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Terrestrial borne litter in the marine environment – evidence review and quantifying the issue

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Summary

This report has been prepared for Defra in order to provide a summary of evidence on the sources of terrestrial borne litter and the pathways by which these may enter the marine environment.

From the available data, public-sources were identified as having the greatest contribution to overall quantities of litter within a range of environments and land-use types, however data deficiencies prevented quantifying the emissions from industrial and agricultural sources. Anecdotally, agricultural sources may be a substantial contributor to litter in some (rural) regions. Further studies are required to quantify emissions from agricultural sources. To some extent, the types of litter identified in different land-uses varied, for example certain public-related items like cigarette stubs and food packaging were identified as litter within urban, riverine and coastal environments, while other items such as wet wipes were only identified along coasts and river. This information can assist in determining the potential pathways by which items may enter the environment.

There is a scarcity of data regarding the quantities of litter transported via different pathways, and while scavenging by wildlife and wind were anecdotally identified as contributing to litter emissions there are no quantifiable estimates for these pathways. Therefore, with the current state of knowledge, estimating the relative importance of different pathways for distributing terrestrial litter is not possible.

What is clear, is that different modes of littering, intentional, unconscious and unintentional all contribute towards the emissions of litter into the environment. For instance, litter disposed of in public bins may blow out or spill from an overfull bin; household waste can become scavenged by wildlife, which can result in litter dispersing into the environment. In these examples, the individual has perceived they have disposed of their litter correctly, yet factors after the point of disposal (e.g. wind, wildlife) have caused that litter to enter the environment (*unintentional littering*). Further unconscious littering, where consumers dispose of waste next to an overfull public bin (rather than taking the item with them/finding a less full bin) is anecdotally cited as a factor influencing environmental litter. Further research is recommended to address the knowledge gaps rand quantify litter emitted via unintentional and unconscious routes.

Local, regional and national assessments utilising standardised monitoring methods and modelling approaches are required to yield quantitative data in the following topics (i-ii), to establish the major sources and pathways of litter emissions within the UK which will inform where targeted interventions could be implemented.

i) Quantify the sources of litter emanating from different environments and land use types in the UK. This would be particularly valuable for industrial and agricultural sources which are lacking data, as well as more enable a detailed investigation into litter in rural and recreational areas.

ii) Assess the comparative role of different pathways (e.g. wind, wildlife scavenging, river transport, flooding and other weather events) at distributing terrestrial litter into the marine environment and elucidate how these may vary for different sources of litter and regions of the UK.

Contents

1. Introduction

1.1. Context for the terrestrial borne litter in the marine environment – evidence review and quantifying the issue

This review has been prepared for Defra in order to provide a summary of evidence on the sources of terrestrial borne litter and the pathways by which these may enter the marine environment. While developing appropriate policy is a key challenge to dealing with this issue, the report is primarily evidence, rather than policy, driven.

Within the scope of this report were materials and items intentionally littered as well as those which unintentionally enter the environment, for example items which may blow out of bins. The remit of the report was to examine terrestrial litter within the context of the United Kingdom, however international studies have also been incorporated to illustrate and contextualise the UK situation, and further illustrate the role of different pathways in the transport of litter to the marine environment.

The relative scale of different litter sources and pathways have been assessed based on published quantitative data, yet differences in sampling methods and data deficiencies (identified within the report) precluded direct comparisons. In addition to the main remit provided by Defra, qualitative data in the form of stakeholder interviews are also included to provide further insights.

1.2. Background

The UK Environmental Protection Act 1990 (s.87) (1990) defines litter as “anything that is dropped, thrown, left or deposited that causes defacement, in a public place”. This definition includes a wide range of manufactured or processed solid material including glass, metal, plastic, rubber paper and processed timber, as well as natural materials such as discarded food (Defra, 2019a). Items may become litter when they are improperly discarded, abandoned or lost in public spaces and the natural environment, during any stage of their production – use – disposal – treatment lifecycle (Veiga et al., 2016, OSPAR Commission, 2014).

Litter has been recognised to threaten environmental quality, with a range of potential impacts on wildlife, the economy and human health and safety (Beaumont et al., 2019, Hartley et al., 2018b, Werner et al., 2016, Wyles et al., 2016). Annually, local authorities spent in excess of £695,000,000 on street cleansing (National Statistics, 2021) and >£15,500 on coastal clean-ups (Mouat et al., 2010), money which could otherwise be invested in other local services (DEFRA, 2017).

Originating from both marine and terrestrial based origins, the sources of litter are varied and extensive. This report will focus on the terrestrial sources, which encompass items emanating from domestic, industrial and agricultural activities. While the origin of litter are not always easily discernible, it is estimated that the vast majority of the man-made items entering the ocean are from terrestrial based sources (Lau et al., 2020, Jambeck et al., 2015). It is estimated that the UK generates over 31 million tonnes of waste per year (0.4 tonnes/capita/annum) (Kaza et al., 2018). Modelling approaches suggest that in 2016, ~50,000 metric tonnes of plastic waste was emitted into aquatic ecosystems globally (including rivers, lakes and oceans), under a ‘business as usual’ scenario this is predicted to more than double to 120,000 metric tonnes by 2030 (Borrelle et al., 2020). These estimates only consider plastic, which accounts for 75-95% of marine litter (Hanke et al., 2019, OSPAR

Commission, 2000), and so are likely to underestimate total solid waste emissions emanating from all material types. Thus it is clear that interventions are required to reduce the leakage of waste into the environment and understanding the sources of litter and the pathways by which emissions occur are a prerequisite to identify and prioritise potential mitigation strategies.

1.3. Policy relevance

Despite both the UK Marine Strategy (HM Government, 2012) and the OSPAR Commission (OSPAR Commission, 2014) setting the aim to reduce the amount of litter on coastlines and in the marine environment, beach surveys in the UK over the last three decades, indicate that litter is still common and not markedly decreasing (Kinsey, 2018, Marine Conservation Society, 2019a) (Figure 1). Therefore, it is apparent that further work is needed to identify the sources of litter entering the marine environment and take effective action to reduce waste.

One of the strategic ambitions in the Resources and Waste Strategy is to eliminate avoidable waste by 2050 (DEFRA, 2020a), and both the Litter Strategy for England (DEFRA, 2017) and the UK 25 Year Plan (Defra, 2018a) set out the aim to deliver a cross-sectoral approach to substantially reduce litter and littering. Developing appropriate evidence-based interventions to reduce litter on land is fundamental to reduce litter emitted into the marine environment.

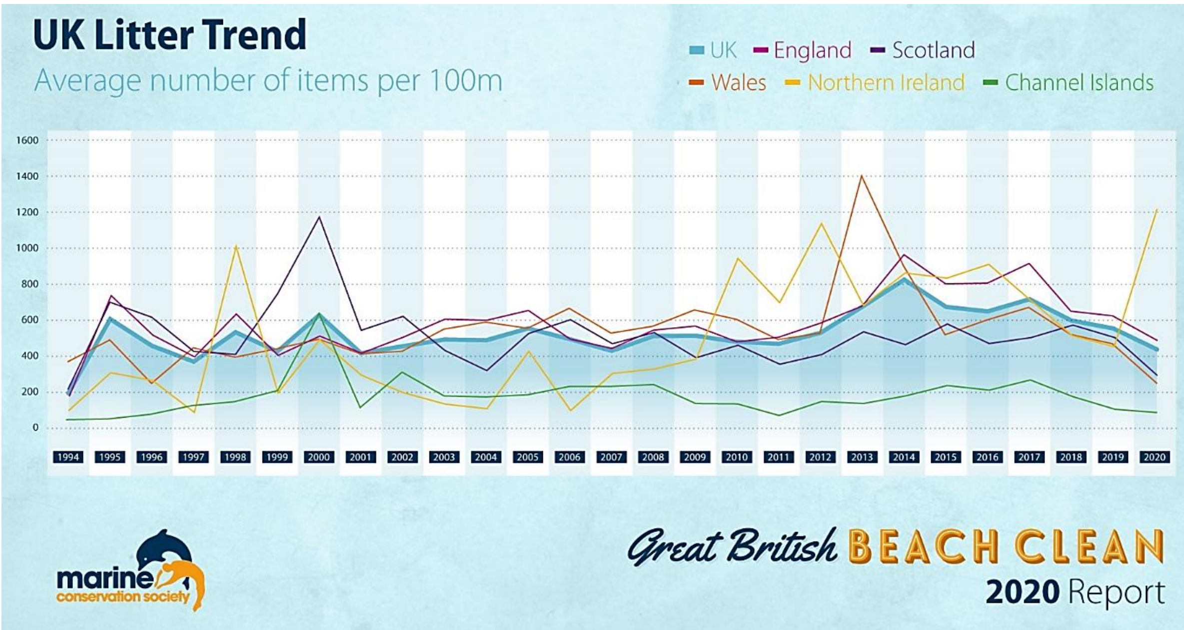

Figure 1. The average number of litter items per 100m transect on UK beaches between the years 1994 – 2019. Reprinted with permission from The Marine Conservation Society

2. Method

2.1. Literature review

Aspects of a Quick Scoping Review systematic search approach in addition to hand-searching were used to identify published research papers that addressed the primary and secondary research areas (Box 1). Each research topic was formed as a separate open-ended, non-impact research question in order to identify studies on each source of litter, type of litter and pathway that litter takes from the land to marine environment. Keywords and relevant synonyms were identified and for each topic several search strings were formulated. The same search strings were used in a series of Web of Science and Scopus searches restricting results to those published since 2015 and de-duplicated using an Endnote library. Whilst geographic limiters were applied within the databases to identify UK based studies, inevitably these did not fully restrict the search to those studies conducted within the UK. The defined 'Environment' subject category in both databases was used to quickly reduce any large sets of results.

Primary research areas:

- Examine the pathways that litter takes from land to the marine environment
- Assess and quantify litter items according to their source

Secondary research areas:

- Assess the composition and/or abundance of litter by items and material types

Box 1. The primary and secondary research areas examined in this report

The numbers of peer-reviewed studies identified through the literature search process for each broad research topic area are shown in the appendix (Figure A1). The final set of references was further expanded by searching Google Scholar and mining citation networks of papers already discovered for other studies that were not identified through the keyword searches themselves. In addition, further important papers were also identified through the author's existing network of experts in the field of plastics and marine litter. We acknowledge that this latter approach introduces a degree of bias however this was balanced against the need for rapid identification of key research papers. The wider systematic search, offered an opportunity for an unbiased approach to identify what recent research, if any, exists in the broader field of land-based litter studies in the UK. Finally, relevant grey literature sources and citizen science reports were also consulted.

2.2. Datasets

Several pertinent dataset on the quantities of litter items in different terrestrial environments and land-use types, including those collected by citizen scientist/volunteer groups and organisations, were identified. Reports on litter composition obtained from local environmental quality surveys within the home nations provided a valuable source of information (Keep Britain Tidy, 2020, Resource futures, 2019). Additionally datasets were utilised to investigate litter sources, such as the Marine Conservation Society's 'Great British beach cleans' annual coastal surveys (Marine Conservation Society, 2019a) and their inland 'Source to Sea Litter Quest' (Marine Conservation Society, 2021). Data logged via the citizen science planet patrol app and supplied by Planet Patrol (Planet Patrol, 2020) were manually examined with any incomplete or ambiguous entries removed, and filtered to identify litter logged within riverine systems in the UK, which along with monitoring conducted by Thames21 (McConville et al., 2020) provided insights into litter quantities within UK waterways.

