284 PROC. ROYAL SOC. B DOI: 10.1098/rspb.2017.1000.

The potential threat of microplastics to human and environmental health warrants scientific investigation to determine the transport, fate, and impact of this pollutant in coastal and freshwater environments. To address this concern, the Clinic is collaborating with Duke research labs, both on the main campus and at the Duke University Marine Lab in Beaufort, NC, to examine the presence of microplastics in Durham's urban stormwater, to compare inland and coastal microplastics loading, as well as examine the prevalence of microplastics in North Carolina's marine animals and its impact on them. As a first step, the Clinic collaborated with Dr. Lee Ferguson's lab at Duke to conduct a pilot survey of microplastics in the Ellerbe Creek in December 2017, mirroring the macro-litter surveys conducted by the Clinic in summer 2017. The pilot survey will help Dr. Ferguson's lab refine their methods for detecting microplastics in sediment samples, and will provide important baseline data concerning the presence of microplastics in Durham's urban streams. Taken together with the macro-litter results, these pilot surveys will provide information about the potential human and environmental health impacts of plastics, building the case for the City of Durham to address litter in its stormwater system.

Because of its status as an emerging contaminant, there are no well-established legal or regulatory methods to control microplastic presence in waterways. As this research progresses, the Clinic will assess the legal, regulatory, and policy tools that are available to aid in monitoring and limiting microplastics in urban streams, wastewater, animal tissue, and ocean ecosystems.

V. COLLABORATIONS TO PROMOTE PUBLIC EDUCATION AND CONDUCT MARINE DEBRIS CLEAN-UPS

Building effective and diverse networks of advocates, organizations, researchers, and government representatives has been a key goal of the Clinic's work on marine debris. Because of the multifaceted nature of the marine debris problem, this challenge cannot be addressed with a narrow approach, and is therefore beyond the capacity of a single organization. In North Carolina, approaches to controlling the sources of marine debris must span the state, as stormwater litter and microplastics that enter waterways upstream may be transported to the ocean via large rivers including the Neuse, Tar, Cape Fear, Roanoke, and Chowan.[43] Along the coast, these rivers discharge into sounds, estuaries, barrier island habitats, and nearshore environments that host nesting sea turtles, juvenile fish, migrating seabirds, and endangered marine mammals.[44] Although these rivers are not the sole source of debris into North Carolina's marine environment, limiting the contribution of stormwater litter is a tangible and feasible goal within the more expansive and undefinable challenge of marine debris.

Highlighting the connectivity between litter that is generated by an individual household in North Carolina and the presence of debris in the ocean is a key component in building an understanding of the impact of human activities on the environment. Reports of microplastics floating in the middle of the North Atlantic,[45] or plastics accumulating on an isolated beach in the South Pacific,[46] often seem far removed from the daily activities of North Carolina residents. However, the continued use, irresponsible disposal, and ineffective regulation of plastics by residents and governments is responsible for the ever-growing presence of debris in the world's oceans.[47] As a result, solutions to this challenge must address all of these contributing factors.

In an effort to build a diverse and effective coalition to address marine debris in North Carolina, the Clinic has partnered with organizations in Durham and at the coast to promote litter cleanups, increase awareness of steps the public can take to reduce their contribution to environmental litter, and improve public education on the causes and consequences of litter in the environment. In Durham, the Clinic is collaborating with local nonprofits and researchers,

43. North Carolina Department of Environmental Quality Office of Environmental Education and Public Affairs, *Discover North Carolina's River Basins* at 3 (2013) http://www.eenorthcarolina.org/Documents/RiverBasin_pdfs/final_web_BOOKLET.pdf.

44. Ashita Gona, *Estuaries: Understanding Their Vital Roles,* COASTAL REVIEW ONLINE (Sep. 20, 2016), https://www.coastalreview.org/2016/09/estuaries-understanding-vital-roles/.

45. Amy L. Lusher, Ann Burke, Ian O'Connor, & Rick Officer, *Microplastic Pollution in the Northeast Atlantic Ocean: Validated and Opportunistic Sampling* 88 MARINE POLLUTION BULLETIN 325, 325 (2014).

46. Nsikan Akpan, *This Tiny Island With No Humans is Getting Burried in Plastic Trash*, PBS (May 15, 2017), https://www.pbs.org/newshour/science/remote-south-pacific-island-buried-worlds-plastic.

47. Joana Mira Veiga, David Fleet, Susan Kinsey, Per Nilsson, Thomas Vlachogianni, Stefanie Werner, François Galgani, Richard C. Thompson, Jeroen Dagevos, Jesús Gago, Paula Sobral, & Richard Cronin, *Identifying Sources of Marine Litter*, MSFD GES TG Marine Litter Thematic Report; JRC Technical Report; EUR 28309 (2016), http://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/MSFD_identifying_sources_of_marine_litter.pdf.

