Institution: Anglia Ruskin University (ARU)

Unit of Assessment: UoA 14

Title of case study: Reducing the environmental impact of single-use plastics

Period when the underpinning research was undertaken: 2016 - 2020

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:
Dr Dannielle Green	Senior Lecturer	October 2016 to present
Dr Bas Boots	Lecturer	January 2018 to present
Leon Stone	Technician	June 2018 to present

Period when the claimed impact occurred: 2018 - 2020

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

1. Summary of the impact

Our research on the environmental impacts of plastics influenced decision-making for businesses and national/international governments. Specifically, it:

1) strengthened the European Chemicals Agency's (ECHA) intentionally-added microplastics restrictions;
2) shaped a new British Standards Institute testing standard for biodegradable plastics;
3) enabled DP World London Gateway businesses to commit to reductions in single-use plastics usage;
4) helped introduce extended producer responsibility of tobacco companies to mitigate impact of cigarette butts on environment; and
5) raised awareness of plastic pollution amongst policymakers (including UK Government Department for Environment, Food and Rural Affairs (DEFRA) and United Nations Environment Programme) and citizen communities (e.g. via significant media coverage).

Collectively, this has helped safeguard the environment from single-use plastics and will help prevent the substitution of conventional plastics with harmful biodegradable alternatives.

This impact is underpinned by pioneering research led by ARU that was the first to:

- demonstrate ecological impacts of conventional and biodegradable (micro)plastics;
- test the effect of cigarette butts on plants; and
- test the environmental effects of glitter (a unique type of microplastic).

ARU was the ecological lead in all policy and business engagement activities detailed herein, which used this research to drive impact.

2. Underpinning research

Single-use plastics account for 40% of global plastic production annually, and 50-70% of the plastic litter in marine, freshwater and terrestrial environments. Microplastics (pieces <5mm) are the most abundant solid waste on Earth. The threat that (micro)plastic litter can pose to individual organisms is quite well understood, but less is known about the harm caused to biodiversity and ecosystem functioning. Furthermore, the effects of bio-based, biodegradable plastics, which have been increasingly adopted as an alternative to conventional, single-use plastics, are not well understood.

Research by Green and Boots was the first to evaluate how plastic pollution can affect entire communities of organisms and ecosystem functioning, rather than individual species in isolation.

The research was also pioneering because outdoor mesocosm experiments were used with natural, flowing seawater in combination with intact sediment cores. This better represents nature, allowing assessment of the impacts of conventional or biodegradable microplastics on marine invertebrate assemblages from ecologically important habitats. Our experiments provided evidence that the addition of microplastics altered nutrient cycling by decreasing the flux of inorganic nutrients (including ammonium and silicate) from the sediment. Furthermore, the biomass of microphytobenthos (microscopic, primary producers in sediment) were reduced. In muddy sediment, dominated by *Ostrea edulis* (European flat oysters), the addition of 25 µg L-1 of microplastics caused a shift in biodiversity, where species known to be indicators of pollution (e.g. oligochaetes) became dominant (Reference 1).

Another type of single-use plastic litter is smoked cigarette butts. Research by Green and Boots demonstrated that smoked cigarette butts reduced the germination success and shoot length of *Trifolium repens* (white clover) by 27% and 28% respectively, and that of *Lolium perenne* (perennial ryegrass) by 10% and 13%. Moreover, the root biomass of clover was 60% less when butts were present. By comparing smoked cigarette butts with unsmoked ones, our research also found that the plastic filter itself, composed of cellulose acetate, had an inhibitory effect on the measured variables (Reference 2).

