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# Planet Patrolling: A citizen science brand audit of anthropogenic litter in the context of national legislation and international policy

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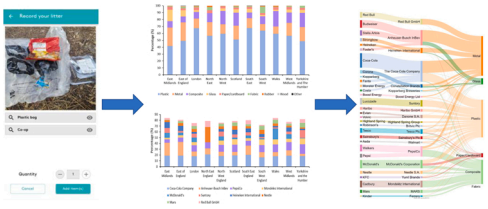
## HIGHLIGHTS

- Plastic is the dominant AL material recorded by citizen scientists.
- The majority of UK AL is associated with the beverage industry and packaging.
- The Coca-Cola Company, Anheuser-Busch InBev and PepsiCo were associated 26.2% of branded AL.
- Brand audits should inform ESG statements.
- ESG statements focus on the ideal, not realised, fate of products.

## GRAPHICAL ABSTRACT



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## ABSTRACT

Anthropogenic Litter (AL) is ubiquitous in distribution and diverse in type and impact. Citizen science AL clean-ups engage citizens with the environment and have the potential to generate data that can inform policy. Here we present a detailed citizen science survey of AL across freshwater, terrestrial, and coastal environments of the United Kingdom (UK), coordinated by the not-for-profit Planet Patrol throughout 2020. Key materials, industries, brands, and parent companies associated with AL are identified. Plastic dominated AL (63%), followed by metal (14%), and composite materials (12%). The majority of AL (56%) had been used as beverage containers and non-beverage packaging, and 38.8% of AL was branded. Of the branded AL, 26% was associated with The Coca-Cola Company, Anheuser-Busch InBev, and PepsiCo. These three companies were associated with significantly more branded litter than any other. We place these data in the context of upcoming UK legislation and the Environmental Social Governance (ESG) statements of the companies associated with the majority of the recorded litter. Knowledge gaps and recommendations for AL surveying are made, and the focus of corporate and government actions are discussed.

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## 1. Introduction

'Anthropogenic Litter' (AL) describes a diverse and pervasive group of materials that contaminate aquatic and terrestrial environments globally, and has received considerable attention from public, scientific, industry, and government stakeholders. AL has been defined as 'any persistent, manufactured or processed solid material' that has been 'discarded, disposed of or abandoned' (UNEP, 2009). Hotspots of AL have been associated with socioeconomic variables including population and GDP (Vincent et al., 2017; Xu et al., 2021) and environmental variables such as proximity to river mouths (Lebreton et al., 2017) and ocean currents (Lebreton et al., 2018).

The deleterious impacts of AL are well documented for plastic debris, encompassing wildlife entanglement and entrapment (Lavers et al., 2020), lesions (Barreiros and Raykov, 2014), and drowning (Simpson and Fisher, 2017; Jepsen, de Bruyn, 2019). Plastic ingestion can abrade and block gastrointestinal tracts (Lusher et al., 2013), lead to malnutrition and starvation (Eriksen et al., 2021) and bioaccumulate and biomagnify (Lwanga et al., 2017). Plastic litter can also leach harmful chemicals associated with its manufacture (De Frond et al., 2019) and concentrate chemical (e.g. metal) (Roman et al., 2020) and biological (e.g. pathogenic) (Viršek et al., 2017) pollutants.

The impacts of non-plastic AL are comparatively underrepresented in scientific literature. Glass, pottery, and metal debris represent hazards if they possess sharp edges (Rangel-Buitrago, 2019a). Like plastic, their ingestion can lead to gastrointestinal blockages and abrasion (Olsen, WISE, 2001; Seif et al., 2018), with metal AL ingestion recorded in similar numbers to that of plastic in some bird species (English et al., 2015). Metal debris can be utilised by hermit crabs in lieu of shells (Lewis and Rotjan, 2009) and some metals, such as lead, are also highly toxic and persistent in their elemental and compound forms, and bioaccumulate in the tissues of organisms with significant detrimental impacts, including mortality (Mateo et al., 1998).

Sources of AL are varied, commonly originating from both consumer (e.g. food and beverage containers, textiles, sanitary products) and industrial (e.g. fishing gear, masonry, medical) stakeholders (Cheshire et al., 2009). Surveys that categorise AL to the product level have considerable potential in aiding source attribution, and in efforts to associate pathways of AL with key stakeholders. Categorising AL beyond the material has also successfully informed environmental policy. For example, though focussed only on single-use plastic items, the European Union (EU) has identified ten priority plastic items found on its beaches, supporting targeted efforts to minimise their future prevalence through its Single Use Plastic (SUP) Directive (European Parliament, 2019). Such an approach can also inform targeted efforts to mitigate AL pollution through education, industrial action, and legislation; can provide an evidence base to support principles of 'polluter pays' and Extended Producer Responsibility (EPR); and can direct organisations' Environmental and Social Governance (ESG) policies.

To accomplish such an intricate categorisation of AL at meaningful temporal and spatial scales is a resource intensive exercise. Citizen science, the generation of scientific data by non-professional scientists, offers an opportunity to generate large datasets at national and international scales, and has previously identified common sources of AL (Nelms et al., 2017; Falk-Andersson et al., 2019). The quality of citizen science data can be high where validation and standardisation is employed; for example, citizen science beach litter surveys have been found to be comparable to those of professional surveys (Falk-Andersson et al., 2019). Citizen science therefore has the potential to inform evidence-based policy, but its approach to litter characterisation must be simple and benefits from standardisation (Nelms et al., 2022). Beyond data generation, citizen science can also educate members of the public and increase individual and community awareness and engagement with environmental issues (Pocock et al., 2019).

In Europe, organisations and initiatives associated with surveying AL include Marine Litter Watch, the OSPAR Commission and, in the United Kingdom, the Marine Conservation Society. These organisations have either used, or their approaches have informed, citizen scientists' efforts to collect data on the AL composition of European beaches. These schemes provide valuable insights into the environmental health of the sampled environments. However, their ability to inform environmental knowledge of the AL composition of terrestrial and freshwater environments cannot be assumed given the different sources and pathways of marine litter.

Addressing the problem of AL does not come without costs (Horton, 2022), but who should bear this cost is debated in discourses of environmental responsibilities that consider 'cost' in primarily monetary terms – terms that are not well-able to quantify the value of the environments that stakeholders' profits afflict. During the current decade, the governments of the United Kingdom (UK) are set to introduce environmental legislation that will change the nature of waste management and waste accountability across its four nations, including introducing policies that are long-established elsewhere, particularly across Europe. Over the same period, time-defined targets and pledges have been set within the Environmental Social Governance statements of many transnational corporations which, if successful, may reduce the abundance of some common items of AL internationally. The United Nations Environment Programme (UNEP) have also announced their resolution to *End plastic pollution: Towards an international legally binding instrument*, establishing a committee to develop an international instrument on plastic pollution until the end of 2024 (UNEP, 2022).

These forthcoming changes to international policy and national legislation have the potential to change the profile of anthropogenic litter. However, there is a paucity of data against which their efficacy can be assessed. This is particularly true for the assessment of corporate policy. Brand audits have been recommended in surveys of anthropogenic litter (Barnardo and Ribbink, 2020), though the recording of brands in anthropogenic litter surveys is not always included in academic literature (notable exceptions include Okuku et al., 2021; Baxter et al., 2022; Okuku et al., 2022). It is, however, more common in literature published by environmental organisations (e.g. Hold Norge Rent, 2021; McDermott et al., 2021; Surfers Against Sewage, 2021).

Here we present a comprehensive citizen science dataset of AL by material, application, and brand from across the UK, generated by the not-for-profit organisation Planet Patrol. The aim of this manuscript is to compare this environmental data to the focus of upcoming changes to UK legislation and relevant corporate policies. It is not to quantify the amount or density of AL in the environment. Recommendations to cross-sector stakeholders are made at local, national, and international levels. This method of AL categorisation represents a simple and detailed means of citizen science AL surveying that builds on previous approaches (Nelms et al., 2017), and aligns with that of others (Hold Norge Rent, 2021; Surfers Against Sewage, 2021; Okuku et al., 2021, 2022) who have adopted similar approaches.

## 2. Methods

### 2.1. Planet Patrol

Planet Patrol, formerly Plastic Patrol, is a not-for-profit organisation that engages citizen scientists with the clean-up of AL through organised and independent clean-up events. Participants use the Planet Patrol mobile phone application (hereafter app) to record AL. Since 2016, Planet Patrol's app-based AL logging has engaged citizen scientists in 113 countries and has recorded over 395,000 items of AL spanning all continents except Antarctica. The interface that enables users to log litter to brand level has been live since April 5th 2019. In recognition of the amount of non-plastic AL recorded by its app users, Planet Patrol rebranded from Plastic Patrol in 2020.

Here, data recorded using the Planet Patrol app is used to ascertain whether particular material types and brands dominate AL in the UK. This information is then used to inform a discussion of the

Environmental Social Governance statements of brands associated with the AL recorded and pending UK environmental legislation.

