FOLLOW THE FLOATING FOAM: EVALUATING STREAM TRANSPORT OF PLASTIC WASTE IN A LAKE MICHIGAN WATERSHED

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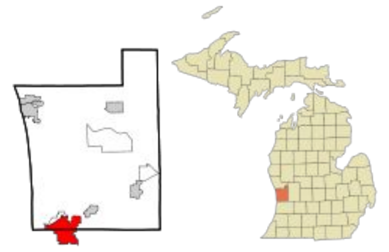


Abstract

Plastic and microplastic pollution in the world's oceans is acknowledged as a global problem. Comparing roadside litter on land to floating litter captured in streams can give insight into the origin, transportation, and alteration of mismanaged plastic waste that ultimately becomes ocean plastic. We manually collected roadside litter at three 300-m stretches of roadside in Holland, Michigan, consisting of two residential streets and a 4-lane road in a commercial area, with the commercial site having more litter overall. Both aquatic and terrestrial litter were dried and processed by photographing, sorting and counting materials, massing various categories such as foam, bottles, and plastic fragments, and conducting a brand analysis when possible.

We used a combination of industrial and homemade litter booms and a floating cage trap to sample floating litter at 3 field sites in June and July, 2022: a stream draining extensive proximal wetlands (velocity = 0.11 m/s, discharge = 0.32 m^3/s, days sampled = 17), a small urban stream integrated into the local storm drain network (0.12, 0.24, 15), and a smaller stream in a residential area (0.15, 0.18, 9). Most sampling occurred during normal flow conditions. In capture and release experiments homemade booms, made of pool noodles strung on a rope and sewn into a sleeve along the top of a 30 cm wide strip of burlap, retained 100% of floating test debris but in field use failed under high flow when damaged by woody debris.

Whereas expanded plastic foam accounted for 10.0% of all items of roadside litter, it made up 88.9% of floating litter (range 63–100%) captured in streams. The stream with extensive storm drain input was intermediate in velocity and discharge but had the greatest variety of litter composition. Larger amounts of floating plastic were captured following rain events than under normal flow conditions. Our results suggest that foam is the most mobile kind of plastic waste under normal flow. Other plastic materials may move more episodically during rain events or spring snowmelt. Furthermore, cheap homemade litter booms may be useful for monitoring many sites simultaneously during normal flow conditions but more robust and expensive commercial devices may be needed to capture litter movement during high flows, which could possibly represent the majority of litter movement.

Introduction

Plastic and microplastic pollution from anthropogenic litter is a world-wide issue that is causing many ecological effects (Gregory, 2009; Rochman, 2013). While the more recognized effects on marine life are events such as entanglement, ingestion, or suffocation, traveling litter can have effects as far as distributing invasive species. Litter enters marine environments in a variety of ways, all originating from human production (Rech et al., 2018). The pathways that litter takes to pollute these environments are still not very well understood. As the world population increases, plastic production does as well (Smith and Bernal, 2021) while recycling rates remain relatively low. With more being made and not enough being recycled, plastic has become an epidemic.

In order to understand the manner and type of litter entering the watershed, it is necessary to first understand what pollutants are being mismanaged. Roadside cleanups were conducted and trash was categorized to quantify what has the potential to be swept into waterways by means of wind, water, and human invention. These results were then compared to sequestered stream litter to identify trends in mismanaged waste. This research into litter composition and quantity was conducted in Holland, Michigan, in an attempt to (1) identify roadside litter variety and amount, (2) make comparisons to data found via stream litter, and (3) test the effectiveness of homemade litter booms. As plastic pollution has the ability to enter drainage systems during rain events (Erikson et al., 2013), this study focused on litter entering the watershed through streams and drains as the primary pathway.

Sampling Sites

Roadside Sites	Stream Sites
Lakewood North side **(LN)** – residential and vacant, sidewalk South side **(LS)** - railroad, undeveloped, no sidewalk 4 lanes Lat. 42.804772, Long. -86.098318	**Pine Creek (PC)** Velocity of 0.1079 m/sec Discharge of 0.3156 m^3/s Width of 6.83 m Lat. 42.797560, Long. -89.145970
Pine Ave. (PA) West collection, park and residential, sidewalks 2 lanes Lat. 42.777803, Long. -86.111916	**DeGraaf Nature Center (DN)** Velocity of 0.1475 m/sec Discharge of 0.1785 m^3/s Width of 4.12 m Lat. 42.775428, Long. -86.138777
Lincoln Ave. East side **(LE)** - residential with sidewalk West side **(LW)** – residential with sidewalk 2 lanes Lat. 42.784819, Long. -89.097146	**Maplewood Drain (MD)** Velocity of 0.124 m/sec Discharge of 0.2355 m^3/s Width of 6.35 m Lat. 42.787480, Long. -86.091073