2.3. Structured interviews

Local authorities were contacted directly and via e-newsletters disseminated by the professional networks The Local Authority Recycling Advisory Committee (LARAC) and Keep Britain Tidy. In addition a request was submitted via the Association for Public service excellence (APSE) to their network of local authorities. The aim was to recruit three individuals from at least five authorities in England. Structured interviews were conducted with employees of local authorities within the UK to provide qualitative data primarily on the pathways by which litter may enter the environment. The purpose of the interviews were to gather the professional opinions from individuals involved in kerb side collection and street cleansing activities to provide a broad overview regarding different factors which may influence litter. The interviews were not designed to compare councils or regions and as such respondents and authorities are anonymous. The same series of questions were asked to each individual in March 2021. The interviews covered a range of topics seeking their perspectives on the effects of weather, wildlife, one-off events and public/householder behaviour on litter, and any noticeable effect of COIVD-19. Authorities were contacted directly and the interviews were promoted via two professional networks.

3. Defining sources and pathways of terrestrial litter

While the importance of identifying the sources and pathways of litter, and in particular plastics, are stated within different National and European directives, such as the UK Marine Strategy (HM Government, 2012) and the Marine Strategy Framework Directive (2008), currently there appears to be a lack of consensus on what constitutes a 'source' and a 'pathway' of litter into the marine environment (Appendix Table A1). For example, within the body of literature rivers and sewage/sewage systems are categorised as both sources and transport pathways. Indeed, waste water treatment (WWT) works and sewage systems can be considered a source if the process itself releases plastic, such as bio-beads. Bio-beads are used by WWT facilities to treat sewage but may be lost into the environment during this process (Turner et al., 2019); as such the WWT facilities themselves can be a source of pollution as well as a transport pathway for litter coming from other sources. These categorisation discrepancies give rise to challenges when trying to retrieve relevant information and subsequently assess the relative importance of different sources and transport pathways for terrestrial litter. Broadly, these differences seem to arise from various perceptions on how human behaviour, socio-economic aspects, and socio-technical regimes in different areas may impact the way litter enters into the terrestrial and marine environment (DEFRA, 2019d).

This report adopts the broad definitions of categorisation (Table 1), similar to those used by the Marine Strategy Framework Directive Technical group on Marine Litter (Veiga et al. 2016) and organisations such as the Marine Conservation Society.

Table 1. Definitions and categories used within this report of the 'source' of terrestrial borne litter, the 'mode of littering' and the 'transport pathways' by which this litter may enter the marine environment.

Source *(Section 4)*	**Mode of littering** *(Section 5)*	**Transport pathway** *(Section 6)*
The economic sector/activity from which litter originates • Public related • Medical • Industrial • Agricultural • Fly-tipped • Non-sourced • Fishing-related (*marine source*)	The broad mechanistic category by which items enter the natural or urban environment • Intentional • Unintentional • Unconcious	Physical and/or technical means by which litter enters the marine environment. • Rivers/Waterways • Wind • Extreme weather events (flooding, erosion) • Sewage • Rain runoff and storm drains • Scavenging by wildlife

4. Sources of terrestrial litter

Litter enters the ocean from a variety of land- and ocean-based sources. Within this report the focus is on litter originating from land and therefore only terrestrial sources are discussed further. Terrestrial litter can enter the coastal and marine environment directly or be brought indirectly to the sea by a number of transport pathways including rivers, sewage outflows and wind (discussed in section 6). Source identification can be challenging, especially when litter has been present in the environment for a long period, as items may degrade or fragment over time. Transport processes may also distribute litter far from its origin, further complicating source appointment. Also, for certain items it is difficult to be certain of their origin, for example plastic film collected during beach clean-ups may arise from plastic bags or food packaging (*public-sources*), or from industrial, agricultural or maritime sources. Despite these challenges, categorising items into their sources enables the identification and implementation of regulations, which are a key part of any strategy to reduce marine litter.

4.1. Public-related sources

Public-related sources are a major contributor to litter, a trend which has been observed for several decades. Even when considering some uncertainties attributing items to different sources (see above), it is clear that the majority is still derived from public-sources. Numerous studies and organisations have monitored litter on beaches, and routinely report the prevalence of public-related items. Early reports in the mid-1990s, identify plastic food containers as one of the most commonly found items of beach litter along the Bristol Channel and Severn estuary (Tudor and Williams, 1994). The Marine Conservation Society (MCS) has conducted an annual 'Great British Beach Clean' since the early 1990s, which consistently identifies public-related items as the greatest source of litter on beaches around the UK (Nelms et al., 2020, Nelms et al., 2017). A ten-year assessment of beach litter around the UK (2005-2014 inclusive) found that 36% was attributed to public sources (Nelms et al., 2017). This figure has remained relatively constant on UK beaches, with the latest data from MCS identifying that 30.4% of litter was from public-related sources (Marine Conservation Society, 2019a). Indeed public-sources of litter are not only the most commonly identified category of litter in coastal locations but also within urban areas, where it accounts for 77.5% of litter on streets in England (Keep Britain Tidy, 2020) and 88.6% of litter on streets in Wales (Keep Wales Tidy, 2019).

By virtue of their function, some areas may have higher quantities of litter than others, for example where people congregate or there is high footfall in business/commercial areas and public open spaces (WRAP, 2020, DEFRA, 2017). At transport interchanges passengers are often waiting around consuming on-the-go, or need to quickly extinguish cigarettes or get rid of chewing gum (*public-sources*) when transferring between modes of transport (WRAP, 2020). Rest stops and laybys attract litter because they are places where people stop to consume food and drink or dispose of waste that has accumulated in their vehicle during their journey (*public-sources*). Litter may also be thrown from moving vehicles (*intentional littering*), or may blow out of vehicles when people get in and out (*unintentional littering*) for example at motorway service stations.

Items composed of plastic are far more numerous in the environment than other materials (card/paper, metal, glass), and can account for up to 75 - 95% of the material found on European beaches (Hanke et al., 2019, OSPAR Commission, 2000). Monitoring of beaches in northern Cornwall over a 6 year period indicated that plastic far outnumbered any other material (89%, as compared to 4% paper/card, 3% metal, < 1% glass) (Watts et al., 2017). The prevalence of plastic on beaches is in part due to the low density of plastics causing them to float and become strand on beaches. That said, plastic is also reported to dominate the composition of seafloor litter (65 – 94%) (Maes et al., 2018).

Beach surveys in northern Cornwall indicate public related items as the most common source of terrestrial-borne litter (18%), of which drinks lids/caps, food wrappers, cigarette stubs and drinks bottles were most numerous (Watts et al., 2017). The authors also note a significantly higher abundance of litter in summer months linked to the numbers of beach visitors, indicating direct public littering (*intentional/unintentional littering*).

The range of surveys undertaken around the UK, each with differing methods and categorisation systems as well as reporting units, makes comparing these datasets to ascertain the most numerous litter items challenging. To overcome this litter items can be ranked according to their numerical frequency for each survey and thus the relative ranks can be compared for different urban and rural environments (Table 2). While the most numerically abundant litter items differ over spatial and temporal scales, items attributed to public sources consistently rank among the top ten items recorded (Table 2). Based on the most commonly recorded items identified in Table 2, along with considering the pathways by which they might enter into the environment, three items are discussed in more detail below (sections 4.1.1-4.1.3).

Table 2. The top ten litter items/categories (based on count data) in rank order and colour coded according to their source as identified in different urban and rural environments in the UK.*

Key to the sources of litter			
(yellow)	*Public-related*	(green)	*Fishing-related*
(grey)	*Non-sourced*	(white)	*Industrial*

	Items					
Rank	**Urban, England, 2019[1]**	**Urban, Wales, 2017/2018[2]**	**Beaches, UK-wide, 2019[3]**	**Willow Brook (tributary of River Soar), 2019[4]**	**Rivers, UK-wide, 2019[5]**	**River Thames, floating litter 2015-2018[6]**
1	Cigarette stubs	Newspapers/ magazine	Plastic/polystyrene fragments	Plastic food wrappers	Packaging (material not stated)	Food wrapper (majority chocolate & biscuits)
2	General litter- other	Tissue/napkins	Cigarette stubs	Film plastic	Plastic bottle	Cotton bud stick
3	Paper	Thin card	Glass	Paper/card	Drinks can	Drinks bottles & lids
4	Smoking related (not stubs)	Sweet & chocolate wrappers	String/cord	Plastic bags	Glass bottle	Unidentified
5	Drinks cans (non-alcoholic)	Drink cans	Packets	Foam plastic	Plastic bag	Beverage cups
6	Sweet packaging	Plastic packaging (non-food)	Fishing net	Hard plastic fragments	Polystyrene	To-go food packaging
7	Plastic bottles (non-alcoholic)	Food packaging (films & dense plastics)	Caps/lids	Cigarette litter	Plastic lid/bottle cap	Building insulation pieces
8	Chocolate wrappers	Cigarette butts	Wet wipes	Tin foil	Disposable plastic cup	Straw
9	Not determined	Dense plastics (non-packaging)	Fishing line	Wet wipes	Other plastic	Cigarette stubs
10	Fast food packaging	Wet wipes	Plastic/polystyrene (other)	Metal drinks cans	Fishing net/rope/line	Lollipop sticks

Data Sources: [1](Keep Britain Tidy, 2020), [2](Resource futures, 2019), [3](Marine Conservation Society, 2019a), [4](Gabbott et al., 2019) [5] (Planet Patrol, 2020), [6](McConville et al., 2020).** N.B. The methods used in each of the separate studies differ and therefore direct comparison should be interpreted with caution.*

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4.1.1. Cigarette litter

Cigarette stubs are commonly found littered on shorelines and urban areas worldwide. In the UK, cigarette stubs are one of the most commonly found items in beach cleans (Nelms et al., 2017, McConville et al., 2020). In 2019, the MCS's Great British beach clean reported cigarette stubs as the greatest contributor to public-related litter sources (and second most common litter item overall), with on average 42.6 stubs recorded/100m (Marine Conservation Society, 2019a), an annual increase from 2018 (35.8/100m (Marine Conservation Society, 2018)) and 2017 (34.5/100m (Marine Conservation Society, 2017)).

Cigarette stubs are also commonly identified within urban centres, especially noted around roads and pavements (Araujo and Costa, 2019). Within England cigarette litter was present on 79% of 7200 streets surveyed in 2017/18 (Keep Britain Tidy, 2018) and a litter composition study carried out in England revealed cigarette stubs were the most frequently collected type of litter; accounting for 66% of the total number of litter items collected (Keep Britain Tidy, 2020). Within Wales, smoking related litter, primarily comprised of stubs, has been the most common type of litter identified on streets since routine monitoring began in 2007 (Keep Wales Tidy, 2019) most recent surveys identified smoking-litter on 79.6% of streets surveyed (ranking it 8th within the most identified litter items), which is the first time the figure has dropped below 80% of streets (Keep Wales Tidy, 2019).

Data strongly suggest that littering rates, based on number of items, are higher for cigarette stubs than general litter, which some studies partly attribute to smokers not perceiving cigarette stubs as litter. Behavioural studies found that over half of smokers (52%) thought that disposing of a cigarette down the drain was acceptable, and that 39% of those surveyed admitted to having done so within the past month (Keep Britain Tidy, 2018) and similar results are found Internationally (Rath et al., 2012, Patel et al., 2013).

Cigarette stubs may have a high dispersal potential as they are lightweight and so can be transported by wind, or float for long periods before becoming saturated and sinking, allowing for long-distance transport in rivers or drainage systems (Armitage and Rooseboom, 2000).

4.1.2. Wet wipes

Wet wipes are frequently identified within the top ten litter items on UK beaches (Nelms et al., 2017, Marine Conservation Society, 2019a) and within rivers (McConville et al., 2020), however are largely absent from litter counts in urban and open recreational areas (CPRE, 2020, Keep Britain Tidy, 2020). This is likely explained by the transport pathway of wet wipes into the environment, which is primarily considered to be via the sewage system which discharges effluent into riverine and coastal ecosystems (see section 6.4). Wet wipe dispersal via sewage systems emphasise how transport pathways can influence the distribution of litter items. Wet wipes were not recorded on the urban surveys in England, while they were the 10th most common item identified (by count) in litter pick surveys in Wales (Resource futures, 2019). This variation is due to the number of Welsh counties surveyed which were 'coastal' supporting the occurrence of wet wipes as also noted during beach cleans (Marine

Conservation Society, 2019a), compared to the English surveys which were mainly conducted inland (Keep Britain Tidy, 2020).

