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SEA TO SOURCE: GANGES EXPEDITION

SUMMARY REPORT

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Executive Summary

This report summarizes the key research findings from the National Geographic **"Sea to Source: Ganges"** river expedition.

Between May and December 2019, an international, female-led interdisciplinary team traveled 2,575 kilometers (1,600 miles) of the transboundary Ganges before and after the monsoon season. The "Sea to Source: Ganges" river expedition (hereafter referred to as the "Sea to Source Expedition") used rapid assessment methods published in the ***Sea to Source Methods Toolkit*** to provide the first empirical baseline data on the source, quantities, and flow of plastic pollution along the length of the Ganges River system (which is known as the Ganga in India and Padma and Meghna in Bangladesh, where it also receives waters from Brahmaputra, hereafter referred to as the Ganges) from the Bay of Bengal to the Himalaya. These methods included two novel open-source technologies: the **Debris Tracker** app to record geospatial data on litter and a "bottle tag" innovated for the expedition, which tracked plastic bottle movements over 2,845 kilometers over a period of 94 days.

The Sea to Source Expedition found that a lack of comprehensive data on plastic waste and waste management in Bangladesh and India hampers efforts to meet national policy commitments around plastic waste reduction. There are no formal waste collection or waste management systems in rural communities and smaller towns, and while some collection and management infrastructure does exist in urban settings, rates remain low. Across five cities in India, 70-80 percent of all plastic is film (on a mass basis). Plastic film has very little end-of-life value; consequently, it is poorly managed. The most common litter items documented in Bangladesh were cigarettes and food wrappers; in India the most common items were tobacco sachets and food wrappers. In India, 60 percent of waste materials are managed by the informal sector; consequently, only items that have value are collected and recycled by this sector. In Bangladesh this figure was 50 percent.

From interviews with over 1,400 community members in rural settings, the expedition team found that people with low incomes were negatively impacted by single-use plastic, and identified concerns about how plastic pollution affects their health, their livestock, and their livelihoods. The key barrier to reducing plastic waste that the team identified was the lack of access to alternatives, which the community members said were expensive and too far away. Most people have no savings available and live day to day, preventing them from buying in bulk or using alternatives. Women report that buying cheap plastic products leaves them with more money to spend on their children and buying plastic-packaged goods also saves them valuable time.

The Sea to Source Expedition documented that plastic waste is entering the river and making its way to the ocean. Analysis of water samples taken from the Ganges, with the combined flows of the Brahmaputra and Meghna rivers, shows that plastic

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is constantly being discharged from the river into the Bay of Bengal, with a higher concentration of microplastics near the sea compared with near the source. The rate at which these microplastics entered the Bay of Bengal varied with the seasons; potentially 1 billion microplastics per day were discharged during the pre-monsoon season, and 3 billion per day were discharged during the post-monsoon season. Of those microplastics, 91 percent were fibers, likely from clothing, and the remaining 9 percent were fragments. Discarded fishing gear was also identified as a major source of plastic pollution in the river; this finding improves our understanding of how abandoned, lost, or otherwise discarded fishing gear impacts non-ocean aquatic environments. Fishing gear was also found to pose the additional threat of entanglement to wildlife, including the critically endangered three-striped roofed turtle (*Batagur dhongoka*) and the iconic Ganges river dolphin (*Platanista gangetica gangetica*).

A series of stakeholder workshops was held over the course of the expedition that identified a range of solutions intended to address these findings, including improved waste management infrastructure, government legislation, extended producer responsibility schemes, community refill systems, product innovation, and incentives for participating in recycling schemes or generating non-plastic products. The Sea to Source Expedition team is now building effective partnerships and collaborating with stakeholders to strengthen local, national, and regional initiatives intended to foster a better understanding of the plastics problem and tackle this pollution. At the point of publication (February 2021), the team has four scientific papers published; several more in draft form pending final analysis and submission; and others in development, including a cross-cutting synthesis paper.

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Background

Plastic pollution in our land and aquatic environments is now recognized as one of the most pressing issues of our time.

Over 8 billion metric tons of plastic have been produced since 1950, and production is projected to increase to 34 billion metric tons by 2050 [1]. As of 2015, only around 9 percent of plastic was estimated to have been recycled, with around 12 percent incinerated and 79 percent ending up in landfills or in the environment, where it continues to break down into smaller particles [1]. Marine plastic pollution poses a serious threat to marine biodiversity through ingestion, entanglement, and habitat degradation [2, 3] and is impacting animals as small as zooplankton and as large as whales throughout the food chain. Humans may be consuming plastic directly from fish and shellfish [4], as well as breathing in airborne microplastic particles [5, 6], and we still do not have a good understanding of the consequences of this intake [7]. Plastic pollution has become an issue that is global, visible, and harmful—but also solvable.

While research has shed light on the quantity of plastic being produced and where it is ending up through mismanaged waste and leakage [1, 8, 9], there are still many gaps in our knowledge of the circulation of plastics in marine and freshwater environments around the world. Mismanaged waste is one of the biggest contributors to land-based plastic pollution, and it has been estimated that land-based plastic pollution constitutes a significant portion of all plastic that ends up in the ocean [8]. Recent research has found that by 2030, even with current interventions, 20 million metric tons (MMT) will still be reaching our aquatic systems (lakes, rivers, and the ocean) annually. Without aggressive interventions, both immediately and over the long haul, the annual flow of plastic into aquatic environments will continue to increase, reaching upwards of 600 MMT cumulatively over the next 20 years [9, 10]. Rivers have been identified as major conduits of the plastic that ends up in the environment and in the ocean, and data suggest that 10 rivers in Asia and Africa contribute nearly 90 percent of plastic transported from rivers to the ocean [11, 12]. Yet these and other models are lacking comprehensive empirical data, and knowledge of the impacts of plastic pollution on rivers is also relatively limited.

