The Plastic Path

Teacher Guide

Learn how far plastic pollution can travel in the ocean and waterways by analyzing data from a study that tracked plastic bottles with satellites.

Grade Level: Middle school

Learning Objectives

- Students identify the sources of plastic pollution, how plastics get to the ocean, and the problems posed by plastic pollution in the ocean.
- Students learn how GPS and satellite technology are used to track the movement of plastic pollution through waterways.
- Students consider the impacts of plastic pollution on their local watershed.
- Students design strategies to stop plastic pollution.

Educational Standards

NGSS

- DCI ESS3.C: Human Impacts on Earth Systems
- DCI ESS2.C: The Role of Water in Earth's Surface Processes
- SEP: Analyzing and Interpreting Data
- CCC: Patterns, Cause and Effect

National Geography Standards

- Standard 1: How to use maps and other geographic representations, geospatial technologies, and spatial thinking to understand and communicate information

Ocean Literacy Essential Principles and Fundamental Concepts

- Principle 1g: The ocean is connected to major lakes, watersheds, and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments, and pollutants from watersheds to estuaries and to the ocean.

Time:

- 50 minutes
- Optional student projects: 1-2 class periods or out-of-class time

Materials

- Projector and computer with Internet access
- Laptops or tablets with student access to the Internet or paper maps of your region
- *The Plastic Path - Student Activity Sheet* pages 6-8
- Video segment (0:26 - 4:55): *Plastic Disaster* (https://www.youtube.com/watch?v=1acjqraXMhs)
- Optional Infographic: *Plastics in the Ocean at the NOAA website:* oceanservice.noaa.gov/hazards/marinedebris/plastics-in-the-ocean.html
- *Message in a Bottle figure* page 9
- Video: *Argos-4: Tracking from Space* (https://www.youtube.com/watch?v=aBc_MeKRMNc)
- Video: *See the Journey of a Plastic Bottle in the Bay of Bengal* (https://www.youtube.com/watch?v=v1EtjcVc5es)
- *Map of Ocean Gyres* page 10

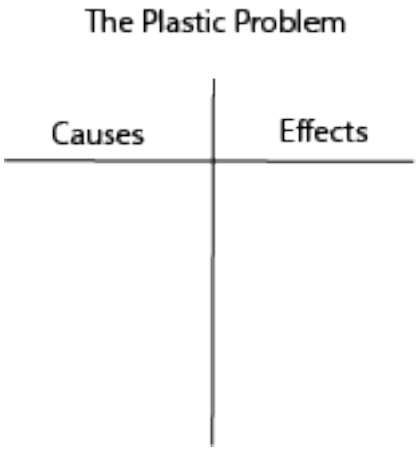
Preparation

- Print copies of the student page (one per student).
- In preparation for Part 3, you may wish to identify one or more nearby rivers that students will explore. Selecting major rivers will increase the chances that students will be able to follow their path. Before class, follow the path of each river on a map to learn where it ends (typically in the ocean) and what locations students should find 50 and 200 km from your location.

Directions

Part 1: Introduce the Problem

1. Start with the phenomenon of plastic in the ocean. There is a growing problem on Earth today - the collection of plastic pollution along the coastlines and in the ocean. Share a few plastic pollution facts to help students understand the scale of the problem:
   - There are now 5.25 trillion pieces of plastic in the ocean, weighing about 269,000 tons.
   - Between 8-14 million tons of plastic enter the ocean every year.
   - In the next ten years, the amount of plastic entering the ocean is projected to increase to between 22-58 million tons per year.
2. Tell students that they will watch a video and use a T-chart to jot down notes about causes and effects as they watch. Have students make the T-chart (shown on the right) in their science notebooks or on a piece of paper.
3. Show the video segment (0:26 - 4:55).
4. After the video, hold a short discussion and ask students:
   - Where have you seen plastic pollution?
   - Where do you think it came from? (sources of plastic pollution)
   - How could plastic get into the ocean?
   - What are the effects of plastic in the ocean?
5. **Optional**: Project the *Plastics in the Ocean Infographic* as a way to visually summarize understandings related to plastic in the ocean.
6. Wrap up the discussion by posing the questions: How far do you think plastic pollution can travel once it enters the water? How could we study this?
   - Allow students to share 1-2 ideas