A key observation from our research is that microplastics made from polymers that are marketed as biodegradable or compostable (e.g. polylactic acid: PLA) can have similar effects on marine and terrestrial ecosystems as those of commonly-used non-biodegradable polymers (e.g. high-density polyethylene: HDPE; and polyvinyl chloride: PVC). Based on experimental work, our research provided evidence that these types of microplastics have similar effects on organisms, by disrupting the immune system of blue mussels (Reference 3), filtration rates of blue mussels and Pacific oysters (Reference 1) and biomass of terrestrial earthworms (Reference 4). Furthermore, they have similar effects on a community level by altering biodiversity and abundance of marine organisms (Reference 1), and on ecosystem functioning by decreasing the biomass at the base of the food chain (algae and plants) in marine and terrestrial ecosystems (Reference 1 and 4), and altering marine sediment nutrient cycling (Reference 1). In addition, the impacts of glitter as litter (a type of primary microplastic) on freshwater ecosystems was assessed for the first time. Our research demonstrated that glitter manufactured of biodegradable, cellulose-based and traditional (PET) polymers, but also mineral (mica) glitters, had similar effects on plants and algae. Although there were no overall community level responses, cellulose-based glitter led to an increase of non-native snails (Reference 5).

3. References to the research

Reference 1: Green, D.S., Boots, B., O'Connor, N. and Thompson, R., 2017. Microplastics affect the ecological functioning of an important biogenic habitat. Environmental Science & Technology, 51, 68-77. https://doi.org/10.1021/acs.est.6b04496. Submitted in REF2.

Reference 2: Green, D.S., Boots, B., Da Silva Carvalho, J., and Starkey, T., 2019. Cigarette butts have adverse effects on initial growth of perennial ryegrass (gramineae: *Lolium perenne* L.) and white clover (leguminosae: *Trifolium repens* L.). Ecotoxicology and Environmental Safety, 182, 109418. https://doi.org/10.1016/j.ecoenv.2019.109418.

Reference 3: Green, D.S., Colgan, T.J., Thompson, R.C. and Carolan, J.C., 2019. Exposure to microplastics reduces attachment strength and alters the haemolymph proteome of blue mussels (*Mytilus edulis*). Environmental Pollution, 246, 423-434. https://doi.org/10.1016/j.envpol.2018.12.017.

Reference 4: Boots, B., Russell, C.W., Green, D.S., 2019. Effects of microplastics in soil ecosystems: Above and below ground. Environmental Science & Technology, 53, 11496-11506. https://doi.org/10.1021/acs.est.9b03304. Submitted in REF2.

Reference 5: Green, D.S., Jefferson, M., Boots, B., Stone, L., 2021. All that glitters is litter? Ecological impacts of conventional versus biodegradable glitter in a freshwater habitat. Journal of Hazardous Materials, 402, 124070. Published online on 22 September 2020. https://doi.org/10.1016/j.jhazmat.2020.124070.

4. Details of the impact

Headline impact – ***Our research on the effects of plastic pollution in aquatic and terrestrial environments has been used as evidence to shape national and international policy, develop a testing standard for biodegradability and reduce the single-use plastic footprint of key businesses at DP World London.***

Impact 1 – ***Improved the stringency of biodegradability testing for intentionally-added microplastics in the EU, through changing European Chemicals Agency policy***

Our research has directly influenced European policy making. Green was nominated – jointly by Flora and Fauna International (FFI) and the European Environmental Bureau (EEB; Europe's largest network of over 160 environmental citizens' organisations from more than 35 European countries) – as a technical expert to the Risk Assessment Committee (RAC) of the European Chemicals Agency (ECHA). ECHA is the central agency which implements the EU's chemicals legislation across all 27 member states and ensures that companies comply with European law.

Green made several formal interventions at ECHA RAC's Helsinki meeting (RAC-51) on 26 November 2019, particularly relating to restricting the use of intentionally-added microplastics. These interventions, alongside submission of supporting evidence to the RAC, led to two specific changes:

(i) change to <u>what</u> part of the plastic is tested: Green made an intervention regarding primary microplastics composed of a blend of biodegradable and conventional polymers (using evidence from Reference 5 on biodegradable glitter, which can have a non-biodegradable, acrylic coating), and inquired whether testing is applied to the whole item as it appears on the market, or only the biodegradable part (Source 1). This led to the RAC approving an amendment to the proposal to stipulate that materials made of a blend of polymers must have either each of the polymeric components of the blend tested separately, or that chemical analysis must be performed to demonstrate that each polymeric component achieves the threshold of degradation. Specifically, the recommendation is now that the test material should be comparable to the microplastic *on the market* in terms of the composition, form, size, and surface area, as these parameters have an influence on the (bio)degradation behaviour of the microplastics (page 38 in Source 2; and page 19 under "Prevent blends with conventional plastic" in Source 3). This will prevent materials composed of a blend of non-biodegradable and biodegradable plastics being derogated based only on their biodegradable component rather than on the whole item as it appears on the market.

(ii) change to <u>how</u> the plastic is tested: Green also used evidence from References 1, 3, 4 and 5 to emphasise that biodegradable microplastics can have the same biological and ecological impacts as non-biodegradable microplastics and that the precise effect can vary depending on the environmental context (i.e. type of habitat). She recommended that biodegradation testing should be conducted in environmentally realistic conditions simulating marine, freshwater and terrestrial habitats, as opposed to only needing to pass testing in one of these (Source 1). It was subsequently agreed by RAC at the RAC-52 meeting (March 2020) that ISO biodegradation tests and simulation tests should be carried out for soil, marine, estuarine and fresh water and marine sediment or seawater/sediment interface (Page 36 in Source 2; and page 20 under "Test all environment compartments" in Source 3). Testing in marine, freshwater and terrestrial settings will help to safeguard the environment from biodegradable plastics which only degrade in one habitat whilst persisting in others.

Impact 2 – ***Contributed to the development of a new international testing standard for biodegradability of biodegradable plastics***

ARU ensured that the British Standards Institute's (BSI) publicly available specification for a new standard of biodegradation of plastics in open air terrestrial environments (PAS9017) better accounted for assessing potential ecotoxicological impacts, as a result of Green's BSI PAS9017 steering committee membership. In particular, more stringent ecotoxicology testing was introduced: using three test taxa (water fleas, plants and earthworms), as opposed to one, were now required. Furthermore, the requirement to perform testing both before and after simulated weathering, as opposed to only testing the simulated post-weathered sample, where a material is comprised of multiple components or is heavily inked (Table A1 and Clause 5.1. in PAS9017; Source 4). More stringent ecotoxicological testing will help to minimise environmental impacts of littered biodegradable plastics.

Impact 3 – *Changed professional practice and attained business commitments to reducing use of single-use plastics, via collaboration with Network Rail, Goldcrest Oil, Railscape, Clean Green, Castle Point Motors and DP World London Gateway*
Green is the Advising Environmental Scientist on the 'Ocean's Together' business forum, led by DP World London Gateway, which aims to influence the actions of businesses in order to help them to reduce their use of single-use plastics. Businesses involved include Network Rail, Goldcrest Oil, Railscape, Clean Green, Castle Point Motors and DP World London Gateway itself. Since Green joined the forum in 2018, the businesses involved have used 12,800 kg less single-use plastic. The evidence from References 1, 3, 4 and 5, showing the impact of biodegradable (micro)plastics, was presented by Green to the 'Ocean's Together' forum and influenced the actions of several businesses by inspiring them to switch to reusable alternatives, instead of biodegradable plastics (which are single-use and require industrial composting).

For example, 48,000 fewer single-use plastic cups (saving £800 a year) have been used at water coolers at DP World; employees must now take reusable containers. 10,000 fewer plastic bags have been used by Castle Point Motors, as they are now using reusable cardboard boxes to store and transport car parts. Railscape used 2,000 fewer plastic bags, and they are now using reusable woven bags instead (Sources 5 & 6).

Impact 4 – *Encouraged commitment to extended producer responsibility of cigarette butts, through working with Keep Britain Tidy and UK Parliament*
In July 2020, research on cigarette butts (Reference 2) was presented by Green at a Tidy Britain All-Party Parliamentary Group meeting organised by Keep Britain Tidy on smoking-related litter. This contributed to the introduction of voluntary extended producer responsibility (EPR) for tobacco companies (Sources 7 & 8). This will hold tobacco companies to account over the collection, transport, processing and safe disposal of their tobacco product waste, thereby helping to reduce contamination of the environment with this prevalent litter item.

