COMMENT

Check for updates

# The status and fate of oceanic garbage patches

*Laurent Lebreton*[1,2]

Floating plastic is accumulating in the five subtropical oceanic gyres, but little is known about their composition, sources, and fate. Monitoring has provided insight into persistence and accumulation processes in the North Pacific Ocean, but their relevance in other gyres is unknown. Identifying the sources of plastics, in all subtropical gyres, is necessary for cleanup efforts to be effective.

Most plastic introduced to the ocean will sink or float back to land. However, buoyant debris can become entrapped and circulate for years in subtropical oceanic gyres, slowly accumulating; resultingly, floating plastic waste totals on the order of $10^5$ tons at the ocean surface[1]. Although the occurrence of plastic accumulation in gyres is well-established, the long-term fate of these oceanic garbage patches is unclear. Here, I describe a brief history of discovery, monitoring and the challenges to quantify the scale of the problem.

## Garbage patches

Plastic accumulating at the sea surface was identified by oceanographic expeditions from the 1970s, mainly in the North Pacific and the North Atlantic Oceans, collecting data with surface plankton net tows[2]. With concentrations increasing in subtropical gyres, further expeditions (mostly in the 2000s) discovered the formation of five garbage patches in the North Pacific, North Atlantic, South Pacific, South Atlantic and South Indian Oceans, leading to estimates of the plastic mass accumulated at the ocean surface[1].

The Great Pacific Garbage Patch (GPGP), located in the North Pacific subtropical gyre (FIG. 1), has attracted the most public and scientific attention. It is possibly the densest accumulation of all five garbage patches, having an area of 1.6 million $km^2$ of ocean surface with concentrations of millimeter-sized plastic debris that frequently reach up to $10^6$ pieces $km^{-2}$. However, debris is not homogeneously spread, and concentrations can vary substantially between surface net tows. The exact location of the GPGP varies annually but at the edge of the accumulation zone, mean surface concentrations can sharply increase by two orders of magnitude[3].

The garbage patch in the North Atlantic subtropical gyre covers a similar surface area as the GPGP, but concentrations are commonly found in the order of $10^5$ pieces $km^{-2}$. This area of debris accumulation is also known as the Sargasso Sea for its characteristic Sargassum seaweed discovered by early Portuguese renaissance explorers, and now aggregating with plastic debris.

Unfortunately, observational data for the three southern subtropical gyres is limited to a handful of crossings that confirm the presence of plastic pollution, but not the extent of it. The highest average concentrations of plastic debris in the Southern Hemisphere have been reported in the South Atlantic subtropical gyre (in the order of $10^5$ pieces $km^{-2}$), with the lowest in the South Pacific subtropical gyre (~$10^4$ pieces $km^{-2}$). Because of the proximity to global sources of plastic pollution, a substantial mass of debris is expected to travel to the South Indian subtropical gyre, but the presence of a large accumulation is contested by numerical models. There, the monsoon system resulting from the presence of the Eurasian continent in the Northern Hemisphere, likely affects the fate and transport of debris and the subtropical gyre might be much more dispersive than in other oceans. Furthermore, the connectivity of the South Indian Ocean garbage patch with the two other southern subtropical gyres is not well understood.

## Plastic lost and found

The amount of estimated plastic contained in the garbage patches is substantial, yet it is lower than estimated flux of plastics into the ocean (up to $10^7$ tons annually)[4]. This discrepancy led to the belief that most floating plastic pollution does not persist at the surface of subtropical gyres. As most samples returned by expeditions were targeting particles the size of plankton, it was therefore commonly accepted that garbage patches were like plastic soups filled with millimeter-sized plastics. These small particles would sink rapidly to the bottom of the sea, accounting for some of the missing plastic. This hypothesis was supported by the apparent scarcity of sub-millimeter-sized plastic fragments reported from early oceanographic missions[5] and motivated several deep-sea plastic sampling campaigns

[1]The Ocean Cleanup, Rotterdam, Netherlands.
[2]The Modelling House, Raglan, New Zealand.
e-mail: laurent.lebreton@theoceancleanup.com
https://doi.org/10.1038/s43017-022-00363-z