At the turn of the 21st century wet wipes were seldom recorded in the environment, yet between the years 2005 - 2019 there has been a 0.9-fold increase in their abundance on UK beaches (Nelms et al., 2017). The latest data from the Marine Conservation Society indicates that on average wet wipes have an abundance of 19.2/100m transect. Similarly, increasing trends were also reported in the river Thames (McConville et al., 2020). Surveys in the tidal Thames estuary in 2019 identified wet wipe products as the most numerous litter items, with densities in the upper 4cm of sediment quantified to range between 0 – 143/m^2 along the transects (average 24.61 ± 40.49 standard deviation) (McCoy et al., 2020). Monitoring over the last six years by Thames21 have indicated that accumulations of wipes have increased in size and depth, despite efforts to remove them (McCoy et al., 2020) the mounds are so large that in parts of the River Thames they are changing the shape and sediment properties of the foreshore (McConville et al., 2020).

In 2019, the UK water industry introduced the 'Fine to Flush' specification (WIS4-02-06), which aims to ensure that products labelled under this voluntary scheme meet criteria, including limiting plastic content, which do not affect the sewer or treatment system (UK Water Industry, 2019). Participation in the 'Fine to Flush' scheme is voluntary, with no legal requirements, therefore the level of compliance will largely be up to individual participating organisations. Further recommendations were made under the UK Environment Bill to extend producer responsibility to address damage to infrastructure and the environment caused by wet wipe pollution (Water UK, 2020), and European regulation (EU2020/2151) requires harmonisation of labelling (European Commission, 2021). These interventions aim to reduce improper disposal of wet wipes and their subsequent emission into the environment, therefore ongoing monitoring (both in the environment and at wastewater treatment facilities) should be implemented to evaluate the efficacy of these measures.

4.1.3. Food packaging

Food packaging is routinely identified within different UK environments. Within urban areas, three of the top ten items were attributed to food packaging in England and two from surveys in Wales (Resource futures, 2019, Keep Britain Tidy, 2020) (Table 2). Indeed over half of the streets surveyed in Wales (53%) contained confectionary litter (Keep Wales Tidy, 2019). Food packaging and utensils such as plastic forks were also the most frequently littered items on UK motorways (DEFRA, 2017).

Packaging was the most commonly identified item recorded in UK riverine environments (Planet Patrol, 2020), and a high proportion (21.4%-28.1%) of the litter recorded during seabed surveys within the River Thames were food wrappers (Morritt et al., 2014). To-go food packaging such as polystyrene food containers were present on the majority of inland surveys undertaken in England (47%), Scotland (55%) and Wales (80%) during the MCS 'Source to Sea Quest' 2020 (Marine Conservation Society, 2021). The majority (69%) of parks and open areas surveyed in Essex contained food packaging ranking this as the second most common type of litter after cigarettes (CPRE, 2020).

Within the coastal environment, the abundance of plastic food packaging increased significantly on UK beaches between 2005 to 2014 (Nelms et al., 2017). More recently the abundance of food packets on coastlines have decreased from 52.3/100m in 2017, ranking this the second most common litter item (Marine Conservation Society, 2017), to 30.9/100m in 2019, placing it as the 5th most common litter (Marine Conservation Society, 2019a), and while methods differ this was a slightly lower relative abundance than in rivers (Morritt et al., 2014, McConville et al., 2020) and recreational areas (CPRE, 2020).

Food packaging is primarily made of plastic; of the >360 million tonnes of plastics produced annually 40% is used for packaging (food and non-food related) (Geyer et al., 2017). This light-weight material has a high transport potential via wind and can float for long periods allowing for long-distance dispersal in rivers, drainage systems or in rain runoff.

Summary: Public-sources

- While the most frequently recorded litter items differ spatially, public-sources consistently dominate litter composition in urban environments and public open spaces, including beaches.

Data deficiencies:

- Data and reports, particularly scientific publications, are primarily focus on plastic waste with comparatively few reports documenting other materials such as metal, glass and paper/card which can also arise from public-sources.

4.2. Medical sources

Historically, medical waste has had a limited contribution to overall litter compared to other sources. Over the last 25 years of MCS beach clean data, only 0.2% of litter is attribute to medical sources (Nelms et al., 2020). As a result of the COVID-19 pandemic, personal protective equipment (PPE) such as single-use gloves, face masks and face shields have been recorded in both urban and rural areas globally. In the UK, a survey conducted by Thames21 to examine litter in the River Thames identified COVID-19 related PPE, such as discarded gloves and masks, within 70% of the locations monitored, with an average of 6 PPE items/100m, however they note that in some areas this was much greater, with up to 30 items/100m (Thames21, 2020). During the 2020 MCS Great British beach clean, COVID-19 related PPE was found on 30% of the beaches surveyed. Additionally inland surveys conducted as part of the 'Source to Sea Litter Quest', also run by the MCS, identified the presence of PPE on 69% of surveys (Marine Conservation Society, 2021). Littering rates of COIVD-19 PPE are not estimated in the UK, but a study in Toronto, Canada, found that the accumulation rates ranged between 1.8 items/day to 16 items/day for the small residential area and large grocery store surveyed, respectively (Ammendolia et al., 2020). This indicates that areas with higher footfall, i.e. grocery store carparks, may have greater quantities of PPE, attributed to the higher numbers of people frequenting these areas. When taking into account the different areas surveyed in Toronto, the authors estimate that 14,298 PPE items would be littered annually (Ammendolia et al., 2020).

While medical related litter is now more frequently observed than in previous years, it is important to contextualize these sources within overall litter composition. A report issued by Planet Patrol, assessing litter logged via their citizen science app, noted the presence of PPE during 2020, however this was the 15th most frequently recorded type of litter, with food packaging, drinks bottles, cans and cigarette stubs more numerously recorded (Planet Patrol, 2021), a similar result was also recorded in urban and rural areas during local environmental quality surveys (CPRE, 2020).

The majority of gloves and face masks do not come with disposal instructions, and while the UK government published information online detailing how to dispose of COVID-19 related PPE (Gov.uk, 2020), it is unclear how many people consulted this website, or know the appropriate way to dispose of these items, especially when outside the home. Relatively simple interventions (e.g. better communication of disposal printed on the items/their packaging) and increased public awareness could reduce COVID-19 related sources of litter.

Summary: Medical sources

- Medical sources account for only a small proportion of litter, however this has increased in urban and rural areas as a result of the COVID-19 pandemic.
- While medical-related litter has increased in 2020 compared with previous years, other public related items were considerably more numerous.

4.3. Industrial sources

Industrial-sources of litter can be attributed to those accidentally released/lost from industrial facilities, spilt during handling and transportation, or arising from construction and demolition work.

Plastic pre-production pellets are used by industry to manufacture plastic products. It is estimated that 53 billion plastic pellets may be spilled from UK land-based sources each year (Eunomia, 2016), and pellets have been well documented on UK coastlines (FIDRA, 2021). In the UK, there are over 6000 companies which are part of the plastics industry who produce, import and convert plastic pellets into products. At an Austrian facility it was found that around 200g of industrial plastic pellets were discharged each day under normal operating condition, while between 50 – 200kg may be lost during heavy rainfall events (Lechner and Ramler, 2015). There are no estimates for losses within the UK. Recently the British Standards Institution has been developing a Publically Available Specification (PAS 510) which is intend to provide guidance to reduce the leakage of plastic pellets from industry, this is currently under public review (BSI, 2021). Participation would be voluntary and the level of compliance will largely be up to individual participating organisations however the Publically Available Specification (PAS) is auditable and as such compliance can be verified by third party auditors.

Where coupled with clearly defined and well-governed certification schemes requiring verification of compliance, standards could be effective in bringing about change across the whole plastic supply chain - the PAS, for example, is applicable to all companies handling pellets (i.e. producers, hauliers, logistics companies, storage facilities, converters and manufacturers). Several parallel processes have advocated the development of a so-called supply chain approach to tackling pellet loss, including the European Commission (European Commission, 2018) and OSPAR contracting parties (OSPAR, 2021). While voluntary certification schemes have the potential to fulfil those recommendations, it is recognised that up-take may be limited and legislation may be necessary to effectively address the issue of pellet pollution. Where legislative frameworks are developed, they should oblige all companies placing pellets or plastic products on the market to provide independent verification that best practice measures are in place to prevent pellet loss (i.e. via third party certification) and competent authorities should be empowered to intervene where compliance fails.

Within England, construction, demolition and excavation generated ~120 million tonnes of waste in 2016, an annual increase since 2010 (101 million tonnes) (DEFRA, 2020a), and in Wales 3.4 million tonnes were generated in 2012. However, it cannot be estimated how much of the generated waste was recovered and how much remained in the environment. Street litter surveys in Wales indicate that 16.6% of litter, including bricks, rubble, screws and wall plugs, was attributed to construction and demolition (C&D) industrial sources in 2018-2019 (Keep Wales Tidy, 2019). In the river Thames, building insulation pieces were the 7th most common item identified during floating litter surveys between 2015 -2018 (McConville et al., 2020)

Global estimate suggest around 1.3 million tonnes of plastic waste is generated annually from C&D activity (Geyer et al., 2017), however plastics only account for around 5-6% of C&D waste (Christensen and Andersen, 2010), indicating that overall estimates of C&D waste in the environment is likely to be greater.

With the exception of plastic pellets, there is a lack of data indicating the presence or quantity of terrestrial-based industrial litter in the marine environment, including on beaches. Therefore questions remain regarding the transport potential of these materials as many have a high density e.g. metal, rubble; and the relative scale of industrial sources of litter compared to other terrestrial sources.

Summary/Data deficiencies: Industrial sources

- While there are estimates of quantities of pre-production pellets in the environment, generally there is a lack of information on the quantity of industrial waste entering the environment within the UK.
- Data deficiencies prevent contextualising the contribution from industrial litter with other sources.

4.4. Agricultural sources

Utilised agricultural land covers 17.5 million hectares which is nearly three-quarters of the UK (National Statistics, 2019). The non-organic waste generated by the agricultural sector include silage/bale wraps, plastic netting, bale string, sheeting and mulch films, drums, feed buckets and sacks and old tyres. Within rural areas, agricultural practises dominate much of the land and its therefore estimated that the main use and disposal of plastic arises from agricultural practise (termed ‘plasticulture’), i.e. from wrapping hay bales, plastic films in polytunnels and mulching (Briassoulis et al., 2013). In Europe, 1,175,000 tons of plastic agricultural waste in generated each year (APE Europe, 2020). Within the UK, this figure is around 118,000 tons per annum, of which 60% is from silage/bale wrap and string, and 32% is from ‘cultivation plastic’ (mulch films, tunnels, covers) (Briassoulis et al. 2013). The UK estimates are based on data from 2003-2007, and therefore quantities may have changed in the proceeding years, however more up to date estimates are lacking. It is also important to note that this is waste generation and not the quantities escaping into the environment, for which there are no estimates.

Very few studies have assessed the quantities of litter on, or emanating from agricultural land due to these areas being largely privately owned, with the occasional exceptions of permissive paths through fields. As such the same routine monitoring which occurs in urban areas (such as the Keep Britain Tidy Local Environmental Quality Surveys) and on beaches (e.g. MCS surveys) is absent from agricultural land hampering the quantification agricultural litter and its relative contribution compared to other sources. Further, challenges may be presented with the source allocation of certain items. Agricultural waste which becomes litter may also arise from other sectors; for example, plastic netting, string and twine might be attributed to fishing, maritime activities or agriculture, while films used as mulch and bale/silage wrap could also be categorised as other sources. In part this source allocation may be context specific; there is a greater likelihood that string and twine present on a beach has come from fishing/maritime sources than from agriculture, however an estimated 1,224,900 hectares of agricultural land in England, and 111,100 hectares in Wales are situated in floodplain and at risk from rivers, the sea, or both (Roca et al., 2011). Litter, and particularly those composed of light-weight plastic, which is within these areas may be susceptible to being transported from land to sea within rivers (section 6.1), during flooding or rain runoff (section 6.5) or mobilised during coastal erosion (section 6.3). Indeed during the interviews undertaken for this report, an employee from a rural county council indicated that heavy rainfall or wind can carry farm litter, e.g. feed buckets or bale wrap to the sea/estuary. In their opinion, agricultural sources contributed the greatest quantities of litter over an annual cycle within their area.

