Plastic in the Thames: a river runs through it

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A B S T R A C T

Although contamination of the marine ecosystems by plastics is becoming recognised as a serious pollution problem, there are few studies that demonstrate the contribution made by freshwater catchments. Over a three month period from September to December 2012, at seven localities in the upper Thames estuary, 8490 submerged plastic items were intercepted in eel fyke nets anchored to the river bed. Whilst there were significant differences in the numbers of items at these locations, the majority were some type of plastic. Additionally in excess of 20% of the litter items were components of sanitary products. The most contaminated sites were in the vicinity of sewage treatment works. While floating litter is visible, this study also demonstrates that a large unseen volume of submerged plastic is flowing into the marine environment. It is therefore important that this sub-surface component is considered when assessing plastic pollution input into the sea.
Keywords: Estuary; Fyke-nets; Plastics; River Thames; Sanitary Products; United Kingdom

Highlights

- Sub-surface rubbish items intercepted in fyke-nets in the River Thames.
- The trapping of 8,490, mainly plastic, items during a three month period.
- Over 20% of rubbish items were components of sanitary products.
- Most contaminated sites were in the vicinity of sewage treatment works.
- Evidence for significant sub-surface transport of rubbish in the Thames Estuary.

1. Introduction

The contamination of the marine environment by litter, especially persistent plastics, is a serious environmental problem (e.g. Barnes et al. 2009; Ramirez-Llodra et al., 2011) and one that has recently prompted scientists to press for policy changes such as classifying plastic waste as hazardous (Thompson et al. 2009; Rochman et al. 2013). The effects range from the obvious and highly visible impacts on marine wildlife such as entanglement (Moore, 2008) to the ingestion of microplastic fragments by a range of organisms including bivalve molluscs (Browne et al. 2008), decapod crustaceans (Murray and Cowie, 2011) and both pelagic and demersal fish (e.g. Lusher et al. 2013 for English Channel species). Furthermore there is increasing evidence that potentially harmful chemicals leach from these ingested plastics (e.g. Teuten et al. 2009; Tanaka et al. 2013).Whilst the issue of accumulating plastics in the world's oceans has become a high profile topic in recent years, e.g. "Great Pacific Garbage Patch" (Pichel et al. 2007) and North Atlantic Sub-tropical gyre (Law et al. 2010), the issue of plastics flowing down the major rivers, ultimately contributing to this problem, has received less attention. Indeed there appears to be relatively little published literature describing riverine input of plastics to the marine environment (e.g. Moore et al. 2011). However, some studies have demonstrated the prevalence of river-borne litter rather than litter of marine origin in a range of estuarine locations (e.g. Caulton and Macogni, 1987; Williams and Simmons, 1997).

For many years the Port of London Authority (PLA) has operated a 'driftwood service' which collects around 250 tons of debris and rubbish each year from the tidal Thames. In 2011, 248 tons were removed from the river and 239 tons in 2012. The PLA operates two purpose-built vessels and about ten floating 'passive debris collectors' (PDCs), which are located at a number of key locations in the tidal Thames to intercept floating litter on both ebb and flood tides. In addition various "clean up" programmes co-ordinated by Thames 21 and partner organisations regularly remove large quantities of litter from the foreshore and riverbed of the tidal Thames at low water.

As part of an ongoing project, based at the Natural History Museum (NHM), a feasibility study into the commercial exploitation of the invasive Chinese mitten crab, *E. sinensis,* in the River Thames was completed between November 2005 and January 2007 (Clark et al. 2008; Clark 2011). From the start of the trial the fyke nets accumulated rubbish and this had to be sorted and cleared before the traps could be set again. Amongst this litter were large amounts of sanitary products, especially the plastic backing strips from sanitary towels, used condoms and a wide range of plastics waste. Recently, further trials have been completed using different designs of fyke nets in the River Thames (Crossness to Broadness Point) capable of catching mitten crabs but releasing trapped eels (Clark et al. 2013). As a result of the previous Thames fishing experiences all the rubbish that accumulated in each fleet of fyke nets during each deployment (approx. three days soak time) was documented. The purpose of this paper is, therefore, to report upon the submerged litter flowing down the River Thames to provide further evidence for the problem of plastics pollution in our major waterways.