In collaboration with local partners, National Geographic set out to better understand and document the characteristics, composition, and flow of plastics in a river system—from the plastic waste mismanaged on land, to the waterways, and to the ocean. The Sea to Source Expedition focused on the Ganges River Basin, which is known as the Ganga in India and Padma and Meghna in Bangladesh, where it also receives waters from Brahmaputra, hereafter referred to as the Ganges. This provided an unprecedented and unique opportunity to get a holistic view of the plastic pollution issue over the course of a major river system.

During the team's work in the Ganges, we pursued the following goals:

- **Validate the existing estimates of plastic entering the ocean** from the Ganges and identify the route of plastic into the ocean from the Himalaya to the Bay of Bengal.
- **Collect representative baseline data** that can be used to inform local management, policies, businesses, organizations, and other stakeholders, in order to better target and track interventions that reduce and prevent plastic from entering the river, and ultimately the ocean.
- **Develop a comprehensive and multi-disciplinary data collection framework** that could be replicated in other parts of the world to conduct similar assessments that can inform intervention strategies.
- Identify and work with local communities, government, agencies, businesses, NGOs, and the media to help **translate scientific findings into effective action.**
- **Use storytelling and communications to effectively engage the public**, businesses, and other stakeholders to raise awareness, educate, and encourage systems change.

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The Expedition

From May to December 2019, the National Geographic Society, in collaboration with local partners (Indian Institute of Technology Kharagpur, the Isabela Foundation, University of Dhaka, the Wildlife Institute of India, and WildTeam Bangladesh), successfully conducted an expedition to better understand and document the characteristics, composition, and flow of plastics along the entire Ganges River system.

Figure 1. *Sea to Source Expedition route highlighting focal sampling sites, surveyed pre- and post-monsoon 2019.*

The international, female-led interdisciplinary team assessed plastic waste from land, into the waterways, and into the ocean, to identify locally-appropriate interventions with local stakeholders. The expedition was conducted in two phases: pre-monsoon from May to June 2019 and post-monsoon from October to December 2019. Three days were spent at each of the 11 sampling sites (three in Bangladesh, eight in India) along the main stem of the Ganges, collecting data and samples on the river, in cities and villages [Figure 1]. The team traveled 2,575 kilometers (1,600 miles) of the mainstream Ganges during each of the two phases of the expedition.

Photo by Sara Hylton

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Sea to Source Expedition by the Numbers

Team of 28 Women and 7 Men from 5 Countries

98 Expedition Days

6,800 KM Traveled

11 Sites Surveyed

701 Discarded Fishing Gear Items Recorded

89,691 Litter Items Tracked on Debris Tracker App

993 Plastic Products Recorded

4,580 Photo Quadrats Taken

672 Samples Collected for Microplastic Analysis

25 Bottle Tags Deployed

1,446 People Interviewed for Socioeconomic Surveys

274 Students, 111 Teachers, and 26 Schools Involved in Education Program

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Methods

The Sea to Source Expedition investigated land-based plastic use and pollution, microplastic characterization in the river's sediment and surface water, microplastic in the air near the river, and knowledge, attitudes, and perceptions of plastic in local communities. The team developed a rapid assessment methodology and tested new technologies to aid data collection; these processes are described in the open access ***Sea to Source Methods Toolkit***. This toolkit was produced to support continued work by other researchers in the Ganges and other locations (cities, river basins, and coastal environments) around the world.

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Results

The Sea to Source Expedition generated data that can empower participant communities and inform decision-makers in Bangladesh and India.

Feedback from the various stakeholder groups engaged throughout the expedition also demonstrated that there is considerable interest in understanding and addressing local plastic pollution. At the point of publication (February 2021), we have four scientific papers published [13, 14, 15, 16], several in draft form pending final analysis and submission [17, 18, 19, 20, 21, 22, 23] and others in development. All currently published papers are listed **here**. Findings are presented under the thematic areas that correspond to the *Sea to Source Methods Toolkit*.

Land-Based Systems

Our background research and in-country team of experts found that a lack of comprehensive data on plastic waste and waste management in Bangladesh and India hamper efforts to meet national policy commitments around plastic waste reduction [13]. There are no formal waste collection or waste management systems in rural communities and smaller towns, and while some collection and management infrastructure does exist in urban settings, rates remain low. Through our partnership with the Indian Institute of Technology Kharagpur, detailed waste management and characterization data were collected across five cities in India, where approximately 70-80 percent of waste is collected by urban local bodies (ULBs). Of that waste, 72-78 percent is disposed of in open dumpsites [24]; several of the dumpsites were observed in close proximity to the Ganges. The results of sampling the waste stream at dumpsites showed that Rishikesh had the highest levels of plastic in the municipal waste stream (17 percent), while Anupshahr had the lowest levels of plastic (8.6 percent) [22]. It was also observed and recorded through interviews that no waste segregation was occurring at the household level and many types of waste, including medical waste, can end up at dumpsites [22].

