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# **The environmental impacts and health hazards of abandoned boats in estuaries**

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## **Abstract**

Decaying boats are a common sight in the coastal zone and yet the practice of abandonment appears to be exempt from any clear or enforceable regulation. In the present study we surveyed two estuaries in eastern England hosting an abundance and variety of abandoned vessels. An inventory of items and materials associated with or adjacent to each boat was recorded in order to gain an insight into the hazards and pollution risks related to abandonment. Items and materials most commonly recorded were plastics, tyres, timber, polystyrene, canisters, masonry, electronic equipment and a variety of metal objects that were either fixed to or contained by the boats. As well as representing an eyesore and inhibiting access to the shore, decaying boats are a hazard to human health and safety and are a source of pollution (e.g. plastics, heavy metals, oil-related hydrocarbons) to local sediment and interstitial waters. Recommendations to deal with the problem of boat abandonment include compulsory boat registration, making boaters aware of (and providing incentives for) safe disposal, and providing authorities and landowners with clear information on existing or new agencies and legislation.

### *Keywords:*

Abandoned boats; coast; shoreline; hazards; contamination; litter

## **1. Introduction**

Abandoned boats are a common sight and a growing problem on the foreshores, beaches, mudflats, harbours, marinas, reefs and mangroves of the coastal environment (National Association of State Boating Law Administrators, 2009; Eklund, 2014). Boats that have been damaged, are commercially obsolete, or are simply no longer wanted, affordable or repairable may have been deliberately grounded or sunk offshore or abandoned on the substrate in the inter-tidal zone. Boats range from small rowing boats and dinghies to much larger commercial craft, and from recently discarded and in a reasonable state of repair to derelict wrecks abandoned many decades ago.

In a recent study, Stevenson (undated) investigated the issue of boat abandonment in Southampton Water, southern England, and its adjacent estuaries, with particular attention paid to fibre-reinforced plastic hulls. Various boaters and authorities were interviewed and recycling and disposal options explored. The author highlighted the difficulties in identifying and quantifying the problem of boat abandonment and concluded that there was insufficient waste disposal legislation and a general unwillingness to deal with the issue. Additional, related problems identified at a Nordic workshop on end-of-life plastic leisure boats included a lack of knowledge on how to reuse and recycle materials, no defined senior authority, and no system for financing collection and disposal (Eklund, 2014). With similar issues recognised in the US, a number of states now have funding and expertise at hand for the recovery and disposal of boats that pose a navigational hazard if the owner cannot be traced (Aquatic Resources Program Policy Unit, 2007).

Despite the scale of the problem globally, and perhaps because of a lack of legislation, support or willingness to deal with the issue, little attention has been paid to the hazards to human health and safety and the threats to the local ecology, substrate and water column. The National Oceanic and Atmospheric Administration (NOAA) surveyed abandoned, derelict boats in sensitive habitats of various US territories in the Caribbean and Pacific and focussed on hazards relating to pollution and public safety (Lord-Boring et al., 2004). The magnitude of the impacts varied depending on the nature of the habitat, the degree of boat clustering and the extent to which boats were moved by wind and wave activity. Most of the impacts identified, however,

were specific to boats and debris abandoned on hard-bottomed, benthic substrates of tropical regions that were characterised by frequent storms. In the Nordic countries, boats abandoned offshore or along the coastal zone have been recognised as a potential source of pollution arising from paints, electrical components, furnishings and mechanical parts (Eklund, 2014). However, the principal considerations in this respect related to the hazards incurred during boat dismantling rather than environmental issues arising at the point of abandonment.

In the present study, we address the hazards to human health and safety and environmental impacts arising from the deliberate, in situ abandonment of boats along the inter-tidal zone of estuaries. Here, boats are subject to gradual, partial burial in the sediment but are otherwise relatively immobile. Unlike boats abandoned in the benthic environment, they are subject to decay through periodic saltwater inundation and exposure to the elements. We address the hazards and impacts resulting from the boats themselves, their contents, and debris on the foreshore that may or may not have been derived from decaying vessels. This was achieved through a qualitative analysis and characterisation of the types of materials and items associated with individual boats and clusters of boats on the mudflats and saltmarshes of two estuaries in eastern England. Legislation relating, directly or indirectly, to in situ abandonment along the foreshore is described and recommendations regarding best practice for boaters are addressed.