Summary/Data deficiencies: Agricultural sources

- Lack of studies and quantitative data estimating (non-organic) litter generation by agricultural sources, and the proportion entering the environment.
- It is recommended that assessments (monitoring and computational modelling) are undertaken to establish where losses may occur, the scale of loss and the major pathways (establishing their relative importance) for agricultural litter to enter the marine environment.

4.5. Fly-tipping/illegal dumping

In England during 2018/19, local authorities dealt with over 1 million fly-tipping incidents, an increase of 8% from 2017/18, which in turn has shown an annual increasing trend since 2011/12 (DEFRA, 2019c). In Wales the number of fly-tipping incidences steadily decreased from 54,841 in 2006/07 to 31,713 incidences in 2014/2015, and remains fairly static around this figure (Welsh government, 2020). By weight, it is estimated that around 42,000 tonnes of waste is fly-tipped or illegally dumped annually in Wales (Natural Resources Wales, 2021). Recent estimates are lacking in Scotland, however figures from 2013 indicate that ~ 26,756 tonnes of waste is illegally fly-tipped/dumped each year from an estimated 61,227 incidents (Zero Waste Scotland, 2017). This is estimated to have decreased in recent years, however changes to the reporting system mean that data is not directly comparable. It is important to note that across the UK, incidents occurring on private land are not adequately recorded and so the quantities reported below may be underestimates (Table 3).

Consistent between years, the most common place fly-tipping occurred was on highways, with ‘footpaths and bridleways’ and council land being the next most numerous area where fly-tipping events were recorded in England and Wales (DEFRA, 2019c, Welsh government, 2020), while in Scotland the order was reversed with council land being the most common location (Zero Waste Scotland, 2017). The large majority of items are categorised as ‘household’ including old furniture, carpets, waste from DIY work and house and shed clearances.

During the interviews undertaken for this report, several of the respondent indicated that the fly-tipping occurred most frequently within residential and rural areas, and noted that the frequency of incidents have increased during 2020 (Figure 2), likely associated with COVID-19 pandemic (see section 14.1.5).

Table 3. The frequency of fly-tipping/illegal dumping incidents in England, Wales and Scotland between 2013 – 2019.

Year range	Frequency of incidents, England[1]	Frequency of incidents, Wales[2]	Frequency of incidents, Scotland[3]
2018/19	1,072,000	35,076	-
2017/18	998,000	35,434	-
2016/17	1,011,000	38,614	-
2015/16	936,000	36,259	-
2014/15	906,000	31,713	-
2013/14	858,000	32,934	61,227
Sources: [1](DEFRA, 2019c), [2](Welsh government, 2020), [3](Zero Waste Scotland, 2017)			

Figure 2. Examples of fly tipping recorded in urban residential areas during March 2021 by Wyre Council

Summary: Fly-tipping sources

- Fly-tipping incidents have been relatively stable across the UK but anecdotal evidence indicates fly-tipping has increased in frequency due to the COVID-19 pandemic.

Data deficiencies

- Challenges assessing the extent of fly-tipping on privately owned land and in rural areas.

5. Mode of littering

Terrestrial borne litter may enter the environment through different mechanisms, termed 'mode of littering'. There are numerous social/behavioural factors which may influence littering however detailed discussion of these factors are not within the scope of this report and several studies have been conducted on this topic (Zero Waste Scotland, 2012, Tehan et al., 2017, WRAP, 2020). Determining the motivations which led someone to litter are problematic, and the distinction between the three categories listed below (a-c) can be difficult to ascertain in certain situations, presenting challenges when trying to estimate the proportions of littering attributed to each category.

Three categories are defined for the way littering can occur:

a) **Intentional littering**: this is the deliberate action of releasing litter into the environment which is a criminal act, for example dropping items in the street, or fly-tipping and dumping of items.
b) **Unintentional littering**: This occurs when items accidentally enter the environment, or where release is uncontrolled. For example, material which falls from overflowing bins. Unintentional littering can also occur where bin infrastructure is not fit for purpose, for example litter bins with wide/open apertures can allow litter to blow out. Bin and bags may also be raided by wildlife, such as rats, foxes or seagulls, leading to the uncontrolled release of litter items.
c) **Unconscious littering:** A third and more nuanced mode of littering exists, which we term 'unconscious littering'. Take the example where litter is placed on, or next to a full waste bin. Here it can be inferred that the consumer had the correct intentions to dispose of their litter in a waste bin; however due to the bin being full they were not able to place the item inside, and instead inappropriately disposed of the item outside, albeit near to, the waste receptacle. This form of littering is a criminal act under the Environmental Protection Act.

6. Pathways of terrestrial litter into the marine environment

There are a multitude of pathways by which terrestrial borne litter may enter the marine environment, which include transport via rivers, wind, sewage discharge or overflows, scavenging by wildlife, as well as direct input by the public or due to the lack of waste facilities (Nollkaemper, 1994). Items may be distributed differently according to their properties such as material type/density, size, shape and propensity to become waterlogged. Understanding the pathway of entry from land to sea is important in order to assess and focus measures to reduce marine litter.

6.1. Rivers and inland waterways

Rivers and waterways can act as pathways which transport litter towards the marine environment, or as a sink where litter can become retained or temporarily stored to be released at a later date or after physical degradation (Hoellein and Rochman, 2021). Modelling indicates that ~80% of the global land area is in watershed that drains directly to the ocean (Lehner and Grill, 2013), and as such waterways are considered to constitute a major pathway for the emission of terrestrial borne litter into the marine environment (Lebreton et al., 2017).

The quantities of litter within rivers can depend on a number of factors, including the population density and level of urbanisation and industrialisation in the catchment area (Lechner et al., 2014, van der Wal et al., 2015). Additionally the transport potential of rivers are influenced by a number of factors, including vegetation, river discharge and morphology, rainfall rate, and the presence of anthropogenic structure e.g. weirs and dams (Liro et al., 2020, Mani et al., 2015). Litter contained within rivers and canals may have been dropped directly by recreational users (*intentional or* *unintentional littering*), may have fallen from or been blown from litter bins in the surrounding areas close to the waterway, as well as being carried in the river from upstream areas (*unintentional littering*).

The role of rivers in transporting lightweight plastic litter has received increasing attention in recent years, with other types of litter largely unconsidered. Attempts have been made to assess the flux of plastic litter entering the ocean from different rivers. For example, the Saigon River in Vietnam, is estimated to emit $7.5 \cdot 10^3$ - $13.7 \cdot 10^3$ tons of macroplastics per year (van Emmerik et al., 2018). Considering only plastics between 300µm – 25 mm in size, the estimated transport amounts to 20-30 tonnes/year for the River Rhine into the North Sea, 500 tonnes/year for the Danube into the Black Sea and 120 tonnes/year emitted into the Mediterranean sea from the River Po (van der Wal et al., 2015). Over a global scale, rivers are estimated to emit between 0.4 – 2.75 million tonnes of plastics into the ocean each year (Lebreton et al., 2017). However model estimates such as these have large uncertainties associated with the lack of empirical data on riverine plastic litter, and they also fail to assess litter comprised of other material types such as glass, paper and metal, and as such may lead to underreporting of rivers as a litter transport pathway. As such the flux of litter transported by rivers and other inland waterways remains challenging and incomplete.

The River Thames, the largest river in the UK, has been studied in terms of its litter composition for many years. Recent surveys have identified plastics on every section of river surveyed, with an average of 322 pieces/100m (Thames21, 2020). The Port of London Authority has operated a 'driftwood service' which collects around 250 tons of debris (natural and man-made) each year from the tidal Thames. Examining footage from time-lapse cameras fitted onto passive debris collectors located within the Thames tidal estuary indicated that plastic bottles (*public-related source*) accounted for half of all the litter (excluding manufactured wood) recorded (Tysall, 2016). Further studies in the Thames found that much greater quantities of macro-plastics were transported in the surface waters than on the riverbed (Bernardini et al., 2020).

An average litter density of 3.79 items/m² were recorded along Willow Brook, an urban tributary of the River Soar, which passes through Leicester City (Gabbott et al., 2019). The authors identified a high prevalence of metal items (e.g. drinks and food cans) in the channel compared to the surrounding river banks. They suggest rivers can be important pathways for high density objects which can be transported through rolling and saltation along the river channel (Gabbott et al., 2019).

Surveys of 15 UK locations during December 2018 - January 2019 undertaken by the Canal and River Trust calculated that over 1562 items of plastic such as bottles, food packets, and bags, leave UK waterways and head towards the sea each day, which equates to > 500,000 items/year (Canal and River Trust, 2019). While such extrapolations are useful to estimate annual flows, care is needed when making such broad scale assertions due to the high variability of litter transported as a function of river discharge rate, rainfall, levels of urbanisation and industrialisation within a catchment, river morphology and season (van Emmerik et al., 2019) and the lack of monitoring data to validate these estimates.

Summary: Rivers as a pathway

- Compared to other pathways, rivers are relatively well-studied.
- Globally, rivers appear to be a relatively major pathway for terrestrial litter to enter into the ocean.

Data deficiencies

- Estimates quantifying the flow of litter in UK rivers (as implemented in other countries) is largely lacking.
- Monitoring of litter in rivers coupled with modelling approaches would yield valuable data on the role of rivers and waterways as a transport pathway within the UK.

6.2. Wind

The dispersal of litter by wind has been considered within the marine setting, with a number of studies from different geographies indicating relationships between wind (direction and force) and the abundance and types of litter present on beaches (Blickley et al., 2016, Ribic et al., 2010, Schoneich-Argent et al., 2019, Kako et al., 2010, Turrell, 2018). These studies conclude that wind has a function in the beaching, remobilisation and transport of litter, and particularly light weight (i.e. plastic) items. By contrast, there are a lack of data investigating the influence of wind on the transport of terrestrial litter to the ocean.

Litter may blow out of bins and in parts of the UK public bins have been designed or modified to reduce this from occurring (Keep Britain Tidy, 2015, WRAP, 2020). WRAP issued guidance on ensuring bin designs are fit for purpose particularly in coastal/waterside locations and in public open spaces where wind may remove litter from bins (WRAP, 2020). To issue guidelines and implement design changes indicates that wind removal of litter must be a problem, however there are a lack of reports evidencing this, or how effective these measures are compared to the previous designs.

The lightweight nature of plastic material means that, in terrestrial systems, items have the potential to be transported by wind over large areas. In the Namibian desert plastic bags and balloons can be wind dispersed > 2 km into remote desert regions (Zylstra, 2013). Anecdotally, wind greatly influences the movement of plastic litter. In Namibia, 75% of people interviewed identified that wind as responsible for distributing plastic litter, with the majority stating that this caused a major problem for tourism and business (Richter, 2021, pers. comm.). In the UK, interview respondents from local authorities also identify that wind is a large contributor to the dispersal of litter in the environment, particularly light weight plastic and card/paper recycling (see section 14.1), with one respondent stating "it was literally Armageddon when the wind was strong, [the bins would] blow over and then you'd see this on the beach". The varied geography and prevailing winds over the UK may cause regional differences in wind-dispersed litter, which warrants further investigation.

Summary/Data deficiencies: Wind as a transport pathway

- The role of wind as a transport pathway for litter is unquantified.
- Anecdotal evidence indicates wind can have a substantial contribution to dispersing litter.
- Further research (empirical and computational modelling) is required to assess the role of wind at dispersing and transporting litter into the marine environment within different regions of the UK.