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Waste characterization from dumpsites across all five cities in India (Sahibganj, Varanasi, Kannauj, Anupshahr, Rishikesh) shows that 70-80 percent of all plastic is film (on a mass basis), largely because there is no recycling market for plastic film [22]. This is particularly notable because film weighs so little, and means most other plastics are being collected and recycled before reaching the dumpsite. In-depth interviews with 87 owners of entrepreneurial informal recycling centers illustrated how valuable materials are managed by the informal sector in Bangladesh and India. For example, items that have value, including metals or plastic beverage bottles (made of polyethylene terephthalate, or PET), are collected and recycled by this sector. A more detailed analysis of the informal recycling system at the kabadiwalla (recycling collection center) level in India is underway by expedition team members [21, 23]. The team collected data showing what kinds of waste end up in the environment as litter and how much of it there is along random stratified sampling locations within 5 kilometers of the river. They collected these data in each city during the pre- and post-monsoon seasons, and also in villages during the post-monsoon season [18]. Of the over 89,000 litter items logged with Debris Tracker during the combined pre- and post-monsoon expeditions, the most common items found in Bangladesh were cigarettes and food wrappers; in India, tobacco sachets and food wrappers were found most often. Those items are consistent with the results of our waste characterization work, which showed a significant fraction of plastic in the waste stream was film due to its low value and infrequent recycling of this kind of material. Further characterization and quantification of the litter data are also underway [23].

Aquatic Systems and Air

An initial background review found very few studies had been conducted on plastic pollution in aquatic systems in Bangladesh and, of those few, only one was of a freshwater environment[13], with a comparable study for India currently in progress [17]. The results of the Sea to Source Expedition will help to fill knowledge gaps, as well as provide an opportunity to catalyze future research, particularly for local team members and their collaborators.

Microplastic surface water sampling during the Sea to Source Expedition indicated that an estimated 1 billion microplastics per day are being discharged from the combined flows of the Ganges, Brahmaputra, and Meghna rivers into the Bay of Bengal during the pre-monsoon and 3 billion microplastics per day during the post-monsoon season, with higher microplastics concentrations nearer the sea versus the source [16]. Most microplastics recorded in the Ganges water were fibrous in shape, which are likely to come from clothing. Laboratory analysis revealed rayon (synthetically-altered cellulose) as the dominant polymer (54 percent), followed by acrylic (24 percent), PET (8 percent), polyvinyl chloride (PVC) (6 percent), polyester (5 percent) and nylon (3 percent) [16]. Due to the transboundary nature of the river, and the combined flows of the Brahmaputra and Meghna rivers in Bangladesh, it was not possible to attribute the amount of microplastics by country, although variation in abundance and type of microplastics across the sample sites were documented [16]. Analysis is underway to investigate the comparative abundance and types of microplastics found in sediment and air samples [19], and approaches to understanding microplastic mass are being explored for future research by the team.

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The expedition team documented abandoned, lost, or otherwise discarded fishing gear (ALDFG), which is a well-known problem in the ocean, but little is known about its impact on rivers. Our study found that ALDFG is also a significant source of plastic pollution in the Ganges, with discarded fishing gear density increasing with proximity to the sea [15]. All fishing gear analyzed was made of plastic, with nets the most dominant gear type by volume, and most of these were made of nylon 6. Short gear lifespans, high turnover rates, lack of appropriate disposal methods, and ineffective fisheries regulations are key drivers of input [15]. ALDFG poses entanglement risks to species in the Ganges that need protection, with river turtles and the Ganges river dolphin (*Platanista gangetica gangetica*) the most vulnerable to negative interactions with fishing gear [15].

Knowledge, Attitudes, and Perceptions

During the expedition, the research team conducted focus group discussions and household surveys with over 1,400 people in Bangladesh and India. To ensure a sufficient sample size and enable meaningful comparisons, we surveyed at least 100 people per site. The analysis is being finalized, but the discussions and surveys concluded that affordability is the main driver for single-use plastic consumption by people with low income in rural communities [21]. Most people have no savings available and live day to day, preventing them from buying in bulk or using alternatives. These rural communities also lack access to alternatives to plastic, both in terms of physical proximity and price. Women report that buying cheap plastic products leaves them with more money to spend on their children and buying plastic-packaged goods also saves them valuable time. These findings highlight the financial and time constraints experienced by women, who are primary caregivers and household managers, which drives the consumption of single-use plastic. Seasonality also influences single-use plastic usage, which increases during the monsoon, and is linked to access and the durability of plastic during the heavy rains. In the absence of other waste management options, there is a perception that the regular flooding of the river may help to wash away waste from communities, particularly during the monsoon season.

Our education program ran in parallel with the scientific sampling and reached 274 students, 111 teachers, and 26 schools during the post-monsoon expedition. We encouraged students to think critically, learn in an active and scientific way, and empowered them to make change. Training teachers proved to be a resource-efficient scaling mechanism, piloted in Bangladesh as **Teachers for Planet Earth**. The feedback from these sessions concluded that there is considerable interest and demand for plastic pollution as an educational topic, particularly when linked with nature conservation.

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Technology and Tools

The mobile application and citizen science platform **Debris Tracker** was used to collect geospatial data on litter, waste collection, and influencing factors (such as stores, restaurants, parks, canals). Over 89,000 data points were recorded. All collected data are free and openly available to the public at the **Debris Tracker website**. The app was also used in conjunction with municipal training workshops and education programs, which trained participants to regularly monitor sites in their communities, in order to better document the quantities and types of litter and document changes over time.

Bottle tags—a low-cost, open-source technology to track the movement of plastic pollution—were developed exclusively for the expedition. Cellular and satellite tags built to resemble a plastic bottle were successfully tracked through the Ganges River system and into the Bay of Bengal. The maximum distance tracked so far has been 2,845 kilometers over a period of 94 days, and some tags are still actively transmitting [14]. This tool has wider application for the study of plastic movement through aquatic systems, as well as for education and raising awareness of the issue.