## **2. Study sites and boats**

The Blackwater and Orwell estuaries are in the county of Essex, eastern England, and have been described in detail by Rees et al. (2014) as part of a previous study in which remnants of external and internal boat paints were sampled and analysed for heavy metals. In the present study, we targeted the Heybridge Creek, Tollesbury and Mersea regions of the Blackwater estuary, and the Pin Mill region of the Orwell estuary (Figure 1) because of the density, variety and accessibility of abandoned boats on the respective foreshores. A total of 54 boats were inspected visually and with the aid of digital photography during April 2013. The boats are described in Table 1, along with their approximate dates of abandonment (and as ascertained from public records and use of the time slider facility in Google Earth), and a selection of photographs of boats and boat clusters are presented in Figure 2. Boats were between

about 5 and 20 m in length and, apart from a few small fibreglass craft and two metal vessels, were of timber construction. Abandoned vessels included yachts, trawlers, sailing barges and houseboats, and a cruiser, ferry and a tender for a lightship. We note that some of the barges appear to be part of “hulk assemblages” that have been catalogued by English Heritage and identified as being of archaeological significance (Davies, 2011). All boats were submerged within the intertidal mud to different extents and, while some lay on their sides, others were propped upright by their moorings and/or through substantial burial in the sediment. Many boats had been partially covered in tarpauling, perhaps for protection or as some signature of ‘ownership’.

Items and materials associated with each vessel and that were visible from the outside and from safely accessible locations were recorded and described. While the interiors of some boats were viewable, boats were not boarded or disturbed for inspection. Some items were still attached to the boats with their original fixtures, but many appeared to have been dumped on the deck or were contained by the remains of the hull. In addition, we recorded items that were observed on or partly submerged within the inter-tidal sediment or saltmarsh vegetation in the vicinity of the boats.

### **3. Inventory results**

The inventory of items and materials identified on or associated with each boat is shown in Table 1. For the first four categories of expanded polystyrene, rope, tyres (evidently used as fenders) and painted boat surfaces, presence or absence is noted; for the remaining categories, however, more specific information on the nature and abundance of the items is given. Among the latter categories, plastic, metallic and wooden items were most commonly observed. It is surmised that many of the plastic items were not part of the original boat or its contents on abandonment; for example, sheeting may have been used for some kind of protection during any restoration or salvage, while plastic bottles and other small items are likely to have been simply thrown into the hull as litter. In contrast, wooden items appeared to have been derived directly from the boat’s construction, and usually the hull or deck. From discussions with a local boater and the charred remains of planks of wood it appeared that timber was often salvaged for firewood.

The variety of metallic items in the boats displayed different degrees of aging (rusting) and, in many cases, paint coverage, with several larger items, including winches, frames and tanks, fixed in their original positions. Electrical items and appliances recorded included various pumps, stoves and ovens, and a television, car battery and sewing machine, while canisters and cans appeared to contain (or at some stage contained) paint, oil and gas. Textiles observed included foam and a cushion, while miscellaneous items not categorised above included adhesive taping, felt roofing, concrete blocks and a toilet.

Items scattered on the intertidal mudflats and within the saltmarsh vegetation throughout the region were broadly similar to those contained by abandoned boats and as described above, and included tyres, plastic litter, various wooden and metal components and electrical items. Many of these items will have been derived from abandoned boats, although the means by which they ended up on the shore (deliberate dumping or via the gradual decay of the boat) is not known. We also noted an abundance of masonry, foam debris and what appeared to be a mattress on the littoral zone. Masonry is likely to have been derived from dilapidated coastal constructions, moorings and embankments, while evidence of soft furnishings suggests that fly-tipping of bulky household items takes place in the vicinity of abandoned boats.