6.3. Weather events and coastal erosion

There is a general lack of empirical data regarding the effect of weather events, such as floods, storms and extreme winds, at transporting terrestrial litter into the marine environment in the UK. Most information exists about flooding as a dispersal pathway for litter, than for other extreme weather events. Flooding of river and other inland waterbodies may have complex effects on litter acting to both distribute items above the river bank where they can be stored, as well as scouring and removing debris. Riparian zones are the main interface between terrestrial and freshwater systems. Litter can be temporarily stored here, for example during floods light-weight plastic litter can deposit above the riverbank, especially if riparian vegetation increases retention. However this can be transported by wind and rain back into the river, or may mobilise during the next flood event. Surveys around a tributary of the River Soar, Leicester indicated a different composition and much higher density of litter trapped in riparian vegetation (19.58 items/m^2) than in the river channel itself (3.79 items/m^2) (Gabbott et al., 2019), which could be mobilised during high flow or flood events. Indeed, floods have the potential to remove substantial quantities of plastic litter. The 2015/2016 winter floods in the United Kingdom were found to scour riverbeds and transport around 70% of the microplastics which were stored within their sediments (Hurley et al., 2018). During this flood event an estimated 0.85 ± 0.27 tonnes of microplastics were scoured and removed from channel bed storage in the upper Mersey and Irwell rivers (Hurley et al., 2018). The same estimates have not been undertaken for macroplastics, or litter composed of other material types (metal, glass, paper), making it challenging to quantify the role of seasonal flooding as a transport mechanism for terrestrial litter to enter the ocean. It is also important to consider the role of flood defences in capturing litter; a global assessment indicated that in certain countries flood defences can effectively reduce plastic mobilisation (Roebroek et al., 2021). Thus it cannot be assumed that all of the plastic, and more broadly litter, mobilised during a flood are deposited in the marine environment.

Historically landfills were frequently located on low-lying floodplains and coastal plains, and are therefore at risk of fluvial and coastal flooding and erosion. Over 1200 historic coastal landfills are identified in England, and the erosion of several have been identified in England, e.g. East Tilbury in the Thames estuary (Brand et al., 2018). This can cause the physical mobilisation of solid waste into the marine environment, as has been reported in Lyme Regis (Pope et al., 2011).

Internationally, studies have found that tsunamis can cause large scale release of terrestrial debris into the ocean (Lebreton and Borrero, 2013, Maximenko et al., 2018). While these devastating events are infrequent, they can contribute the equivalent of thousands of years' worth of 'normal' litter emissions in a single pulse event (Lebreton and Borrero, 2013).

Despite the lack of quantifiable evidence to estimate the relative importance of flooding, coastal erosion and other weather events, the frequency and intensity of floods in the UK have increased over the last century (Stevens et al., 2016, Environment Agency, 2013) and are expected to continue on this trajectory largely as a result of climate change. Coastal erosion may also become more frequent as sea levels and storms are predicted to increase (Environment Agency, 2013, MCCIP, 2020). As such the UN predicted that extreme weather events currently contribute only a 'low importance' to terrestrial litter losses, however increase this rating to a 'medium importance' given future climate change impacts (UN Environment, 2018).

Summary: Extreme weather as a pathway

- Extreme weather, such as flooding and erosion are shown to mobilise and transport litter.
- As extreme weather events increase due to climate change, their role in transporting litter into the UK marine environment may also become increasingly important.

Data deficiencies

- Limited empirical data on the effect of extreme weather events on the mobilisation and transport of litter in the UK, hindering the ability to quantify this pathway.
- Lack of data assessing the effect of flood or erosion defences at preventing terrestrial litter from reaching the marine environment.
- Further research is recommended to examine the current and future effects of weather events in mobilising litter.

6.4. Sewage

Products such as cotton buds, sanitary products, condoms, nonwoven (wet) wipes and dental floss, that are inappropriately disposed of down the toilet may enter the marine environment via waste water from domestic sources. In some reports sewage debris is categorised as a source (Marine Conservation Society, 2019a, OSPAR Commission, 2010), however it is important to note that the original source is from the public and the sewage system is the means of transport.

Wet wipes are among some of the most commonly found items on UK beaches (Marine Conservation Society, 2019b) and river catchments (McConville et al., 2020), and within the River Thames quantities of sanitary waste were higher around sewage outflows (Morritt et al., 2014) indicating that the sewage system is an important emission pathway for particular items.

Disposal of items (primarily wet wipes and menstrual absorbent products) are a considerable component of accumulations and blockages within sewer systems. Analysis of sewer pipe blockages at selected UK sites, indicated that 94% of the material causing the blockages were identified as wipes and 2% as sanitary items (Water UK, 2017). In London alone, Thames Water clears around 65,000 blockages/year (Thames Water) and removes over 1500 tonnes of material per treatment site annually (Thames water, 2021). Such blockages are costly to fix and according to the UK water industry the sum can reach £88 million per year. Blockages or very high sewage flow conditions can cause overflows which may lead to the release of crude sewage and other debris contained within the waste water. While figures of sewer blockages indicate that input through the deliberate yet inappropriate disposal of flushable items (attributed to public-sources), the quantities subsequently entering the environment via this pathway are not altogether clear. WWT works have screens to remove large debris along with numerous treatment stages to remove other material, and have been shown to effectively remove microplastics with 88 – 98% efficiency (Bayo et al., 2020, Blair et al., 2019, Iyare et al., 2020, Murphy et al., 2016). There is a notable lack of data providing similar estimates for the flows of large debris through WWT facilities preventing an evaluation of this pathway, comparison to others and estimation of the efficacy of WWT works at intercepting litter.

Summary: Sewage system as a pathway

- The sewage system is a pathway for specific public-related items inappropriately disposed of via the toilet/sink, to enter into the environment.

- Data indicate there are substantial economic costs and potential health risks, associated with removing blockages caused by ‘flushable’ product.

Data deficiencies

- The quantities of macro-litter items i) entering and ii) being emitted from wastewater treatment facilities are not estimated, presenting challenges quantifying the role of this pathway.
- studies required to examine the inflow and outflow of macro-litter to evaluate their efficacy at intercepting litter and where further interventions could be implemented

6.5. Rain runoff and storm overflows

Periods of heavy rainfall can mobilise terrestrial plastics dispersing them into rivers (Lebreton et al., 2017). Storm water overflows transport surface water run-off from gutters, drains and some highways into sewerage system and directly discharge this into rivers and the sea, bypassing waste water treatment works. The design of combined sewerage systems means that foul water can also be discharged from storm water overflows during periods of intense rain. There is statutory reporting of these events by the water industry, and authorities provide publicly available online information e.g. the Coastwatch map run by Wessex water (Wessex water, 2021). In England during 2019 there were over 204,000 overflow events (Carver, 2020), yet it is not possible to estimate the volumes of raw sewage discharged in these incidents. Estimates of raw sewage discharge are available for the River Thames, where ~ 39 million tonnes of raw sewage flow into the River Thames annually, via storm water overflows (Carver, 2020). In addition to sewage, road and tyre wear particles have been identified in the environment and indicating their transport via storm water overflows (Horton et al., 2017, Parker-Jurd et al., 2019, Unice et al., 2019), however further analysis of these small particles are outside the scope of this report.

While storm drains are fitted with a grating to prevent blockages from large debris, flexible materials such a films, plastic bags and packets, may be able to pass through the screens. Additionally anecdotal evidence indicates increased litter on beaches following storm events where large deluges of water cause sewage and storm drain systems to be flushed (see section 14.1). In Australia, storm drains were identified as a major contributor to litter (Cunningham and Wilson, 2003), however in the UK the extent of large debris transported by storm drains remains unquantified and still largely unexplored.

Summary/Data deficiencies: Rain runoff and storm drains as a pathway

- Lack of data on the amount of litter transported via rain runoff and storm water overflows, which prevents quantifying this pathway.
- Research required to develop knowledge and provide a comparative assessment with other pathways.

6.6. Scavenging by wildlife

There is an absence of data and literature examining the effect of wildlife on the dispersal of litter, however anecdotal evidence (see section 14.1.2) and newspaper reports indicate urban wildlife removing litter from bins and ripping open bags is undoubtedly a country-wide problem (Rougvie, 2020, Smith, 2021, Britten, 2019). Numerous councils issue advise to prevent wildlife from attacking and ripping open waste bags (Aberdeen city council, Cheltenham Borough council, Plymouth city council) and some city councils have installed 'seagull safe' covers on their public bins to prevent seagulls from removing litter from the bins (P&G Blacksmiths, East Devon district council, 2020). Fisherman surveyed in Scotland and the South West of the UK, as part of the Fishing for Litter scheme, indicated that seagulls attacked and ripped open bags at fishing ports (Wyles et al., 2019), and consequently lightweight litter (e.g. plastic items) was able to blow around the quayside and into the water. As such seagulls and other wildlife may constitute an unintentional mean of release whereby uncontained litter scavenged by animals could become spread further by wind and rain, thus entering the marine environment.

Summary: Wildlife as a litter pathway

- Anecdotal evidence indicates scavenging by wildlife is a problem in urban areas.
- Wildlife may be an underreported and largely overlooked 'pathway' not considered within the literature, by which litter enters into the environment.

Data deficiencies

- Further research should be undertaken to quantify the role of wildlife in litter dispersal, which could inform interventions (e.g. bin design, public awareness).

7. Results from the structured interviews with local authorities

Local authorities were contacted directly, via e-newsletters disseminated by the professional networks LARAC and Keep Britain Tidy, and via a network query to members of APSE. The aim was to recruit three individuals from at least five authorities in the UK, however take-up rates were low and a total of 13 individuals from 10 local authorities participated in the structured interviews. Individual job titles varied between participants, but included roles leading street cleansing, kerb side and residual waste collection, waste crime enforcement and litter and hazard patrols of inland and coastal areas. Participants had between 2 to 16 years' experience within their roles. Despite the low response rate some valuable insights were obtained. While the perceptions of the individuals cannot be generalised across the entire UK, these preliminary interviews served to highlight where additional quantitative research could be undertaken.

The main factors which respondents identified as contributing to terrestrial litter emissions were public behaviour (including overfilling and misusing waste bins, failure to dispose of domestic and commercial waste/recycling correctly, inappropriately containing waste and the general attitude of the public to litter), scavenging by animals and dispersal by wind. In addition several respondent indicated that rain would carry ground litter into drains or water courses. There was a scarcity of empirical data considering the role of wind (section 6.2), rain (section 6.5) and scavenging by wildlife (section 6.6) on the dispersal of litter, and the results of the preliminary survey indicated these may be potentially overlooked pathways which should be prioritised for further study.

One respondent from a rural county counsel stated that in their opinion, agricultural sources contributed the greatest quantities of litter over an annual cycle within their area.

The effects of the COVID-19 pandemic varied, with several local authority members stating there was less roadside litter as there were fewer vehicles, but that waste/litter in public and recreational areas had increased by as much as 2.9-fold in some areas, based on the authority's waste collection data.

Further, respondents made several suggestions of where, in their professional experience, they perceive that interventions could be made to reduce litter entering the environment. These included more/better waste-crime enforcement; increased education surrounding the appropriate use and containment of household waste and its timely presentation for collection; national support for local authorities to clean waterways which pass through their region (currently outside of their statutory duty); and a large-scale national endeavour (similar to the campaigns to increase seat belt use) to alter public behaviour and perceptions on littering, including that disposing of waste via overflowing bins or placing these next to bins constitutes as littering.

Some individuals also remarked on successful interventions in their region, such as separate food waste collections which has reduced animal scavenging and the redesign of on-street and household bins which has reduced litter being attacked and dispersed by wildlife and the wind.

More detailed responses to the interviews are provided in the Appendix (14.1).

