**Institution:** University of Plymouth

**Unit of Assessment:** UoA7

**Title of case study:** Reductions in microplastic pollution through changes to legislation, industrial innovation and societal awareness

**Period when the underpinning research was undertaken:** 2001-2016

**Details of staff conducting the underpinning research from the submitting unit:**

| Name(s): | Role(s) (e.g. job title): | Period(s) employed by submitting HEI: |
|---|---|---|
| R.C. Thompson | Professor of Marine Biology | 2001- present |
| SJ Rowland | Professor of Organic Chemistry | 1984 – 2019 |
| T.S. Galloway | Reader in Ecotoxicology | 1997 – 2007 |

**Period when the claimed impact occurred:** 2014-2020

**Is this case study continued from a case study submitted in 2014?** N

## 1. Summary of the impact (indicative maximum 100 words)

University of Plymouth (UoP) research on microplastic pollution has led to international changes to legislation:

- In the UK, we directly informed legislation leading to a ban on microplastics in rinse off personal care products in 2017.
- At an EU level, we worked with the European Commission, this led to a call for a ban on intentionally added micro-plastics by 2020. The EU Chemicals Agency said this will reduce emissions by at least 70 % and prevent the release of 500 000 tonnes of microplastics over the next 20-years.
- In an international level, we provided evidence to the United Nations and governments worldwide (including in Canada, New Zealand, and Japan) leading to policy changes.

We have sparked innovation in the laundering industry to reduce the release of microfibres, worked with Anglian Water to develop an international standard on flushable products and raised public awareness resulting in behaviour changes demonstrated through the environmental action of NGOs and charities.

## 2. Underpinning research (indicative maximum 500 words)

In 2001, Richard Thompson secured a Leverhulme Trust (LT) Pilot Grant to describe and quantify small plastic fragments that, he considered, were being overlooked during marine litter monitoring. He established that sub-millimetre sized fragments of plastic were widespread in sediments and in the water column in the north-east Atlantic. He showed that a range of marine organisms could ingest these fragments; and using archived plankton samples, he showed that the abundance of this material had increased significantly over the previous 40 years. The resultant paper (3.1) was published in the journal Science, using, for the first time, the term 'microplastic' to describe these pieces, the majority of which were fibres. In 2003, Thompson (together with UoP Co-Is Rowland and Galloway*) secured further funding from the LT to quantify microplastic contamination and examine the potential environmental consequences. His team were the first to show that laundering of textiles was an important source of microplastics; that wastewater was a key pathway to the environment; and that microplastics had accumulated on shorelines worldwide (3.3).

To examine the potential for environmental impacts, staff at UoP investigated the mollusc Mytilus edulis. These filter feeders provide key ecosystem services removing bacteria and toxins and are harvested for food worldwide. Laboratory experiments showed that, after ingestion, microplastics translocated from the gut to the haemolymph of the mollusc, where they could be retained for more than 40 days (3.2). Thompson and colleagues subsequently showed wide-scale ingestion of microplastic by several species of commercially important fish from the English Channel (3.4). Research by the team later demonstrated the potential for adverse effects on organisms that ingested microplastic.

More recently, Thompson's team characterised and quantified microplastic particles (microbeads) that were used as exfoliants in cosmetics (3.5). This showed that up to 2.8 million submillimetre spherical polyethylene pieces could be present per 150ml tube of exfoliant; with every use potentially resulting in release of 90,000+ particles to wastewater (3.5).

The team at UoP then quantified the release of textile fibres to wastewater during laundering, calculating that 720,000 fibres could be released by every single washing load. These fibres can evade wastewater treatment, reaching aquatic environments where they can be swallowed by fish and other animals, potentially also finding their way into our food chain (3.6).

This body of research is important because it describes a previously neglected, but widespread, constituent of marine litter, microplastics, and explains why, despite exponential increases in the quantity of plastic waste generated, monitoring of large items of litter in the environment showed no related increase in plastic debris; whereas Thompson (3.1) showed that microplastics, many of which had arisen by the fragmentation and deterioration of larger items, had increased significantly over time.