Part 2: A New Way to Study Plastic Pollution in the Water

1. Introduce the Ganges River study, called *Message in a Bottle*. Pass out copies of the student page and read the background information section of Part 1 together.
2. Pull up Google maps to orient students to the Ganges River and the Bay of Bengal. Share the following facts:
   - The Ganges River system is one of the largest in the world.
   - Out of all the rivers of the world, the Ganges River is responsible for the second-highest amount of ocean plastic pollution (after the Yangtze River in China), adding about 120,000 tons of plastic per year to the ocean.
3. Show students the *Message in a Bottle Figure* which shows the bottle design and what it looked like in the water. Explain that the technology used to track the bottles (Argos satellite tags) is the same technology used to track wild animals.
4. Show students the video *Argos 4: Tracking from Space (3:05)* to get a better understanding of how the technology works.
5. Orient students to the data table on their student page and introduce the column headings. The data describes the journey of the study bottles. Give students time to work with a partner to interpret the data in the table and answer the questions on the student sheet.
6. Bring students back together and debrief, sharing their responses to questions 1 and 2 to learn what students found most interesting and what questions they still have. Describe some results of the study:
   - 40% of the A bottles became beached on the riverbanks. These bottles were released before the monsoon season when water level was low.
   - The B bottles were released after the monsoon season when the water level was much higher. The bottles encountered severe weather and were caught up with fishing activity.
   - Many of the bottles sent their final GPS locations from approximately the same location, suggesting that they got caught up by something in the water or along the shore. This explains why we see large concentrations of trash in some areas and not in others.

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7. Show the video entitled *See the Journey of a Plastic Bottle in the Bay of Bengal (1:13)* to see the journey of bottle B2, which traveled the longest distance (2844.6 km) and was tracked for the longest amount of time (94 days).
    - Ask students what they think could explain the path of movement of B2 once it entered the Bay of Bengal (winds and ocean currents).
8. Project the *Map of Ocean Gyres* and explain that it shows patterns of ocean currents.
    - Explain that due to ocean circulation patterns, much of the trash in the ocean ends up in one of five ocean gyres. (Some students may have heard of the "trash islands" accumulating in the ocean, which are at the center of ocean gyres.)
    - Ask students to predict where the plastic bottles in the Bay of Bengal could eventually end up.

Part 3: Where Will Plastic Pollution Near Me End Up?

1. Shift to focus on the path of plastic pollution in local waterways. Remind students about the rivers in their region and that rivers typically connect to the ocean. (If students have learned about watersheds, connect this activity with their prior learning.)
2. Share the question that students are exploring in this part of the lesson: If plastic pollution got into a local river near our city or town, where would it travel?
3. Have students, working in pairs, identify the location of their city or town and the location of a nearby large river on a digital or printed map.
    - If students will be using digital maps (such as Google Maps or Google Earth), orient them to searching, zooming in, moving along the map, and how to measure distance.
    - If students will be using paper maps, orient them to the map and demonstrate how to measure distance using the scale.
4. Tell students that their objective is to trace the path of a local river and figure out where it goes. (If reservoirs are common in your areas, some rivers might lead to a reservoir instead of the ocean.) Ask students to find the locations where plastic would end up if it traveled 50 km and if it traveled 200 km.
5. Allow students to work with their maps and measure distances.
    - Distances will be approximate as students will most likely be measuring straight-line distance and not the meanders in a river.
6. Have student pairs share the locations they came up with for both scenarios.
    - If your region is far inland, ask students to estimate how far the pollution would need to travel to get to the ocean and where it would enter the ocean.
7. Project the *Map of Ocean Gyres* (from Part 2) and ask students to predict:
    - Where plastic pollution from their community could end up if it got to the ocean
    - Where plastic pollution that entered the ocean at that place would travel in ocean gyres
8. Remind students about the example of the satellite-tracked plastic bottles in the Ganges River and how most of them did not end up in the ocean (they instead remained as pollution within or along the banks of the river itself).