8. Evaluation of terrestrial litter sources

Quantities and sources of litter can vary between geographic regions and land-use types. The extent of data varied for each of the five different sources considered within this report.

Based on quantitative data available and the insights obtained from the structured interviews, public-sources were identified as the major contributor to litter and dominated the composition within urban (Resource futures, 2019, Keep Britain Tidy, 2020), riverine (Gabbott et al., 2019, McConville et al., 2020), recreational (CPRE, 2020) and coastal (Marine Conservation Society, 2019a) environments (Table 2). While medical sources of litter have increased in the UK as a results of the COVID-19 pandemic, overall medical sources still remain low when compared to quantities of public-related litter (CPRE, 2020, Planet Patrol, 2021), for example masks/face coverings were the 15th most common litter item logged in 2020, with drink bottles and food packaging far more numerous in their abundance (Planet Patrol, 2021).

Limited data indicate the presence of industrial litter in the environment (McConville et al., 2020, Resource futures, 2019) and there is a deficiency of information regarding agricultural sources of litter; thus estimating the quantities emitted from these sources into the environment and subsequently transported into the sea are currently not possible.

The reporting of fly-tipping events occur in a different manner to routine litter monitoring. Incidents occurring on private land or in remote rural location may also go unreported meaning figures may be underestimates. These factors provide challenges when comparing emissions from fly-tipping with other sources. Finally, while fly-tipping generates large volumes of waste in very specific locations, there are no data regarding the proportion which remain in the environment or which can be transported to the marine environment.

It is clear that monitoring is required and should be focused on addressing some of the data deficiencies identified within this report, namely considering industrial and agricultural sources of litter, while continuing to build evidence on the quantities of public, medical and fly-tipping litter in different environments and land-use areas.

Citizen science initiatives can be useful in generating data; members of the public may routinely (e.g. dog walkers) or recreationally interact with their local environment and may be able to collect data more frequently or over increased temporal scales than formal monitoring. Additionally the wide network of the public participating in events, such as the MCS Great British Beach clean, gives a much broader regional coverage than could be achieved by individual scientists. Citizen scientists may visit areas/land-use types which have been under-sampled previously, for example rivers and park land, where knowledge of litter is lacking. Harnessing citizen scientist is therefore a powerful tool to gain more extensive data on local, regional and national quantities and sources of litter. A final consideration is that the benefits of participating in citizen science projects transcends data acquisition, and can in itself act as an empowerment and awareness raising tool to tackle littering (Kelly et al., 2020, Locritani et al., 2019).

9. Evaluation of the pathways for terrestrial litter into the marine environment

Quantifying the transport of litter from land to sea in the UK, via different pathways is hindered by fundamental knowledge gaps and a lack of empirical evidence on the different pathways. This is further complicated as many pathways may all contribute towards the transport of a single item, for example, scavenging by wildlife may remove litter from a bin or bag which may then be blown into a river before being transported into the ocean.

Based on the information collated within this report and the qualitative insights obtained from the structured interviews, a logical mapping exercise was carried out to examine the most likely pathways for different sources of litter to reach the marine environment (Figure 3). This approach facilitates the identification of which pathways may contribute a greater potential to transporting litter (overall and each source separately) from terrestrial to marine environments, and where potential interventions could be made.

The mapping exercise was useful to indicate that public-related litter, which is the most commonly identified source in urban, riverine and coastal environments around the UK (see section 4) has the potential to be distributed via the greatest number of pathways compared with other sources. Transport via wind and rivers may also play a role in distributing all sources of litter, while scavenging by wildlife and transport via storm drains are only likely to be pathways for specific sources. The sewage systems is primarily a pathway for public-sources, emanating from the improper disposal of items (e.g. wet wipes, hygiene products, cotton bud sticks) down the toilet, while is an improbable route for industrial and agricultural litter.

Qualitative data indicated that wind and scavenging by animals may be large contributors to litter emitted into the marine environment, however there are no scientific studies to corroborate this. This report highlights that quantitative data on the different litter pathways is severely lacking and it is recommended that both empirical and modelling studies should be designed to examine the role of different pathways at distributing terrestrial litter into the marine environment.

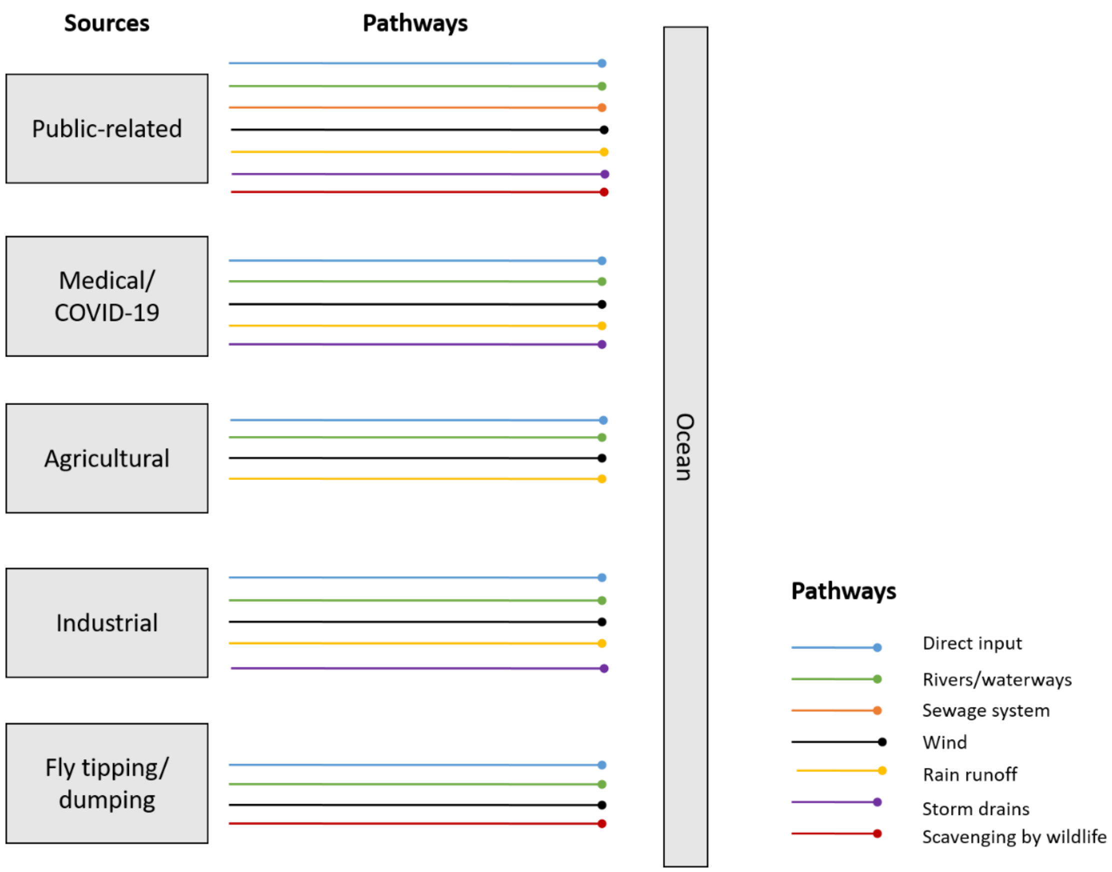

Figure 3. A simplified schematic illustrating the pathways (colour coded) by which terrestrial litter arising from different sources may be transported into the marine environment.

10.Emerging challenges: biodegradable plastics

While biodegradable plastics occupy a very low market share (~0.3%) of overall plastic production (European bioplastics, 2021), over recent years their use in a number of applications have increased. Biodegradable plastics are most widely used in agricultural settings, packaging or other consumer products such as wet wipes and to-go food containers (SAPEA, 2020, Steinmetz et al., 2016, Dilkes-Hoffman et al., 2019, APE Europe, 2020).

Approximately 1% of plastics used in agriculture within Europe are described as 'biodegradable' (APE Europe, 2020). Developing understanding of how agricultural litter composed of biodegradable plastics may be transported into marine ecosystems is necessary to evaluate the biodegradation of these polymers within different parts of the open environment and evaluate the fate of this material.

Research indicates that consumers perceive items which are labelled as biodegradable/compostable to be more environmentally friendly than conventional plastics (Herbes et al., 2018), despite evidence that many plastics that are labelled as biodegradable do not readily biodegrade in the natural environment (SAPEA, 2020, UNEP, 2015, Napper and Thompson, 2019). As such biodegradable plastics do not offer a solution to littering; they must be disposed of through the appropriate managed waste streams, however due to misunderstanding of their labelling there is consumer confusion about the correct disposal of these items (Taufik et al., 2020). Research shows that the general public find it more acceptable to drop items composed of biodegradable plastics than non-biodegradable plastics because it is thought they are less harmful for the environment (Dilkes-Hoffman et al., 2019) and people surveyed reported a greater likelihood of doing so themselves (Zero Waste Scotland, 2012). There is a lack of empirical evidence on the quantities of the public-related sources of litter which are composed of materials labelled as biodegradable/compostable/bioplastic, however monitoring studies should consider adding these details as effective monitoring of the extent of biodegradable plastics can contribute towards the identification of suitable interventions to prevent this form of litter.

11.The impact of the COVID-19 pandemic on litter

Since the COVID-19 outbreak in late 2019, regulations in many countries globally recommend the use of personal protective equipment (PPE). In some countries, although not in the UK specifically, the use of disposable items (e.g. cutlery, containers, cups, bags) for restaurants and businesses to operate safely has also been recommended. In addition to the increase PPE litter directly attributed to medical sources (detailed in section 4.2), Thames21 also report that the pandemic seemed to be driving an increase in other public-related single-use plastics litter (Thames21, 2020). During the survey period July to September 2020, 1600 plastic cups were recovered, which was twice as many as the same period in 2019, despite that pubs and restaurants were closed for the four months prior to conducting the surveys. The assessment also found that plastic bottles were more widespread than previous, with 92% of the stretches of the Thames surveyed containing plastic bottles (Thames21, 2020). Citizen scientists logging litter via the Planet Patrol app recorded significantly more metal drinks cans and plastic bottles during 2020 than in 2019 (Planet Patrol, 2021), while this cannot be directly attributed to the pandemic, the findings are in line with other studies and reports.

The pattern of land use by people also altered as a consequence of the pandemic. Surveys carried out by CPRE showed that on average a third of people visited parks and countryside more frequently than they did before, while more than two-thirds of people visited town centres/high streets less frequently (CPRE, 2020). This shift in where people spend more of their time appeared to alter litter distributions, with virtually no litter observed in city centres during the early parts of the UK lockdown, from March 2020 (CPRE, 2020). However, local parks saw a marked increase in public-related litter, particularly drink and food containers and disposable barbecue trays. Within Essex the surge in people frequenting open spaces (parks and beaches) saw bins overflowing with litter, and while many local authorities increased the frequency of bin emptying they could not keep up (CPRE, 2020). CPRE report that one Essex coastal authority remarked that the deluge of litter could have been “a direct consequence of restaurants and cafes being closed for indoor eating. This meant many people ordered takeaways or bought picnics from nearby supermarkets, with the discarded packaging, cans and bottles ending up on the beaches” (CPRE, 2020).

Reports of fly-tipping in some locations have increased by 300% during periods of lockdown (March – July 2020) (Countryside Alliance, 2020). During the interviews conducted for this report, all of the local authority employees stated that they have noticed increased amounts of fly-tipping during the pandemic (section 14.1.5), with one respondent indicating that on average during 2020 they had 18 more incidents/month than in 2019.

While media coverage portrays large quantities of littered PPE, we must place this in the context of other litter. By no means does this report conclude that PPE is not contributing to litter, indeed the presence of PPE litter has increased, however it is important to note that PPE comprises only a small proportion of total litter derived from all sources and may only represent a relatively short-term spike in the background patterns of data.