### 2.2. Data collection

The data presented here was submitted by citizen scientists who used the Planet Patrol app to upload a time-referenced and geotagged photograph to the Planet Patrol app (Fig. S1). Because this work does not aim to quantify the amount of litter per unit area, users are able to contribute to the dataset at their convenience, whether it be through individual efforts, independently organised clean-up events, or at Planet Patrol organised clean-up events, with all litter being logged in the same way. The data was generated between January 1st and December 31st 2020, and app users logged litter from a variety of environments including riverbanks, canals, parks, beaches, waterways, and urban streets. Throughout this period, data was logged in every UK nation except for Northern Ireland.

To contribute to the database, every clean-up effort must upload a photograph of the litter collected to the Planet Patrol app. With each photograph submitted, the user is required to describe the type of AL and its material (e.g. 'bottle' is not an option, however, 'plastic bottle' and 'glass bottle' are) (Table S1). Where litter has not been collected after being logged, it is possible that the same item of litter could have been logged multiple times, however, at the scale of this survey the influence of this is thought to be negligible. The assignation of AL to predefined categories is a standard approach in the generation of citizen science AL litter data. International programmes including OSPAR and the European Environment Agency (through Marine Litter Watch, hereafter MLW) have dedicated categorisation tools used in their coastal clean-up and surveying programmes. These codes informed the categorisation process used in the present study.

Both OSPAR and MLW utilise a coded system that assigns each item of litter to a material and an application, however, without slight modification these systems are not suitable for the goals of Planet Patrol's work, or for work on inland environments. For example, the MLW codes group multiple items to some of their codes; for example, code G153 groups paper/cardboard food trays, wrappers, cups, and drink containers, combining food and drink applications which Planet Patrol focus on separately. Both of these coding systems also categorise mixed-materials as single materials, including crisp packets, sweet wrappers, and drinks cartons, limiting the accuracy with which they can report on the relative proportions of different materials.

The categorisation of litter in the Planet Patrol app therefore uses a modified OSPAR protocol, with the pre-set categories included as of April 5th 2019 informed by the types of litter identified by citizens scientists engaging with the Planet Patrol app since its 2016 launch. To account for material that cannot be assigned to one of these categories, users are able to add their own category when using the app, however, user-generated categories are only approved if it is deemed appropriate in the validation process (see below). In 2020, all AL logged using the Planet Patrol App could be assigned to one of 54 categories (Table S1). Where possible, the user is also encouraged to identify the brand associated with the AL.

### 2.3. Data validation

In line with previous citizen science surveying of AL (Nelms et al., 2017), Planet Patrol employees validate every image uploaded for quality control purposes. They also identify the parent company of each brand. This moderation ensures that the text-based information inputted by the user matches the photo uploaded, and identifies any issues with the information such as typographical errors and mis-categorisation. App users also have the option, where available, to scan the barcode of any AL they collect, which pre-populates all the necessary fields. AL categorised by the scanning of a barcode still undergoes validation. Only data that has been validated is used by Planet Patrol and presented here.

As with all citizen science data acquisition, potential biases associated with subconscious preconceptions of certain items of AL do exist. In the present study, the potential for this bias is reduced by the large size of the dataset and the simplicity of the data collection procedure (Syberg et al., 2020). It is further reduced through the study's focus. Where studies attempt to quantify the density of litter, it is important to ensure that participants sample standardised areas. Users of Planet Patrol's app were not required to quantify the area surveyed in their clean up efforts to maximise the accessibility of the survey. Because litter densities cannot be quantified, the research questions of this work focus on proportions of AL materials, applications, and brands found in the UK environment.

### 2.4. Statistical analysis

Statistical analysis of the Planet Patrol data was conducted in the SPSS Statistical Software (Version 26). Data was grouped by material and by parent company to compare AL profiles across UK regions. The intention was not to compare abundance or density, but to compare the consistency in the contribution of materials and brands nationwide; the null hypothesis being that the proportions of the materials and brands found in the environment are equal across the UK.

Shapiro-Wilk normality tests were used to determine the distribution of the data and demonstrated that datasets were non-normally distributed, necessitating the use of non-parametric analysis of trends across the groups. Kruskal Wallis tests were used to determine the significance of differences observed across each of these groups, with Dunn's post hoc tests with Bonferroni correction performed to identify the significance of differences for pairwise comparisons between groups. For all tests, p values are reported to three decimal places.

### 2.5. UK legislation and corporate policy

The environmental data generated by Planet Patrol citizen scientists is discussed in the context of upcoming changes to UK legislation, and the ESG statements of the top ten companies associated with the branded litter data. The information regarding the relevant UK legislation was obtained from the UK government website. Information relating to corporate ESG statements was obtained from the published literature of each company detailed and its associated online material. The URL of each of these resources is provided in the relevant tables throughout the results and discussion section and the supplementary material.

## 3. Results and discussion

### 3.1. AL overview

Throughout 2020, users of the Planet Patrol app recorded 43,187 items of AL across the United Kingdom via 17,576 app engagements (Fig. 1). Engagement varied across the UK regions, with the majority of items being recorded in London (12,804 items) and the southwest and southeast of England (8775 and 8613 items respectively) (Fig. 1). Of the 43,187 items of AL recorded, 8001 were recorded during 62 organised clean-up events. Of the 17,576 app engagements, 2160 occurred within 500 m of the coastline, accounting for 6320 of the 43,187 items of litter. Though this survey was conducted in 2020, the litter collected is not all thought to all have been introduced to the environment in 2020. It is not possible to determine the year in which AL was introduced to the environment, however, where available, use-by-dates of collected items can approximate when littered items have been purchased. This has identified litter with use-by-dates from years, and even decades, prior to its collection (Fig. S2). It is not possible to constrain the influence of the COVID-19 pandemic on this dataset, however, as the pandemic continues to affect the UK two years on from the first UK lockdown (23rd March 2020), the data does reflect the social and political landscape of the early 2020s in the UK.

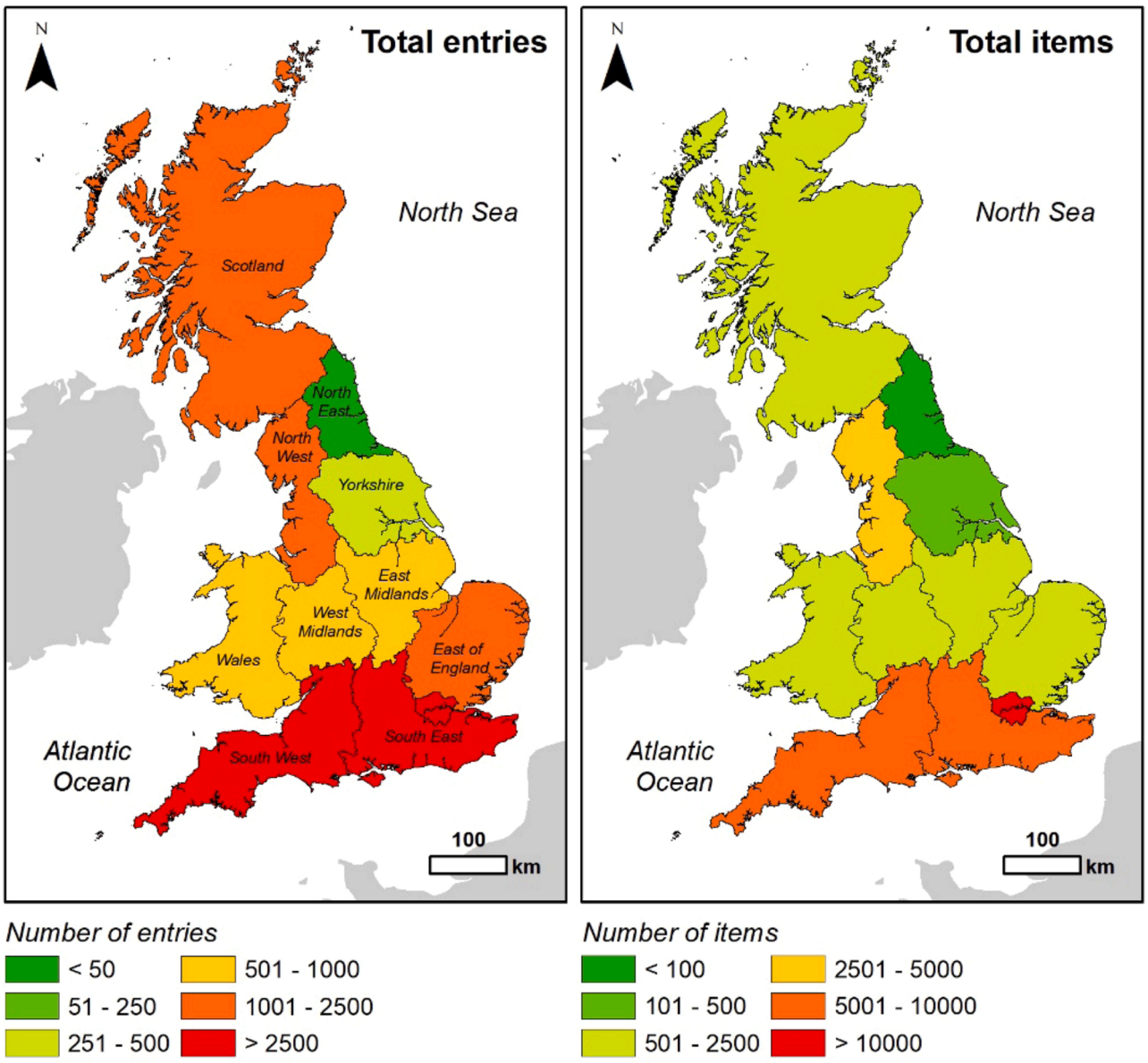


**Fig. 1.** Maps detailing the number of citizen science entries and items of AL logged in the Planet Patrol App across 11 regions of the UK. Note these results do not imply litter is more prevalent in southern regions of the UK.