We collected roadside litter from three locations around Holland, Michigan. One initial site (Lakewood) was chosen to allow collection along 300 m of roadway in an area with limited residential frontage that might experience frequent litter cleanup, that crossed a stream, and that had a sidewalk on one side but not on the other. Two additional sites (Pine Avenue and Lincoln Avenue) were added on residential streets with some park frontage.

Google Earth image of Holland, MI area with study site locations.

Methods

Roadside Litter Collection

To study waste in multiple environments, collections were done in one commercial area and in two residential areas. These collections consisted of at least two researchers using extended grab tools to collect waste along 300 meters of roadway frontage. At each site, for both transects of the road, all observed waste was collected into plastic bags for later laboratory analysis. At the commercial site, waste was collected from the curb to the edge of the roadside mowing area. In residential areas, waste was collected from the curb to a meter beyond the opposing edge of the sidewalk. All observed waste was collected from all sites regardless of grass cover or other environmental factors.

Stream Litter Collection

Methods for stream cleanups varied according to the equipment used. The Pine Creek collection site utilized a Trash Trout Jr., a bottomless floating metal collection cage anchored using stainless steel cables run through litter booms that extended from bank to bank to deflect floating trash into the cage. The Trash Trout Jr. was checked every 1 to 2 days and all trash sequestered in the cage was collected for laboratory analysis. The Maplewood Drain site used a manufactured litter boom extending diagonally from bank to bank. Trash was deflected to the downstream shore where it was regularly checked during the week to ensure maximum efficiency. The DeGraaf Nature Center site utilized a homemade boom. The boom was installed at an angle across the stream to collect trash in a single area. Like our other sites, this waste was collected approximately daily and brought to the laboratory for analysis.

Methods

Homemade Boom Effectiveness

We experimented with creating cost effective, simple floating litter collection booms in an attempt to expand our stream litter monitoring and capture capabilities. The booms consisted of ~62 cm strips of burlap with the top and bottom folded over and sewn to create two sleeves. The top sleeve held floats consisting of hollow 8.2 cm diameter pool noodles strung on cotton rope. Small pieces of rebar sewn into the bottom sleeve kept the burlap extended down below the water's surface.

We conducted an experiment to determine the effectiveness of the homemade booms at trapping an assortment of items. A variety of plastic and foam items were used including plastic cups, lids, bottles, plastic containers, grocery and ziploc bags, straws, zip ties, plastic wrappers, bottle caps, and plastic eating utensils as well as foamed plates, cups, foamed containers, and metal cans. Items were dropped 10 meters upstream and entrapment success or failure was observed and recorded. Items that merely sank were also recorded. Additionally, we ran an overload experiment to determine how much waste the booms are able to hold. A total of 112 items were used and the number of pieces that were successfully and unsuccessfully trapped were recorded. Both experiments were conducted under normal stream flow conditions at the DeGraaf Nature Center site.