Optional Student Project:

1. As a wrap-up assignment, ask students to come up with a way to communicate about the problem of plastics in the ocean. Let them choose what aspect of the problem they would like to focus on and how they would like to communicate about it. Students could work on this with a partner, in small groups, or as a whole class. Examples of ways to communicate about plastic pollution:
    - A poster showing sources of plastic pollution and how individuals can reduce their impact.
    - A video explaining the problem with plastic pollution in the ocean, or one specific part of this issue.
    - A map of where plastic pollution from your community ends up.
    - Art made from collected plastic pollution.
    - A story of a plastic bottle.

2. To help students organize their thinking, describe the main components that students need to include in their plan including the project goal, description, steps to create or implement it, a materials list, etc.
    - Encourage students to do background research to further inform their project plan. The list of websites about plastic pollution (see References) may be helpful for student background research.
3. Have students take turns presenting their project plans.
4. Give students additional class time to create their project or have them work on it as homework.
    - If project ideas are at a large scale, you may wish to have the class complete one of the projects together. If so, consider assigning parts or tasks to specific students.
5. Once completed, have a gallery walk or presentation of learning.

Extensions:

- Have students research other watersheds of the world, such as the Amazon or the Ganges. Make connections between the river drainage basin they research and ocean gyres by figuring out which ocean gyre the plastic pollution might end up in.
- Consider actions you could take as a class to help reduce plastic pollution, such as sharing communication projects with the community at a school function, school board meeting, or local community event, starting or supporting a plastic recycling program at the school, or organizing a plastic clean-up around the school property or at a local waterway.

Background

Plastic Pollution in the Ocean

Because the use of plastics, especially single-use plastics, is so prevalent and continues to increase each year, the impacts of plastic pollution are an increasingly pressing issue. Plastics that aren't recycled and don't end up in a landfill can often end up as litter on the coast or in a local waterway. Once in the waterway, plastics travel down rivers and can end up in the ocean. After entering the ocean, plastic is carried by surface currents and dispersed to large rotating systems called gyres. Plastics in the ocean can cause animals to become entangled and die. The gyres act as giant blenders, grinding up larger plastic pieces into microplastics. Microplastics can be ingested by marine animals and dispersed up the food chain all the way to humans. The microplastics are too tiny to be easily removed from the ocean, and most cannot be seen with the naked eye. Giant collections of plastic trash circulate within the Earth's subtropical gyres.

Argos: Satellite Tracking Technology

The NOAA Argos instruments aboard satellites are used to collect data from radio transmitter tags that are fitted to animals or equipment. Satellite tracking technology allows scientists to collect data about animals that may be difficult to study in their natural habitat because they travel long distances or are hard to see. Argos satellites have collected and relayed scientific and environmental data for over 30 years. Learn more about Argos from their website, including examples of how the Argos technology is being used in scientific research and the news story about the use of Argos to track plastic bottles in the Ganges River.

Message in a Bottle

The example and data students use in this activity come from the Message in a Bottle study. Researchers conducted two phases of the study: Phase 1 took place during the pre-monsoon season and used cellular phone transmitters, which are less expensive but rely on cellular coverage. Phase 2 took place post-monsoon season and used satellite transmitters, which are more costly but also more reliable in terms of connectivity. The researchers were able to modify the bottle design based on learnings from their study, such as making them less visible in the water so they won't be captured by the public. Further studies using the Argos technology to study plastic dispersal in water have also taken place.