#### **4. Hazards and environmental impacts of abandoned boats**

The impacts and hazards arising from boat abandonment are many and varied, and are related to the size of the boat, its condition, the condition of any fixtures (e.g. deck, mast, winch, cleat, railings, caging, exhaust piping, rudder, propeller), the quantity and degree of containment of hazardous substances, and the extent to which items are littered on the sediment or vegetation.

##### ***4.1. Aesthetic and obstructive impacts***

Depending on its size and precise location of abandonment, a boat may represent a significant navigational hazard and require immediate removal or disposal. This is generally the case if the boat has been grounded and abandoned in the sub-tidal zone. Abandonment on the inter- (or supra-) tidal environment is of more concern to the landowner and/or the public. Thus, decaying boats are an eyesore and result in loss of amenity and right of way and restriction of access to the shore and water; access to

privately owned facilities or industries (e.g. aquaculture) may, likewise, be impeded by boat abandonment. Loss of amenity and access is compounded by the clustering of abandoned boats, an effect that we observed throughout the region visited and on a scale of up to a dozen vessels per cluster. Clustering appears to be the result of the perceived acceptability or justification of abandoning boats (and dumping of other structures and wastes) at locations where the practice has already begun (Lord-Boring et al., 2004).

#### ***4.2. Human health and safety***

Abandoned boats along the shoreline also represent a hazard to human health and safety. In our study, and despite the obvious dangers of rotting, algal-matted wood, and rusting, friable metal objects and fixtures, we noted a warning notice on only one of the abandoned boats inspected. Moreover, there was ample evidence (e.g. new tarpauling fixtures, gang planks, charred wooden remains) that several boats had been recently boarded.

Health hazards also exist from chemicals or materials used to construct, protect or decorate components of the boat. Such hazards are generally greatest when material is disturbed and airborne, a condition that is most likely to occur while vessels are being renovated, salvaged, restored or disposed of. Asbestos was employed extensively in boats as an insulator on exhausts, engine parts, heating systems and pipes, and as tiles in kitchen areas and engine rooms; it was also used in many caulking agents, sealants, resins and vinyl products. Although we did not observe any asbestos components on the exterior of the boats we inspected, this does not preclude the possibility of the material being hidden from view below the decking of larger boats, a possibility that we were alerted to by staff from a local maritime museum.

Residual paint on abandoned boats also poses a health risk if painted structures are disturbed. In our earlier study we highlighted the issue of leaded paints on the external and internal surfaces of many boats in the region (Rees et al., 2014). Although banned or restricted in use in most contemporary paints, lead, a neurotoxin, was commonly used in formulations for boats as a corrosion inhibitor, drying agent and colour pigment (Booher, 1988). Paints on abandoned boats likely contain other chemicals that have been banned since their original application, including triorganotin biocides



and mercuric compounds employed as antifouling agents (Eklund and Eklund, 2014). The human health impacts of tributyltin are not fully understood (Antizar-Ladislao, 2008) but those of Hg are well established (Park and Zheng, 2012). With regard to the latter, it is worth noting a case of acute mercury poisoning in an infant exposed to residual mercuric antifouling paint that was being sanded from a boat hull (Schrager, 1964).

An additional route of exposure to paint-bound chemicals and to any other agents used to treat or join timber is from burning wood. Reports suggest that some boats are deliberately burned as a means of ‘disposal’ or through vandalism (Stevenson, undated; Eklund, 2014). However, as inferred from our observations above, boaters and other members of the public appear to be sampling parts of the hull, deck and interior of abandoned boats in the region under study for firewood; if used for domestic heating, householders will be at serious risk of inhaling significant quantities of toxic chemicals as the wood is burnt (Niyobuhungiro and Blottnitz, 2013).