2. Materials and Methods

Four types of fyke net, a standard eel net and three modified nets were being trialled in the upper Thames Estuary between Crossness and Broadness Point (see Fig. 1) between 17 September and 13 December 2012. Each fleet of nets consisted of three double fykes (or six fyke net ends) with the cod ends of two doubles being tied together and an otter guard was secured into the opening. Anchors were tied at both ends of the fleet to attach the net firmly to the river bed, and to keep it taught and upright. This type of net is sometimes referred to as "fixed engines". These nets were therefore effectively intercepting organisms and litter moving within 40cm of the river bed which is the height of the "leader" net connecting each pair of ends and also the diameter of the metal ring holding open each end. Buoys were not used to mark the position of the nets in the river as this attracts attention and the potential for unwanted net disturbance. In order to eliminate this problem, as the nets were set, their positions are recorded on a GPS navigational plotter in the wheel house of the boat. The nets were always set in same methodical way and direction so that each fleet of nets was set parallel to the shore and in line with the tidal direction. They were set sub-tidally so as not to become exposed on the shoreline at low water and on the margins of the river in shallow water; not in the deep water navigational channel. As the Thames is tidal at the sampling sites the actual depth of deployment will vary with neap and spring tides. Retrieval was then a relatively straight forward matter of returning to each net using the GPS guidance system, crossing the fleet and trailing a grapple to hook the fykes. The time that the nets were set and hauled, was noted with the intervening period represents the soak time for each net type. After the nets were hauled they were re-set at a different locality. The same station was not immediately fished again and allowed to "rest" for at least five days before fishing the same area again. During this period, 29 visits were made (once every three days) to haul the nets and to record numbers of trapped eels, Chinese mitten crabs and by-catch.

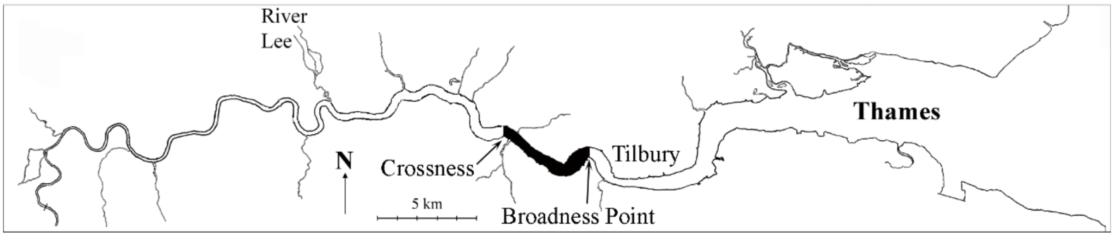

Fig. 1. Fyke net trials were undertaken in the Thames Estuary between Crossness and Broadness Point, Greenhithe.

While sorting through the nets, all the rubbish collected (see Fig. 2) was set aside, bagged up and transported to the wet laboratory at the NHM (see Fig. 3) for sorting into litter catagories (Appendix A. Supplementary data). Rubbish was simply recorded by counting numbers of items and recorded on a data sheet based on the Ocean Conservancy's International Coastal Cleanup data card (www.oceanconservancy.org). Items were allocated to seven major categories and these used for further data analyses. The proportion of each litter category was calculated overall and also for each of seven broad locations within the upper Thames Estuary. Actual numbers of items were also compared between sites for each of the seven locations (Kruskal-Wallis with post-hoc tests to identify significant differences). Analyses were carried out using Microsoft Excel and SPSS Version 19.0.

3. Results

A total of 8,490 items of rubbish (Appendix A. Supplementary data) were counted during the fishing programme with fifty-four different categories of rubbish identified. These categories were subsequently grouped into seven main contributory groups for further analysis and data presentation. The main contributory items are summarised in Fig. 4.

Fig. 2. Rubbish trapped in the cod end of a fyke net set in the River Thames.

Fig. 3. Assorted submerged rubbish collected from Thames fyke nets trials.