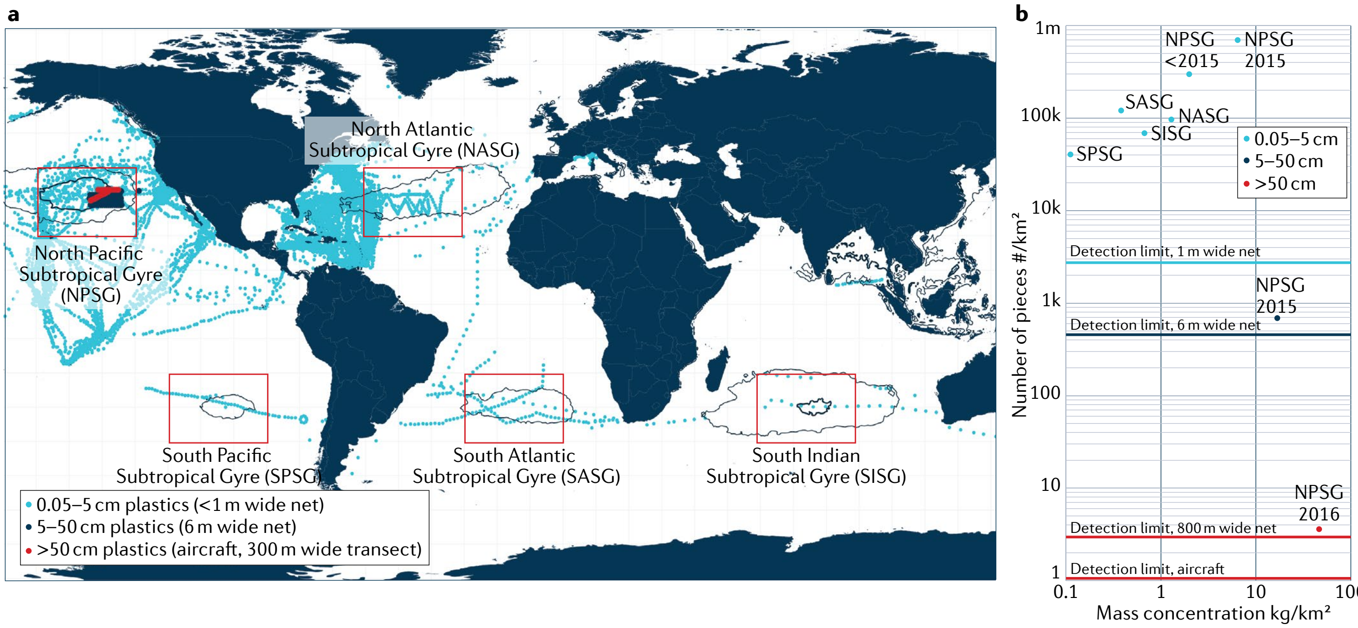


Fig. 1 | **Observing the oceanic garbage patches. a** | Global observational effort for floating plastic debris. Most data have been collected with plankton net tows quantifying debris 0.05 to 5 cm in size[1]. Dark contours depict modelled concentrations showing accumulation. Red boxes depict the general location of accumulation and were used to extract average concentrations in each subtropical gyre. **b** | Average number of pieces per surface area versus average mass concentration measured for different size of plastic debris. Detection limit at 90% confidence for one hour of surface net tow at 2 knots for different net opening sizes and for an aircraft covering 300 m wide transects.

underneath garbage patches of the Pacific and Atlantic Oceans. These efforts identified positively buoyant sub-millimeter-sized plastic fragments and fibers in the water column, but the mass concentration was several orders of magnitude lower than at the surface[6].

Alternative observation and collection technology deployed in the GPGP since 2015 revealed a different nature to this accumulation. Larger debris is less frequently collected by surface net tows than millimeter-sized particles, but it can greatly influence the total plastic mass concentration found at the ocean's surface owing to its dimension and weight. To accurately map this large debris, expeditions began using visual sightings, cameras mounted on vessels, aircraft, drones, and the deployment of wider collecting nets. Although far less numerous than small fragments, debris >5 cm — mainly fishing gear — represented three-quarters of the accumulated plastic mass in the region, dwarfing previous mass estimates by an order of magnitude[3].