The Sea to Source Expedition also trialed a machine learning analysis of 78,767 drone images taken from 42 flights along the riverbank at nine of the 11 sites (due to logistical constraints, Anupshahr and Uttarkashi were not surveyed). In the pre-monsoon survey, an average of 1.17 litter items per square meter were found, ranging from 0.36 items per square meter at Rajbari, Bangladesh, to 3.08 items per square meter in Patna, India [25].

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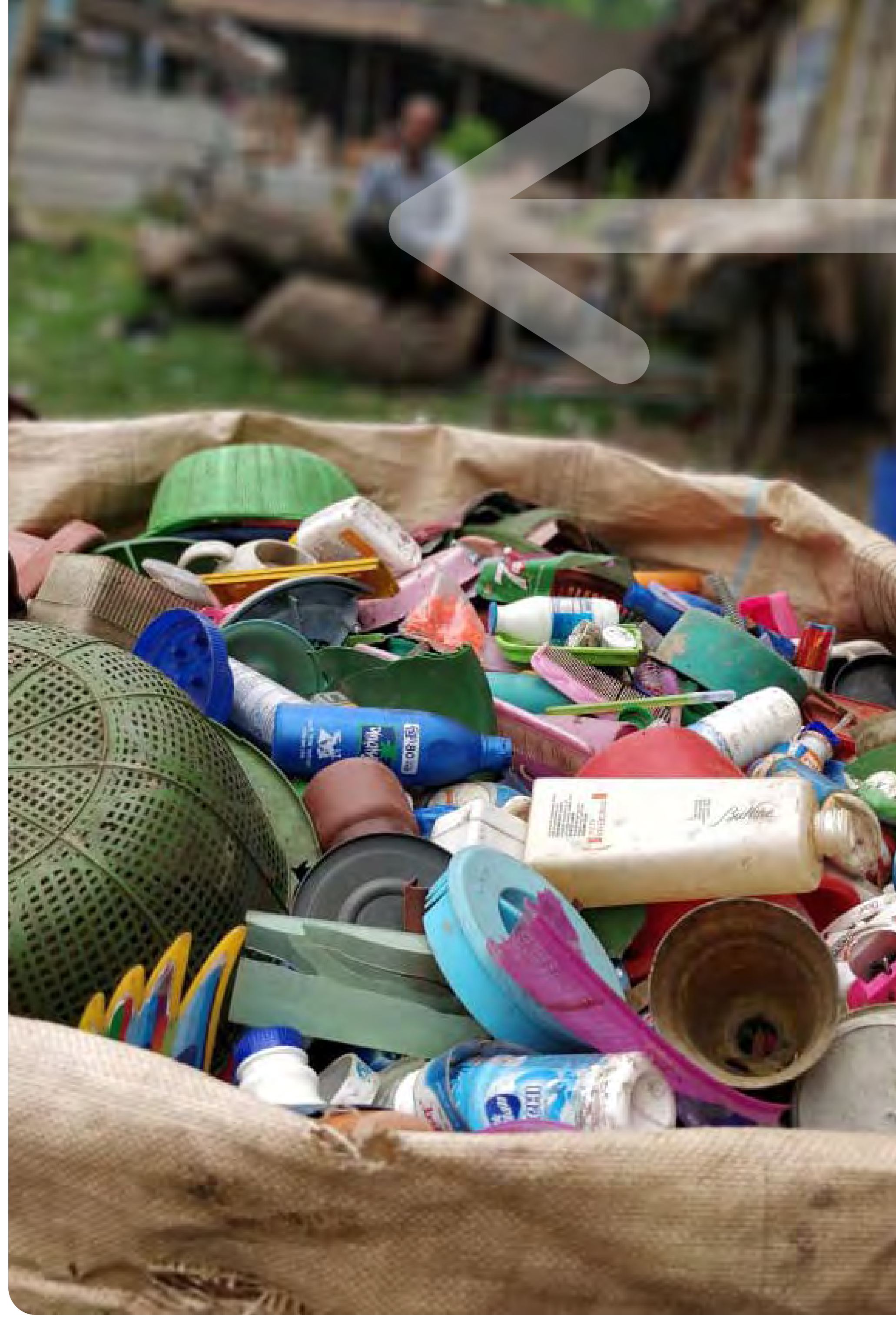


Photo by Ekta Sharma

Photo by Sara Hylton

Potential Solutions

Potential solutions to the problem of plastic waste entering the Ganges were identified through a series of stakeholder engagement activities in Bangladesh and India, including:

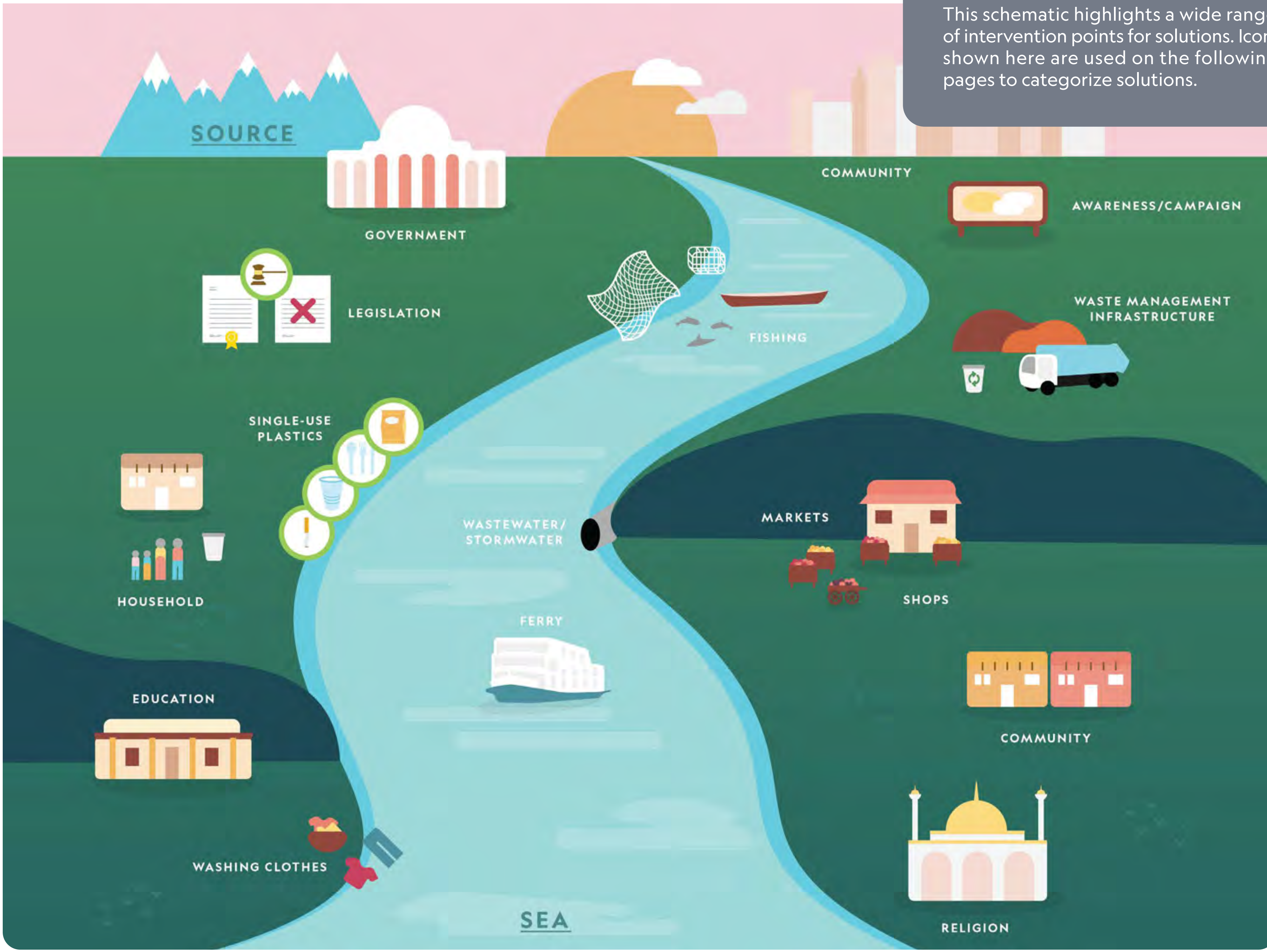
- **A series of World Café workshops in India**, implemented during the pre-monsoon expedition, organized and facilitated by Paperman, a non-profit that accelerates recycling in India.
- **Post-monsoon municipal government workshops** run in Varanasi and Rishikesh, India.
- **Post-monsoon community workshops** focused on identifying and documenting solutions at each of the expedition sampling sites in India.
- **Three internal team solutions workshops** in Bangladesh and India during the post-monsoon expedition, and an online team workshop in May 2020.

The Sea to Source Expedition highlighted a general need for further research and monitoring, particularly for government-led schemes to provide robust data on plastic waste for the design and implementation of waste management strategies. Education programs were also consistently recommended, from those targeting children, to awareness and behavior change campaigns tackling specific litter items or stopping plastic from being thrown into the river. The following pages include solutions offered by stakeholders, aligned with some of the expedition's key research findings.

> ***We have no problem using alternatives to plastic such as paper and cloth, but the barrier is affordability and availability of the alternatives locally.***
>
> -Participant from Patna community solutions workshop

Photo by Sara Hylton

This schematic highlights a wide range of intervention points for solutions. Icons shown here are used on the following pages to categorize solutions.



Sea to Source Expedition Research Finding

Plastic was found at all tested sites. Across all sites tested, the highest levels of plastic found in the municipal waste stream were in Rishikesh (17 percent)—mostly of plastic films. The cities of Kannauj, Sahibganj, and Varanasi were in similar ranges (11-12 percent in each city). The lowest levels of plastic were found in Anupshahr (8.6 percent).

Potential Stakeholder-Generated Solutions

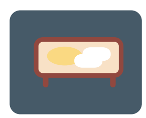
Waste infrastructure: Support the Clean City model (expand to additional cities and adapt to village level).

Tax measures with incentives for reusable packaging and penalties for single-use plastic items. For example, charge a higher price for purchasing drinks in a takeaway cup, and a lower price for a refillable cup.

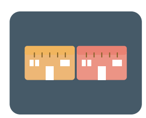
Deposit scheme to encourage people to bring back used plastics for recycling.

Legislation/management of single-use plastic items in tourist/cultural/biodiversity locations.

Businesses in tourist centers establish refill/plastic reduction mechanisms.



Promoting reuse over single-use practices (campaigns/education).



Develop a model targeted at tourists or export. For example, for “Ganges-bound plastic” products (like “ocean-bound plastic”).

Sea to Source Expedition Research Finding

Waste characterization across all five cities shows that 70-80 percent of all plastic is film.

