Sources of marine pollution for remote islands in the west Indian Ocean

Marine plastic pollution is a major environmental threat. Scientists at the University of Oxford have used the computing power of ARCHER2 to carry out one of the most ambitious marine pollution simulations to date, making it possible to identify the likely geographic sources of plastic pollution.

Marine plastic pollution accumulates in vast quantities on coastlines across the world, representing a major environmental threat to marine ecosystems and the communities that depend on them. In the case of remote islands, debris may have been transported over great distances across the ocean. These islands, many of which belong to small island developing states, are faced with the deeply inequitable situation of bearing the costs of removing waste they were not responsible for generating, contrary to the "polluter pays" principle.

For example, a recent study estimated that over 500 tonnes of plastic had accumulated on Aldabra Atoll (Seychelles), a UNESCO world heritage site – despite zero permanent population (Burt et al., 2020). Identifying the sources of debris accumulating at these remote islands would be a positive step towards accountability and prevention, but this is challenging. Studies have inferred countries of origin through intact labels on bottles, but this method has been limited to small sample sizes, and is biased against debris lacking (intact) labels.

Figure 1: Dead turtle on Aldabra Atoll, strangled by abandoned fishing gear. (Image credit: Rich Baxter)

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Alternatively, 'virtual' plastic items can be simulated based on estimates of plastic input at coastlines and at sea, and the effects of ocean currents, winds and waves. This approach is challenging for remote islands, because their small size and distance from land means that enormous numbers of virtual items have to be simulated over long periods of time. As a result, previous studies were limited to larger countries, or qualitative assessments of pollution sources.

By running many thousands of simulations in parallel on ARCHER2, we simulated the trajectories of over 40 billion virtual plastic items from the coastlines of 60 countries, as well as marine sources (such as debris discarded from ships and fisheries) across the Indian Ocean. This is one of the most ambitious marine pollution simulations to date, and was made possible by the large number of cores and memory available on ARCHER2.

Due to the variable geometry and composition of marine plastic pollution, items sink and beach at different rates, and may also experience different forces from the wind. The methodology we developed for this project allows users to investigate the influence of these parameters on pollution source attribution through postprocessing, rather than re-running the simulations (which would be considerably more computationally expensive). However, this postprocessing step requires a lot of data to be read from the storage medium. Thanks to the SSD file system that was recently installed on ARCHER2, we were able to compute debris sources across hundreds of different parameter combinations, revealing that debris buoyancy has an enormous influence on which coastlines debris ends up on, whereas beaching rates are comparatively less important.