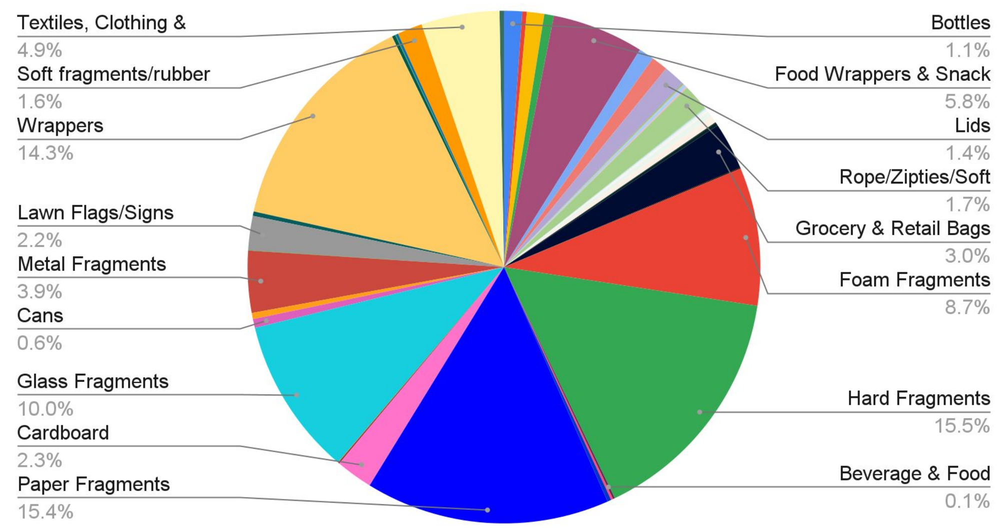
Laboratory Analysis

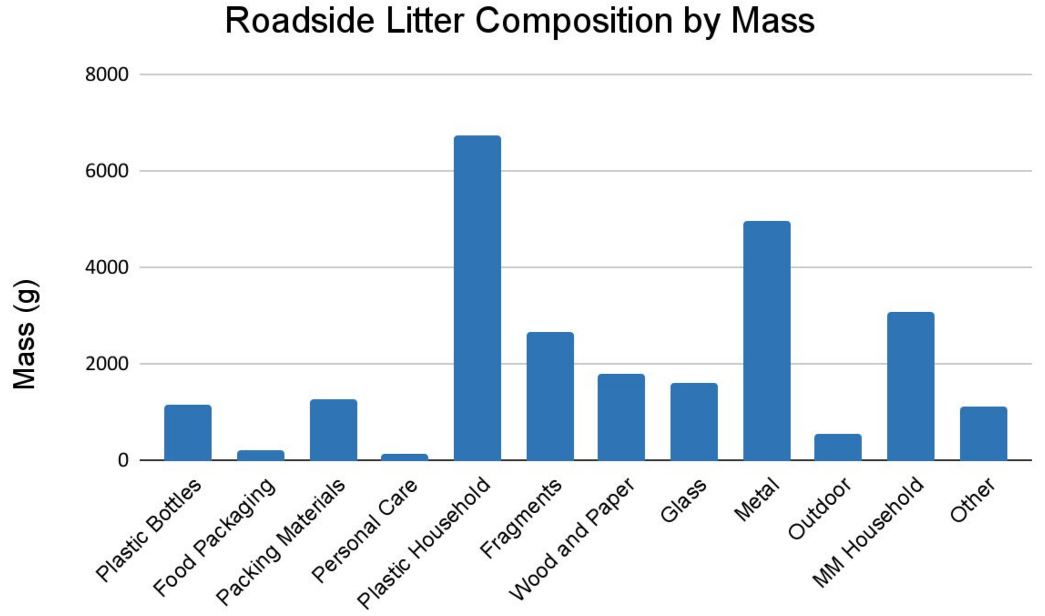
All items collected on roadsides and in streams were dried, sorted, counted, weighed, and photographed. All waste was then separated first by material (i.e., plastic, paper, or metal) and then categorized further into more specific groupings. Item identification schemes were based on those provided by Dr. Sherri Mason, as a similar research experiment is being conducted at Behrend College.

Results

Roadside Litter by site

Items—We collected 4,643 items across all roadside locations. The dominant items at our locations were hard plastic, paper, and glass fragments. Mixed material wrappers and plastic food wrappers/snack bags were also highly abundant. There were many spots where fragmented individual items were scattered in a small area.

