

Impact case study (REF3)

Institution: Imperial College London		
Unit of Assessment: 9 – Physics		
Title of case study: B9-2 Quantifying the scale and dynamics of marine plastic pollution and influencing policy including UK and EU bans on microbeads.		
Period when the underpinning research was undertaken: 2015-2017		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): Dr. Erik van Sebille	Role(s) (e.g. job title): Lecturer in Climate Change and the Environment	Period(s) employed by submitting HEI: 1.3.2015 – 31.3.2017
Period when the claimed impact occurred: 2015 – 31 December 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact (indicative maximum 100 words)		
<p>Dr van Sebille and colleagues from Imperial's Department of Physics and Grantham Institute developed a Markov model of the ocean surface flow based on observations of GPS-tracked drifters and used this to compute the transport of microplastic in oceans. This showed that only ~1% of all plastic that has ever gone into the ocean has been reliably mapped. The research also quantified the impact of cleaning up plastic in different locations.</p> <p>This research alerted the public to this planetary environmental threat and was used by policymakers to influence UK and EU policy solutions to mitigate plastic pollution. This contributed to the UK ban on microbeads in September 2016 (into force Jan 2018), the UK ban on single-use plastics (May 2019) which came into force on 1st October 2020, and the EU ban on single-use plastics in May 2019, coming into force in 2021.</p>		
2. Underpinning research (indicative maximum 500 words)		
<p>Marine plastic pollution is a major environmental problem, that is now drawing considerable attention from scientists, policy makers and the public. Dr van Sebille's research team developed novel scientific techniques to model the transport of plastic debris in the ocean and found that only about 1% of all plastic that has ever gone into the ocean has been mapped reliably; the other 99% is 'missing' [1].</p> <p>To resolve this mystery of missing plastics, we combined the trajectories of a dataset of more than 20,000 free-floating GPS-tracked drifters at the surface of the ocean into a transition matrix, that holds for any position in the ocean the probability that a drifter moves to any other position at a time scale of two months. With this transition matrix, we created an empirically driven Markov model of global ocean surface plastic flows.</p> <p>We used the Markov model to compute the transport of microplastic from coastlines to the open ocean. This yielded spatial patterns of plastic concentration at the surface of the ocean, which we regressed against more than 11,000 measurements of plastics floating at the surface of the ocean to perform a comprehensive, statistically robust validation of the predicted spatial distribution of floating microplastic.</p> <p>The drifter-based ocean surface Markov model was used to analyse the destinations of plastics, after release to the ocean. We also used the model to calculate the likely origin of plastic floating in the Arctic Ocean [2], concluding that the most likely origin of most of the small plastic around Svalbard, for example, originated from northwest Europe and the UK.</p> <p>The Markov model also allowed us to quantify where cleaning up of plastic would be most effective [3]. We showed unequivocally that removing plastic is much more cost-effective and maximises</p>		

environmental impact near coastlines than in the middle of the open ocean because plastics would be captured much closer to the beginning of their journey through the environment, causing less environmental harm.

Prior to this research, the fate of the majority of the global plastic waste was unknown, and speculations included the seafloor, coastlines, ingested by organisms, or degraded and dispersed. Thus, the potential for environmental harm was largely unknown. We combined our maps of the plastic on the surface of the ocean with data on species' distributions to provide information about where concentrations of plastic debris coincide with the habitat of vulnerable and at-risk species ([4] for sea birds; [5] for turtles), to help policy makers prioritise plastic clean-up efforts.

Subsequently, the Grantham Institute team (Van Sebille, Spathi, and Gilbert [6]) wrote a briefing paper for general policy and NGO audiences that combined these academic outputs highlighting the UK's contribution to marine plastic in the Arctic ocean, with a summary of the policy solution landscape, bridging the academic-policy gap for the target audience.

3. References to the research (indicative maximum of six references)

[1] van Sebille, E, C Wilcox, L Lebreton, N Maximenko, BD Hardesty, J Van Franeker, M Eriksen, D Siegel, F Galgani, KL Law (2015). [A global inventory of small floating plastic debris](#). *Environmental Research Letters*, 10, 124006, DOI: 10.1088/1748-9326/10/12/124006

[2] Cózar, A, E Martí, CM Duarte, J García-de-Lomas, E van Sebille, TJ Ballatore, VM Eguíluz, JI González-Gordillo, ML Pedrotti, F Echevarría, R Troublè, X Irigoien (2017) [The Arctic Ocean as a dead end for floating plastics in the North Atlantic branch of the Thermohaline Circulation](#). *Science Advances*, 3, e1600582, DOI: 10.1126/sciadv.1600582

[3] Sherman, P, E van Sebille (2016) [Modeling marine surface microplastic transport to assess optimal removal locations](#). *Environmental Research Letters*, 11, 014006, DOI: 10.1088/1748-9326/11/1/014006

[4] Wilcox, C, E van Sebille, BD Hardesty (2015) [Threat of plastic pollution to seabirds is global, pervasive, and increasing](#). *Proceedings of the National Academy of Sciences*, 112, 11899-11904, DOI: 10.1073/pnas.1502108112

