Civic TECHNOLOGIES for Monitoring Marine Plastics

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Plastic sample from a single trawl tow on the surface of the Hudson River outside of New York City, 2015.


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The number of studies on marine plastics has dramatically increased in the past ten years, yet the contaminant is still not regularly monitored in most regions, though plastics continue to enter the environment in ever increasing quantities. Technological tools for monitoring the state of this pollution, from the quantity of plastics in certain locations to the types of harm they engender, are essential to understanding and intervening into marine plastic pollution. Ensuring these tools are adaptable to local environments and accessible so they can contribute to regular monitoring is equally important.

Civic Laboratory for Environmental Action Research (CLEAR), like many other research groups that focus on marine plastics, does basic research to quantify and describe the state of marine plastics in our region. We also build the instruments to help us do so, especially because the landscapes and weather of Newfoundland, where we are based, present challenges to many common monitoring devices and protocols. What makes Civic Lab unique, however, is that we simultaneously focus on the social aspects of science and technological design with the aim of making positive change in the world not just with our findings, but also with our design processes. We attempt to "bake" civic values of responsibility to stakeholders, equitable access, and openness into our instruments. This is not a new approach; "values in design" is a design methodology premised on the idea that the ways things are built has an effect on how they are used, experienced, and understood has long been a part of architecture and information technology design. "Values in design" considers how the values we usually think of as social can be – and already are – expressed in technological objects, and how these designs in turn shape cultures of use. Since marine plastic technologies and protocols are still emerging, we have the chance to be thoughtful and intentional about what sorts of technologies we want to become "normal" in the future.

Civic Science, Civic Technology

One of the main values we design into our instruments is accessibility. Civic Lab designs devices and protocols so that both accredited scientists and people without formal science degrees can build and use them. The term "citizen science" describes situations as diverse as when scientists ask people to collect data for them (such as the Audubon bird survey), as well as when there are no accredited scientists involved and people create their own research questions, experimental designs, and use their findings to address local problems (such as the Pesticide Action Network). Civic Lab works within this range of citizen science projects; fishermen and women collect samples for our studies, but we also ensure all our technologies are under open source licenses rather than private patents, are published online, are inexpensive to build, are able to be built with local materials, and have straightforward protocols that make them usable by a wide range of people so individuals and community groups can conduct their own research.

Accessible instruments are about more than open hardware licenses that allow anyone to build, use, or modify our technologies. Civic technology is also about democratizing science so more types of people and research questions are involved in knowledge production. It is about building on what others have done and sharing our results and tools so others can do the same in an effort to change the culture of science towards a collective experience of mutual aid and collaboration that can achieve more with low-cost tools. We believe that changing how instruments are built can change how science is done, and by whom. This is what we mean by "civic" science and technology. Civics refers to thinking about and acting upon the duties of being part of a community. Civic science and technology, then, is science and technology designed with social relations of users and communities in mind. We follow design that place human and community rights (decentralization, openness, accessibility, interoperability, and sustainability) at the core of all instrumentation design in an effort to be responsible to the vast number of people affected by marine plastics. Since we know that plastics act as vectors for persistent organic pollutants and other industrial chemicals to move into food webs, the communities we keep in mind are those that depend on marine life for sustenance and livelihoods. In Newfoundland, this includes rural outport communities, fish harvesters, and Aboriginal communities. If our technologies are inaccessible or unusable for these stakeholders – too expensive, too many moving parts, too heavy, or require hard-to-find materials – we go back to the drawing board.

BabyLegs

Surface trawls are one of the most common ways to monitor marine plastics in oceans. These trawls use plankton nets, usually with a mesh of 300 micrometers, to skim the surface and/or subsurface of the water and collect neuston (floating) plastics. While neuston catamarans, bongo nets, and other devices have been used, the most common technology for studying surface plastics is the manta trawl. Its side wings stabilize it as objects floating on or near the water surface enter through a square opening that leads to a plankton net with a cod end where items accumulate. The manta trawl costs around $3,500, making it inaccessible to citizen scientists and even some research laboratories, particularly in the global south.