As a total of all AL recorded, plastic represented the dominant single material (63.11%; mean±SD = 57.90 ± 9.21%), followed by metal (14.28%; mean = 16.16 ± 7.55%) and composite materials (11.57%; mean = 13.03 ± 6.48%), with the majority of items made from composite materials (71.12%) being composites of plastic and metal (e.g. crisp packets and sweet wrappers). A Kruskal-Wallis test confirmed a significant difference between the proportions of AL attributed to these three material categories, which were the only materials associated with > 10% of the data, across the 11 UK regions (Kruskal-Wallace test: H=22.25, d.f.=2, $p < 0.001$) (Table S2). Dunn's posthoc tests with Bonferroni correction confirmed plastic was associated with a significantly greater proportion of AL than metal ($p = 0.001$) and composite ($p = 0.000$) litter (Fig. 2). Plastic also contributed to items within the composite and fabric groupings of AL, for which determining a single material was not possible. Its prevalence is therefore likely an under-estimate.

The material composition of AL recorded through Planet Patrol's app differs from that previously reported by both professional and citizen science generated data. Though plastic dominated the material characterisation in this study, it did so to a lesser extent than recent citizen science surveys of UK AL (Nelms et al., 2017, 2020). Plastic represented 76% (Nelms et al., 2017) and 68.4% (Nelms et al., 2020) of AL in UK beach surveys when grouping polystyrene with plastics, though these surveys combined common composite items (e.g. crisp packets and sweet wrappers) with plastics, which may explain some of this discrepancy. The prevalence of metal within the AL documented using the Planet Patrol app is also higher than expected based on previous citizen science surveys of marine, coastal, and freshwater anthropogenic litter (Table 1). The variability in material type both across and within environments, particularly throughout the depth profile of aquatic environments, as highlighted in Table 1, is a key avenue for future research that is outside the scope of this citizen science programme.

### 3.2. Proportions of AL by type and brand

When grouped by application, 38,179 items of AL (88.4% of all AL) were assigned to ten categories (Table S3). Beverage items (defined as any item associated with beverages, including containers, lids, stirrers and straws) and non-beverage packaging represented 56.0% of AL,

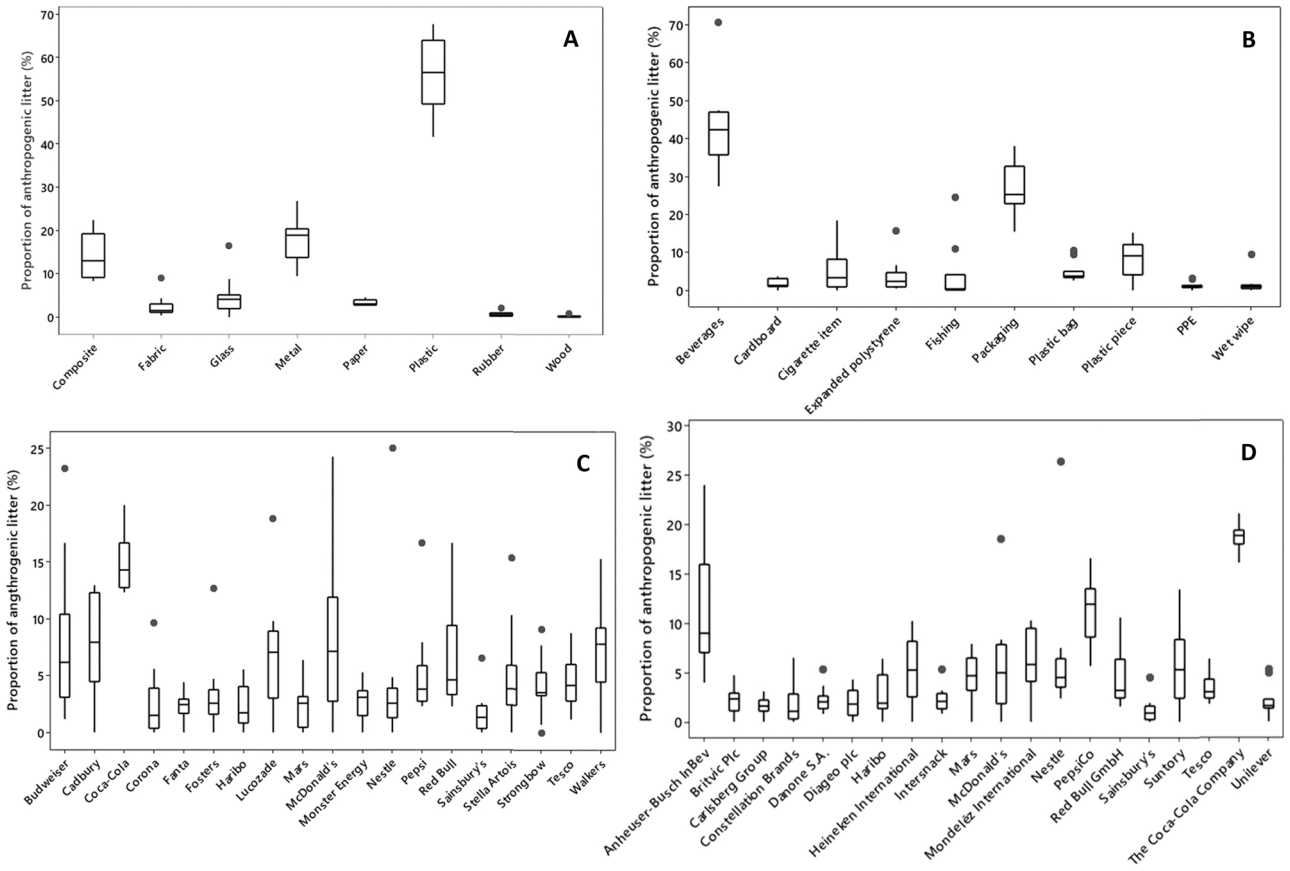


**Fig. 2.** Boxplots of proportions of AL recorded in the Planet Patrol app across UK regions in 2020 showing A) all material types logged with the exception of 'other', B) the ten most common categories of AL items recorded (Packaging excludes beverage packaging, and PPE stands for Personal Protective Equipment), C) all brands that accounted for > 1% of branded data, and D) all parent companies that accounted for > 1% of branded data. For each box plot the centre line represents the median, with the box limits indicating the upper and lower quartiles and the whiskers representing 1.5x interquartile range. Outliers are represented by points. The data used to generate the graphs in this figure are provided in Tables S5-8.

accounting for 33.4% and 22.6% respectively. Following these, plastic fragments, cigarette items (packaging, filters, and butts) and expanded polystyrene were the only other categories to represent > 5% of the AL recorded, at 9.4%, 6.0% and 5.6% respectively. The presence of Personal Protective Equipment (PPE) is assumed to be associated with the Covid-19 pandemic; the United Kingdom entered its first national lockdown in response to this pandemic on 23/03/2020, and all 649 items of PPE were logged after May 12th 2020.

Of the 14,427 items associated with the beverage industry, 4848 (33.6%) were metal cans and 4282 (29.7%) were plastic bottles. Estimates of beverage sales in the UK and their containers vary but are in the region of ~13 billion plastic bottles and up to ~9.6 billion metal cans annually (Voluntary and Economic Incentives Working Group, 2018). The Planet Patrol data therefore does not reflect reported market shares. Despite brands including Red Bull and CanO Water promoting their products on the potentially infinite recyclability of aluminium cans, this work identifies metal cans as the dominant AL type associated with the beverage industry. It is possible that this discrepancy is influenced by the broad awareness of the environmental impacts of plastic litter.

Where possible, AL was also associated with a brand and parent company. A brand was identifiable for 16,751 (38.8%) items of AL, with 19 brands associated with > 1% of these (Fig. 2). Coca-Cola was the most frequently reported brand (6.81%). The majority of AL items associated with Coca-Cola were made from metal (58.63%) followed by plastic (40.66%) (Fig. 3).

Twenty parent companies were associated with > 1% of the 16,751 branded items of AL (Fig. 2). The top ten of these were associated with 50% of the AL recorded (Table 2). A Kruskal-Wallis test confirmed a significant difference between the proportions of AL associated with the top ten parent companies across the 11 UK regions (Kruskal-Wallis test: H=56.674, d.f.=9, $p < 0.000$). Dunn's posthoc tests with Bonferroni correction confirmed The Coca-Cola Company (11.9%) was associated with a significantly greater proportion of AL than all other parent companies except for Anheuser-Busch InBev (7.4%) ($p = 1.000$) and PepsiCo (6.9%) ($p = 1.000$) (Fig. 3).