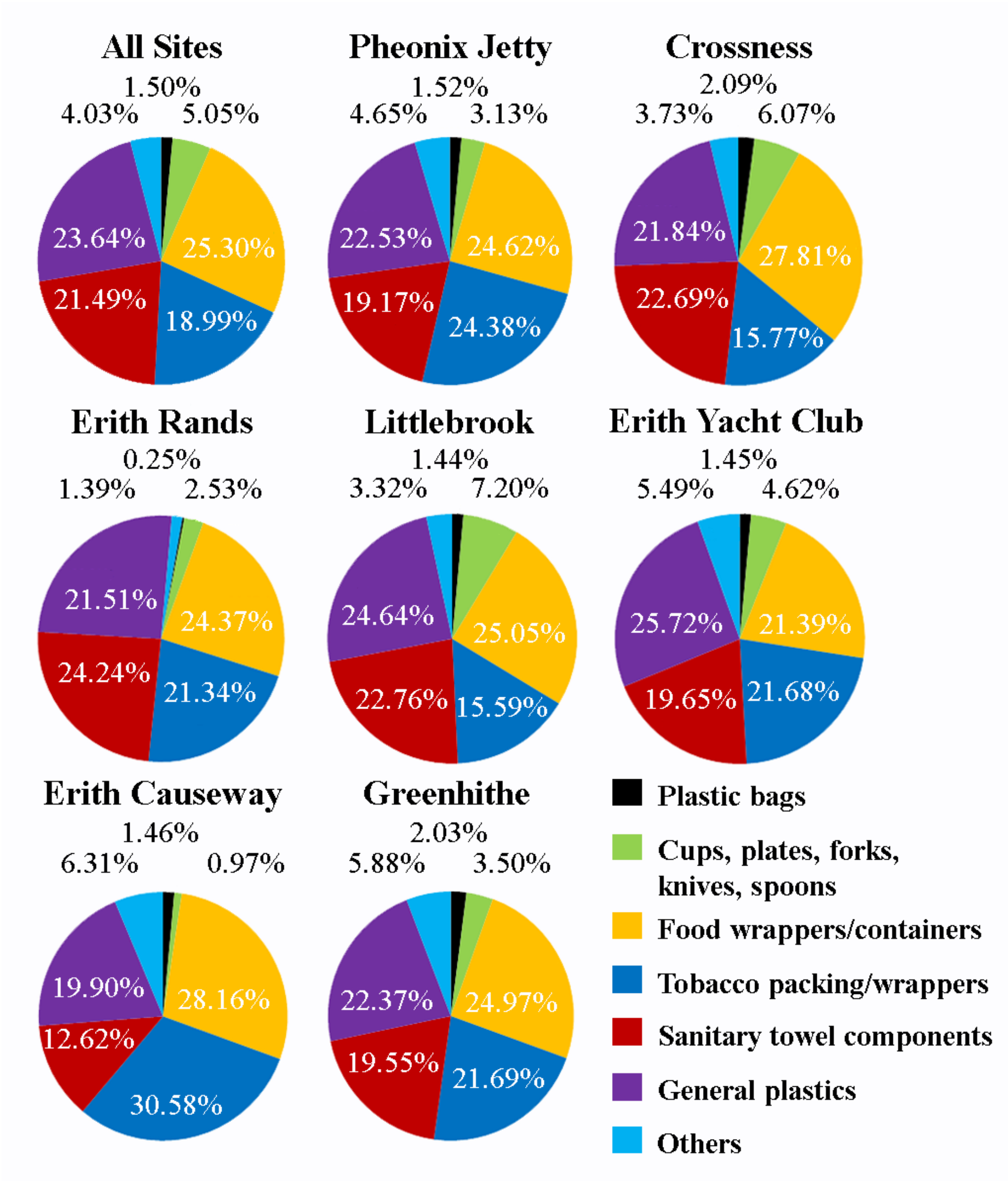

Fig. 4. Composition of litter intercepted in fyke nets located at different sites in the upper Thames estuary between 17 September - 13 December 2012.