Thompson's ground-breaking work has created a significant new area of enquiry with over 300 scientific papers using the term microplastics published in 2019. As cited by Ryan P.G. in Marine Anthropogenic Litter, Springer Open Access 2015 – "Thompson et al. 2004 was largely responsible for the recent resurgence in interest in the marine litter problem". Furthermore, the Food and Agriculture Organisation (FAO) of the United Nations states "only reports from the early 2000s gained a sufficient following that research into microplastic contamination became a priority" - citing only Thompson et al. 2004. The research and the associated impact were recognised by a NERC Impact Award (2018) and in 2020 the Queen's Anniversary Prize; in recognition of this 'pioneering research on microplastics pollution in the oceans and its impact on the environment and changing behaviour''.

* Leverhulme funding ran until 2007 supporting the underpinning research in 3.2 and 3.3. In 2007, Galloway relocated to University of Exeter (UoE). Research Assistant Browne subsequently moved to Australia and there was some delay in publishing 3.2 and 3.3. None of the research outlined in these papers was undertaken at UoE. Collaboration with UoE has continued via subsequent projects funded by Defra and NERC.

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

All of the papers below result from staff who, at the time of the research, were based at UoP (Thompson, Rowland and Galloway, shown in bold), the majority of the other co-authors were also based at UoP as part of the research team (International Marine Litter Research Unit) led by Thompson. Other UoP authors (shown underlined) were either Research Assistants or technicians employed on grants where Thompson was PI or postgraduate research students with Thompson as Director of Studies. Thompson's role in leading this team is reflected by him being the last author on most publications. Arabic Numerals, after each output, indicate sources corroborating impact (Section 5).

3.1 **Thompson, R.C**., Olsen, Y., Mitchell, R.P., Davis, A., **Rowland, S.J**., John, A.W.G., McGonigle, D. and Russell A.E. (2004). Lost at sea: Where does all the plastic

go? Science, 304, 838. http://dx.doi.org/10.1126/science.1094559. (Cited in 1, 2, 3, 5, Section 5)

3.2 Browne, M. A., A. Dissanayake, **T. S. Galloway**, D. M. Lowe, and **Thompson, R. C.** (2008). Ingested microscopic plastic translocates to the circulatory system of the mussel, Mytilus edulis (L.) Environmental Science and Technology 42:5026-5031. https://pubs.acs.org/doi/10.1021/es800249a. (Cited in 1, 2, 3, 4, 5 Section 5)

3.3 Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., **Galloway, T.** and **Thompson, R.** (2011). Accumulation of Microplastic on Shorelines Woldwide: Sources and Sinks. Environmental Science & Technology 45, 9175-9179. http://dx.doi.org/10.1021/es201811s. (Cited in 1, 2, 3, 5, 6, 9 Section 5)

3.4 Lusher, A. L., M. McHugh, and **R. C. Thompson** (2013). Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Marine Pollution Bulletin 67:94-99. https://doi.org/10.1016/j.marpolbul.2012.11.028. (Cited in 1, 2, 3, 5, 9, Section 5)

3.5 Napper, I. E., Bakir, A., **Rowland, S. J.** and **Thompson, R. C**. (2015). Characterisation, Quantity and Sorptive Properties of Microplastics Extracted From Cosmetics. Marine Pollution Bulletin 99, 178-185. http://dx.doi.org/10.1016/j.marpolbul.2015.07.029. (Cited in 1, 2, 3, 5, 9 Section 5)

3.6 Napper, I. E., and **Thompson, R. C.** (2016). Release of synthetic microplastic plastic fibres from domestic washing machines: Effects of fabric type and washing conditions. Marine Pollution Bulletin 112:39-45. https://doi.org/10.1016/j.marpolbul.2016.09.025. (Cited in 1, 2, 3, 6, 7, 8, 9, 10, Section 5)

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

As plastic use continues to increase, our research on microplastics has demonstrated their prevalence in our oceans (3.1, 3.3) alongside evidence that they are entering the food chain (3.2, 3.4) with potential detrimental impacts on animal health. Moreover, our research has evidenced the sources of microplastics, from textiles (3.4) to microbeads (3.5) which has allowed policy makers, charities, NGOs and industry to implement interventions to reduce microplastic pollution.

**Bans on microbeads across the globe.**
Our research has led to bans of microplastics at UK, EU and global scales through sustained governmental engagement, the provision of evidence to enquiries, and its contribution to legislation.