Surfers Against Sewage (SAS) and Hold Norge Rent (HNR) (Keep Norway Clean) are two organisations that have also conducted brand audits of AL (Surfers Against Sewage, 2021; Hold Norge Rent, 2021). Surfers Against Sewage (2021) lists the top 12 brands and top 12 parent companies associated with AL from their May 2021 survey of plastic litter on UK beaches, whilst HNR list the top ten parent companies associated with an international effort to document AL from coastal, terrestrial, and freshwater environments, as well as 'at home' brand audits of domestic waste. Of the top 12 brands and parent companies SAS report, eight brands and ten parent companies are shared with the Planet Patrol dataset (Table 2). Both Planet Patrol and SAS surveys share the same top five parent companies, though their orders differ. However, only five of the top ten parent companies associated with the HNR survey are common to Planet Patrol and SAS. 'Top' brands associated with litter beyond the UK by Planet Patrol and SAS also vary from those identified in Canadian (Baxter et al., 2022) and Kenyan (Okuku et al., 2012; 2022) surveys of AL, indicating that brand audits vary nationally. The choice of environment and material focus may also influence the findings of brand audits. Surfers Against Sewage, (2021), Hold Norge Rent (2021), and Baxter et al. (2022) only report brands associated with plastic items, which may explain the absence of some organisations

**Table 1**
A selection of professional and citizen science studies of AL that highlight variability in the proportions of recorded anthropogenic litter of different materials in different environmental matrices. Studies that only survey plastic materials have been intentionally excluded. Values are reported are consistent with the significant figures used in the cited literature which therefore vary.

| Authors | Citizen science? | Location | Sampled environment | Material proportions (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Plastic | Metal | Glass | Paper / Cardboard | Rubber | Wood | Composite | Other |
| Chen et al. (2020) | ✓ | China | Beach | 78.0 | 1.6 | 6.1 | 1.7 | 1.7 | 4.1 | 6.7 | 0.0 |
| Consoli et al. (2020) | ✓ | Mediterranean Sea | Seafloor | 55 | 23 | 11 | 2 | 2 | 1 | 0 | 6 |
| Nelms et al. (2017) | ✓ | United Kingdom | Beach | 76 | 4 | 3 | 4 | 2 | 2 | 0 | 9 |
| Nelms et al. (2020) | ✓ | United Kingdom | Beach | 68.4 | 5.3 | 3.7 | 6.4 | 5.4 | 2.4 | 0.0 | 8.4 |
| Wilson et al. (2021) | X | United Kingdom | Freshwater sediment | 34.03 | 27.08 | 31.94 | 0.00 | 0.00 | 0.00 | 0.00 | 6.95 |
| Rangel-Buitrago et al. (2019a) | X | Colombia | Beach | 88.58 | 2.92 | 4.25 | 0.00 | 0.14 | 0.97 | 0.00 | 3.14 |
| Rangel-Buitrago et al. (2019b) | X | Colombia | Beach | 78 | 1 | 1 | 1 | 4 | 1 | 0 | 14 |
| Rangel-Buitrago et al. (2020) | X | Colombia | Beach | 89 | < 8 | < 8 | < 8 | 3 | < 8 | 0 | 8 |
| Kiessling et al. (2019) | ✓ | Germany | Freshwater banks | 30.5 | 11.5 | 16.0 | 13.0 | 0.0 | 0.0 | 0.0 | 29.0 |
| Williams and Simmons (1999) | X | United Kingdom | Freshwater banks | 49 | 7 | 0 | 0 | 0 | 0 | 0 | 44 |
| Van Emmerik et al. (2020) | X | The Netherlands | Freshwater banks | 85.1 | 2.8 | 2.3 | 2.3 | 0.4 | 0.9 | 0.0 | 6.2 |
| Castro-Jiménez et al. (2019) | X | France | Freshwater (floating) | 77 | 5 | 0 | 14 | 2 | 2 | 0 | 0 |
| González-Fernández et al. (2018)* | X | Europe | Freshwater (floating) | 80.8 | 3.52 | 0.00 | 8.8 | 0.95 | 2.19 | 0.00 | 3.74 |
| Present study | ✓ | United Kingdom | Beach / Freshwater (floating and benthic) / Riparian / Terrestrial | 63.11 | 14.28 | 3.87 | 3.35 | 0.60 | 0.29 | 11.57 | 2.95 |

*Data presented only for the top 20 items, representing 96.8% of all items in that study.

identified in the Planet Patrol data, such as Red Bull GmbH whose products are predominantly made from metal.

### 3.3. Planet Patrol data within the context of government and corporate responsibilities

#### 3.3.1. Legislation

Waste policy across the four United Kingdom (UK) nations (England, Northern Ireland, Scotland and Wales) is devolved, meaning that policy specifics and their timescales of implementation are not consistent across these nations. However, the UK does have a track record of recent legislative action to minimise plastic pollution. Legislation discouraging the use of plastic bags across Europe has been associated with a decline in their observation in some environments since the mid-2000s (Maes et al., 2018). A charge for the purchasing of plastic carrier bags, which were previously free, was introduced in England in 2015 at a rate of GBP 0.05 per bag (UK Government, 2015). The phased expansion of this legislation, which applied first to organisations with more than 250 employees, encompassed all organisations in 2021 (DEFRA, 2021a). Timescales and scope of this legislation in the other UK nations differed. In 2018 the UK also banned the use of microplastic particles in some cosmetic products (UK Government, 2017), which followed widespread industrial shifts away from such products, but was limited to wash-off products only (Dauvergne, 2018). The UK is now set to implement further legislation with the potential to reduce the amount of AL in the environment. This legislation, summarised in Table 3, is designed to specifically target packaging.

The implementation of a Plastic Tax aims to address the material that is consistently found to dominate both professional and citizen science AL surveys (Table 1). Though there is little debate that plastic is the most prevalent anthropogenic material in the environment, the extent of this prevalence varies with geographical location (Fig. S3) and environment (Table 1), with non-plastic anthropogenic materials accounting for 36.9% of items in this study, rising to 70.3% for items associated with the beverage industry. In addition, though surveys of benthic environments highlight the fact that plastic does not always represent the dominant material (Hoellein et al., 2014; McCormick and Hoellein, 2016), there is a paucity of research documenting the environmental impacts of non-plastic materials. Whilst the Plastic Tax has the potential to reduce the amount of plastic that enters the environment, on its own it does not address the problem of littering. Consumption has previously been shown to increase in scenarios where consumers have been informed of the lesser environmental footprint of their lifestyles (Borg et al., 2020). It is therefore important that future efforts to assess the success of the Plastic Tax consider changes in the abundance of non-plastic materials and items that may act as substitutes. In the UK, national assessments of AL on UK coastlines are available (Nelms et al., 2017, 2020). However, to the authors' knowledge, data of comparable spatial coverage that encompasses non-coastal environments is limited.

Current UK Extended Producer Responsibility (EPR) legislation was introduced in 1997. The pending EPR legislation is therefore a reformation, rather than introduction, of the principle of EPR to UK law. The proposed legislation is not prescriptive with respect to the materials that it applies to. This legislation will make producers responsible for costs associated with waste management including, but not limited to, contributing to the costs incurred by local authorities in efforts to manage waste, and contributing to the cost of public education, AL clean-ups, and the provision of bins (DEFRA, 2021b). However, costs of EPR legislation also has the potential to disproportionately affect the consumer over the producer when the producer does not absorb them (Maitre-Ekern, 2021).

Associated with the principle of EPR, the UK is also due to introduce a Deposit Return Scheme (DRS). As with the plastic bag tax, the introduction of this legislation to the UK lags behind similar policies that have been implemented in other European nations, where this system has reported return rates of > 90% in some countries including