[5] Schuyler, QA, C Wilcox, KA Townsend, KR Wedemeyer-Strombel, G Balazs, E van Sebille, BD Hardesty (2016) [Risk analysis reveals global hotspots for marine debris ingestion by sea turtles](#). *Global Change Biology*, 22, 567-576, DOI: 10.1111/gcb.13078

[6] Van Sebille, E, C Spathi, A Gilbert (2016). The ocean plastic pollution challenge: towards solutions in the UK. Grantham Briefing Paper 19, *Grantham Institute, Imperial College London*, 16 pp. Available [here](#)

4. Details of the impact (indicative maximum 750 words)

Dr van Sebille applied his fundamental physics-based oceanography research to consider the challenges of plastic pollution in the ocean, beginning in 2015, and leading to scientific publications on ocean microplastics that built an evidence base that identifies microplastic sources and sinks and focusses on how best to reduce the negative impact of plastic waste in the ocean. His work also highlighted the role of the UK on marine plastic pollution in the Arctic Ocean.

Informing policy

Based on the body of research on marine plastics the Grantham Institute and Dr. Eric van Sebille submitted written evidence to the House of Parliament's Environmental Audit Committee on microplastic pollution (May 2016) [A]. As a result, Dr van Sebille was invited to give oral evidence [B]. In July 2016 the Environmental Audit Committee published a report on the "Environment impact of microplastic". Dr van Sebille's evidence, research or quotes are on pages: 7, 9, 10, 21, 27 and 29 [C]. This report concluded with the recommendation to ban microbeads. The UK

government accepted this and announced plans to ban microbeads in November 2016. This led to Dr. van Sebille's research informing DEFRA policy surrounding the UK ban on microplastics. The Head of Ocean Climate Science at DEFRA and science lead on the ban policy writes "*they [Dr van Sebille and the Grantham Institute] provided key information to the Department and met with us on many occasions to discuss the main areas and gaps in the evidence on marine litter and microplastics in the ocean. Their openness and extensive knowledge were a valuable contribution to what was one of the key environmental policies of the UK Government and led to, what is still described as, the World's toughest ban on microbeads.*" [D]. In addition, during the parliamentary debates of the ban, the Committee report was highlighted as a key piece of evidence for supporting the ban [E]. In December 2017 the ban was approved and came into force in January 2018.

During 2016 the Grantham Institute and Dr van Sebille delivered a wide range of engagement activities targeting both policy makers and society at large. Based on the launch of the policy paper [6], a regular dialogue with key contacts was established to kick start joint projects. The team met with many external stakeholders over this period, including [Government Office for Science foresight team: Future of the Sea](#), [Defra](#), [WWF UK](#), [ZSL](#), Coca Cola, [IEEP](#), [Green Alliance](#), Greenpeace UK, Galapagos Conservation Trust, the then UK Chief Scientific Advisor, Prof Sir Mark Walport and MPs Calum Kerr and Daniel Zeichner. This led to Dr van Sebille presenting his research at Greenpeace UK events during 2016 [F]. Following his first presentation, Greenpeace UK noted that "*Erik's presentation was fundamental in cementing the concept of marine litter as a truly global issue that we need to tackle at both a government policy and corporate level.*" [F]. Following this, later in 2016 Greenpeace UK organised a lobbying event with MPs, retailers such as Marks & Spencer and Tesco and other key stakeholders. The event featured Dr van Sebille's research on the impacts on plastics and microplastics once in ocean flows. The event was well received and "*the audience at the event came away with the knowledge that Greenpeace's lobbying efforts are steeped in scientific evidence, that prevention really is better than cure when it comes to plastic pollution and that we must turn off the plastic tap at source. We were very grateful for this opportunity to platform Erik's research*" [F].

Press coverage of Dr van Sebille's research [G] highlighted the issue of UK marine plastic waste to the public. As public opinion shifted the UK government, all major UK supermarkets and high-profile organisations such as the BBC pledged to ban all single-use plastics in April 2018. Following this, on 17th May 2018 the research from the Grantham Briefing paper and research by Dr Erik van Sebille was directly referred to during an UK parliamentary debate on "Plastic Bottles and Coffee Cups" in relation to Environmental Audit Committee (EAC) reports and single-use plastics. In the opening of the debate by Mary Creagh MP, she stated, "*Research by Dr Erik van Sebille at Imperial College London shows that most of the UK's marine plastic pollution ends up in the Arctic, so the UK has a particular responsibility to clean up our act and protect the Arctic.*" [H]. During the same inquiry the ZSL collaborated with Dr Erik van Sebille to include his research and the Grantham Institute briefing paper to form their written and oral evidence. The Project manager for ZSL writes "*The evidence we provided informed EAC recommendations to the government in-line with our asks around single-use plastic water bottle reduction targets across the UK and an increase in freely available refill points – a big success for the #OneLess project. This collaboration Dr Erik van Sebille and his team helped us to run a successful, evidence-lead campaign.*" [I] In May 2019 the UK government confirmed the ban of single use plastics. This came into force on the 1st October 2020 after being delayed from April 2020 due to the Covid-19 pandemic [J]. This ban should reduce plastic in the oceans, as well as stimulating a growth in reuse and recycling [J].