Data from each net retrieval have also been grouped by broad location within the upper Thames estuary such that the composition of litter at seven different locations are presented separately (Fig. 4). Of these Crossness (Upper) represents the furthest upstream location and Greenhithe the furthest downstream. Generally speaking the proportions of different major components do not differ greatly from the overall values or between different sites; there do not appear to be any trends moving from upstream to downstream sites. The site with the greatest proportion of sanitary products is Erith Rands with 24.24%; Crossness and Littlebrook had 22.69% and 22.76% sanitary products respectively. General plastic waste generally made up 20 – 25% of the litter at all sites and food wrappers and containers 21-28%. Erith Jetty /

Causeway, in the immediate vicinity of the town of Erith, had proportionately less sanitary items and general plastic waste but interestingly had by far the highest proportion of tobacco packaging and wrappers (30.58%) which is much higher than the overall mean value (19%) across all sites. Another observation is that relatively few plastic bags (≤ 2.09%) were recorded across all sites.

Whilst these percentage data give an overall impression of the composition of litter items at different locations the comparison of the actual numbers of items recorded at different locations paints a rather different and more detailed picture. The results of Kruskal-Wallis analyses are summarised in Table 1.

Table 1

Comparison of the number of litter items at different locations in the Upper Thames estuary. Site numbers: 1 = Crossness, 2 = Littlebrook, 3 = Erith Jetty, 4 = Phoenix Jetty, 5 = Erith Rands, 6 = Erith Yacht Club, 7 = Greenhithe / Broadness. NS: no significance, >: site(s) with statistically significant higher number of litter items, =: sites with no significant differences.

Litter category	Site comparison	Significant differences between sites
Plastic bags	X^2 = 14.097, d.f. 6, P= 0.029	1 > 3,5,6,7
Cups, plates, forks, etc	X^2 = 15.629, d.f. 6, P= 0.016	1 = 2 > 3,5,6 and 1 > 7
Food wrappers	X^2 = 16.125, d.f. 6, P= 0.013	1 > 3,6,7 and 2 > 3,7 and 4=5 >3
Tobacco packaging	X^2 = 17.821, d.f. 6, P= 0.007	1 > 3,6,7 and 2 > 3,7 and 4=5 > 3 and 4 > 6,7
Sanitary components	X^2 = 17.495, d.f. 6, P= 0.008	1 =2 > 3,6,7 and 4=5 > 3
General plastic	X^2 = 17.404, d.f. 6, P= 0.008	1 > 3,7 and 2 > 3,6,7 and 4 > 3
Others	X^2 = 11.097, d.f. 6, P= 0.064	NS

Significantly higher numbers of plastic bags (median = 13.0 per deployment) were recorded at Crossness than at four sites further downstream (median = 3.0 – 5.0 per deployment). A similar picture emerges for plastic cups and cutlery (median = 24), food wrappers (median = 186.33) and tobacco packing (median = 105.67) which were all found in significantly higher numbers than at Erith Jetty, Erith Yacht Club and Greenhithe / Broadness (and Erith Rands for cups and cutlery only). Further downstream Littlebrook had higher numbers of cups and cutlery (median = 39.0) than the three Erith locations upstream and higher numbers of food wrappers (median = 135.6) and tobacco packing (median = 84.4) than Erith Jetty (upstream) and Greenhithe / Broadness (downstream). A similar pattern emerges for general plastic waste with both Crossness (median = 146.33) and Littlebrook (median = 133.4) having the highest number of items. Thus these two sites have the highest numbers of plastics with Phoenix Jetty and Erith Rands, being broadly comparable and the next most contaminated locations. Erith Yacht Club and Greenhithe / Broadness are broadly comparable and less contaminated sites. Overall Erith Jetty appears to be the "cleanest" location with median values for plastic bags, food wrappers, tobacco wrapping and general plastic waste of 3.0, 19.33, 21.0 and 13.67 respectively.

The patterns outlined above are also seen when it comes to the components of sanitary products recovered in the nets. Again both Crossness (median = 152) and Littlebrook (median = 123.2) had significantly higher numbers than Erith Jetty (median = 13), Erith Yacht Club (median = 22.67) and Greenhithe / Broadness (median = 24.71). As for other categories of litter Phoenix Jetty (median = 59.75) and Erith Rands (median = 64) showed intermediate levels of sanitary product contamination that were significantly higher than that recorded for Erith Jetty.