#### ***4.3. Ecological impacts and pollution***

An impact arising from the process of abandonment itself is the crushing and smothering of infaunal and epifaunal communities and the displacement of resident biota. The long-term presence of decaying boats and any associated debris represents a loss of habitat and a loss of or reduction in sunlight. The presence of large quantities of plastic material around abandoned boat may also represent a loss of habitat as well as a potential threat to seabirds and invertebrates through entrapment and strangulation. Smaller pieces of plastic and expanded polystyrene discarded in situ or derived from the breakdown of larger or composite items (and in particular rope, rigging and netting) can be mistaken for food by birds. If particles cannot be regurgitated and become lodged in the digestive tract they may afford a sense of feeling full and result in starvation (Sheavly and Register, 2007). Suspension- and deposit-feeding invertebrates are also known to accumulate microplastics, although the effects of accumulation on animal health are unclear (Van Cauwenberghe et al., 2015).

Chemicals shed from components of the boat or its fittings have the propensity to contaminate the local sediment, interstitial waters and water column. Subsequently,

chemicals may be accumulated by macroalgae, epifaunal and infaunal invertebrates, wading birds and waterfowl. Metals in paint on abandoned boats represent an important source of contamination that has been dealt with in an earlier publication (Rees et al., 2014). Briefly, compounds of Cu, Zn and Pb in flaking paint on decaying boats resulted in enrichment of these metals in local sediment that, relative to a control site, exceeded 100 in some cases. Enrichment was attributed to both the presence of small fragments of paint among the sediment grains and to the gradual dissolution of metals from the paint and subsequent adsorption to the sediment surface.

Another group of chemicals that is likely to exhibit a similar pathway and fate to paint-borne metals is flame retardants. These are compounds added to combustible materials, like the fabric and foam of soft furnishings, plastic housings of electronic devices and various coatings (including paints), that resist ignition and inhibit the spread of fire. Polybrominated diphenyl ethers and organophosphates have been used extensively in this respect, and tend to gradually leach from corroding electrical equipment and decaying textiles and plastics, especially if not chemically bonded to the matrix (Choi et al., 2009).

Additional contaminants associated with abandoned boats or their discarded contents include Hg, Cd, Pb and polychlorinated biphenyls (from corroding batteries and electronic equipment; Dimitrakakis et al., 2014), alkylated Pb, polycyclic aromatic hydrocarbons and other oil-related hydrocarbons (from residual fuels and oils; Rogowska et al., 2010), and metallic Zn (from sacrificial anodes on metal-hulled boats; Rousseau et al., 2009). The impacts of asbestos and fibreglass on marine life are not known but recent studies suggest that these types of materials can be accumulated by sediment-ingesting invertebrates (Galimany et al., 2009).

## **5. Management and legislation**

Despite the hazards and impacts associated with decaying boats, and unlike the case for motor vehicles and household waste, there appears to be little or no specific regulation regarding this form of ‘fly-tipping’ within or among the international community; moreover, if related legislation is available on, for example,

transportation, property disposal, operator liability or environmental protection, it is rarely effectively enforced. Although, in principle, the owner of a boat (i.e. the polluter) could be traced since registration of commercial craft and, in some countries, leisure boats is required, identification numbers or boat names are easily removed. Boat owners themselves (and, in some instances, boat yards) may not always be aware of the best practice or any formal procedures for disposing of vessels and may perceive clusters of abandoned boats as a justifiable or acceptable option for abandoning vessels. Motivation for safe removal and disposal through breaking and landfill may also be low because of the costs involved and the lack of material worth recycling. With respect to the region under study, Maldon District Council (2013) has recently been provided with estimates of between £3,500 and £5,000 for the proper, consented removal and disposal of each abandoned boat from Heybridge Creek. Regarding older and more dilapidated boats that are partially submerged in the substrate, excavation costs will be significantly higher and an evaluation of whether disturbance of the structure will increase hazards and environmental impacts may be necessary.

In the UK, the local authority is responsible for litter above the mean high water mark, while the harbour master is responsible for litter below the line. However, local authorities rarely initiate the removal of abandoned boats and the restoration of grounding sites, while harbour masters appear to be concerned only if the boat is relatively large and represents a shipping hazard or if harbour dues have not been paid. Regarding pollution, the Environment Agency (EA) has an interest only if a hazardous liquid is spilling out. In the region under study, there appears to have been one documented case in which abandoned boats were removed. Thus, a task group, including representatives from the EA and local houseboat owners, gained County Council funding to safely excavate and subsequently landfill a number of decaying vessels that were obstructing a hardstanding at Pin Mill (East Anglian Daily Times, 2003).