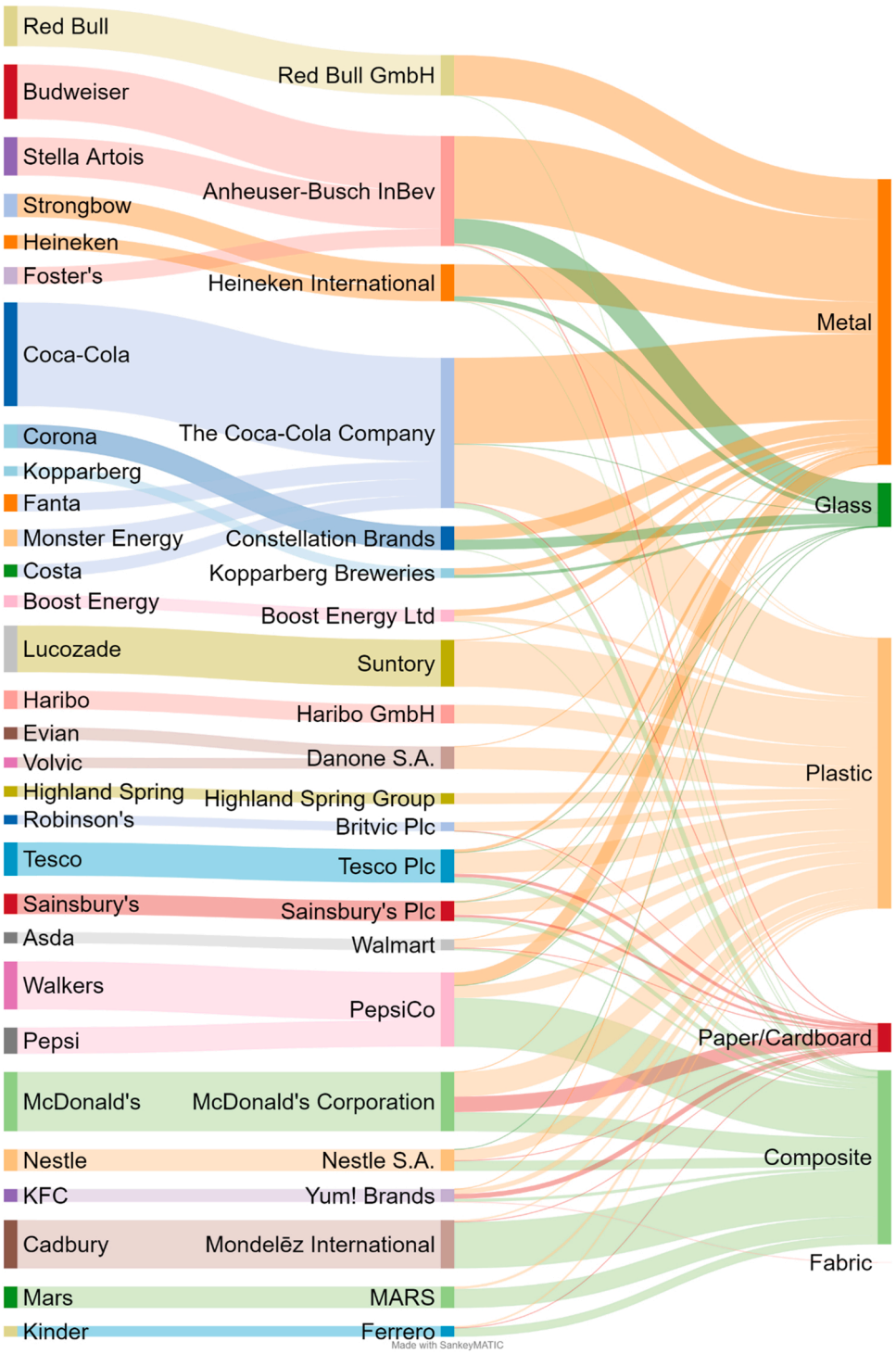


**Fig. 3.** Sankey diagram illustrating proportion (bar height) of the branded data associated with each brand (left), their parent company (middle) and material (right) for each brand that was logged in the Planet Patrol app more than 100 times across the UK in 2020. Diagram produced using SankeyMATIC (https://sankeymatic.com/build/).

Germany, Norway and Finland (Zhou et al., 2020). Accounting for 33.4% of the items recorded here, the beverage industry was associated with the highest proportion of litter recorded in the Planet Patrol app in 2020 (Table S3). The implementation of planned DRS schemes in Scotland, and across England, Wales and Northern Ireland which target beverage containers has also been delayed. As the dominant contributor to AL recorded here, these data identify the environmental importance of such schemes, and highlight the value of not delaying their implementation.

Though separate, links do exist between each of these pieces of upcoming legislation that some have suggested may compromise their efficacy (Burgess et al., 2021). Nevertheless, legislative changes have previously been associated with changes to the environmental profile of AL over sub-decadal time periods (Maes et al., 2018). Collectively, this legislation may, therefore, change the future profile of AL in the UK. However, the success of this legislation is not a given, and thought must be given to how their success is assessed.

This dataset also highlights the importance of considering more than

**Table 2**
The top 12 brands (a) and parent companies (b) associated with the 16 751 branded items of litter recorded in the Planet Patrol app and, where applicable, the position of these brands and parent companies in Surfers Against Sewage (2021) and Hold Norge Rent (HNR) 2021 reports. The Hold Norge Rent (2021) audit does not identify brands, and so is not include in Table (a) below.

| (a) | | | | (b) | | | | |
|---|---|---|---|---|---|---|---|---|
| Brand | Percentage of branded items | Planet Patrol rank | SAS rank | Parent Company | Percentage of branded items | Planet Patrol rank | SAS rank | HNR rank |
| Coca Cola | 6.81 | 1 | 1 | **Coca-Cola Company** | 11.91 | 1 | 1 | 1 |
| McDonald's | 3.88 | 2 | 3 | **Anheuser-Busch InBev** | 7.43 | 2 | 3 | – |
| Budweiser | 3.59 | 3 | 8 | **PepsiCo** | 6.90 | 3 | 2 | 2 |
| Cadbury | 3.17 | 4 | 4 | **Mondelez International** | 4.04 | 4 | 5 | 5 |
| Walkers | 3.15 | 5 | 2 | **McDonald's** | 3.90 | 5 | 4 | – |
| Lucozade | 3.07 | 6 | 6 | **Suntory** | 3.62 | 6 | 9 | – |
| Red Bull | 2.64 | 7 | – | **Heineken International** | 3.43 | 7 | 6 | – |
| Stella Artois | 2.51 | 8 | 10 | **Nestle** | 3.25 | 8 | N/A | 4 |
| Tesco | 2.19 | 9 | 5 | **Mars** | 3.07 | 9 | 11 | 9 |
| Pepsi | 1.73 | 10 | – | **Red Bull GmbH** | 2.64 | 10 | N/A | – |
| Corona | 1.57 | 11 | – | **Tesco** | 2.27 | 11 | 7 | – |
| Strongbow | 1.53 | 12 | – | **Haribo** | 1.78 | 12 | 10 | – |

**Table 3**
A summary of three pieces of upcoming UK legislation that aim to reduce AL in the environment. The information summarised is taken from the webpages provided in the URLs associated with each table row and from documents downloadable within.

| Legislation | Purpose | Requirement (s) | Rate | Implementation date |
|---|---|---|---|---|
| Plastic Tax https://www.gov.uk/government/publications/introduction-of-plastic-packaging-tax/plastic-packaging-tax | To provide an economic incentive for businesses to use recycled plastic material in their plastic packaging | All packaging that is, by weight, predominantly plastic, produced in, or imported into, the UK that does not contain at least 30% recycled plastic will be taxed | GBP200 per tonne | April 2022 |
| Extended Producer Responsibility (EPR) https://consult.defra.gov.uk/extended-producer-responsibility/extended-producer-responsibility-for-packaging/ | To reform the current Producer responsibility legislation for packaging from 1997 | Packaging producers, instead of the public purse, will be responsible for the entire cost of managing the packaging they sell | N/A | Phase 1: January 2023 Phase 2: April 2024 |
| Deposit Return Scheme (DRS) https://consult.defra.gov.uk/environment/consultation-on-introducing-a-drs/supporting_documents/Impact%20Assessment.pdf | To introduce infrastructure that will enable consumers to return drinks packaging made from different materials at dedicated collection centres | Introduction of a refundable deposit, that consumers pay at the point of purchase and is refunded when packaging is returned `to collection points | N/A | Scotland: 2023 England / Wales / Northern Ireland: 2024 |

just coastal and marine environments when directing environmental legislation. The EU SUP Directive aims to prevent and reduce the impacts of ten single-use plastic products on the environment. However, the ten items that are the focus of EU SUP Directive do not reflect the composition of litter recorded in the present study (Table 4). The specific products it focuses on are informed by surveys of beaches across the EU, and the Directive states that 'As they are not among the single-use plastic products that are found the most on beaches in the Union, glass and metal beverage containers should not be covered by this Directive' (European Parliament, 2019). The absence of these containers from beaches may be explained by the higher density of metal and glass materials, compared to plastic, meaning that once these beverage containers enter the marine environment they are less likely to be washed ashore. Indeed, seafloor surveys of AL have in fact recorded beverage cans (Consoli et al., 2018) and beverage cans and glass bottles (Consoli et al., 2020) in higher abundance than plastic bottles. Whilst we recognise the value of simplicity in legislative efforts to minimise the prevalence and impacts of AL, and though the UK is not part of the EU, here we demonstrate that by limiting focus to data generated from a single environment this directive misrepresents AL composition beyond beaches.

**Table 4**
The ten single-use plastic groups addressed by the EU SUP Directive (European Commission, n.d.), and the top ten most common groups, in order first to tenth, recorded in the Planet Patrol 2020 dataset. Identifiable items are defined as items that can be directly attributed to a source, requiring the exclusion of the following non-specific categories: 'Plastic fragment', 'Plastic packaging', and 'Styrofoam / polystyrene fragment'. These would otherwise have placed 4th, 5th, and 7th respectively in the Planet Patrol top ten.

| EU SUP ten items | Planet Patrol top ten items |
|---|---|
| Cotton buds | Drinks cans |
| Cutlery, plates, straws & stirrers | Crisp packets / Sweet wrappers* |
| Sticks for balloons and balloons | Plastic bottles |
| Food containers | Cigarette butts |
| Cups for beverages | Plastic bottle lids |
| Beverage containers | Plastic bags |
| Cigarette butts | Glass bottles |
| Bags | Plastic cups |
| Crisp Packets / Sweet wrappers | Wet wipe / Sanitary items* |
| Wet wipes / Sanitary items | Metal bottle caps |

* Denotes Planet Patrol items that have been grouped in line with the European Commission groupings for comparability.