4. Discussion

The current study does not suggest any trend in the prevalence of different litter types. There is, however, a consistent pattern with the numbers of items for most categories of litter being highest for two locations, Crossness and Littlebrook, which are both in the vicinity of sewage treatment outfalls. The next two most contaminated sites (again across most litter categories) are Erith Rands and Phoenix Jetty which are both located on the north shore of the Thames. In terms of decreasing contamination these are followed by two southern shore locations, namely Erith Yacht Club and Greenhithe / Broadness, which are located upstream and downstream respectively of Littlebrook. The "cleanest" location sampled in the current study appears to be Erith Jetty which has consistently fewer litter items than other sites. Whilst certainly far from conclusive the patterns in the current data can at least be partially explained by the juxtaposition of the sampling sites to easily identifiable sources of contamination.

It is noticeable that over 22% of the items at the most contaminated sites are the components of sanitary products. Indeed one of the most striking features of this study is the large number of sanitary products intercepted by the nets across all sites. These were mainly the plastic backing strips from sanitary towels which have been previously identified as a significant contributor to debris accumulating on river banks and beaches, largely as a consequence of their longevity (e.g. Williams and Simmons, 1996). In a study of litter in Bristol Channel the majority of estuarine, shore-based litter items were of riverine origin with relatively few items deemed to be of marine origin (Williams and Simmons, 1997). This generally concurs with findings described for the Firth of Forth, where there was little evidence for litter from overseas or derived from shipping activities (Caulton and Macogni, 1987). In a separate study in the Firth of Clyde, the majority of beach litter was of recreational or sewage-related origin (Storrier et al. 2007). It is worth noting at this juncture that such sanitary products are not designed to be disposed of via lavatories, which is presumably how the majority have entered the river system (Berkley, 2007). This in itself suggests that a significant change in consumer behaviour is required and /or pressure applied to manufacturers of such products to improve their biodegradability.

The prevalence of plastic waste in our recent survey is less surprising as the problems associated with the persistence of plastics in aquatic environments has received considerable attention in the media as well as scientific literature (Thompson et al. 2009 for review). Relatively low numbers of plastic bags were recorded in the present study and this is almost certainly a function of the design of the nets which, due to the fitting of an otter guard, will tend to exclude larger plastic bags. It should also be noted that these nets are deployed on the riverbed and are designed to catch primarily benthic / demersal organisms so the litter intercepted is being carried lower in the water column or along the river bottom by the tidal water flow. So whilst systems such as the PDCs operated by PLA do an excellent job in intercepting considerable quantities of floating litter it is clear that there is also a “hidden” element to the plastics moving down our rivers. Indeed in order to estimate the true scale of the problem a longer term sampling programme is required, employing a range of sampling strategies designed to intercept a range of litter, is probably necessary (e.g. Moore et al. 2011).

There is little doubt that significant quantities of litter, especially plastics, are moving down the River Thames and thus providing a major input of such debris to the North Sea. The visible effects of such debris are well documented (e.g. Moore, 2008) but of increasing concern are the less obvious effects, including the gradual fragmentation of macroplastics generating microplastic fragments which ultimately find their way into the bodies of a wide range of marine organisms (e.g. Browne et al. 2008; Murray and Cowie, 2011; Lusher et al. 2013). Indeed the movement of plastics along the Thames river bed, with successive ebb and flood tides, will no doubt contribute to this fragmentation as items are abraded against the substratum. Certainly the current study suggests that the “unseen” litter moving along river beds may represent an additional significant input which has perhaps, to date, been underestimated. The authors acknowledge that the present data represent only a snapshot and, as such, it is difficult to estimate the volume of litter that is actually entering the North Sea. They do, however, highlight the problem of submerged plastics in the River Thames. This is no doubt an issue for other river catchments nationally and watersheds globally.