Civic Lab's answer to the manta trawl is BabyLegs (Figure 1). Made with nylon baby tights instead of a plankton net, a plastic container for the body and mouth of the trawl, and a plumber's clamp to keep them together, BabyLegs costs around $15 to make. Materials are easy to find, and the design is modifiable depending on the type of vessel being used and the local water conditions. BabyLegs has been pulled behind a slow-moving canoe on an urban river in Boston, where we used air-filled soda pop bottles as pontoons to keep the mouth of the trawl at the surface of the water. BabyLegs has also been used in the North Atlantic gyre from the deck of a tall ship travelling over 5 knots, where we added a heavier body to keep it from skipping over chop. We have lowered BabyLegs into fast-flowing rivers from bridges, and dragged it through tidal pools. In all cases, the trawl held up to widely different environmental strains and local conditions and successfully collected marine microplastics (Figure 2).

BabyLegs is licensed under a CERN open hardware license (CERN OHL v1.2) that allows anyone to use, copy, modify, build, and share its design plans and protocols, both of which are documented and publicly available on the Civic Lab web site. This dedication to open use and sharing is also why BabyLegs has been built to be as charismatic as possible. BabyLegs looks like a little human. We could have made the trawl less anthropocentric by using one nylon leg instead of keeping both legs from the baby tights (users are welcome

Figure 1: BabyLegs being used in the Atlantic Ocean (left) and in the Slocan River, British Columbia (right).