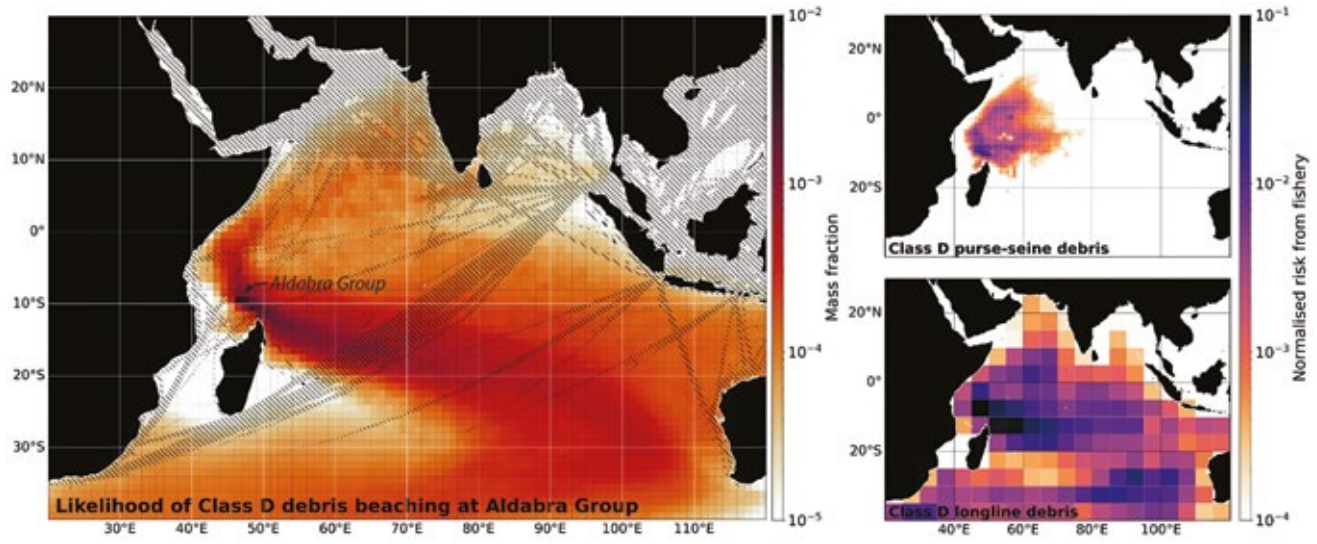

Figure 2: (Left) Risk map of highly buoyant plastic pollution for the Aldabra island group in Seychelles, overlaid with major shipping corridors in the Indian Ocean. (Right) Predicted sources of pollution for the Aldabra island group from purse-seine fisheries (top-right) and longline fisheries (bottom-right).

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Based on these simulations, we believe that most plastic pollution of terrestrial origin accumulating at remote islands across the west Indian Ocean comes from south and southeast Asia, particularly Indonesia and India. However, crucially, a significant proportion of the debris beaching at these remote islands (including the majority of debris at some islands, like Aldabra) entered the ocean from sea, rather than land. Much of this debris is abandoned or discarded fishing gear, but our study suggests that commercial items (such as bottles) discarded from ships may also represent a major source of pollution for some remote islands. For instance, around half of all bottles washing up at Aldabra Atoll came from China (the origin of many shipping routes crossing the Indian Ocean), but our simulations show that these bottles could not have floated directly from the Chinese coastline. The disposal of plastic at sea is illegal under international law, but this research highlights potentially widespread infringement of these regulations across the Indian Ocean.

As well as identifying geographic sources of plastic pollution, the computing power available on ARCHER2 also allowed us to investigate the temporal variability of pollution transport, across multiple decades. We predict that, particularly for islands in the southwest Indian Ocean, monsoonal winds imprint a strong seasonal signal on plastic accumulation rates on beaches, with most plastic being deposited on beaches at the end of the northwest monsoon. When large plastic debris remains on beaches, breaking waves may rapidly fragment items into unmanageable microplastics. This suggests that beach clean-ups should be prioritised following the northwest monsoon, to minimize the time that debris is exposed on beaches.

In summary, our research provides stakeholders in small island developing states across the western Indian Ocean with a first, quantitative estimate of where pollution accumulating on their islands is coming from, as well as practical suggestions to mitigate the impact of pollution on their beaches. Our findings also highlight the urgent need for a global plastics treaty due to the transboundary nature of marine plastic pollution, and the fact that much of the waste may be generated in the high seas, beyond regions of national jurisdiction. These findings contribute towards UN development goals 6, 10, 12, and 14, and supports the United Kingdom's international development goals. This research was only possible thanks to the computational power of ARCHER2.

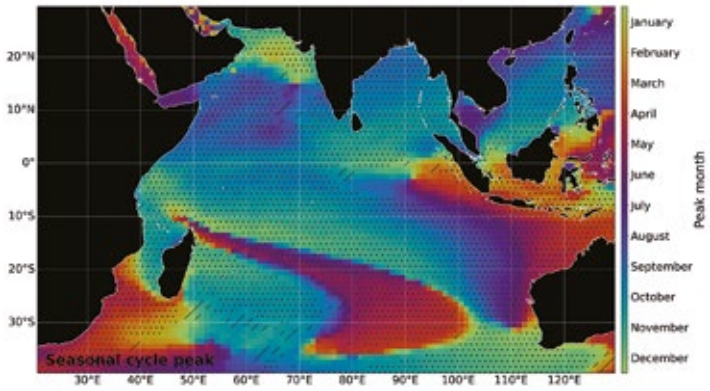

Figure 3: Which month during the year highly buoyant debris discarded at sea is most at risk of beaching at the Aldabra island group. Fisheries may wish to be particularly vigilant when fishing during these months to avoid generating harmful pollution for remote islands.