Potential Stakeholder-Generated Solutions

Nationwide or statewide ban on certain products (such as plastic bags, microbeads, and styrofoam food and drink containers).

Nationwide or statewide ban on certain polymers and chemical additives, with fines and enforcement on bans.

Support/subsidies for economically feasible alternative materials (or businesses with alternatives).

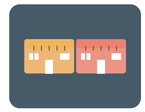
Incentivize recycling for plastic film items.

Sea to Source Expedition Research Finding

No formal waste management in rural communities.

Potential Stakeholder-Generated Solutions

Implement aggregation and segregation of waste at the household level.



Establish community composting.

Sea to Source Expedition Research Finding

50 percent (Bangladesh) and 60 percent (India) of waste is managed by the informal sector.

Potential Stakeholder-Generated Solutions

More funding provided for waste management infrastructure (such as bins and collection) and more integration and collaboration of the informal recycling center with community waste management.

Engage informal waste management infrastructure chain to assure 100 percent recycling—access to capital is crucial (such as microfinance).

Regulation of plastic industries on producing or importing virgin plastics, to encourage more recycling.

Government controls and systems in place for **management and disposal of medical waste** to prevent it from going into landfill.

Sea to Source Expedition Research Finding

Significant quantities of waste are ending up in the environment near the Ganges. The most common litter items in Bangladesh were cigarettes and food wrappers; in India they were tobacco sachets and food wrappers.

Potential Stakeholder-Generated Solutions

Extended Producer Responsibility [26] **scheme** developed and introduced.

Corporate Social Responsibility funds allocated to support development and use of sustainable packaging/alternative materials.

Clearer labeling on packaging that includes recycling and waste management options.

More resources in place to support more frequent **cleaning of stormwater drainage systems** to improve their functionality.

[26] Filho, W.L., Saari, U., Fedoruk, M., Iital, A., Moora, H., Klöga, M., Voronova, V. (2019). An overview of the problems posed by plastic products and the role of extended producer responsibility in Europe. *Journal of Cleaner Production*, 214: 550-558. DOI: 10.1016/j.jclepro.2018.12.256

Sea to Source Expedition Research Finding

An estimated 1 billion microplastics per day are discharged in the pre-monsoon and 3 billion per day in the post-monsoon season. Most microplastics recorded in Ganges River system water were microfibers compared with microplastics, which are likely to come from clothing.

Potential Stakeholder-Generated Solutions

Controls and alternatives in place to reduce/eliminate single-use plastic in water transport such as ferries.

Assessment of wastewater treatment plants, especially new installations, to factor in removal of microplastics.

Policy for wastewater treatment plants on disposal of sewage sludge (which traps microplastics), noting burning results in emissions and use as fertilizer transfers microplastics onto land.

Installation of appropriate waste discharge controls for industry to avoid microplastics entering the aquatic environment, especially clothing manufacturers.

Introduction of washing machine filters to reduce microfibers entering the aquatic environment, including proper disposal of the filtrate.

Innovations to trap microfibers in municipal drains and/or areas of the river designated for washing clothes.

New methods introduced to clothing manufacturing processes that reduce shedding of fibers.

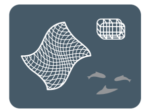
Research the number of microplastic fibers that result from hand washing clothes (research to date is from washing machines).

Sea to Source Expedition Research Finding

Discarded fishing gear is likely a significant source of plastics in the Ganges that negatively impact wildlife.

Potential Stakeholder-Generated Solutions

Implement nylon 6 recycling schemes for end-of-life fishing gear–ideally those that take products into a circular economy. This could include government buyback schemes.



Encourage/incentivize use of traditional bamboo traps over plastic traps linked with fisheries management and wider livelihood interventions, such as value chains/increased value on fisheries-related products.

Sea to Source Expedition Research Finding

Low-income communities are more negatively impacted by single-use plastic.

Potential Stakeholder-Generated Solutions

Community organizing to foster women's leadership to strengthen the informal sector.

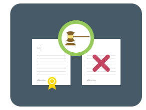
Engagement of religious leaders.

Develop incentive schemes linked to plastic collection for recycling in exchange for education/health/food vouchers.

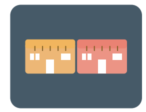
Sea to Source Expedition Research Finding

Lack of access (because of either proximity or price) of rural communities to non-plastic alternatives.

Potential Stakeholder-Generated Solutions



Support/subsidies for economically feasible alternative materials (or businesses with alternatives).



Increase community capacity for production of washing/toiletry products to replace sachets using natural products such as bioenzymes.

Encourage bulk buying or introduce a local refill system.

Foster efforts by individuals/groups within a community, or an entire community, to **replace single-use plastic items with sustainable alternatives** (such as paper/cloth bags, leaf plates/bowls, bamboo straws, wooden/bamboo utensils, clay chai cups, metal cups, banana leaf food packaging).

Photo by Sara Hylton

Context and Conclusions

The accumulation of plastic litter has been identified as a major global problem by the United Nations Environment Assembly and in the 2015 G7 Leaders' Declaration [27, 28] and the G20 Implementation Framework in 2019 [29].

Based on the Sustainable Development Goals (SDGs), the Member States of the United Nations have recognized the threat of pollution to ocean ecosystems, and have committed to the following under SDG14.1: *"By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution."*

These international policy commitments, combined with growing public awareness, have resulted in the rapid growth of a wide range of research initiatives, business enterprises, campaigns, and other interventions. However, even with current actions and interventions, the quantity of plastic entering the gloabl aquatic environment is set to increase to an annual 20-53 million metric tons by 2030, telling us that even more aggressive and comprehensive interventions are needed to reduce this pollution [9]. Recent research has identified that we can cut annual flows of plastic into the ocean by about 80 percent over the next 20 years by applying existing solutions and technologies [10]. Toolkits [30] and roadmaps [31] have been designed for practitioners and policymakers considering the introduction of measures to curb consumption and improve the management of single-use plastics.