Impact 5 – *Raised awareness about plastic pollution amongst governments and citizens*
Research by Green and Boots has been used to raise awareness amongst the scientific and policy-making communities, and to direct recommendations for future research including solutions. For example, Green was an invited speaker at a Royal Society of Chemistry event on 'Microplastic pollution: everyone's problem but what can do about it?' (London, 16 October 2017), and an invited expert reviewer and workshop participant at a DEFRA workshop on 'Marine Plastic Pollution Evidence Review underpinning Policy and Gap Analysis on Marine and Fisheries Policy Area' (London, 12-13 March 2019). Similarly, Green is currently working closely with the United Nations Environment Programme on plastics pollution and governance issues; e.g. she is lead author on the United Nations Environment Programme Assessment on Sources, Pathways and Hazards of Litter including Plastic Litter and Microplastics Pollution.

References 1-5 have also all attracted national and international media attention via mainstream media and beyond, thus contributed to raising awareness about plastic pollution. In particular, Reference 2 generated widespread public engagement (88% of the known engagement from the general public) and widespread reach including inclusion in Wikipedia. It is in the top 5% for media attention of any research article tracked using Altmetric, scoring higher than 99% of its contemporaries and being featured on television (BBC), radio and on social media. For example,

on Twitter, it has so far had 726 tweets from 693 users, with an upper bound of 2,163,070 followers and has been used in 155 news stories from 139 outlets. An additional article written by Green for *The Conversation* accrued >4,000 comments on Facebook and has been read >30,000 times. Furthermore, Reference 4 has been used to inspire further action; as evidenced in posters as part of anti-litter campaigns in New Zealand, as inspiration for a cigarette butts clean-up app by Bogna Haponiuk for Omni Calculator (Source 9), and as evidence in support of a smoking ban proposal at Lake Tahoe, Nevada, California (Source 10).

5. Sources to corroborate the impact

- **Source 1:** *Letter of support from European Environment Bureau,* corroborating the contribution made by Dr Green towards improving policy on plastic microbeads restrictions across the European Union.
- **Source 2:** *Latest RAC ECHA report*, featuring proposed improvements to testing criteria as described in section 4.
- **Source 3:** *European Environment Bureau and Client Earth Policy Note*, which Dr Green contributed to (see Source 1).
- **Source 4:** *National Geographic article about new testing standard PAS9017*, with quote from Dr Green, demonstrating her contribution the development of the new standard.
- **Source 5:** *Letter of support from DP World London Gateway*, explaining Dr Green's role in the Ocean's Together Forum.
- **Source 6:** *DP World London Gateway Ocean's Together Forum webpage*, documenting key public commitments from businesses and reduction in single-use plastics in 2019, with Dr Green explicitly named as an advisor.
- **Source 7:** *Letter from Parliamentary Under Secretary of State at the Department for Environment, Food and Rural Affairs to Keep Britain Tidy*, commending ARU and Dr Green on the research provided as evidence during the Tidy Britain All-Party Parliamentary Group on smoking-related litter meeting.
- **Source 8:** *Department for Environment, Food and Rural Affairs webpage*, detailing Dr Green and ARU's contribution to a Tidy Britain All-Party Parliamentary Group meeting on smoking-related litter, on the 8 July 2020.
- **Source 9:** *Awareness raising campaign poster from No Butts New Zealand*, based on ARU research on cigarette butts. *Email confirming how the research inspired the creation of the awareness raising app* and *website for cigarette butt clean up calculator*.
- **Source 10:** *Minutes from the Incline Village General Improvement District meeting* showing that Reference 2 has been used as evidence in support of a smoking ban proposal at Lake Tahoe, Nevada, California (page 208-209).