including the Ellerbe Creek Watershed Association (ECWA), Don't Waste Durham (DWD), Keep Durham Beautiful, and Dr. Lee Ferguson and Dr. Dan Ritschoff at Duke to conduct expanded litter surveys to quantify macro- and micro-plastics in Durham's urban waterways using the methodology developed by the Clinic in 2017. These collaborations also involve developing and piloting structural control measures within the Ellerbe Creek and promoting campaigns and policies to reduce single-use plastic use throughout the City. For example, the Clinic recently partnered with Don't Waste Durham, Keep Durham Beautiful, local restaurants including Pompieri Pizza and Bull City Burger and Brewery, and other organizations to advocate for a plastic straw-free month in Durham.[48] As part of this campaign, our coalition wrote a proclamation that was signed by Durham Mayor Steve Schewel, declaring March 2018 "no straws month" in Durham, and developed a "no straws" pledge for individuals and businesses to join.[49]

Along North Carolina's coast, the Clinic has joined a long list of organizations working to clean up marine debris, including derelict fishing gear. For example, the Clinic has partnered with Crystal Coast Waterkeeper, Plastic Ocean Project, and Carteret Big Sweep to develop and implement a "Fishing 4 Plastic" educational model, which engages the fishing community and the general public in a semi-annual competition to remove marine debris from North Carolina's offshore *Sargassum* habitat.[50] *Sargassum*, a type of seaweed, accumulates in mats at the surface of warm water eddies off North Carolina's coast and provides vital habitat and foraging grounds for juvenile sea turtles and other marine life. However, the same ocean currents that cause *Sargassum* to accumulate draw plastics and other floating debris into these areas.[51] Plastic bags and balloons are often mistaken for food (e.g., jellyfish) by sea turtles and consumed.[52] Other floating debris,

48. *Plastic Is Choking Our Oceans*, KEEP DURHAM BEAUTIFUL, https://keepdurhambeautiful.org/straws/ (last visited Mar. 26, 2018).

49. Jeff Reeves, *Durham Looks To Go Straw-Free For March,* CBS (Feb. 27, 2018), http://wncn.com/2018/02/27/durham-looks-to-go-straw-free-for-march/.

50. *Fishing 4 Plastic,* PLASTIC OCEAN PROJECT, http://www.plasticoceanproject.org/ fishing-4-plastic.html (last visited Mar. 26, 2018).

51. Bonnie Monteleone, *Studying Sargassum and Plastic off the North Carolina Coast*, PLASTIC OCEAN PROJECT, INC. (May 20, 2012), http://theplasticocean.blogspot.ca/2012/05/studying-sargassum-and-plastic-off.html.

52. Qamar A. Schuyler, ChrisWilcox, Kathy A. Townsend, Kathryn R. Wedemeyer-Strombel, George Balazs, Erik van Sebille, & Britta Denise Hardesty, *Risk Analysis Reveals Global Hotspots for Marine Debris Ingestion by Sea Turtles* 22 GLOBAL CHANGE BIOL 567, 567 (2016).

including rope, derelict fishing gear, and plastic wrap can entangle marine life, causing physical harm and death.[53] The Fishing 4 Plastic model serves dual purposes of removing floating debris from these eddies, while raising public awareness of the presence of litter off North Carolina's coast.[54] During the October 2017 Fishing 4 Plastic tournament, volunteers on four charter boats brought in over 150 pounds of debris from the *Sargassum* off Beaufort, NC.[55] More recently, the Clinic joined the Duke University Marine Lab to participate in a three-boat Fishing 4 Plastic tournament on Earth Day, April 22, 2018.

VI. CONCLUSION

The Clinic's research thus far addresses only a small portion of the work that must be developed in North Carolina to control marine debris. For example, future efforts could involve an examination of the post-use market for recyclables, including an economic analysis to determine ways to increase the value of post-use materials and encourage more recycling. In addition, the potential for implementing single-use plastic policies in Durham and greater North Carolina, e.g., including banning certain materials such as Styrofoam, could be investigated. Finally, North Carolina does not yet regulate litter or microplastics as pollutants under its Water Quality Standards, presenting an opportunity for legal and advocacy work. Future research could investigate the potential for developing and implementing Water Quality Standards and specific MS4 effluent limitations for litter to control stormwater sources of litter.

The widespread and expanding problem of marine debris necessitates a manifold response that integrates legal, policy, scientific, and outreach expertise. Thus far, the Clinic's work has targeted Durham as a pilot area to test specific approaches that identify and control the potential sources of marine debris, including quantifying the City's urban stormwater litter load, investigating the presence of microplastics, and evaluating the effectiveness of public education campaigns and single-use plastic regulation. The Clinic's research has concluded that to be effective, litter reduction provisions in NPDES permits should require MS4s to assess the sources and baseline load of

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53. Allison Guy, *17 Critically Endangered Right Whales Died in 2017 - The Time for Systemic Change is Now*, ECOWATCH (Dec. 27, 2017), https://www.ecowatch.com/north-atlantic-right-whale-2520326598.html.

54. Monteleone, *supra* note 51.

55. Bonnie Monteleone, personal communication (data not yet published).

litter entering surface water via stormwater outfalls, identify and implement control measures, and monitor the effectiveness of control measures over the long term. Litter reduction provisions should also integrate structural control measures with educational measures and monitoring procedures to build an effective and resilient litter management strategy. Because North Carolina's inland environment is intimately connected to its marine environment via large rivers acting as stormwater conduits, the Clinic's goal is to promote approaches that acknowledge this connectivity and utilize holistic strategies to tackle the issue of marine debris.