### 3.3.2. *Corporate policy*

Legislation is not the only means by which the AL profile of the environment may change in the future. As with wash-off cosmetic microplastics, industrial action of key organisations has considerable potential to effect change at a faster pace than legislation. Along similar timeframes of planned UK legislation, key corporations have made pledges and set goals for the period of 2020–2030 that target packaging associated with their products within their ESG statements. Of the ESG statements for the top ten parent companies identified in the Planet

Patrol data, nine had dedicated statements regarding their packaging (Table 4). These statements focus on material type and volume, and it was noted that they place a particular emphasis on the ideal fate of the products they profit from over the realised fate that surveys of AL, like this one, document (Table S4). Reductions in the amount of packaging material used per item and ensuring that waste materials have the potential to be responsibly managed are important. However, such statements place a disproportionate level of responsibility on waste management infrastructure and consumers, and make no reference to the environmental fate of their products documented in work by the likes of Planet Patrol (Table 1). Just one of the ESG statements for these parent companies, The Coca-Cola Company, included the clean-up of AL in the environment, with only four planning to incorporate or trialling refill into their future business models (Table 4 and S4).

Of the three parent companies associated with a significantly greater proportion of litter than any others (The Coca-Cola Company, Anheuser Busch InBev, and PepsiCo), The Coca-Cola Company identifies both plastic and metal litter in its ESG statements which together accounted for 92.8% of the litter associated with it. Anheuser-Busch InBev refer to plastic, metal, and glass. This corresponds to the nature of the materials collected by Planet Patrol app users that are associated with these two companies (Fig. 3). However, though crisp packets, a metallicised plastic film, accounted for 62.9% of the branded litter associated with PepsiCo in the present study, there is no reference to crisp packets in the company's ESG statement (Table S4). Of the PepsiCo crisp packets logged, 92.2% were from a Walkers brand of crisp. Within Walkers' sustainability statement, the only reference to packaging relates to the ability of consumers to take their crisp packets to dedicated, non-kerbside, recycling points (Walkers, 2021).

A refillable future is considered in the ESG documentation of four organisations in Table 4. This demonstrates the potential for business models that enable continued profit alongside considerable reductions in the number of packaging items, not just material volume, associated with commonly littered items. It is also important to note that, though PepsiCo do not refer to a refillable future, they do recognise the potential of at-home carbonation of beverages in reducing packaging requirements by using SodaStream products, for which they are the parent company. Refilling has considerable potential to reduce beverage AL, the dominant industry associated with AL in this survey, in particular. Governmental action can also support a refillable future. Wales intends to become the first 'Refill Nation' (Welsh Government, 2018), demonstrating that packaging for certain beverages could fall within the definition of 'unnecessary' that has supported the UK's microbead and plastic bag legislation. This represents a potential avenue for future progress that can be applied to multiple materials.

The proportions of litter by both material and brand detailed here represent a baseline to assess the influence of the included ESG statements on the future composition of branded litter found in the environment. They also highlight that, though the ESG statements of the organisation that contributed to the majority of branded AL have potential to reduce AL in the environment if targets are met, the environmental relevance of some statements could be enhanced through efforts to remove, rather than replace, materials, and to encompass clean-ups in corporate policy.Table 5.

The current decade has the potential to be a formative period in efforts to address the prevalence of AL in the environment. However, the limitations of current and proposed action must be recognised to ensure that once corporate pledges are met and pending legislation is implemented, the efficacy of this action is monitored, and focus subsequently evolves to continue addressing AL. Citizen science datasets can support policy decision-making, and can monitor these national and international targets (Pocock et al., 2019), however, such monitoring requires a baseline against which these targets can be compared. This baseline is well-quantified for coastal regions across Europe, however, this study demonstrates that their relevance beyond the coastal environment is limited, and that there is a paucity of data against which the progress of industrial policy can be assessed. It provides such a dataset for the UK and presents an accessible and comprehensive approach to litter categorisation for future citizen-science efforts to surveying AL. Minimising AL represents a financial duty that must be shared by all parties, and all parties must recognise that the current model of production, consumption and waste management is not a sustainable one.

## 4. Recommendations

By placing these findings in the context of ESG statement and pending legislation, we make the following recommendations to stakeholders from the scientific community, citizen science programmes, brands and their industries, and local and national governments:

Scientific community.

- Scientific studies must consider more than just plastic materials in their surveys of AL, as is done in established international AL surveying programmes.
- Ecotoxicological studies must consider the impacts of plastic alternatives.
- Surveys of AL in aquatic environments should, where possible, consider sub-surface and benthic AL as well as surface, beach, and riparian AL.

**Table 5**
Summaries of the Environmental Social Governance (ESG) statements relating to the top ten parent companies representing 50% of the branded AL recorded in the Planet Patrol app in 2020. Specifics of environmental pledges, including what is hoped to be achieved by the target dates presented here and the sources of the information, are provided in Table S4.

| Company | Percentage of items recorded by Planet Patrol (%) | Is packaging mentioned in ESG statements? | Materials specified | Is a reduction in packaging numbers mentioned? | Is refillable packaging mentioned? | Target dates |
|---|---|---|---|---|---|---|
| The Coca-Cola Company | 11.9 | ✓ | Plastic and Metal | ✓ | ✓ | 2025, 2030 |
| Anheuser-Busch InBev | 7.4 | ✓ | Plastic, Metal and glass | ✓ | ✓ | 2025 |
| PepsiCo | 6.9 | ✓ | Plastic | ✓ | X | 2020, 2025 |
| Mondelēz International | 4.0 | ✓ | None | ✓ | X | 2025 |
| McDonald's | 3.9 | ✓ | Plastic | ✓ | X | 2025 |
| Suntory | 3.6 | ✓ | Plastic | ✓ | X | 2030 |
| Heineken International | 3.4 | ✓ | Paper / Cardboard | X | X | N/A |
| Nestle S.A. | 3.3 | ✓ | Plastic | ✓ | ✓ | 2025, 2030 |
| MARS | 3.1 | ✓ | None | ✓ | ✓ | 2025 |
| Red Bull GmbH | 2.6 | ✓ | Metal | X | X | N/A |

Citizen science.

- Recording AL to brand level where possible has the potential to inform industrial policy and measure success of legislation and ESG statements.

Organisational ESG statements

- There is scope within the ESG statements detailed here for greater consideration of the necessity of some packaging. Where feasible 'reduce' should refer to the product numbers as well as packaging volume, and statements should consider whether refill is a viable option.
- ESG statements must consider more than just plastic where other materials are used to package their products.
- Focussing only on the potential recyclability of products places the onus of responsible disposal on the consumer and waste management infrastructure. ESG statements should consider product disposal beyond the design stage alone, and recognise and expand their responsibility to clean-up and collect the materials they sell, and to educate their consumers.
- Improvements to consumer education could include negative images of the impacts of AL in the environment on packaging, in line with UK requirements for cigarette packaging.

Local and national governments.

- Implementation of incentivised schemes to discourage littering (e.g. Deposit Return Schemes) should not be delayed further.
- In line with previous plastic legislation that addresses 'unnecessary' plastic waste (e.g. plastic microbeads and plastic bags), we propose that future legislation phases out the production and selling of packaging on the grounds of necessity.
- Allied to this, we call for support for considerable expansion of refill infrastructure, in line with the ambition of some governmental and corporate policies.
- Efforts to monitor the efficacy of the UK's Plastic Tax should consider all anthropogenic materials in environmental surveys, not just plastic.
- Measures of packaging reduction and the approaches used to monitor AL in the environment (e.g. number of items, material volume, material mass) should be defined at the legislative level.

## 5. Conclusion

AL is represented by a diverse group of materials. Data collected by Planet Patrol citizen scientists identifies plastic as the most prevalent material in UK AL, with the majority of AL associated with beverages and non-beverage packaging. Industries and organisations associated with this litter, and waste management legislators, are key contributors to UK AL. Though most of the parent companies to which AL could be attributed were associated with similar proportions of AL, three were found to be responsible for a greater proportion than any others (The Coca-Cola Company, Anheuser-Busch InBev, and PepsiCo). The majority of corporate ESG statements recognise the problem of AL from their products, however, just one of the organisations detailed (The Coca-Cola Company) identified a responsibility for the clean-up of AL. ESG statements are primarily focussed on the recyclability of packaging materials, and reductions in the volume of packaging material, rather than the number of packaging items they produce. ESG statements must consider the end-of-life for their products beyond their desired fate. Reducing AL also relies on effective public engagement and suitable waste management policy and infrastructure.

The UK waste management landscape is set to change over the current decade. Pending UK legislation has the potential to influence the future environmental AL profile, however, its focus on plastic materials alone could change, rather than reduce, the prevalence of packaging on the environment. Effective monitoring of multiple environments is required to ensure the potential of these legislative and corporate changes is realised. The recording of AL in the environment in a manner that identifies not just materials, but also industries, companies and localities is necessary to achieve this. Such an approach also highlights the diversity of stakeholders that are responsible for AL, and has the potential to monitor the efficacy of, and guide, environmental legislation and policy. As such, the method used here represents a model approach for quantification of AL. Comprehensive citizen science campaigns represent a key tool to monitor and report AL in this way in lieu of government and industry efforts to do so.