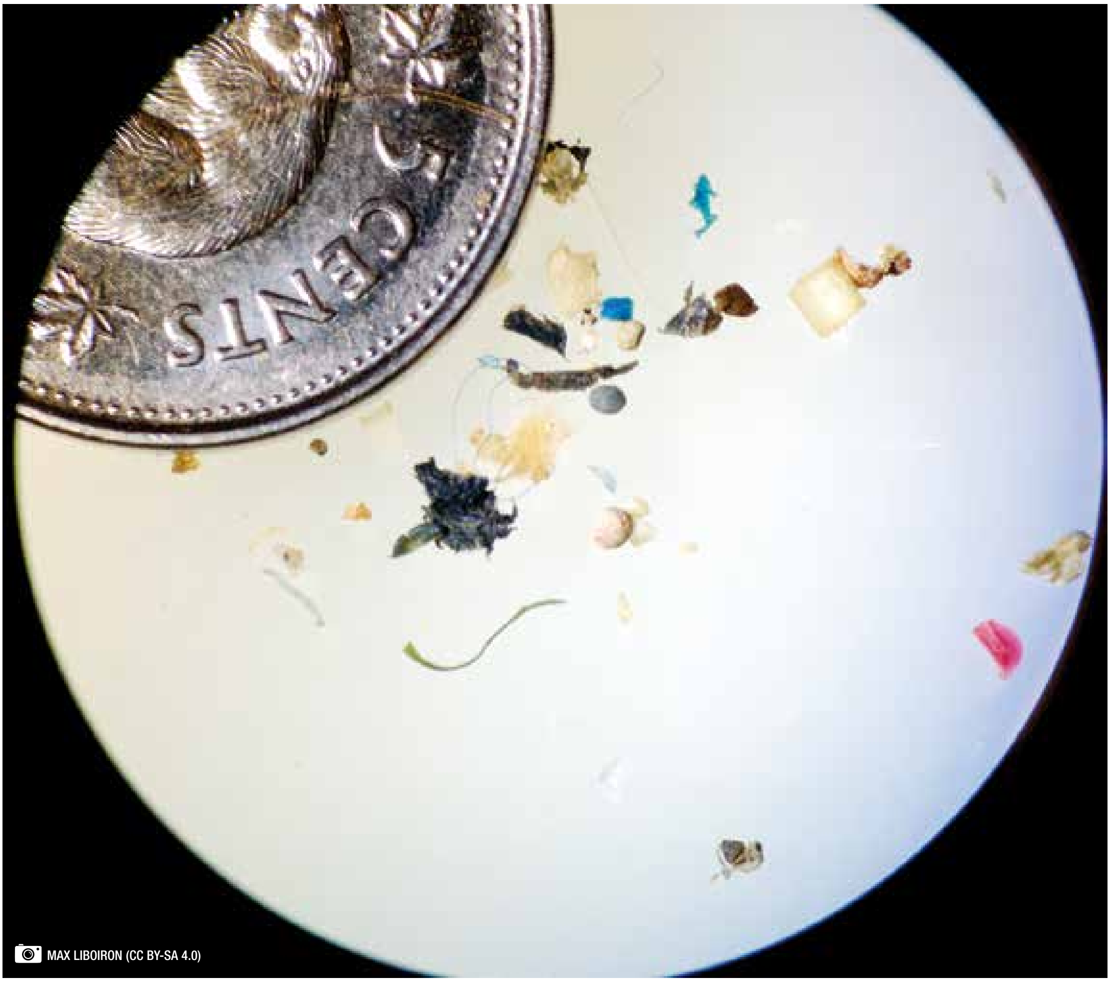

Figure 2: Microplastics. Remnants of a plastic bag (black), a microfibre thread (blue), a microbead (grey), a piece of foam plastic (white, round), and a variety of other fragments, films, and threads pulled from the Hudson River, New York City, by the BabyLegs trawl, 2015.

to modify this), or by naming it something less playful, but we have found that the trawl circulates to a wider audience because it catches the imagination better than many of our other technologies. Indeed, when members of the public, news reporters, and even other researchers approach us about a Civic Lab technology, it is usually BabyLegs they are curious about. BabyLegs is a popular trawl.

BabyLegs is still in development. We have ensured that the technology works in a range of environmental conditions, and the next step is validating BabyLegs against a manta trawl to ensure they capture comparable samples. The inability to compare findings is a major problem in marine plastics research regardless of which technology is used. Even two manta trawls with different mesh sizes present a problem for data comparison. Because we invent new technologies, Civic Lab is particularly invested in validation and calibration so users can understand the type of data they are collecting.

After speaking with some of the groups who have used BabyLegs, however, we realize that validated data from calibrated technology is only one use for a marine plastics trawl. Other users have been interested in learning about marine plastics or testing for the presence of marine plastics rather than collecting data on precise spatial distributions or trends. To that end, our lab has also designed an open source surface trawl called the Ice Cream Scoop (Figure 3) for children and youth to use. It is essentially a butterfly net for water that can be used when children swim or go wading. It is even easier to build and use than BabyLegs, and allows children, parents, and teachers to capture plastics to study their characteristics, such as type, colour, potential source, and estimated age. Civic Lab is working with *Let's Talk Science* to create a curriculum guide so school teachers can use the Ice Cream Scoop and other Civic Lab technologies in the classroom.

Plastic Eating Device for Rocky Ocean Coasts
While surface trawls are the most common way to monitor marine plastics at sea, many more studies focus on plastics that have washed up on shorelines because it is a more accessible and affordable way to conduct studies. It is also one of the most common monitoring techniques used by citizen scientists and community groups. While beach cleanups study large macroplastics, microplastic (<5 mm) studies are conducted by using square quadrats to mark off sections of a shoreline. Microplastics are sampled from within these areas by collecting the top layer of shoreline cover. However, standardized shoreline protocols such as those developed by the National Oceanic and Atmospheric Administration (NOAA) in the USA or the MSFD GES Technical Subgroup on Marine Litter in the European Union assume sandy beaches. Civic Lab is located in St. John's, Newfoundland, in northeastern Canada. Like much of northern Canada, our shorelines are almost entirely rocky, making study protocols designed for sand untenable. When we used the standardized shoreline protocols on a rocky shore on Fogo Island, Newfoundland, we found that the smallest sizes of microplastics were underrepresented, likely because they were falling between the rocks and escaping capture (Figure 4).

Civic Lab's Plastic Eating Device for Rocky Ocean Coasts (PED ROC) is designed to address the problem of sampling microplastics on rocky shorelines. The devices act as a single transect to be buried under rocks and left for a period of time so plastics work their way into the catch hold. The device is then exhumed and collected plastics are extracted. The device is a flat metal box built from a roofing vent with a large grid at the opening and a cotton filter at the bottom (Figure 5). When buried, rocks fill in the cavity within the device and capture plastics. There is a gap in the bottom between the rocks and the cotton filter where microplastics accumulate, and water drains out.

Like BabyLegs, the PED ROC's design parameters privilege accessibility and

Figure 3: The Ice Cream Scoop, a trawl designed for children to capture marine microplastics to learn about their environment.