Acknowledgements

This work was conducted while undertaking a net trial funded by grants from the Marine Management Organisation and the Environment Agency to PFC. We are especially grateful to Philip Lynn (MMO), Heidi Stone (EA) and Darryl Clifton-Dey (EA) for their help in sponsoring the fyke net trial. We would like to thank the Port of London Authority for their support of this project especially Jane Collins (Licensing Officer), Jason Rudd (Deputy Marine Surveyor, Vessel Licensing), and Martin Garside. We thank Tom Cousins (EA) for granting us permission to fish between Crossness and Broadness Point, Greenhithe, in the Upper Thames Estuary. Paris Stefanoudis is grateful to the People’s Trust for Endangered Species for funding his internship at the Natural History Museum from September to December 2012.

Author contributions. DM, PFC and DP designed the sampling programme and all authors contributed to the data collection. PVS carried out data analyses; PVS and PFC produced the figures and all authors interpreted the data. DM and PFC wrote the manuscript with comments from all authors.

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Figure captions

Fig. 1. Fyke net trials were undertaken in the Thames Estuary between Crossness and Broadness Point, Greenhithe.

Fig. 2. Rubbish trapped in the cod end of a fyke net set in the River Thames.

Fig. 3. Assorted submerged rubbish collected from Thames fyke nets trials.

Fig. 4. Composition of litter intercepted in fyke nets located at different sites in the upper Thames estuary between 17 September - 13 December 2012.

Appendix A.

Supplementary data associated with this article can be found, in the online version

Table of litter type counts and % contribution used to categorise rubbish trapped while trialling fyke nets in the River Thames.

	Litter Types	Total Count	% contribution
	Shoreline and Recreational Activities		
1	Bags (plastic)	127	1.5
2	Balloons	32	0.4
3	Beverage Bottles (plastic)	22	0.3
4	Beverage Bottles (glass)	2	<0.1
5	Caps, Lids	20	0.2
6	Clothing, Shoes	2	<0.1
7	Cups, Plates, Forks, Knives, Spoons	429	5.1
8	Food Wrappers/Containers	2148	25.3
9	Straws, Stirrers	69	0.8
10	Toys	5	0.1
	Ocean/Waterways Activities		
11	Fishing Line	2	<0.1
12	Fishing Nets	1	<0.1
13	Rope	2	<0.1
	Smoking-Related Activities		
14	Cigarettes/Cigarette Filters	6	0.1
15	Cigar Tips	2	<0.1
16	Tobacco Packaging/Wrappers	1612	19.0
	Dumping Activities		
17	Building Materials	2	<0.1
	Medical/Personal Hygiene		
18	Condoms	3	<0.1
19	Tampons/Tampon Applicators	1824	21.5
20	Shampoo	2	<0.1
21	Toothpaste	1	<0.1
22	Elastoplast	40	0.5
23	Cotton buds	1	<0.1
24	Tissue Package	8	0.1
25	Air Freshener	1	<0.1
26	Medical Glove	1	<0.1
	Debris Items of Local Concern	1	<0.1
	Others		
27	General Plastic	2007	23.6
28	Roadwork Tape	1	<0.1
29	Vegetable Packing	1	<0.1
30	Photograph	1	<0.1
31	Postal Rubber Band	43	0.5
32	Flower Pots	13	0.2
33	Rubber band (not postal one)	14	0.2
34	Sparkler pot	1	<0.1
35	Plastic tie	1	<0.1
36	Peg	1	<0.1
37	Raw plug	2	<0.1

38	Bank issued currency bag	2	<0.1
39	Fashion accessories	2	<0.1
40	Plastic Towel Spacer	1	<0.1
41	Tape	17	0.2
42	Shaving guard	1	<0.1
43	String	2	<0.1
44	Eye-drops	1	<0.1
45	Washer Tablet	1	<0.1
46	Telephone Network Operators	1	<0.1
47	Plastic bottle tops	2	<0.1
48	Plastic Container	1	<0.1
49	Small adhesive dressing	1	<0.1
50	Sponge	1	<0.1
51	Party Poppers	2	<0.1
52	Music Instrument	1	<0.1
53	Glass	1	<0.1
54	Sports Item	3	<0.1
	Total number of items	**8490**	