Both Bangladesh and India have undertaken strong actions to combat plastic pollution. In 2002, early awareness of this issue led Bangladesh to become the first country in the world to ban plastic bags [32]. In October 2019, Indian Prime Minister Narendra Modi launched a national campaign to phase out single-use plastics by 2022. Both Bangladesh [33] and India [34, 35] have policies and legislation in place that seek to address plastic waste and pollution. Bangladesh is taking action on plastic pollution, with the High Court directing relevant authorities to ban single-use plastic products in coastal areas, hotels, motels, and restaurants across the country in 2021 and the World Bank launching their **Plastic free Rivers and Seas for South Asia Project**. In India, there are also a wide range of initiatives underway, notably including the **Swachh Bharat Abhiyan,** or "Clean India Mission," a countrywide campaign initiated by the government of India in 2014 to eliminate open defecation and improve solid waste management. The National Ganga Council, established in 2016 and chaired by the Honorable Prime Minister, implements activities of the

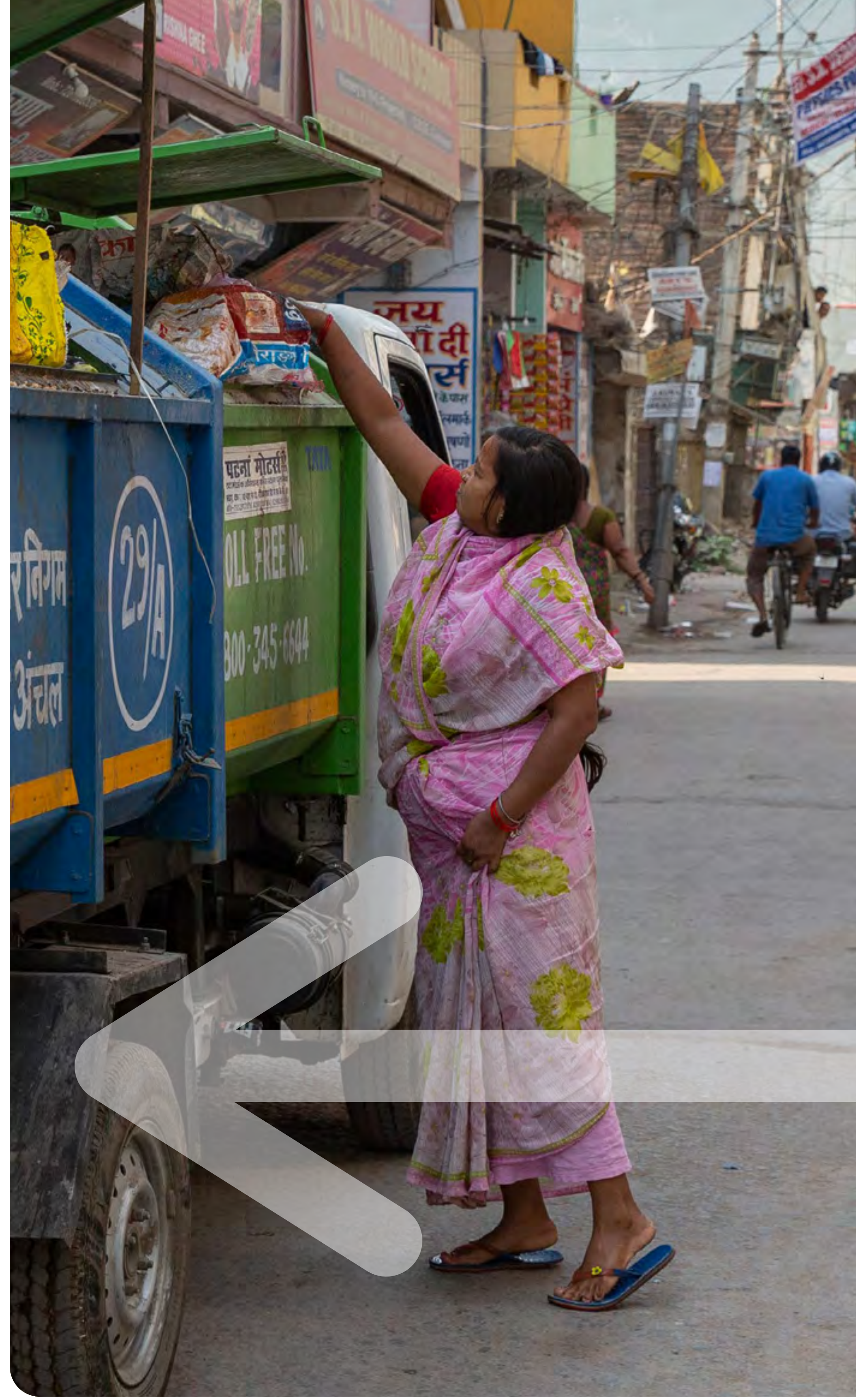


Photo by Sara Hylton

Photo by Sara Hylton

National Mission for Clean Ganga's **Namami Gange Programme**, which enlisted the Wildlife Institute of India as an expedition partner. The "Biodiversity Conservation and Ganga Rejuvenation" project of the Wildlife Institute of India is an integral part of the Namami Gange Programme. The project adopted the systematic conservation approach and demonstrated science-based species conservation and effective community participation for a clean Ganges. The project has recently scaled up to the whole Ganges River Basin in India and plays a central role in biodiversity and Ganges conservation. The **National Mission for Clean Ganga** and National Institute of Urban Affairs have developed a common Urban River Management Plan framework for all towns along the Ganges River to address pollution issues. There are also opportunities to expand models like the **Clean City Initiative** to additional locations, such as Patna and Varanasi that were sites covered by the expedition.