Figure 4: Two types of shorelines undergoing a standardized shoreline protocol for monitoring marine microplastics. The two types of shores – sandy and rocky – result in incomparable data.

Figure 5: Photographs of two PED ROCs on a cobble shoreline, Topsail Beach (left) and the marine plastics that it caught (right). Note that there is a piece of metal (top left of sample photograph) in the sample that is contamination from the PED ROC itself. It is easy to identify as metal and is not easily confused with the marine plastics.

openness: it costs less than $50 to build; it is built from readily accessible materials for people who live in rural areas; and it is under a CERN Open Hardware License. But perhaps the most difficult design parameter is that the PED ROC contains no plastics. One of the ongoing difficulties of monitoring environmental plastics is that they are everywhere. Studies have recently found that microplastic fibres drift through the air and are deposited in the urban environment. People cannot wear fleece in the laboratory because microfibres drift off clothing and contaminate samples. One of our concerns is that monitoring devices themselves will contaminate our samples. This is why BabyLegs usually uses pink baby tights. It is not just for good looks; pink is a rare colour, so if we find a pink nylon thread in our sample we know it is from the trawl. PED ROC, on the other hand, is made entirely of metal and cotton.

In early tests at Topsail Beach just outside of St. John's, Newfoundland, the PED ROC has captured microplastics characteristic of sewage waste, including cigarette filters and nylon fibres that likely came from washing machine effluent. Bell Island, directly across from Topsail Beach, flushes its sewage directly into the ocean like nearly all small communities in Newfoundland. We are continuing to refine the PED ROC so that plastic extraction from the device becomes more streamlined.

The Marine Debris Tracker App

The final technology we will cover here is the Marine Debris Tracker (MDT) app (see **Further Reading** at the end of this essay). The MDT is a free smart phone app created in 2010 through a partnership between NOAA Marine Debris Program and the Southeast Atlantic Marine Debris Initiative (SEA-MDI) within the College of Engineering at the University of Georgia. While Civic Lab did not create the app, we work with one of its founders to adapt it to Newfoundland conditions, including the ability to identify a range of plastic fishing gear and optimizing the interface for cold fingers.

The app logs anthropogenic items found on shorelines. Users enter items they collect in the data sheet according to different categories (plastics, metal, fabric) and subcategories (straws, fishing rope, food packaging), and then geotags each item. Users can enter photographs and notes for individual items, and once users submit them to the server (either in the field or once they return to wifi access), the logged items are mapped and uploaded to a public server where anyone can access the data. While the MDT app has a category for microplastics, most beach cleanups focus on macroplastics larger than 5 mm in size simply because they are the easiest to see and collect. While we consider logged microplastics in our data, we tend to focus on macroplastic data that comes through the MDT because it is more likely to be complete and accurate.

We encourage anyone doing a shoreline cleanup to use the MDT app because it creates accurate, sharable data that allows our collective efforts to scale up over larger geographical distances as well over time as people return to the same shorelines at later dates. This allows us at Civic Lab, and any other researcher, non-governmental organization, decision maker, or member of the public to see trends over time in different places. The MDT app is an excellent civic science tool that broadens who can create and have access to data on shoreline plastics.

The Role of Technology in Mitigating Marine Plastics

There is limited data about the quantity and composition of marine plastics in Canadian Arctic and sub-Arctic regions because of the low human population, limited research infrastructure, and because scientific monitoring protocols are not designed for icy waters and rocky shores. Without knowledge of quantities and providence of plastics, effective interventions are impossible. This is the problem that Civic Laboratory is attempting to address with our civic technologies. We create accessible and open source technologies that can be used by a wide range of users so we can create and share data that outlines the characteristics and origins of plastics in the ocean over as wide an area as possible. We think technology plays a central role in describing the problem of marine plastics so that solutions can accurately target specific aspects of the problem.