Surface Ocean Currents

Surface ocean currents are due to prevailing winds and are affected by the shape of ocean basins and the seafloor. Due to the spinning of the Earth and the resulting deflection of winds which create friction with the ocean surface, ocean currents in the Northern Hemisphere move clockwise around ocean basins, while currents in the southern hemisphere move counterclockwise.

Links to Learn More

About plastic pollution

- Story of Plastic video - solutions for the problem of single-use plastics and creating a zero-waste economy (https://www.youtube.com/watch?v=iO3SA4YyEYU)
- Life of a Plastic Bottle video - Plastic production and how plastic recycling works (https://www.youtube.com/watch?v=erGnf7ws20E)
- What Really Happens to the Plastic You Throw Away video - TedED video about the path of three different plastic bottles (https://www.youtube.com/watch?v=_6xlNyWPpB8)
- Trash Talk: Impacts of Plastic Pollution (NOAA) (https://marinedebris.noaa.gov/videos/trash-talk-impacts-marine-debris)
- Plastics in the Ocean (Infographic from NOAA National Ocean Service) (https://oceanservice.noaa.gov/hazards/marinedebris/plastics-in-the-ocean.html#transcript)
- Map of ocean gyres (https://oceanservice.noaa.gov/facts/gyre.html)
- Ocean Plastics Pollution (Biological Diversity) (https://www.biologicaldiversity.org/campaigns/ocean_plastics/)
- The World's Plastic Pollution Crisis Explained (National Geographic) (https://www.nationalgeographic.com/environment/article/plastic-pollution?loggedin=true)
- Plastic Oceans - Resources (https://plasticoceans.org/plastic-pollution-info-resources/)
- Plastics in the Ocean - Statistics 2020-2021 (https://www.condorferries.co.uk/plastic-in-the-ocean-statistics#:~:text=There%20is%20now%205.25%20trillion,their%20way%20into%20our%20oceans.)

About the science research

- Message in a Bottle: Open Source Technology to Track the Movement of Plastic Pollution (https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0242459)
- Figure 2 (Message in a Bottle) (https://journals.plos.org/plosone/article/figure?id=10.1371/journal.pone.0242459.g002)
- How Argos System Works (https://www.argos-system.org/using-argos/how-argos-works/)
- Argos: Tracking Plastic Bottles from Rivers to Ocean (https://www.argos-system.org/track-plastic-bottles/)

NOAA and CNES have been partners in the Argos data collection system since 1978. For NOAA's latest contribution to the Argos system, NOAA has partnered with CNES to host their Argos-4 instrument aboard a commercial satellite. NOAA is working with USSF to utilize their hosted payload solutions contract and selected General Atomics and their Orbital Ted Bed-3 satellite to host the Argos-4 instrument.

This activity was developed at the UCAR Center for Science Education as an outreach effort of the Argos program under award NA21OAR4310383 from the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.