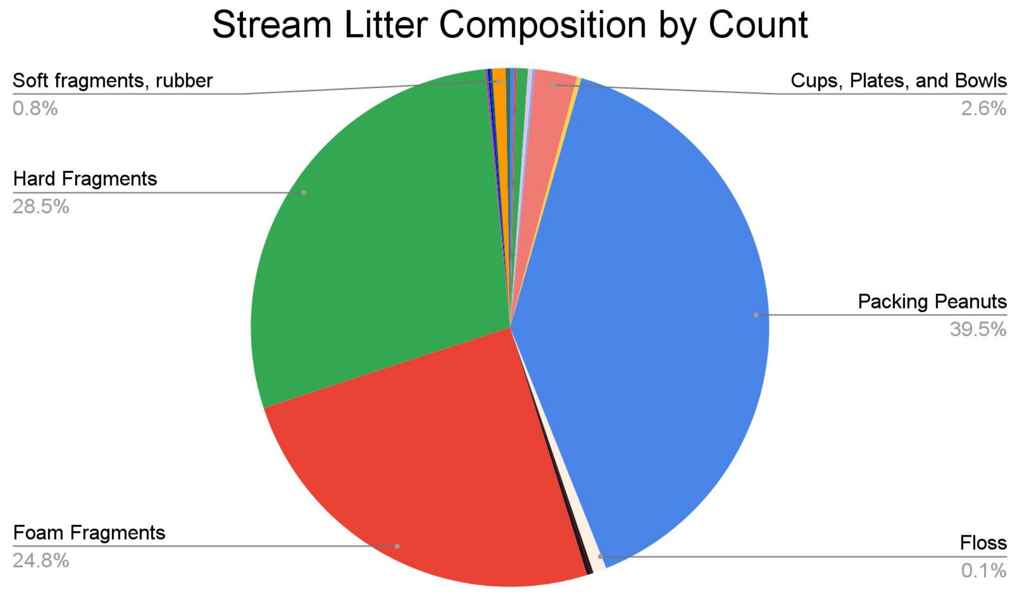


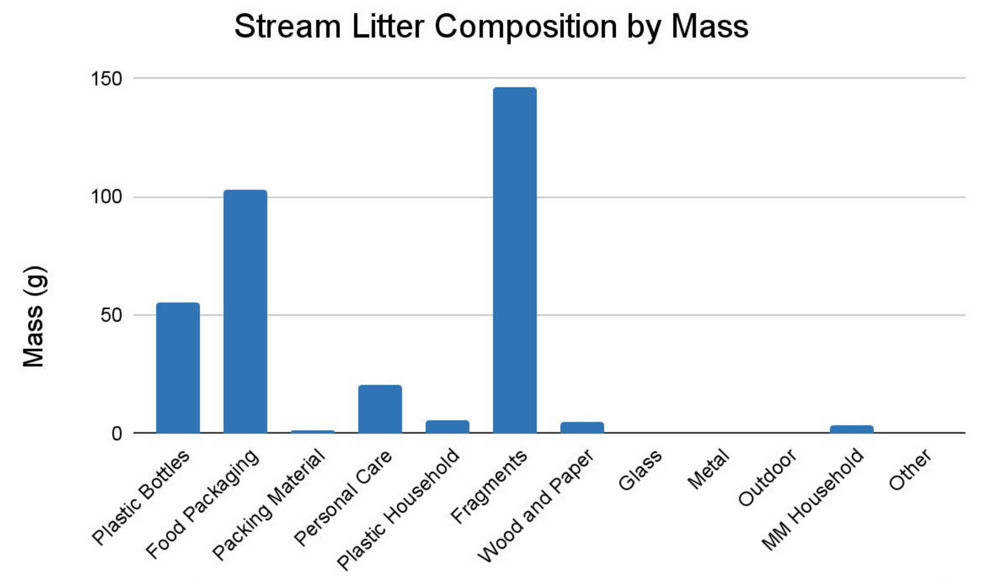


Results

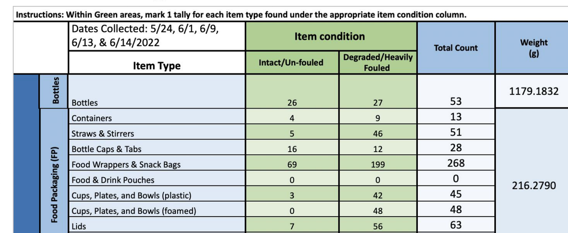
Stream Litter by site

Items—We collected 719 items across all stream locations. The dominant items at our locations were packing peanuts, hard plastic fragments, and foam fragments. Foamed cups, plates, and bowls were also abundant. Item type and amount varied significantly between each site due to differences in stream flow, size, and location.





Portion of the sorting sheet that was used for categorizing collected litter.



Instructions: Within Green areas, mark 1 tally for each item type found under the appropriate item condition column.