The National Geographic Sea to Source Expedition provided the first empirical baseline data on the source, quantities, and flow of plastic pollution along the length of the Ganges River system from the Bay of Bengal to the Himalaya. These data will help to ground-truth models that have predicted the amount of plastic entering the ocean from major rivers. There are also opportunities to align and standardize sampling methodologies in national programs, particularly **UNEP CounterMEASURE** and the new India-Norway Marine Pollution Initiative being initiated in Gujarat. The methods in the ***Sea to Source Methods Toolkit*** are all open access, including new plastic tracking technology and the Debris Tracker citizen science tool. Local community volunteers known as "Ganga Prahari," established by the Wildlife Institute of India under the Namami Gange Programme, supported the expedition and provided a successful example of empowered communities and a model of the citizen science approach.

The Sea to Source Expedition provided valuable insights into the key intervention points to reduce plastic pollution, which range from improving waste management infrastructure, to addressing the impact of plastic film, which makes up most of the plastic waste, to overcoming barriers of access and affordability of alternatives that could reduce plastic at source. There is currently a high dependency on the informal sector workers to manage plastic waste, who often have low social status, poor living and working conditions, and little government support. There are a number of encouraging approaches underway to support and formalize that sector, such as the **Alliance of Indian Waste Pickers**, **WIEGO** (Women in Informal Employment: Globalizing and Organizing), as well as associated initiatives such as the **National Geographic Innovation Challenge** finalist **Kabadiwalla Connect**. There are new financing systems in place to address plastic waste, including recent investments by **Circulate Capital** in a business in Mumbai that specifically targets plastic film and other hard-to-recycle items.

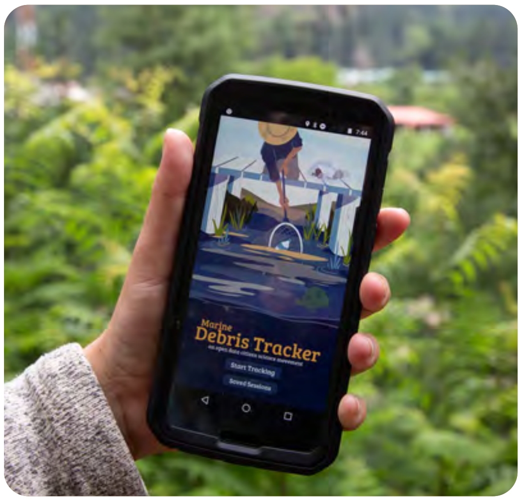


Photo by Sara Hylton

Discarded fishing gear was identified as a major source of plastic pollution which, though well documented in the ocean, has not been well studied in rivers. As most of this gear is made up of nylon 6 nets, there is an opportunity to replicate the **Net-Works** project in the Philippines, which has been so successful it has become a standalone social enterprise called **Coast 4C**.

The quantity of microplastics in the river is a major concern, with the potential of 1-3 billion microplastics per day discharged from the combined river system, just before it enters the sea in Bangladesh into the Bay of Bengal, depending on the season [16]. An average of 0.038 microplastics per liter were detected in the surface water of the Ganges, most of which (91 percent) were microfibers. Studies of other rivers report loads ranging between 0.004-1.700 microplastics per liter, although some of this variation is due to differences in methodology [36, 37, 38]. Tackling riverine microplastics will require a combination of legislation, improved water treatment infrastructure, and innovation. Improved understanding of behaviors, attitudes, and perceptions of local communities around plastic use identified affordability as a major barrier to any changes in the system, including moving to a bulk refill system. Issues particular to women, including managing household expenses and their time, are important to factor into any proposed solutions. However, there are many encouraging initiatives underway, and significant opportunities for research to inform and mobilize locally-appropriate solutions that involve local communities, business, and government.

Since the conclusion of the Sea to Source Expedition at the end of 2019, the global COVID-19 pandemic has added further challenges and complexity to waste management and the systems and behaviors associated with single-use plastic. However, momentum continues towards more sustainable systems that build a circular economy, reducing negative impacts for communities and the environment. There are growing commitments from government and industry, and numerous grassroots efforts underway that are led by local communities and youth. The methods developed by the Sea to Source Expedition are already being applied in a three-year project that began in November 2020—**Risks and Solutions: Marine Plastic in Southeast Asia**, led by the University of Exeter and the National University of Singapore, involving several expedition researchers. In addition, the land-based methods were refined as a part of the **Circularity Assessment Protocol** (CAP) developed by the Jambeck Research Group at the University of Georgia and are being applied in 16 cities located in eight different countries as a part of projects like **Urban Ocean** and **USAID MWRP**. The expedition team is also sharing data and experiences and exploring collaborative solutions with the United Nations Environment Programme, especially the CounterMEASURE Project, the Mekong-U.S. Partnership, World Bank Plastic free Rivers, and the Seas for South Asia Project. The Sea to Source Expedition team is committed to sharing their data and insights, building local and regional partnerships and collaborations, and using these to leverage change. Plastic pollution is an issue that is global, visible, and harmful—but also solvable.

Photo by Sara Hylton

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Acknowledgments

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