In August 2016, UoP research was presented as written and oral evidence to the Environmental Audit Committee on microplastics (the only scientific paper to be cited in the UK proposals). In order to reduce harm to the marine environment, in 2017, the UK introduced a ban on the use of microplastics in rinse-off personal care products. "*This ban was introduced as a consequence of [UoP research 3.5] … together with Prof Thompson's input… [this has] considerably helped shape Defra thinking."* Julius Piercy, DEFRA [5.1]. The ban is estimated to have prevented the release of 680 tonnes of microplastics to wastewater every year.

At an EU level, our research informed the European Parliament's Single-Use Plastics Directive 2016 on the reduction of the impact of certain plastic products on the environment. This resulted in MEPs calling for a ban on intentionally added micro-plastics in cosmetics, personal care products, detergents, and cleaning products by 2020. *''[Thompson's] papers are important because they helped inform the EC to reduce the quantity of litter entering the oceans, and to set up policy instruments such as the Plastics Strategy, the ECHA restriction dossier in 2018 and*

*the Circular Economy Action Plan in 2020"* Werner Bosmans, European Commission [5.2]. The EU Chemicals Agency ECHA said that the ban will reduce emissions by at least 70 % and prevent the release of 500 000 tonnes of microplastics over the next 20-years. It has been estimated that each tonne of plastic entering oceans could result to a loss to natural capital in excess of £2400 hence the projected benefits of this intervention in terms of a reduction in damage to natural capital can be estimated at in excess of £1.2 Billion.
On a global scale, our research was used as evidence in the United Nations Food and Agriculture Organisation 2017 technical paper to assess the potential impact of microplastics on consumers' health and perceptions and to understand the potential consequences on fish productivity [5.3]. This widely cited document has been used to inform governments across the world. In 2018, Thompson's research and expertise led to the Japanese bill to reduce microplastics released into the environment. In the same year, legislation directly citing UoP research includes a New Zealand ban on the import, manufacture and sale of microbeads in rinse-off cosmetics, estimated to apply to over 100 products [5.4] and a Canada wide ban on the manufacture and import of toiletries that contain microbeads [5.5].

**Innovation, entrepreneurial activity, and industry changes**
Our research demonstrated that plastic fragments are shed from synthetic clothes when washed. As the fragments are too small to be caught by the machine's filters, they then flow into the sewage system and eventually into the ocean, where those fibres are often swallowed by invertebrates and fish (3.6). This discovery has contributed to innovation and entrepreneurial activity through the design of new products and the start-up company, PlanetCare Ltd, which was launched in 2017. Inspired by our research, the Slovenian founder designed the first add-on filter system to prevent microfibres being released into washing machine wastewater and entering the environment. Their product is marketed internationally, and the company estimate it will eliminate 500 tonnes of microfiber emissions over the next five years. '*Your research greatly influenced me to start our company, PlanetCare Ltd'. [Your] scientific reports…gave solid evidence of the extent of the pollution. '[Your] publications (3.3, 3.6) … made a strong and lasting impression.'* Mojca Zupan, CEO [5.6]. Planetcare joined industry leaders, NGOs, and policy makers at a round-table discussion in Paris in February 2020. At this meeting, France's Secretary of State for Ecological Transition, Brune Poirson, announced that all new washing machines will require a filter for capturing plastic microfibers from 2025 onwards and attendees agreed that it should also be implemented on a European level.

In addition, our research (3.6) influenced the UK company, Xeros Technologies to develop the XFiltra, a highly efficient external filter which captures microfibres generated in laundry, that is marketed for domestic and commercial laundry and specialist cleaning and apparel manufactures [5.7]. Moreover, it influenced Arcelik to design the world's first washing machine with a built-in synthetic microfiber filtration system, which claims to remove 99.9% of fabric microfibres. The company, which operates in more than 146 countries with brands such as Beko and Grundig, unveiled their washing machine in September 2019 and have committed to making this technology available to their competitors in the industry [5.8].