In the US, state authorities will take action if vessels are abandoned in National Marine Sanctuaries or pose a significant pollution threat (Lord-Boring et al., 2004), although programmes are available in a handful of states whereby funding and expertise is available for removal and disposal of vessels (Aquatic Resources Program

Policy Unit, 2007; Brailsford, 2011). As a consequence of prioritisation, it is the smaller recreational and fishing vessels that make up the majority of pervasive and unattended incidents of abandonment (Lord-Boring and Zelo, 2006).

From a recent investigation into the problem of leisure boat abandonment in Southampton Water, Stevenson (undated) made a number of recommendations. These included surveying areas for the scale and nature of problem, as in the current study, licensing of all pleasure craft, an investigation into disposal or recycling options, and that boat producers should, ultimately, bear the cost of waste management. Among the Nordic countries, recommendations arising from a workshop on end-of-life recreational craft included the registration and tagging of boats, development of a system that considers the risks to humans and the environment, introduction of a mechanism by which boat owners transport boats to a pound whereafter responsibility lies with the boat producer, development of technology for the recycling of boat plastics, and the organisation of collection campaigns (Eklund, 2014).

Problems relating to ownership identification, boater awareness and availability and implementation of relevant legislation have resulted in the recommendation of a series of best management practices (BMPs) for abandoned boats by the US National Association of State Boating Law Administrators (2009). With respect to boaters, such BMPs include making owners aware of their responsibilities and understand where their vessels can be disposed of, dismantled or recycled, providing incentives to undertake these options and disincentives for abandoning vessels, and compulsory titling of boats (and by hidden identification numbers installed by the manufacturer). Regarding the relevant authorities and landowners, BMPs include providing clear information on what agencies and legislation are available and the circumstances under which abandoned vessels should be removed, and allocating appropriate funds to act on boat removal and disposal. While the majority of these BMPs are aimed at tackling recent and future abandonment of boats along the coastline, the latter mechanism (i.e. funding) would be appropriate for the safe and effective demolition and disposal of hazardous vessels that have been abandoned for relatively long periods of time.

## **6. Conclusions**

Boat abandonment in the coastal zone is a growing international problem whose scale and impacts are rarely recorded. The results of our observations of boats and associated debris in eastern England suggest that the main impacts are associated with loss of amenity and access, hazards to human health and safety, loss of habitat and contamination by metals and oil-derived hydrocarbons. Clearly, boaters need to be made more aware of these impacts and specific, enforceable legislation is called for at a local, state or national level. Regarding decaying boats that have been abandoned for long periods of time and/or where ownership is impossible to define, it is recommended that funds be available for the safe removal and disposal of remaining structures.