Dates Collected: 5/24, 6/1, 6/9, 6/13, & 6/14/2022

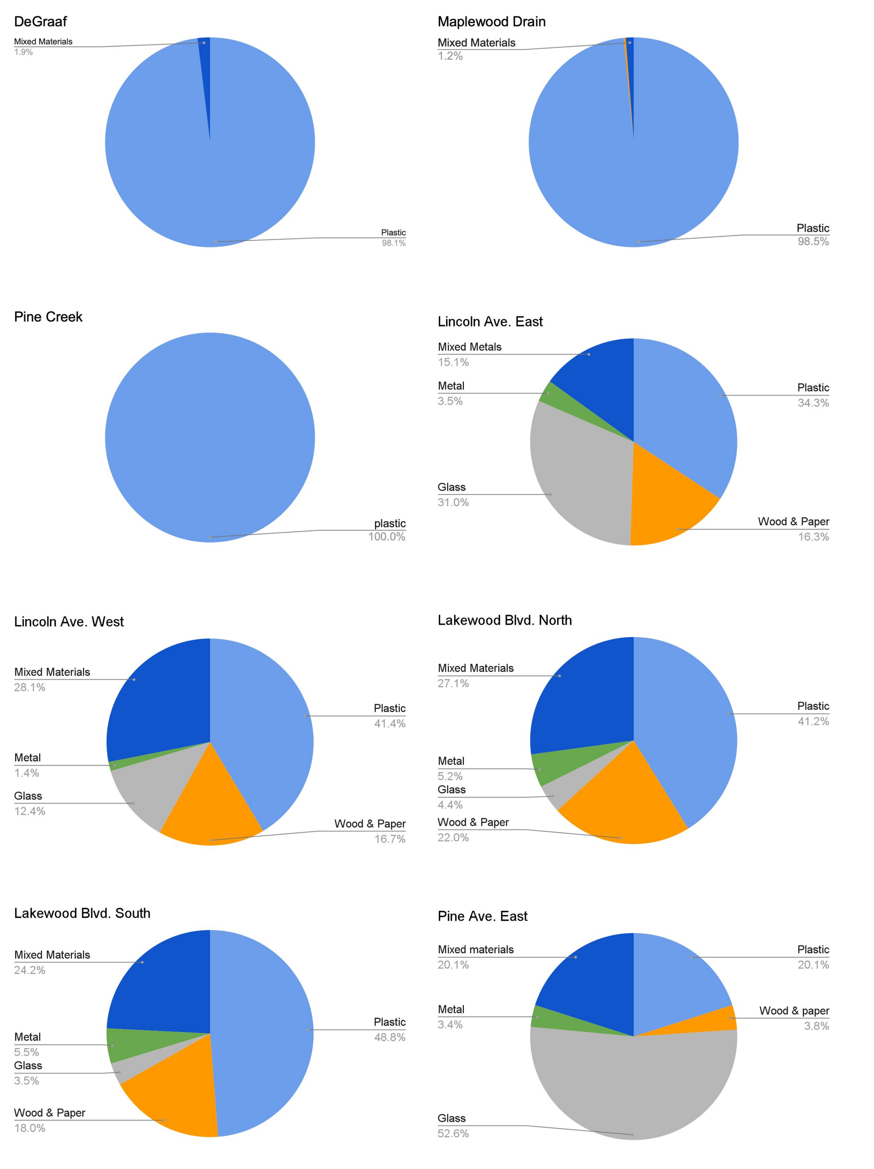
	Item Type	Item condition: Intact/Un-fouled	Item condition: Degraded/Heavily Fouled	Total Count	Weight (g)	Item Notes: Identifying features: Product, Language, Ect.
Bottles	Bottles	26	27	53	1179.1832	
Food Packaging (FP)	Containers	4	9	13	216.2790	
	Straws & Stirrers	5	46	51		
	Bottle Caps & Tabs	16	12	28		
	Food Wrappers & Snack Bags	69	199	268		
	Food & Drink Pouches	0	0	0		
	Cups, Plates, and Bowls (plastic)	3	42	45		
	Cups, Plates, and Bowls (foamed)	0	48	48		
	Lids	7	56	63		
	Utensils	1	2	3		
	Tea Bag	2	0	2		

Trash Trout Jr. installed in Pine Creek.

Results

Comparisons

Roadside litter analysis showed a multitude of litter compositions while stream analysis yielded a much smaller range of data. Plastic accounted for 42.88% of roadside litter compared to 98.47% of stream litter. Out of that percentage of plastic, foam comprised 67.94% of the litter sequestered in streams, demonstrating a relationship between buoyancy and amount.



Homemade Litter Boom Effectiveness

Out of the 112 items used, 82 were captured and 30 made it past our homemade boom. Of those 30 pieces, none were buoyant, meaning that they traveled under the boom; 100% of floating trash was sequestered. The boom was able to capture items smaller than 5 mm such as plastic nurdles. Pieces that made it past included: highly degraded/fragmented plastic bottles, cups, plastic bags, plastic utensils, and zip ties.