## Data accessibility

Any data collected by Planet Patrol, including the data from 2020 used in this manuscript, is freely available upon reasonable request through the corresponding author or through https://planetpatrol.co/contact-us/.

## CRediT authorship contribution statement

**Thomas Stanton:** Conceptualization, Methodology, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Guaduneth Chico:** Conceptualization, Methodology, Formal analysis, Visualization, Writing – original draft, Writing – review & editing. **Elizabeth Carr:** Conceptualization, Methodology, Data curation, Validation, Writing – review & editing. **Sarah Cook:** Methodology, Writing – original draft, Writing – review & editing. **Rachel Louise Gomes:** Writing – review & editing. **Elizabeth Heard:** Conceptualization, Methodology, Data curation, Validation, Writing – review & editing. **Antonia Law:** Methodology, Writing – original draft, Writing – review & editing. **Hazel L Wilson:** Methodology, Formal analysis, Writing – review & editing. **Matthew Johnson:** Methodology, Formal analysis, Writing – original draft, Writing – review & editing.

## Environmental implication statement

The geographical scope of anthropogenic litter (AL) surveys is dominated by marine and coastal surveys. Data from these environments is important, however, it has informed policy that assumes marine and coastal AL compositions are representative of all environments. Using a novel method of AL categorisation, we use citizen science to characterise inland and terrestrial AL across the UK to type, industry, and brand. We relate these data to corporate policy and UK and EU legislation, providing a baseline dataset against which future AL records in the UK can be compared to assess the efficacy of planned policy and legislative change.

## Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Elizabeth Carr reports a relationship with Planet Patrol that includes: employment. Elizabeth Heard reports a relationship with Planet Patrol that includes: employment. Thomas Stanton is an advisor to Planet Patrol. His contribution to Planet Patrol is completely voluntary, and he receives no funds from Planet Patrol.

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## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jhazmat.2022.129118.

## References


Barnardo, T. and Ribbink, A. (Eds.), 2020. African Marine Litter Monitoring Manual. African Marine Waste Network, Sustainable Seas Trust. Port Elizabeth, South Africa.

Barreiros, J.P., Raykov, V.S., 2014. Lethal lesions and amputation caused by plastic debris and fishing gear on the loggerhead turtle Caretta caretta (Linnaeus, 1758). Three case reports from Terceira Island, Azores (NE Atlantic). Mar. Pollut. Bull. 86 (1–2), 518–522.

Baxter, L., Lucas, Z., Walker, T.R., 2022. Evaluating Canada's single-use plastic mitigation policies via brand audit and beach cleanup data to reduce plastic pollution. Mar. Pollut. Bull. 176, 113460.

Borg, K., Curtis, J., Lindsay, J., 2020. Social norms and plastic avoidance: testing the theory of normative social behaviour on an environmental behaviour. J. Consum. Behav. 19 (6), 594–607.

Burgess, M., Holmes, H., Sharmina, M., Shaver, M.P., 2021. The future of UK plastics recycling: one bin to rule them all. Resour., Conserv. Recycl. 164, 105191.

Castro-Jiménez, J., González-Fernández, D., Fornier, M., Schmidt, N., Sempéré, R., 2019. Macro-litter in surface waters from the Rhone River: Plastic pollution and loading to the NW Mediterranean Sea. Mar. Pollut. Bull. 146, 60–66.

Chen, H., Wang, S., Guo, H., Lin, H., Zhang, Y., 2020. A nationwide assessment of litter on China's beaches using citizen science data. Environ. Pollut. 258, 113756.

Cheshire, A.C., Adler, E., Barbière, J., Cohen, Y., Evans, S., Jarayabhand, S., Jeftic, L., Jung, R.T., Kinsey, S., Kusui, E.T., Lavine, I., Manyara, P., Oosterbaan, L., Pereira, M. A., Sheavly, S., Tkalin, A., Varadarajan, S., Wenneker, B., Westphalen, G. (2009). *UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter. UNEP Regional Seas Reports and Studies*, No. 186; IOC Technical Series No. 83: xiiii.

Consoli, P., Falautano, M., Sinopoli, M., Perzia, P., Canese, S., Esposito, V., Battaglia, P., Romeo, T., Andaloro, F., Galgani, F., Castriota, L., 2018. Composition and abundance of benthic marine litter in a coastal area of the central Mediterranean Sea. Mar. Pollut. Bull. 136, 243–247.

Consoli, P., Scotti, G., Romeo, T., Fossi, M.C., Esposito, V., D'Alessandro, M., Battaglia, P., Galgani, F., Figurella, F., Pragnell-Raasch, H., Andaloro, F., 2020. Characterization of seafloor litter on Mediterranean shallow coastal waters: evidence from Dive Against Debris®, a citizen science monitoring approach. Mar. Pollut. Bull. 150, 110763.

Dauvergne, P., 2018. The power of environmental norms: marine plastic pollution and the politics of microbeads. Environ. Polit. 27 (4), 579–597.

De Frond, H.L., van Sebille, E., Parnis, J.M., Diamond, M.L., Mallos, N., Kingsbury, T., Rochman, C.M., 2019. Estimating the mass of chemicals associated with ocean plastic pollution to inform mitigation efforts. Integr. Environ. Assess. Manage. 15 (4), 596–606.

DEFRA (2021a). Guidance Carrier bag charges: retailers' responsibilities [online] Available at: ⟨https://www.gov.uk/guidance/carrier-bag-charges-retailers-responsibilities⟩ (Accessed: 19/09/2021).

DEFRA (2021b). Extended Producer Responsibility for Packaging Consultation Document. London.

English, M.D., Robertson, G.J., Avery-Gomm, S., Pirie-Hay, D., Roul, S., Ryan, P.C., Wilhelm, S.I., Mallory, M.L., 2015. Plastic and metal ingestion in three species of coastal waterfowl wintering in Atlantic Canada. Mar. Pollut. Bull. 98 (1–2), 349–353.

Eriksen, M., Lusher, A., Nixon, M., Wernery, U., 2021. The plight of camels eating plastic waste. J. Arid Environ. 185, 104374.

European Commission, n.d. A European Strategy for Plastics in a Circular Economy. European Commission, Brussels.

European Parliament, 2019. Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment (Text with EEA relevance). European Parliament, Brussels.

Falk-Andersson, J., Berkhout, B.W., Abate, T.G., 2019. Citizen science for better management: Lessons learned from three Norwegian beach litter data sets. Mar. Pollut. Bull. 138, 364–375.

Gonzalez Fernandez, D., Hanke, G., Kideys, A., Navarrao Ortega, A., Sanchez Vidal, A., Bruge, A., Ã–ztÃ¼rk, B., Palma, C., Santelli, C., Duijsings, D., Barcelo, D., Dimitiriu, E., Rojo-Nieto, E., Ferreira, F., Bessa, F., Suaria, G., Siedlewicz, G., Castro Jimenez, J., Germano, J., Pereira De Brito, J., Rigueira, J., Pazdro, K., Cabrera, M., Pogojeva, M., KÃ¶ck Schulmeyer, M., Constant, M., Canals Artigas, M., Paraboschi, M., Tourgeli, M., Machitadze, N., Ratola, N., Savenko, O., Kerherve, P., Sempere, R., Bakiu, R., Crosti, R., Schoeneich-Argent, R., Landry Levesque, S., Agostinho, T., Segal, Y., Galletti, Y., 2018. *Floating macro litter in European rivers - top items*, EUR 29383 EN. Publications Office of the European Union, Luxembourg. ISBN 978-92-79-96373-5, doi:10.2760/316058, JRC108172.

Hoellein, T., Rojas, M., Pink, A., Gasior, J., Kelly, J., 2014. Anthropogenic litter in urban freshwater ecosystems: distribution and microbial interactions. PloS one 9 (6), e98485.

Hold Norge Rent, 2021. *Brand Audit Report 2021*. Hold Norge Rent, Oslo.

Horton, A.A., 2022. Plastic pollution: When do we know enough? J. Hazard. Mater. 422, 126885.

Jepsen, E.M., de Bruyn, P.N., 2019. Pinniped entanglement in oceanic plastic pollution: a global review. Mar. Pollut. Bull. 145, 295–305.

Kiessling, T., Knickmeier, K., Kruse, K., Brennecke, D., Nauendorf, A., Thiel, M., 2019. Plastic Pirates sample litter at rivers in Germany–Riverside litter and litter sources estimated by schoolchildren. Environ. Pollut. 245, 545–557.

Lavers, J.L., Sharp, P.B., Stuckenbrock, S., Bond, A.L., 2020. Entrapment in plastic debris endangers hermit crabs. J. Hazard. Mater. 387, 121703.

Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., Hajbane, S., Cunsolo, S., Schwarz, A., Levivier, A., Noble, K., 2018. Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. Scientific Rep. 8 (1), 1–15.

Lebreton, L.C., Van Der Zwet, J., Damsteeg, J.W., Slat, B., Andrady, A., Reisser, J., 2017. River plastic emissions to the world's oceans. Nature Commun. 8 (1), 1–10.

Lewis, S.M., Rotjan, R.D., 2009. Vacancy chains provide aggregate benefits to Coenobita clypeatus hermit crabs. Ethology *115* (4), 356–365.