However, we caution against the idea that technology can effectively *solve* the problem of marine plastics. There are "miracle" technologies and silver bullets like the Ocean Cleanup Array, a 2 kilometre floating boom with a skirt that collects plastics like a baleen whale, or the Seawer Skyscraper, a hydroelectric power station that sucks up underwater plastics. But these devices do not address the root of marine plastic pollution and can even divert money and attention away from deceasing, mitigating, and slowing the creation of plastic disposables in the first place. Marine plastics are a stock and flow problem, where plastics flow from land into the oceans and accumulate there as stock. Technologies that make big claims to "clean up" marine plastics deal with the stock, but not the flow, or source, of plastics. Civic Lab joins leading research, education, and advocacy organizations such as 5 Gyres that seek to ban microbeads, reduce the production of disposables, advocate for extended producer responsibility, and otherwise stem the flow of plastics by reducing their creation. We also deal with the stock of plastics in the ocean, but stock is a secondary goal to the flow of plastics. Focusing on stock is like bailing out a sinking boat before you have plugged the hole that is sinking it.

Besides missing the source of the problem, marine plastics that are cleaned up and brought back onto land are likely to end up back in the ocean over time. Plastics exist in something called "deep time," geologic timescales that far outstrip the timescales of species. Rather than degrade into their constituent molecules, plastics fragment into smaller and smaller pieces of plastic. According to laboratory studies, this degradation of small plastics results in microscopic particles that remain in Earth's environment indefinitely, or effectively so given the comparative timescales of plastics to the human species. Landfills will eventually erode or be covered in water, so moving plastics from oceans or shorelines to landfills is an act of *deferring* plastic pollution, not stopping it. "Cleaning up" is moving pollution around in space while it endures over time. Again, the source of plastics is skipped over.

Even the technological solution of recycling does not stop marine plastic pollution. The most pressing issue is that recycling perpetuates disposability. First, it "greens" disposable packaging because it seems like there is less environmental harm and thus gives disposables social license to continue. Second, some recyclables are used to make more disposables. Both contribute to more ocean plastics. But recycling also consumes energy, requires virgin materials, and produces pollution. For plastics in particular, recycling is not a robust environmental or economic process. There are many, many types of plastic – well beyond the seven types identified on the bottom of plastic packages – and each one has a different melting temperature, different set of plasticizing chemicals (like bisphenol A (BPA), among hundreds of others), and different densities. This makes them a less than ideal raw material for production because they are not materially similar enough to process, especially when the price of oil is dropping and virgin plastics are more reliable homogenous. Plastics recovered from the ocean are also carrying contaminants, bleached by sun, biofouled with microbes, and saturated with salt, and will be even more heterogeneous and harder to use than raw stock material. This does not make recycling impossible, but it does make it infeasible as a solution to plastic pollution generally, and for cleanup technologies that aim to earn their keep through recycling.

This does not mean that cleaning up is inherently useless – as a local action and an exercise of environmental ethics, cleaning up has value (and it is even better if the MDT app is used to collect data at the same time). The problem is that framing cleanup technologies as overarching solutions to marine plastic pollution is deeply problematic and misses the bigger picture. Some technologies, such as Baltimore's trash water wheel or the Australian Seabin, are small technologies that aim to capture marine plastics at the mouth of rivers or shorelines before they flow out to sea. These technologies tend to frame their role as local interventions for municipal waste management. The problem with technological fixes is when they are seen as solutions to systemic problems. The production of plastics – and particularly disposable plastics used in packaging – is increasing exponentially, and so are the quantities of plastics that end up in oceans. This increasing production is based on cultural, economic, policy and infrastructural elements, and these are the areas solutions need to address if they are going to address the core problem of marine plastics.

How you represent a problem defines the types of solutions that can be brought to bear upon it. Framing marine plastics as a cleanup problem is very different than defining it as an economic stock and flow problem, and will result in fundamentally different interventions. This is why Civic Lab aims to increase the number and types of people researching and defining the marine plastics problem through open source monitoring devices. A diversity of values, points of view, and landscapes means that we are more likely to see different sides and sites of the problem, and thus be able to frame solutions better. A democratization of science hardware is a necessary but insufficient step towards the "civic" aspect of thinking about how science plays into the wider social, economic, cultural, and technical systems in which we work, live, and play.

All of Civic Laboratory's technology plans and protocols are open source and are published online for anyone to access, build upon, and use.

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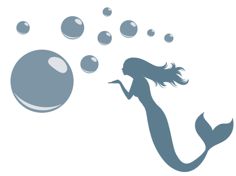
Further Reading

https://civiclaboratory.nl
www.marinedebris.engr.uga.edu



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