12. Interventions to reduce terrestrial litter

Interventions to reduce terrestrial litter have primarily been directed at tackling plastic items and in particular those with 'single-use' applications. The nationwide introduction of the 5 pence plastic bag taxation the sale of bags have dramatically decreased (Welsh Government, 2019, DEFRA, 2020b). A 40% decline has also been observed in the abundance of bags reported on UK beaches following the ban in all home nations (Marine Conservation Society, 2016) and a similar decrease was also noted during seafloor surveys (Maes et al., 2018).

Following awareness campaigns, a number of UK retailers pledged and began to phase out plastic stemmed cotton buds. Additionally following public consultation governments are introducing legislation to ban plastic-stemmed cotton buds (Scottish Government, 2019, DEFRA, 2020c). Through a combination of public awareness, policy and a shift in industry, the abundance of plastic cotton bud sticks have decreased on UK shorelines. In 2017 cotton bud sticks were the 8th most commonly recorded litter item in the MCS annual beach clean (average of 27 items/100 m) (Marine Conservation Society, 2017), while in 2019 cotton buds were only found on a total of 8 UK beaches (Marine Conservation Society, 2019a).

As highlighted within this report understanding the specific items, sources and pathways by which they enter the marine environment are fundamental to design effective intervention strategies. So too are continued monitoring within strategic environments – either within the pathway or the receiving environment. For instance, ongoing monitoring of beaches, rivers and WWT facilities (pathways and receiving environments) will help assess the success of European legislation to standardise labelling of wet wipes (European Commission, 2021), which aims to change public behaviour to prevent disposal of wet wipes down the toilet.

The UK consumes ~14 billion plastic drinks bottles each year (Defra, 2018c) and although they are fully recyclable the current recycling rates are low. Plastic bottles are regularly recorded on UK shorelines (Nelms et al., 2017), urban areas (Keep Britain Tidy, 2020) and feature within the top three items recorded in rivers regionally, nationally and internationally (Planet Patrol, 2021, McConville et al., 2020, González-Fernández et al., 2018). The UK Resource and Waste Strategy aims to move away from a linear economy towards a circular approach, and to generate zero avoidable waste by 2050 (Defra, 2018b) and as part of this are proposing the introduction of a deposit return scheme (Defra, 2019b).

The European Directive on single-use plastics calls for a ban on food and beverage containers made of expanded polystyrene and more sustainable alternatives for food containers, beverage containers and food packets and wrappers (European Union, 2019). Additionally the UK government is consulting on introducing an extended producer responsibility scheme for packaging, with the aim of encouraging producers to use less packaging, opt for more recyclable materials (Defra, 2021). Ongoing monitoring within the urban and natural environment is required to assess the efficacy of these measures.

This is by no means an exhaustive list of current or proposed interventions aimed at reducing terrestrial litter. A combination of approaches including legislation, financial incentives/penalties, behavioural change and education can work in synchrony to bring about change to current litter issues (Xanthos and Walker, 2017, Hartley et al., 2018a). In all cases ongoing monitoring should be undertaken to evaluate the success of these strategies.

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14. Appendix

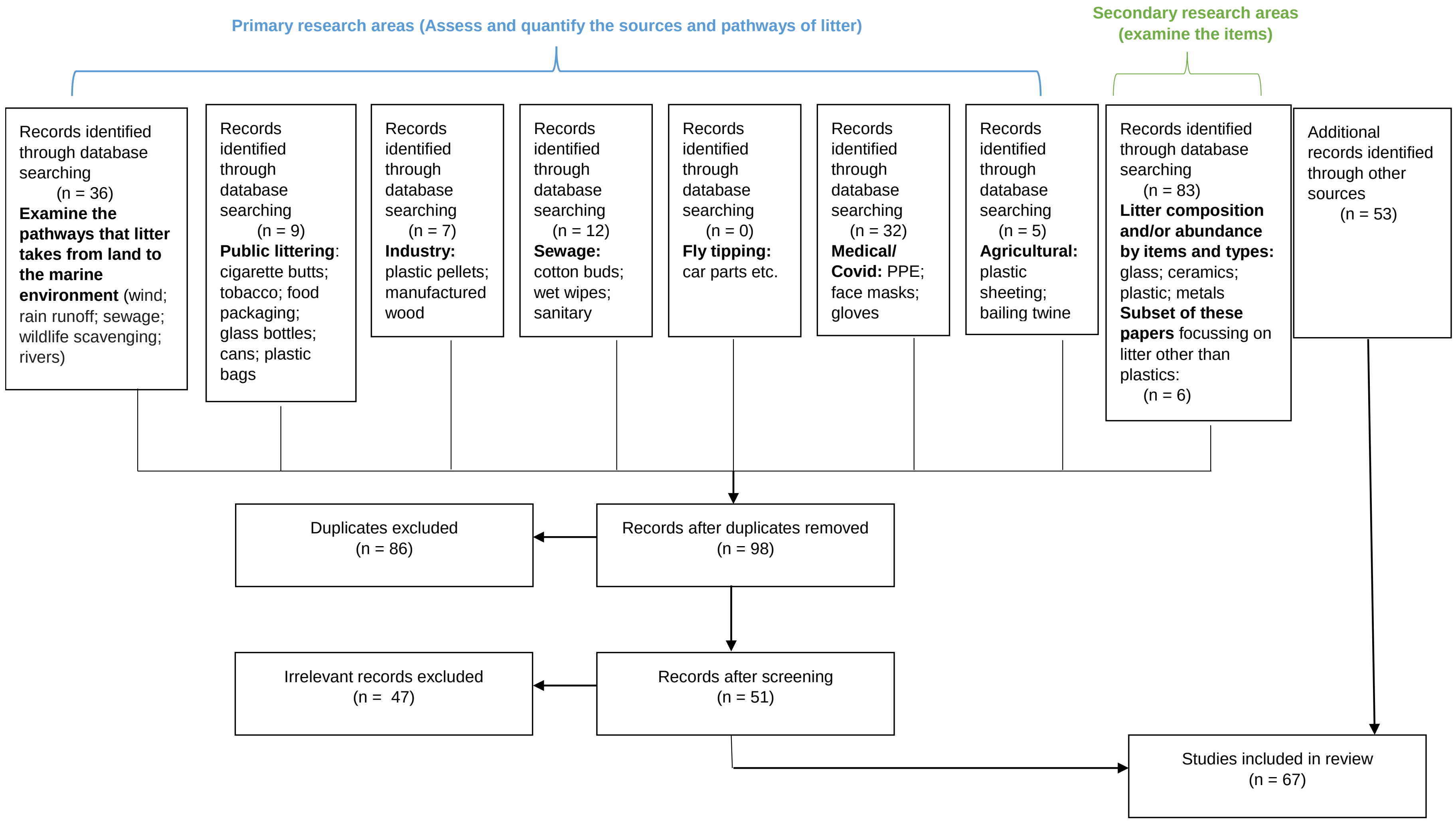

Figure A1. A framework illustrating the numbers of peer-reviewed studies discovered through the literature search process for each broad research area and the number of records identified through other sources.

Table A1. Summary and examples of the definitions of sources, mode of littering, transport mechanisms, and pathways of litter into the (marine) environment adopted by different organisations and reports.

Report/publication & reference	**Terrestrial source: description and categories given**	**Mode of littering**	**Transport Pathway**
Marine Strategy Framework Directive, Technical group on Marine Litter (Veiga et al., 2016)	The economic sector or human activity from which litter originates. e.g. public; coastal tourism; waste management;	The mechanism or the way in which a given item leaves the intended cycle and/or enters the natural or urban environment. e.g. improper disposal, littering, overflowing bin	Physical and/or technical means by which litter enters the marine environment. e.g. sewage system, river, wind, direct input
OSPAR, beach monitoring guidelines (OSPAR Commission, 2010)	OSPAR uses indicator items from different sources, e.g. Sanitary and sewage waste; tourism & recreation;	Not recorded	Not recorded
Marine Conservation Society	Public related; fishing-related; sewage-related; fly-tipping; medical; non-sourced	Not recorded	Not recorded
(DEFRA, 2019d)	land-based (e.g. rivers; wastewater discharge, landfills; industrial, fly tipping), and sea-based sources (e.g. fishing and shipping)	Accidental release/loss; Illegal releases; Deliberate release; Uncontrolled releases	wastewater discharge; urban storm-water drains and combined sewer overflows; surface and sub-surface runoff; atmospheric transport; wind blow; rivers

14.1. Results from the structured interview

14.1.1. The perceived effects of weather on litter

When asked if they thought weather had any effect on litter, several respondents stated that wind was a big factor in their area, primarily dispersing waste intended for recycling, or lightweight plastic items. They identified certain areas of their city were more problematic than others and attributed this to those areas receiving more wind (along with the presence of more litter in lower socio-economic areas). One respondent indicated that their authority had changed the type of container for household recycling, as the small boxes which were used for plastics would blow over on very windy days and there would be a "noticeable increase of plastics in the sea on recycling days…. it was literally Armageddon when the wind was strong, it'd blow over and then you'd see things like household cleaning and washing liquid bottles, that you normally wouldn't see as beach litter, on the beach" (*unintentional littering*). The introduction of mixed recycling wheelie bins by the authority has seen a "dramatic reduction in the amount of visible litter on the streets after a recycling day; it's had the desired effect". Within a different area, changing to a monthly collection for card/paper recycling has made the bins heavier and has stopped them blowing over when they are put out for collection. Wind was also mentioned as a factor distributing litter in rural areas, where a lot of old litter is found in bushes/hedgerows.

Several respondents indicated an increase in public littering during sunny weather, in particular on weekends and bank holiday. This increase in footfall was reactionary to the sunny weather and gave local authorities little time to anticipate and ensure extra staff were in place. People bring more food and drink to the beach in sunny weather, which isn't in re-usable containers so they have no intention of taking it with home, stated one respondent, adding "the increase in litter is staggering, the bins are filled and misused".

It was also noted that in sunny weather, the smells emanating from food contained in residual household waste or from food residues on items intended for recycling (where packaging wasn't cleaned correctly), may increase the rate of scavenging by wildlife; this was particularly problematic where authorities used sacks rather than bins to contain household waste.

One interviewee stated "if it's wet and people go to a drive-through, they'll go to sit somewhere and dump a whole bag of [to-go food] out the [car] window" (*intentional littering*).

An individual from a coastal authority stated that they have issues when there is a storm and the utilities cannot cope with the amount of rainwater, causing the system to overflow and discharge grey and black water into the sea. This resulted in quantities of "sanitary waste, wet wipes and cotton buds" washing on the beach. They stated that recently the council has spent a lot of money on new storm drains and while it was too early to tell what effect this had had, they were optimistic that "there wouldn't be as many instances where we have a big flush out and part of it comes back ….But this used to be a regular occurrence, sometimes it looked like a bin wagon had emptied its contents on the beach".

A member of a rural council indicated that prolonged exposure to sun can break down farm plastic waste (e.g. silage wrap) into smaller pieces which makes them more mobile and more easily picked up by wind or washed into water courses.

14.1.2. The perceived effects of wildlife and domestic animals on terrestrial litter

Participants were asked a series of questions related to the interaction between wild and domesticated animals with kerb side and on-street bins. The majority of respondents indicated that seagulls were the primary animals scavenging at litter (although the perceived frequency differed between interviewees), one individual also remarked that they had observed rooks tearing waste bags open (*unintentional littering*). Within some of the urban regions foxes, squirrels and rats were identified as the main scavengers, while foxes in rural areas did not contribute a problem. Only one respondent indicated that domestic animals (cats) scavenged household bins.

One respondent stated that seagulls were a substantial problem ripping open side-waste [waste which is placed for collection outside (by the side of, or on top) of the normal container] and residual waste bags put out for kerb side collection and in certain areas close to the seafront where "every street you go down has bags ripped open by seagulls". They went on to say that in their opinion seagulls have the largest contribution to daily and annual quantities of litter released to the environment caused by the bags being ripped open. Once the bags are raided and the litter becomes uncontained there is a much greater challenge to clear this up as it "becomes scattered and it's blown by wind and attacked by more animals". Other respondents stated similar observations, where food waste which is contained within a plastic liner, or waste for recycling which is not cleaned appropriately are frequently raided, dispersing the contents which can be carried by the wind or which may go into guttering and enter the waste water system.