Student Activity Sheet

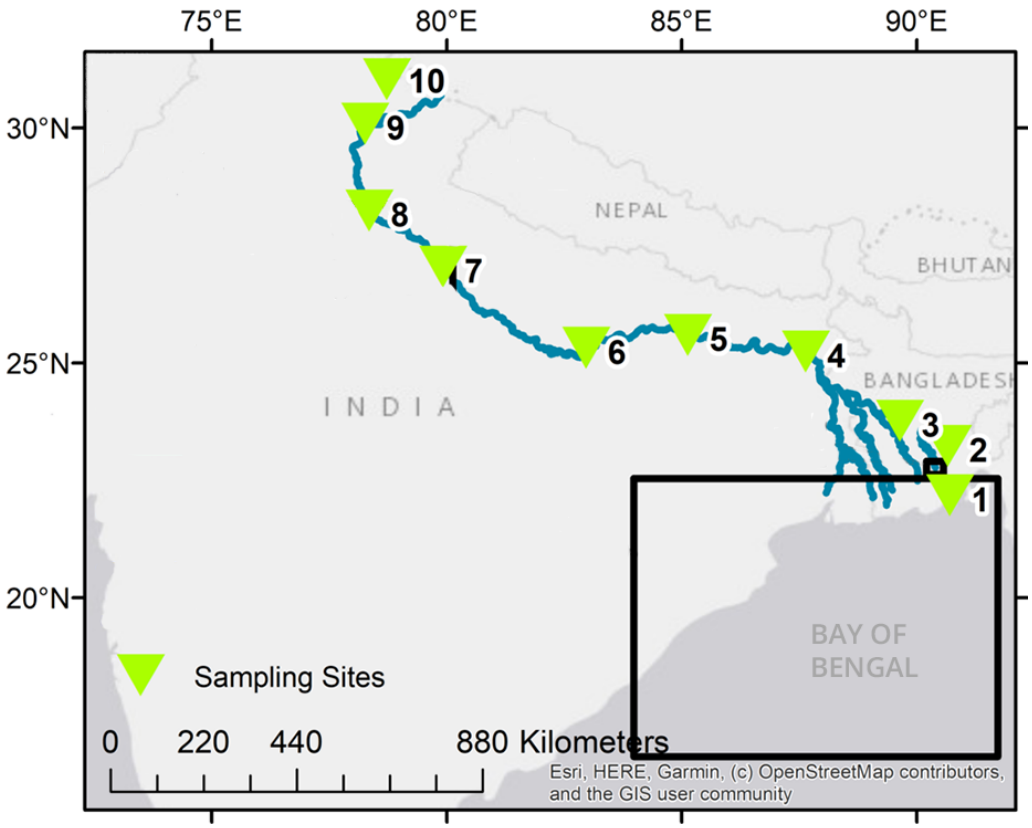
The Plastic Path

A New Way to Study Plastic Pollution in the Ganges River

As the human population increases around the world, so does plastic pollution. One location where researchers are studying this is the Ganges River (shown below). Hundreds of millions of people live in the area surrounding the Ganges River, and the people of India and Bangladesh use more and more plastic each year.

Plastic bottles are a very common form of plastic pollution. To learn more about what happens to plastic bottles once they enter the waterways, scientists designed special bottles that can share their GPS location through radio transmitters. They released them at different places along the Ganges River and in the Bay of Bengal, and tracked their movement using satellites.

The map below shows the study area. The triangles indicate different points along the river where 22 of these bottles were released. Three bottles were also released directly into the Bay of Bengal.



Message in a Bottle Data

The table shows data collected from the bottles that were part of the study. Review the table and then answer the questions below.

Tracking Information					
Bottle ID	**Sampling Site**	**Days**	**Distance (km)**	**Rate (km/day)**	**Fate**
A1	6	6	8.8	0.1	Taken by public
A2	6	4	2.8	0.3	Taken by public
A3	7	34	36.9	0.5	Unknown
A4	7	1	0.8	NA	Couldn't connect
A5	7	31	110	0.7	Unknown
A6	7	25	133.1	0	Unknown
A7	8	51	610	5	Unknown
A8	9	24	167	0.2	Taken by public
A9	9	5	8.7	1.2	Unknown
A10	10	NA	NA	NA	Couldn't connect
B1	Sea	25	780	20.6	Still transmitted
B2	Sea	94	2845	6.3	Unknown
B3	Sea	6	10.2	1.3	Unknown
B4	1	45	941	3	Unknown
B5	1	1	28.6	NA	Unknown
B6	1	3	4.6	0.2	Unknown
B7	1	93	31.7	0.2	Still transmitted
B8	2	1	45.1	NA	Unknown
B9	2	43	55.7	0.8	Unknown
B10	2	21	54.6	2.3	Unknown
B11	2&3	4	0.5	0.1	Water entered bottle
B12	3	22	19.2	0.4	Unknown
B13	3	1	0.3	NA	Antenna damage
B14	3	NA	NA	NA	Antenna damage
B15	3	NA	NA	NA	Antenna damage

1. What do you notice? Write three things that you find interesting about the bottle data.

2. What do you wonder? Write two questions that you have after studying the data.

3. Find the three bottles that were tracked for the most number of days and circle them in the 'Days' column of your table. What might account for these bottles lasting longer than the others?