Additionally, all buoyant items used for the overload test were successfully captured suggesting that our homemade booms are able to successfully trap up to, and likely more than, 82 pieces of floating stream trash under normal flow conditions.

Items that passed the homemade litter boom.

Discussion

Our study of roadside and stream trash led us to several conclusions. First, the dominant items at all of the road locations (plastic, paper, and glass fragments) suggest that items composed of these materials are being broken up and dispersed by automobile and foot traffic. While it is unclear if most of the trash is deposited from automobiles or pedestrians walking by, it is almost certain that there are contributions from both. Mixed material wrappers and plastic food wrappers/snack bags were also highly abundant which suggests that food related products are common litter items on and near roads.

Second, variation between stream sites affected our results. The largest stream, Pine Creek, has a low flow velocity, and it flows through a wetland with substantial vegetation at stream level. Both of these factors limited the amount and the type of trash that was able to make it to our collection site and therefore affected our data. Maplewood Drain has significant storm drain input so there were noticeably elevated trash levels, including cigarette butts, during and after storm events. Additionally, foam fragments may travel as floating waste better than other fragments. Its high air content makes it much more buoyant than most other plastic items and other roadside materials.

Third, our homemade litter boom effectiveness experiment showed that they can be effective under certain conditions. First, relatively cheap homemade booms have the potential to capture 100% of floating trash if constructed properly and anchored securely. Second, homemade booms can be useful for monitoring and collecting floating litter in smaller streams under normal flow conditions. High flow rates may result in boom failure if booms are not properly secured or protected from large floating debris. Third, homemade booms may be most useful when monitoring several sites simultaneously and over a short period of time, especially in smaller streams where flow rates are lower and there is relatively little floating trash. Booms intended for longer deployment should be made of materials other than burlap that are more durable and not subject to rapid decay, which may justify a greater expenditure for commercially provided booms with high quality components.

Items on or near roadsides have the potential to be dispersed or blown into storm drains. These items are then very likely to enter waterways including outfalls and streams especially if they are buoyant. This is important in preventing items like microplastics from entering larger bodies of water and ultimately the global ocean.

References

Eriksen, Marcus, Sherri Mason, Stiv Wilson, Carolyn Box, Ann Zellers, William Edwards, Hannah Farley, and Stephen Amato. 2013. Microplastic pollution in the surface waters of the Laurentian Great Lakes. *Marine Pollution Bulletin* 77: 177–182. [http://dx.doi.org/10.1016/j.marpolbul.2013.10.007]

Gregory, Murray R. Environmental Implications of Plastic Debris in Marine Settings—entanglement, Ingestion, Smothering, Hangers-on, Hitch-Hiking and Alien Invasions. *Philosophical Transactions of the Royal Society B: Biological Sciences*, vol. 364, no. 1526, 2009, pp. 2013–25, https://doi.org/10.1098/rstb.2008.0265.

Rech, Sabine., Yaisel J. Borrell Pichs, Eva García-Vazquez. Anthropogenic marine litter composition in coastal areas may be a predictor of potentially invasive rafting fauna. *PLoS ONE*, vol. 13, no. 1, 31 Jan. 2018, p. e0191859. *Gale In Context: Opposing Viewpoints*, link.gale.com/apps/doc/A525787267/OVIC?u=lom_hopecl&sid=bookmark -OVC&xid=d4bf61d6. Accessed 5 Oct. 2022.

Rochman, Chelsea M. Plastics and priority pollutants: A multiple stressor in aquatic habitats. *Environmental Science & Technology*, vol. 47, no. 6, 2013, pp. 2439–2440, https://doi.org/10.1021/es400748b.

Smith, Stephen D. A., and Edgar Bernal. Quantifying mismanaged waste in a small Balinese coastal village: Comparisons of standing stock in different habitats. *Ocean & Coastal Management*, vol. 202, 2021, p. 105433–, https://doi.org/10.1016/j.ocecoaman.2020.105433.

Acknowledgements

We thank donors to Hope College's VerHey Geology Summer Research and Linda Provo '71 Fulton Geology Student Research funds, and an EPA GLRI Trash Free Waters grant, the Macatawa Area Coordinating Council and the Outdoor Discovery Center for support of this research.