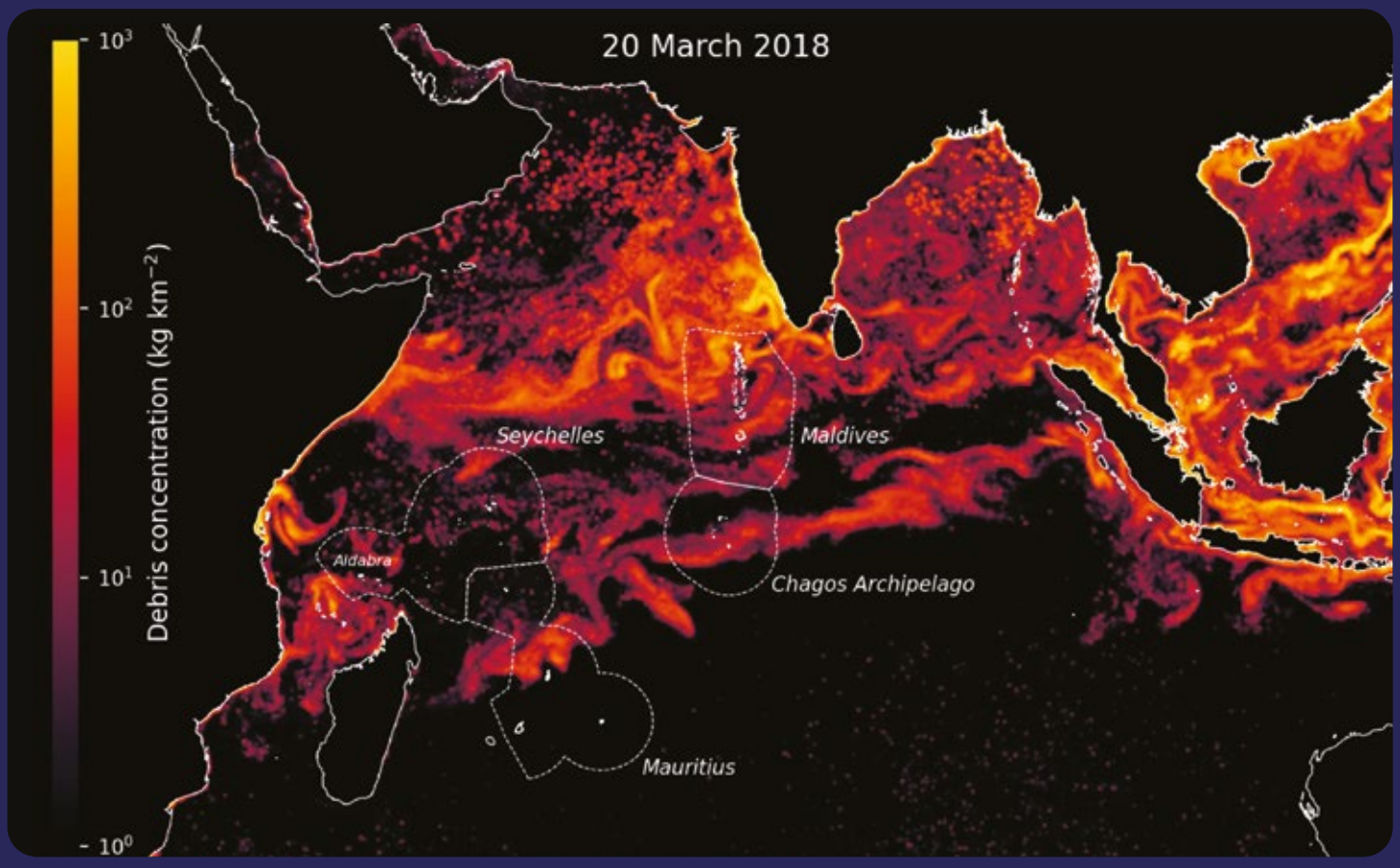

Figure 4: Snapshot of simulated surface concentrations of marine plastic pollution following the northwest monsoon.

Figure 5: Volunteers clearing up some of the hundreds of tonnes of plastic debris that have accumulated on Aldabra Atoll (Image credit: Seychelles Islands Foundation and the Aldabra Cleanup Project)

References:

Burt, A.J., Raguain, J., Sanchez, C. et al. The costs of removing the unsanctioned import of marine plastic litter to small island states. Sci Rep 10, 14458 (2020). **https://doi.org/10.1038/s41598-020-71444-6**

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