4. Find the bottle that traveled the farthest, and label it on your table. What might explain why it traveled so far?

5. Find the three bottles that traveled at the fastest rate (km/day) and circle them in the 'Rate' column of your table. What might explain why these bottles traveled more quickly than others?

6. Describe a pattern you observe in the data. Explain how observing this pattern could be helpful to understanding plastic pollution in the Ganges River basin.

7. Even though many of the bottles were damaged or lost along the way, how is this data helpful in fighting the problem of plastic pollution in the ocean?

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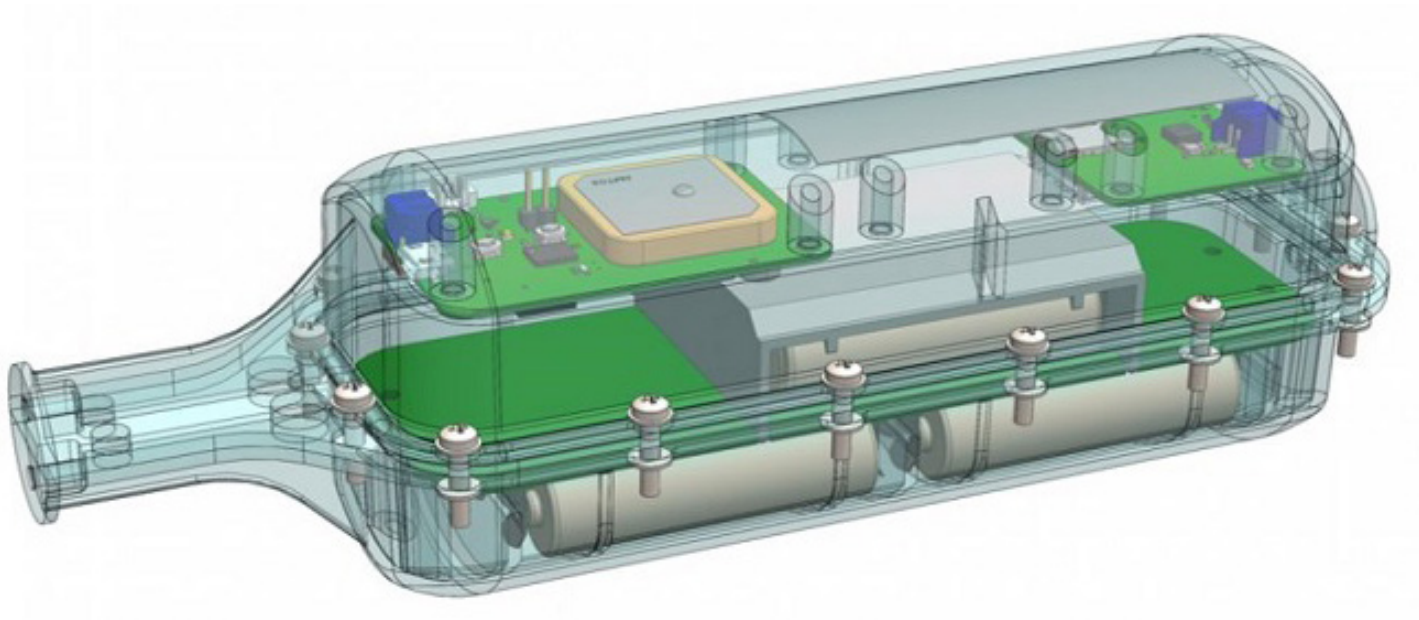
Message in a Bottle Figure