Thompson's research (3.3-3.5) and expertise has also resulted in the demise of environmentally damaging flushable products, such as wet wipes, containing synthetic microfibers. There are approximately 300,000 sewer blockages annually, costing the country £100 million and wet wipes made up more than 90% of the material causing sewer blockages (Water UK 2017). Working with Anglian Water, Thompson influenced the outcomes of the international standard, WG 10 – Flushable Products ISO 24524, which laid the foundation for the successful introduction of the UK Water Industry Standard Fine to Flush (WIS F2F) (January 2019). This symbol will let consumers know that the products will break down in the sewer system instead of clogging up sewers and contributing to fatbergs which cause blockages and sewage overflows. The introduction of the WIS F2F, has resulted in industry leaders making major changes to the products they sold as flushable. Namely one independent company Natracare, two Waitrose products and of special significance is the industry leader Kimberly Clark which has changed the formula of its Andrex Washlets products to meet the F2F specification. *'Thanks…to the steer you provided, the British committee was instrumental in ensuring that for any product to be*

*considered flushable one of the criteria should be that it must not contain petro-chemical based plastics.'* Clare Pillinger and Rachel Dyson, Anglian Water [5.9].

**Raised public awareness leading to consumer behaviour change**
Since Thompson's 2004 publication (3.1), the term 'microplastic' has become widely used in this context, not only in scientific publications but also across the mainstream news and media, for example it was word of the year in Spain 2019. This has resulted in a growing awareness that these tiny fragments of plastic are pervasive. Numerous NGOs, campaign groups and charitable organisations across the world have been influenced by our research increasing consumer awareness and triggering consumer behaviour change resulting in beneficial impacts on the environment (citations include Ellen MacArthur Foundation, Fashion Revolution, Georgian Bay Forever, Plastic Pollution Coalition and the Ocean Wise Conservation Association).

Increased environmental action resulting from our research (3.6) is evidenced through the National Federation of Women's Institute's (NFWI) '*End Plastic Soup'* campaign [5.9]. Launched in 2017, their campaign explored the scale of the microplastic fibre pollution and called on the government and industry to develop solutions to the problem. Their campaign survey of nearly 1,500 members and non-members showed that 62% of respondents reported that they had made some behavioural change, such as washing at a lower temperature or ensuring their washing loads are at capacity, because of the End Plastic Soup campaign [5.10]. Their report received national media coverage and was referenced by the Environmental Audit Committee in Parliament in its inquiry into the environmental impact of fashion. In September 2020, this resulted in the formation of the All-Party Parliamentary Group on Microplastics which raises awareness of the effect microplastics on the environment.

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

5.1 Testimonial DEFRA: Julius Piercy, Head of Marine Litter Policy, Ocean Plastic Pollution Team, Marine and Fisheries Directorate (refers to research papers: 3.1-3.6)
5.2 Testimonial European Commission, Werner Bosman, Team Leader Plastics, (refers to research papers: 3.1-3.6)
5.3 Fisheries and Agriculture Organisation (FAO) of the UN, Microplastics in fisheries and aquaculture http://www.fao.org/3/a-i7677e.pdf (refers to research papers: 3.1-3.6)
5.4 Rethinking Plastics in Aotearoa New Zealand - A report from the panel convened by the Office of the Prime Minister's Chief Science Advisor https://www.pmcsa.ac.nz/topics/rethinking-plastics/ (refers to research paper: 3.2)
5.5 Report for Environment and Climate Change, Government of Canada. Microbeads – A Science Summary https://www.ec.gc.ca/ese-ees/default.asp?lang=En&n=ADDA4C5F-1 (refers to research papers: 3.1-3.5)
5.6 Testimonial Planetcare Ltd: Mojca Zupan, CEO (refers to research papers 3.3 and 3.6)
5.7 Xeros' XFiltra™ https://www.xerostech.com/technology (refers to research paper: 3.6)
5.8 Playing our Part to beat plastic pollution https://www.arcelikglobal.com/en/blog/playing-our-part-to-beat-plastic-pollution/ (refers to research paper: 3.5)
5.9 Testimonial Anglian Water: Clare Pillinger (chair BSI CB/503/-1) and Rachel Dyson (programme manager) (refers to research papers: 3.3-3.6)
5.10 National Federation of Women's Institute's '*End Plastic Soup'* Report 'In a Spin' https://www.thewi.org.uk/__data/assets/pdf_file/0007/327418/WI_EndPlasticSoup_Report_Stakeholders.pdf (refers to research paper 3.6)