Beyond UK policy, information directly from our body of work [6] was included in the European Commission report 'A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions' (March 2019, see Table 3, Page 37) [K] this informed the EU's decision to ban on single-use plastics in May 2019, this will come into force in 2021 [L].

Public engagement

In addition to working with policymakers the Grantham institute led a public outreach programme, centred around the Imperial College public festival of science in May 2016 (15,000 attendees) and a Royal Society Science Exhibition in July 2016 (14,371 attendees). The activities were designed to appeal to a wide range of ages and groups. The high-quality exhibition included a touch-screen interactive ocean model to track the path of plastic litter from different locations, a game linking common plastic litter items with what they become when broken down by simulated wave action, cards gathering solutions for the ocean plastic problem (categorised as better materials, community action, clean-up projects) and a twitter wall displaying live suggestions. Special outreach activities were developed for young people included a research paper written especially for use in secondary schools (750 hard copies distributed). During summer 2016 plasticadrift.org website: 13,000 views, Video on RS website & YouTube: 1,241 views (#3 most viewed of all 23 RS stands). Since mid-2016 the Ocean plastic pollution web page had 13,469 unique views. Dr. van Sebille and his team also presented at the [BlueDot Festival](#) (45,000 attendees over 3 days), [Being Human Festival](#) and at the Royal Geographic Society.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[A] Official written evidence from the Grantham Institute, submitted as one of 49 pieces of evidence in relation to the Environmental Audit committee review on the environmental impacts of microplastics, see submission number 19.

https://publications.parliament.uk/pa/cm201617/cmselect/cmenvaud/179/17911.htm#_idTextAnchor031 (Archived [here](#))

[B] Evidence session, Dr. van Sebille as an expert, providing answers to a number of Parliamentarian's questions. House of Commons Environmental Audit Committee Monday 9th May 2016, Environmental Impact of Microplastics, HC 925

<http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/environmental-audit-committee/environmental-impact-of-microplastics/oral/33273.html> (Archived [here](#))

[C] The documentation associated with the House of Commons report on the environmental impact of ocean plastic. Dr. van Sebille was an expert witness and is referred to, or quoted, on pages: 7,9,10,21,27 and 29.

<https://publications.parliament.uk/pa/cm201617/cmselect/cmenvaud/179/179.pdf> (Archived [here](#))

[D] Letter from Head of Ocean Climate Science at DEFRA

[E] [https://hansard.parliament.uk/Commons/2017-12-18/debates/f330abdd-db3c-4be5-ada0-2bbd5f9e94e3/DraftEnvironmentalProtection\(Microbeads\)\(England\)Regulations2017](https://hansard.parliament.uk/Commons/2017-12-18/debates/f330abdd-db3c-4be5-ada0-2bbd5f9e94e3/DraftEnvironmentalProtection(Microbeads)(England)Regulations2017) (Archived [here](#))

[F] Letter from Greenpeace UK

[G] A range of media reports. Some of this early attention build the public case for acting on UK-sourced plastic waste, for example: Guardian, July 5th 2016, Damian Carrington Plastic waste dumped in UK seas 'carried to Arctic within two years' quotes Dr. van Sebille "What we found, quite shockingly and unexpectedly, is that most UK plastic ends up in the Arctic. It does extreme harm there, we think." Also, on 5th July 2016 the mail online explained that "The team at Imperial College London used PlasticAdrift.org to track ocean currents and follow the trail of plastic north to the frigid Arctic waters." (Available [here](#))

[H] Research mentioned in Parliament debate on single use plastics ban

<https://hansard.parliament.uk/Commons/2018-05-17/debates/6FAA7117-9B47-4553-A2AA-A7AD6711BCD1/PlasticBottlesAndCoffeeCups?highlight=erik#contribution-2F02C009-A7E0-44F0-9F6A-CECEDFC29B97> (Archived [here](#))

[I] Letter from Senior Marine Project Manager at the Zoological Society of London

[J] UK ban on single use plastics <https://www.gov.uk/government/news/start-of-ban-on-plastic-straws-stirrers-and-cotton-buds> (Archived [here](#))

[K] Table on policy approaches (table 3, page 37) of the EU report '*A circular economy for plastics – Insights from research and innovation to inform policy and funding decisions*' https://ec.europa.eu/info/publications/circular-economy-plastics-insights-research-and-innovation-inform-policy-and-funding-decisions_en which was taken directly (with permission) from Grantham Institute Briefing paper 19. (Archived [here](#))

[L] Announcement of the EU ban of single use plastic - <https://www.europarl.europa.eu/news/en/press-room/20190321IPR32111/parliament-seals-ban-on-throwaway-plastics-by-2021#:~:text=On%20Wednesday%2C%20Parliament%20approved%20a,in%20the%20EU%20by%202021%3A&text=Single%2Duse%20plastic%20plates> (Archived [here](#))