The Plastic Path

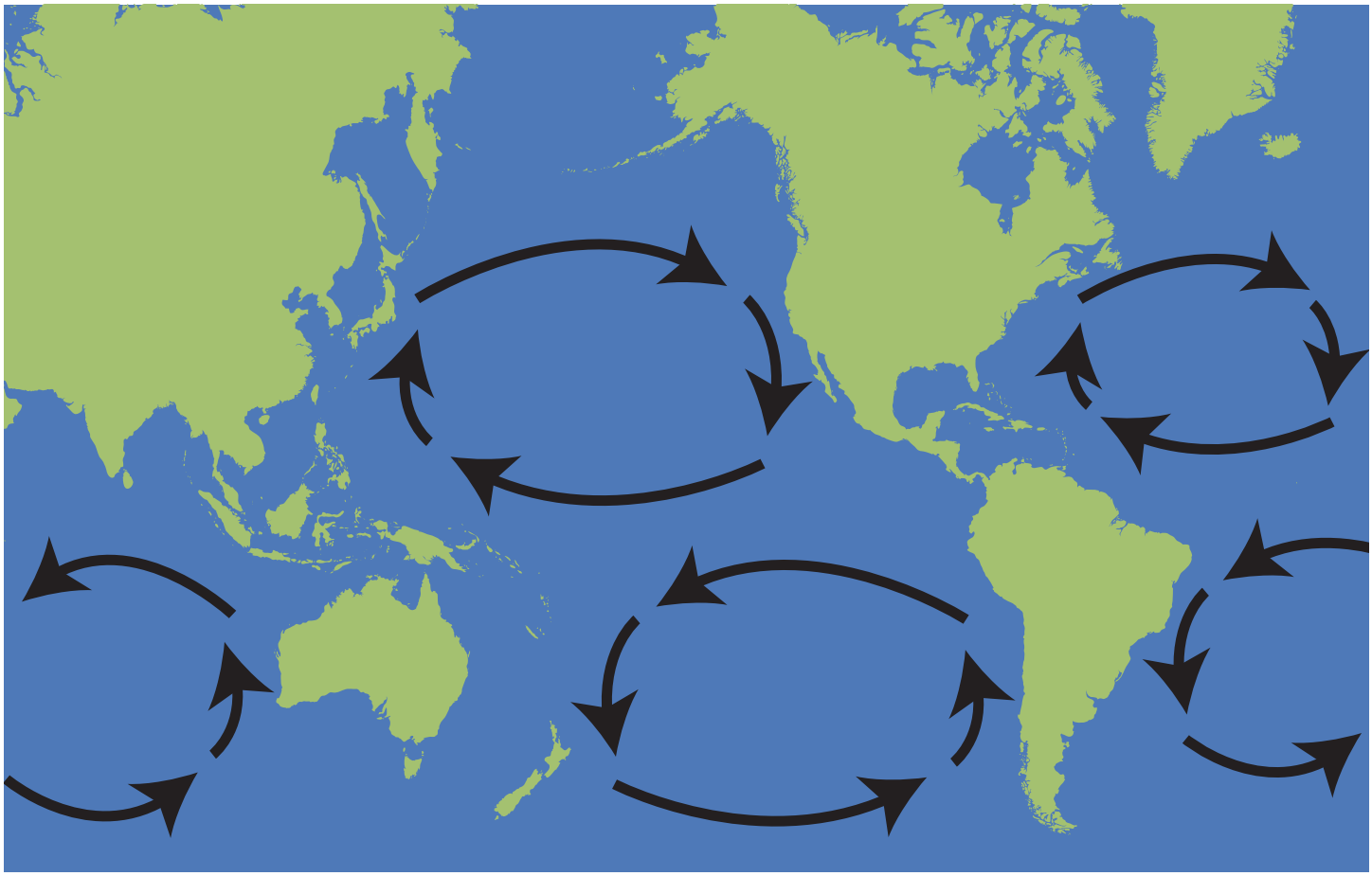


CAD image of the equipped bottles (Credit: Arribada initiative)

Bottle released in the water (Credit: Heather Koldewey)

Map of Ocean Gyres

The Plastic Path



Credit: Lisa Gardiner/UCAR