Lusher, A.L., Mchugh, M., Thompson, R.C., 2013. Occurrence of microplastics in the gastrointestinal tract of pelagic and demersal fish from the English Channel. Mar. Pollut. Bull. 67 (1–2), 94–99.

Lwanga, E.H., Vega, J.M., Quej, V.K., de los Angeles Chi, J., Del Cid, L.S., Chi, C., Segura, G.E., Gertsen, H., Salánki, T., van der Ploeg, M., Koelmans, A.A., 2017. Field evidence for transfer of plastic debris along a terrestrial food chain. Scientific Rep. 7 (1), 1–7.

Maes, T., Barry, J., Leslie, H.A., Vethaak, A.D., Nicolaus, E.E.M., Law, R.J., Lyons, B.P., Martinez, R., Harley, B., Thain, J.E., 2018. Below the surface: Twenty-five years of seafloor litter monitoring in coastal seas of North West Europe (1992–2017). Sci. Total Environ. 630, 790–798.

Maitre-Ekern, E., 2021. Re-thinking producer responsibility for a sustainable circular economy from extended producer responsibility to pre-market producer responsibility. J. Clean. Prod. 286, 125454.

Mateo, R., Belliure, J., Dolz, J.C., Serrano, J.A., Guitart, R., 1998. High prevalences of lead poisoning in wintering waterfowl in Spain. Archiv. Environ. Contam. Toxicol. 35 (2), 342–347.

McCormick, A.R., Hoellein, T.J., 2016. Anthropogenic litter is abundant, diverse, and mobile in urban rivers: Insights from cross-ecosystem analyses using ecosystem and community ecology tools. Limnol. Oceanography 61 (5), 1718–1734.

McDermott, L., Heard, E., Carr, E., Beecham, H., Stanton, T. 2021. Extent of single-use litter in the UK II. Planet Patrol. Coalville.

Nelms, S.E., Coombes, C., Foster, L.C., Galloway, T.S., Godley, B.J., Lindeque, P.K., Witt, M.J., 2017. Marine anthropogenic litter on British beaches: a 10-year nationwide assessment using citizen science data. Sci. Total Environ. 579, 1399–1409.

Nelms, S.E., Easman, E., Anderson, N., Berg, M., Coates, S., Crosby, A., Eisfeld-Pierantonio, S., Eyles, L., Flux, T., Gilford, E., Giner, C., 2022. The role of citizen science in addressing plastic pollution: challenges and opportunities. Environ. Sci. Policy 128, 14–23.

Nelms, S.E., Eyles, L., Godley, B.J., Richardson, P.B., Selley, H., Solandt, J.L., Witt, M.J., 2020. Investigating the distribution and regional occurrence of anthropogenic litter in English marine protected areas using 25 years of citizen-science beach clean data. Environ. Pollut. 263, 114365.

Okuku, E.O., Kiteresi, L., Owato, G., Otieno, K., Omire, J., Kombo, M.M., Mwalugha, C., Mbuche, M., Gwada, B., Wanjeri, V., Nelson, A., 2021. Temporal trends of marine litter in a tropical recreational beach: a case study of Mkomani beach, Kenya. Mar. Pollut. Bull. 167, 112273.

Okuku, E.O., Owato, G., Kiteresi, L.I., Otieno, K., Kombo, M., Wanjeri, V., Mbuche, M., Gwada, B., Chepkemboi, P., Achieng, Q., Nelson, A., 2022. Are tropical estuaries a source of or a sink for marine litter? Evidence from Sabaki Estuary, Kenya. Mar. Pollut. Bull. 176, 113397.

Olsen, G.H. and WISE, M., 2001. Ingested metal in Whooping Cranes: An endoscopic technique for removal and implications for the release program. North American Crane Workshop Proceedings. 70.

Pocock, M.J., Roy, H.E., August, T., Kuria, A., Barasa, F., Bett, J., Githiru, M., Kairo, J., Kimani, J., Kinuthia, W., Kissui, B., 2019. Developing the global potential of citizen science: assessing opportunities that benefit people, society and the environment in East Africa. J. Appl. Ecol. 56 (2), 274–281.

Rangel-Buitrago, N., Gracia, A., Velez-Mendoza, A., Carvajal-Florian, A., Mojica-Martinez, L., Neal, W.J., 2019a. Where did this refuse come from? Marine anthropogenic litter on a remote island of the Colombian Caribbean sea. Mar. Pollut. Bull. 149, 110611.

Rangel-Buitrago, N., Mendoza, A.V., Gracia, A., Mantilla-Barbosa, E., Arana, V.A., Trilleras, J., Arroyo-Olarte, H., 2019b. Litter impacts on cleanliness and environmental status of Atlantico department beaches, Colombian Caribbean coast. Ocean Coast. Manage. 179, 104835.

Rangel-Buitrago, N., Velez-Mendoza, A., Gracia, A., Neal, W.J., 2020. The impact of anthropogenic litter on Colombia's central Caribbean beaches. Mar. Pollut. Bull. 152, 110909.

Roman, L., Kastury, F., Petit, S., Aleman, R., Wilcox, C., Hardesty, B.D., Hindell, M.A., 2020. Plastic, nutrition and pollution; relationships between ingested plastic and metal concentrations in the livers of two Pachyptila seabirds. Scientific Rep. 10 (1), 1–14.

Seif, S., Provencher, J.F., Avery-Gomm, S., Daoust, P.Y., Mallory, M.L., Smith, P.A., 2018. Plastic and non-plastic debris ingestion in three gull species feeding in an urban landfill environment. Archiv. Environ. Contam. Toxicol. 74 (3), 349–360.

Simpson, V.R., Fisher, D.N., 2017. A description of the gross pathology of drowning and other causes of mortality in seabirds. BMC Vet. Res. 13 (1), 1–14.

Surfers Against Sewage. 2021. 2021 Citizen Science Brand Audit Report. Surfers Against Sewage, St Agnes.

Syberg, K., Palmqvist, A., Khan, F.R., Strand, J., Vollertsen, J., Clausen, L.P.W., Feld, L., Hartmann, N.B., Oturai, N., Møller, S., Nielsen, T.G., 2020. A nationwide assessment

of plastic pollution in the Danish realm using citizen science. Scientific Rep. 10 (1), 1–11.
UK Government, (2015). Single Use Carrier Bags Charges (England) Order 2015. Available at: ⟨https://www.legislation.gov.uk/ukdsi/2015/9780111127735⟩ (Accessed: 19/09/2021).
UK Government, (2017). Environmental Protection (Microbeads) (England) Regulations 2017. Available at: ⟨https://www.legislation.gov.uk/uksi/2017/1312/regulation/1/made⟩ (Accessed 19/09/2021).
United Nations Environment Programme (UNEP), 2009. Marine Litter: A Global Challenge. Nairobi: UNEP.
United Nations Environment Programme (UNEP), 2022. Draft Resolution End plastic pollution: Towards an international legally binding instrument. UNEP/EA/L.23/Rev.1. Nairobi.
Van Emmerik, T., Roebroek, C., De Winter, W., Vriend, P., Boonstra, M., Hougee, M., 2020. Riverbank macrolitter in the Dutch Rhine–Meuse delta. Environ. Res. Lett. 15 (10), 104087.
Vincent, A., Drag, N., Lyandres, O., Neville, S., Hoellein, T., 2017. Citizen science datasets reveal drivers of spatial and temporal variation for anthropogenic litter on Great Lakes beaches. Sci. Total Environ. 577, 105–112.
Viršek, M.K., Lovšin, M.N., Koren, Š., Kržan, A., Peterlin, M., 2017. Microplastics as a vector for the transport of the bacterial fish pathogen species Aeromonas salmonicida. Mar. Pollut. Bull. 125 (1–2), 301–309.
Voluntary and Economic Incentives Working Group, 2018, *Voluntary and economic incentives to reduce littering of drinks containers and promote recycling.*
Walkers (2021). Going Green. ⟨https://www.walkers.co.uk/sustainability/going-green/⟩ (accessed 08/04/2022.
Welsh Government. 2018. Wales to become first 'Refill Nation' in the World. Available at: ⟨https://gov.wales/wales-become-first-refill-nation-world⟩ (Accessed: 19/09/2021).
Williams, A.T., Simmons, S.L., 1999. Sources of riverine litter: the river Taff, South Wales, UK. Water, Air, Soil Pollut. 112 (1), 197–216.
Wilson, H.L., Johnson, M.F., Wood, P.J., Thorne, C.R., Eichhorn, M.P., 2021. Anthropogenic litter is a novel habitat for aquatic macroinvertebrates in urban rivers. Freshw. Biol. 66 (3), 524–534.
Xu, Y., Chan, F.K.S., Johnson, M., Stanton, T., He, J., Jia, T., Wang, J., Wang, Z., Yao, Y., Yang, J., Liu, D., 2021. Microplastic pollution in Chinese urban rivers: the influence of urban factors. Resour., Conserv. Recycl. 173, 105686.
Zhou, G., Gu, Y., Wu, Y., Gong, Y., Mu, X., Han, H., Chang, T., 2020. A systematic review of the deposit-refund system for beverage packaging: operating mode, key parameter and development trend. J. Clean. Prod. 251, 119660.