## **Acknowledgements**

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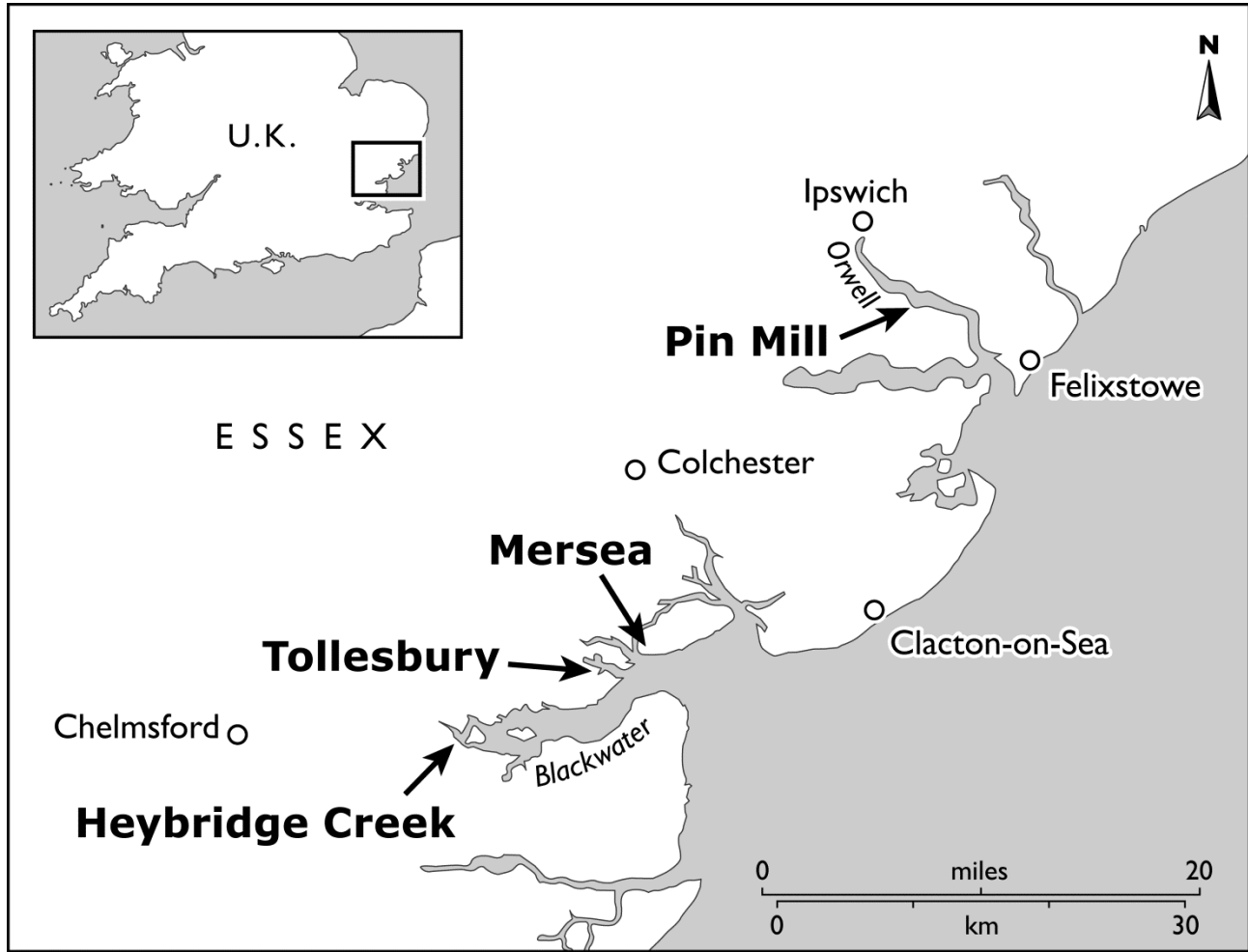
boat (year of abandonment)	painting boat surfaces	expanded polystyrene	rope and netting	tyres	plastic	metal	wood	textiles	electrical	canisters and cans	other
<b>Heybridge Creek, Blackwater</b>											
1. Houseboat (2000-2005)	✓	✓			sheeting, bottles, crate strapping			cloth, foam			
2. Pleasure craft (2000-2005)	✓			✓	sheeting						
3. Barge (1990s)	✓					girder		carpet	pump, oven, cables, sockets, plugs	gas x 2 (butane) gas	felt roofing glass
4. Yacht (2000-2005)	✓										
5. Pleasure craft (f) (2000-2005)	✓										
6. Yacht (2000-2005)	✓	✓									
7. Pleasure craft/yacht (pre-2000)	✓		✓		sheeting						
8. Pram dinghy (2009)	✓			✓	sheeting						
9. Motor boat (2000-2005)											fibreglass fragments
10. Houseboat (pre-2000)	✓	✓			bottles, tubing	chains frame	timber, door			gas	adhesives
11. Barge (1960s)											
12. Motor boat/yacht (2006)	✓					various objects	timber				
13. Motor boat/yacht (2012)	✓		✓		sheeting						
14. Motor boat/yacht (2006)	✓				sheeting	chains, various objects		cushion			toilet
15. Rowing boat (f) (2013)	✓				tubing						
16. Barge (2009-2011)	✓				tubing		timber				
17. Houseboat (2013)					sheeting	sheeting		cloth	generator		
18. Rowing boat (2006-2009)				✓		trolley, various objects					
19. Lighter (m) (pre-2000)			✓			scrap	timber				
20. Yacht/dinghy (f) (2000-2005)				✓						paint, chemical drum	
21. Motorboat (2006)	✓		✓	✓	sheeting	sheeting, corrugated roofing	timber				
22. Motorboat/yacht (2006-2009)	✓		✓		sheeting		oars				
24. Barge (1993)	✓				litter, tubing	winch, trolley	scrap				
25. Barge (1960s)	✓					girder					
<b>Tollesbury, Blackwater</b>											
26. Motorboat/yacht (pre-2000)	✓						firewood			oil x 2	
27. River cruiser (2000-2013)	✓					engine, cooking utensils			television, generator, stove, car battery	oil, several paint	
28. Yule (2000-2005)	✓				litter	engine					
29. Yacht (f) (2000-2005)	✓				sheeting	sheeting			sewing machine	oil	
30. Yacht (f) (2013)	✓		✓		sheeting	sheeting			radio		
31. Yacht (2013)	✓		✓			mast				paint	
32. Trawler (pre-2000)	✓		✓	✓							
33. Remains of hull (unknown)											
34. Motor boat (m) (2011-2013)	✓		✓		fender	chains					
35. Catamaran (before 2000)					buckets		timber				
36. Rowing boat (pre-2000)											