The retrieval of thousands of plastic debris >5cm allowed further investigations into the origin and age of this material from the identification of labels and markings[7]. Most objects with an identifiable country of origin come from major fishing nations around the North Pacific Ocean. Waste from marine sources, like abandoned fishing gear, is less likely to encounter land during its journey in the ocean, and therefore it is the type of debris most identified in the GPGP. A substantial fraction of old material originates from as far back as the 1960s. Given its apparently long residence time, this debris supports a neo-pelagic community where coastal species can thrive on persistent floating plastic rafts for several generations on the high seas[8].

### The fate of garbage patches

This is a much greater persistence of plastic pollution in garbage patches than initially thought, at least for the North Pacific subtropical gyre. Concerningly, there is a lack of objects produced after 2010 in the GPGP, demonstrating a substantial delay between plastic emissions and long-term accumulation in oceanic garbage patches. This delay suggests that the currently observed mass of debris primarily results from previous decades of consuming and discarding plastic, and that more plastic will continue to accumulate in the future. Moreover, for the GPGP, a comparison by size classes showed that between 2015 and 2018–2019, the concentration of larger fragments has been increasing at a faster rate than that of smaller ones, suggesting an exponential growth of inputs[9].

Systematic classification of plastic debris by size is lacking for the other subtropical gyres, and most plastic items retrieved from off-shore expeditions are unidentified fragments of millimetres to several centimetres in size[10]. It is currently impossible to trace the origin of this material, preventing a full understanding of the source and fate of these garbage patches. However, the findings from the North Pacific Ocean could be informative of the status of the four other subtropical gyres. With an exponential increase of global plastic production, there is no reason to believe the situation is not also worsening in other oceans. In situ research for each gyre is needed, though, as a shifting geography of land-based sources and fishing grounds could result in a distinct composition and age of plastics.

In a century, some plastic currently afloat in the oceanic garbage patches might still be there, in some form, but the long-term implications for marine life and the climate are not well understood. The oceanic garbage patches are located in international waters and no jurisdiction is currently responsible for them. Clean-up operations offer an opportunity to mitigate the pollution before it further degrades in the ocean, and they can enable the identification of debris origins. The documentation of this pollution will support international legislation focusing on mitigation of all land-based and marine sources of ocean plastic pollution, without which clean-up is not viable.


1. van Sebille, E. et al. A global inventory of small floating plastic debris. *Environ. Res. Lett.* **10**, 124006 (2015).
2. Wong, C. S., Green, D. R. & Cretney, W. J. Quantitative Tar and Plastic Waste Distributions in the Pacific Ocean. *Nature* **247**, 30–32 (1974).
3. Lebreton, L. et al. Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. *Sci. Rep.* **8**, 4666 (2018).
4. Jambeck, J. R. et al. Plastic waste inputs from land into the ocean. *Science* **347**, 6223 (2015).
5. Cozar, A. et al. Plastic debris in the open ocean. in *Proc. of the National Academy of Sciences* **111**, 10239–10244 (2014).
6. Egger, M., Sulu-Gambari, F. & Lebreton, L. First evidence of plastic fallout from the North Pacific Garbage Patch. *Sci. Rep*. **10**, (2020).
7. Lebreton, L. et al. Industrialised fishing nations largely contribute to floating plastic pollution in the North Pacific subtropical gyre. *Sci. Rep.* **12**, 12666 (2022).
8. Haram, L. E. et al. Emergence of a neopelagic community through the establishment of coastal species on the high seas. *Nat. Commun.* **12**, 6885 (2021).
9. Egger, M. et al. A spatially variable scarcity of floating microplastics in the eastern North Pacific Ocean. *Environ. Res. Lett.* **15**, 114056 (2020).
10. Morales-Caselles, C. et al. An inshore–offshore sorting system revealed from global classification of ocean litter. *Nat. Sustain*. **4**, 484–493 (2021).


**Competing interests**

The author is consulting for The Ocean Cleanup, a not-for-profit organization developing technology to remove floating plastics from the ocean's surface.