One council member stated since they introduced separate food waste collection the number of refuse sacks being scavenged had reduced.

Lidded bins for household waste were reported to reduce the frequency of seagull raids, with bins only being raided if the bins were overfilled and the lids would not close completely. The re-design of on-street bins has also "played a big part in keeping vermin attacking litter down" and now seagulls can only get at litter which has fallen out of the bins from people overfilling them. One respondent said that during summer months the frequency of bag of litter improperly disposed of next to on-street bins increases, which were often torn open by seagulls, and consequently during early morning patrols employees would often spend "quite a bit of time picking up stuff that was in a black bag but is now all over the promenade".

One council employee had noticed increased seagull attacks during their breeding season, and another noted a shift in the behaviour of gulls in line with changes to the area's waste management practises. They stated that since the introduction of wheelie bins for recycling and residual domestic waste, which are sorted at an indoor facility, the amount which gets landfilled has drastically reduced. Now that the landfill site is not being used the breeding and feeding grounds for the seagulls, they "have moved more inland, so now every property in the area I live in has seagulls nesting in the chimneys and they are tearing the side-waste bins…all over residential areas".

Overall, the perceived effect of wildlife scavenging varied considerably, with some respondents indicating this was a frequent and major problem in their region, while others considered that while it was uncommon for scavenging to occur, incidents did generate considerable litter released in to the environment.

14.1.3. The perceived effect of one-off events on litter

Individuals employed within kerb side collection stated that people just had a lot more rubbish out following one-off events (such as Christmas, bank holidays). To combat the increased waste over Christmas the authority deploys extra crews and wagons, but for other one off events like street parties no extra provision are made which can be hard to manage larger volumes of waste.

Several respondents indicated that while planned one-off events generate more waste they are tightly controlled and developing a waste plan including extra bins and post-event litter picking is required to obtain the necessary event licence. All stated that they perceive these measures as "very effective" ensuring litter does not remain in the environment, however acknowledge the challenges are caused by wind-dispersal. They identified that problems arose where there were non-authorised or 'pop-up' events which may get quite large in size and generate large amounts of litter for which additional support (i.e. provision of extra bins) has not been provided. Additionally, the council may not have advanced notification for some events organised by local schools, churches or organisation etc. which may pose litter challenges after the event.

One respondent stated that routine river monitoring enabled them to identify a direct link between the levels of river litter and local football matches, presumably dropped by supporters walking through the city on their way to and from the match.

One respondent commented that they were looking into biodegradable fireworks shells (see section 10) for their annual display.

14.1.4. The perceived effect of public behaviour on litter and littering

Public behaviour was cited by the majority of respondents as the biggest influencing factor for litter emitted into the environment over a daily and annual cycle. Slightly different aspects of public behaviour were identified as influencing factors by the respondents, including the sheer volume of litter generated by people, the general attitude of people to not dispose of waste correctly, failure to recycle correctly, the misuse of household and on-street bins, general littering and the seasonal (i.e. summer) influx of people to certain areas. Residential areas (particularly low socio-economic areas), around cafés serving food and drinks to-go, at the entrances/exits to public transport (e.g. subways) and at 'attractions' such as the seafront/promenade and local beauty spots were all cited as having particularly high levels of litter and littering behaviour.

Several respondents indicated that litter on roadsides was common in their area from people throwing items from the windows of moving cars, or from goods not being secured adequately and falling from commercial vehicles. Removing roadside litter is extremely challenging, particularly on arterial roads where substantial road closures are required for safety. This can result in litter being left on the roadside for long periods of time, causing aesthetic issues but also this can cause the litter to disperse further into the environment.

On-street bins and those in public areas

The majority of council employees interviewed stated that on-street bins are overfilled and/or misused by nearby houses, holiday houses/chalets and in some cases local businesses, who inappropriately use on-street bins to dispose of their refuse. In instances where bins were already full, respondents commented that member of the public still stuff bags in the mouth of the bin even when it's spilling out, leave bags of litter next to the bins (*unconscious littering*) (Figure 4). One respondent stated "there's plenty of bins out there, but they're not being used correctly" while another estimated that in certain areas ~60% of on-street bins were overfilled and consequently had litter spilling out of them. Overfull bins were noted to be a particular issue at 'pinch-points' like car park or promenade entrances and near to to-go food vendors, where bulky-packaging such as fish and chip containers, quickly filled litter bins. They indicated that litter spilling out of on-street bins could be raided by seagulls, further exacerbating the litter problem (see section 14.1.2).

Uncontained litter along with the contents of on-street bins are collected by street-cleansing teams, however challenges were identified in removing litter lying within 'non-adopted' residential areas which are privately, rather than council, owned. One council employee also identified that in certain areas having street-cleansing teams work full days over the weekends, which are busier than weekdays, could help manage the volumes of litter and the likelihood of items escaping from overfilled bins.

One respondent stated that there can be problems with people raiding bins, especially overfilled public clothing recycling bins.

Several respondents emphasised that the majority of people do use bins and should receive credit for disposing of litter appropriately.

The challenges to monitor and adequately remove litter from bins in rural areas or remote beauty spots was emphasised by a few respondents. They also stated that there are less frequent litter picking in rural areas than compared to town centres, and in certain locations caged vehicles cannot access the areas where bins are situated to collect the waste.

Fly-tipping (*intentional littering*) was identified as a challenge, particularly in rural areas where there are no street lights or surrounding houses to witness the illegal activities. The respondent stated that both public/household and industrial waste gets dumped, particularly asbestos-related material which has a high cost to dispose of appropriately. One authority investigated several cases where people employed to removed waste had illegally fly-tipped this on country lanes. Within another authority a pilot was run to provide free waste removal, they found that this did not lower fly-tipping rates and conclude that fly-tipping is largely not due to financial cost of disposing of waste, but more likely people wanting to dispose of waste as fast as possible.

a) b)

Figure 4. Examples of overfilled litter bins (a), with additional bags of waste improperly disposed of and piled up at the base of the bin (b). Images supplied by the Cornish Plastic Pollution Coalition.

Domestic and commercial waste

All respondents commented that there was more litter and littering in lower socio-economic residential areas where they generally felt “people don’t care about their area and have no interest in recycling”. Littering issues with houses in multiple occupation (HMOs) which have limited/no individual bin storage and subsequently use shared bulk bins or sack collections were widely cited by respondents. Common problems stated included dumping side-waste (*unconscious littering*), bins becoming over filled and people coming from elsewhere to use these bulk bins causing them to fill too quickly.

“Contaminated bins are a problem” remarked one respondent, “there can be over 200 contaminated bins in just one area, that’s common”, they elaborated that if a bin is contaminated containing a mixture of recycling and general refuse the waste contractors will not take them. They said this causes a knock-on effect with people putting their waste in the bins of neighbours. The contractor will leave an explanatory sticker on the bin and in some cases will send a letter outlining the issue and will empty the contents so the household can start afresh but “there’s a high re-offending rate”. Where contaminated bins become full or have been confiscated due to repeated misuse, the residents “have to get rid of the waste some other way. Usually just throwing bags over the wall”.

Enforcement teams will investigate illegal dumping of this kind, but this rarely leads to conviction. The respondents called for more education for residents, more enforcement for waste crime and increased responsibility of the owners of social housing to ensure their residents do not cause fly-tipping or littering offences.

One respondent stated that they estimated ~25% of the bags and bins they encountered during their kerb side collection rounds have waste spilling out of them, but this could vary depending on the day. They attributed the spilt litter to bags being overfilled and the sheer volume of waste being disposed of, as well the public putting their bins out too early the day before collection which gave more time for animals to tear the bags. When asked what operatives would do about litter spilling from bags, they stated that the advice they receive is varied and largely dependent on the manager on duty; “We don’t pick up any litter lying in the street, because you don’t know what it is”, and this waste would be collected by street cleansing teams. Conversely, a different respondent said that if litter was spilling from bins (i.e. from ripped or wildlife scavenged bags) operatives would clear uncontained litter within a ~0.5 metres radius, they added, "if it's a really windy day, they aren't going to chase it down the street, but within reason". All interviewees said that operatives had a duty to collect any litter which fell from the wagons or from bags which ripped during handling.

Under the Environmental Protection Act businesses have a duty to securely store waste and dispose of it responsibly, however one respondent indicated that certain businesses did not comply, improperly disposing of commercial waste through duping, overfilling bins or putting out side-waste. These practises can cause the leakage of waste into the environment. Better enforcement and fixed penalties rather than waiting for prosecution, which can be a lengthy process, were suggested as mitigation measures.

The proper separation of waste, cleaning items destined for recycling and not putting bins out too early before collection were all stated by the majority of respondents as measures which could reduce the chance of bags ripping/being scavenged and thus reduce litter entering the environment.

14.1.5. The perceived effect of COVID-19 on litter/littering

All interviewees remarked on the occurrence of PPE litter, which was not present on streets prior to the pandemic, but also commented that changes in people's habits and life-style have influenced littering. For example, "More people had to stay in this country and [not go abroad] so are using beaches and parks more, and litter would build up more in these places", and "before people would sit inside some of these big chains and eat and dispose of litter in there, now they can't do that now so they're hanging around anywhere to eat and disregarding the fact it is litter". Particularly for to-go food contained in paper bags, "I think people think brown paper will go back into the environment, if they think at all. If people can't sit in these places to eat, they are eating on the go more, and there isn't always a street litter bin when they finish their food so they'll just discard it anywhere".

A number of respondents indicated that there was "a large issue" with littering in recreational areas/beauty spots since delivery companies started providing a service during the pandemic to deliver take-away food directly to parks/beaches/picnic sites. One individual remarked "the amount of mess has increased 5-6 fold since that service has been available, that has contributed massively to the amount of litter that gets left behind" (*intentional littering*). Several respondents specifically mentioned extreme litter challenges following the relinquishing of the first UK lockdown in July 2020, "there was such a level of agitation and aggression in the public…the mountains of litter around the base of the bins got really out of hand and the traffic issues meant we couldn't get collection vehicles to empty them". Another local authority was emptying three 20-yard skips per day of waste, when normally they would only empty one per week. They attribute this vast increase in waste and litter to the exceptionally high numbers of people using their parks once lockdown restrictions were eased.

While not strictly defined as litter in the scope of this report, several respondents indicated that they perceived that dog fouling had increased due to "people wanting to get out, so taking more opportunity to walk their dog" with particular sites (access points, coastal promenade, playing fields) identified as hotspots.

Several respondents stated that it is harder to cleanse the streets and collect kerb side domestic waste, as there's "more people home and more parked cars… we can't get to the gullies". One respondent indicated a combination of increased litter with operatives isolating and unable to work or off sick has affected "what we can do and how quickly we can pick up waste".

Roadside traffic was stated to have decreased, especially during the first half of 2020, when there were far fewer vehicles on the road.

Several respondents indicated the volumes of household waste had increased associated with people spending more time at home during the pandemic. One respondent noted that householders seemed more conscientious about dealing with their waste and disposing of it appropriately, than previously. They said that another positive was the number of people who had requested litter pick kits, adding that presumably they were keen to collect litter while taking their allocated exercise. All respondents indicated they had noticed an increase in fly-tipping in rural and urban/residential areas (*intentional littering*). One respondent indicated that during January – December 2019 there were 1417 fly-tipping incidents (~118/month), while this increased to 1499 during January – November 2020 (~136/month). A respondent commented that when tips were closed during the first UK lockdown (March – July 2020), "people driving up [to the tip] were just dumping" their items, they went on to say that the land surrounding the tip was privately owned causing further issues with getting the fly-tipped items removed.