37. Pleasure craft (unknown)			✓	✓		sheeting	timber				
38. Dory (m) (unknown)			✓	✓							
39. Rowing boat (unknown)											
<b>Mersea, Blackwater</b>											
40. Fishing boat (2012-2013)	✓		✓			sheeting, propeller					
41. Fishing boat (2012-2013)	✓		✓		container						
42. Pleasure craft (2000-2006)	✓		✓			tank, various objects					
43. Yacht (f) (post-2009)	✓		✓		sheeting, tarpaulin	girder			cables		
<b>Pin Mill, Orwell</b>											
44. Yacht (2005-2008)	✓					keel					
45. Barge (2006)	✓							cloth			adhesives
46. Barge (1993)	✓		✓			various fixtures					
47. Barge (1986)	✓					various fixtures					
48. Trawler (late 1990s)	✓		✓			mast, tank, metal rope	burnt debris				
49. Pleasure boat (2006-2007)	✓				sheeting				pump		concrete blocks
50. Lightship tender (2010-2011)	✓		✓								
51. Pleasure boat (2008)	✓				sheeting						
52. Pleasure boat (f) (2008)	✓		✓								
53. Ferry (1999)	✓		✓		sheeting	various fixtures					felt roofing
54. Pleasure boat (2008)	✓			✓							
<b>Sediment, saltmarsh</b>											
	✓	✓	✓	✓	litter, piping, crates, cartons, tarpauling	chains, poles, posts, tanks, chair, sheeting, engine parts, piping, buoys, miscellaneous objects	remnants of various hulls, timber, keels, fencing, cabinet, boarding	foam, mattress?	oven, radio cassette, fridges	gas, paint	concrete blocks, bricks tiles, ceramic piping



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Table 1: Description of the boats surveyed in the present study along with an inventory of items associated with each vessel. Also shown are items recorded on the surrounding sediment or saltmarsh. Note that all boats were of timber construction except where noted (f = fibreglass, m = metal).

9 Figure 1: The locations of the regions under study on the Blackwater and Orwell estuaries.  
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12 Figure 2: Photographs of a selection of the boats and debris inspected on the Blackwater and Orwell estuaries. (a) Boat 2 lying on the mudflats of the Blackwater estuary and adjacent to a  
13 decaying jetty; (b) boats 4, 5, 6 and 7 clustered together on the Blackwater estuary and partially covered in tarpauling ; (c) boat 49 on the Orwell estuary at Pin Mill and with various decaying  
14 boats visible behind; (d) boats 50, 51 and 52 clustered together on the foreshore at Pin Mill.

