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# **Remote sensing of boat abandonment using Google Earth**

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## **Abstract**

Abandoned boats represent a pervasive and growing problem in the coastal zone that have received little regulatory or scientific attention. In this study, we show how Google Earth™ can be employed to remotely identify abandoned boats and provide information on their size, age and condition. Based on specified criteria for abandonment, a survey of southern England (1700 km in length) reveals the presence of 266 boats that are mainly located in the intertidal zones of estuaries and inlets and that are often contained within clusters. Boat length ranged from 2.6 to 60 m (median = 10.5 m) and since 2004 abandonment has been increasing at a rate of about eight per year. The majority of boats appear to be of timber construction and exhibit evidence of damage and water-sediment ingress. The environmental impacts are likely to be most significant where boats are clustered on protected mudflats.

## **Keywords**

Abandoned boats; Google Earth™; remote sensing; intertidal zone; antifouling paint; regulations

## 1. Introduction

An abandoned boat is a vessel of any size (e.g., pleasure boat, fishing boat, cargo ship) that has been given up by the legal owner without the intention of reclamation at a later date. Boats are abandoned for a multitude of reasons, but it often comes down to costs. With a life span of around 30-45 years depending on the construction material, boats eventually come to their end of use and need to be restored or disposed of safely and sustainably (European Commission, 2017). However, both options are expensive, with the largest boat recycler in the UK, located in Portsmouth, quoting around £100 per foot of hull length for dismantling and material recovery (Practical Boat Owner, 2020). To avoid these costs, owners may remove any means of identification before the boat is left at its mooring, set adrift, sunk or concealed. These practices are often considered to be less conspicuous and more acceptable at locations where abandoned boats already exist (Turner and Rees, 2016).

It appears to be illegal to abandon a boat in the UK but legislation is unclear and difficult to enforce. The Thames Conservancy Act (1932) refers to removing or destroying “sunk or stranded” vessels at a cost to the owner, and more recently, Environment Agency press releases mention removing “unregistered” boats when they obstruct waterways, damage the environment (principally through oil spillage) or have a significant impact on the aesthetics of the area (Environment Agency, 2017; 2018; 2019; 2020). Coupled with the costs mentioned above, there is, therefore, little incentive to safely dispose of (Summerscales et al., 2016; Turner and Rees, 2016; Dibofori-Orji et al., 2019; Hopkinson et al., 2021).

The Hydrographic Office houses a database on shipwreck locations around the UK derived from insurance claims and boats flagged as a navigation problem (Admiralty Maritime Data Solutions, 2020). However, because abandoned boats are unreported, they are generally excluded. To this end, we present a novel means of remotely and safely identifying and characterising abandoned boats in the coastal zone through the use of Google Earth™ (GE). Specifically, we focus on the south coast of England and systematically examine the scale and locations of the problem and how abandonment has been evolving over the past two decades in order to identify any environments at risk and assist in any remediation measures or decision-making.

GE is a powerful, interactive platform that superimposes satellite images, aerial photography and GIS data onto a three-dimensional globe. It was introduced as Earth Viewer in 2001, changing to its current name and becoming widely available to the public in 2005. The original imagery had a spatial resolution of 15 m but this has been progressively improved to allow detail down to 30 cm or less to

be observed (Boardman, 2016). Because GE is freely available, easy to use, compatible with other systems and data resources, and has a twenty-year timeline range, it is a popular tool in both education and research (Mather et al., 2015; Malarvizhi et al., 2016). GE has been particularly useful in physical and human geography and geology, with specific applications including the mapping, monitoring and management of urban characteristics (San Emeterio and Mering, 2020), wetlands (Hoffmann and Winde, 2010), glacial landforms (Darvill et al., 2014), coastal dunes (Turner et al., 2021), droughts (Khan and Gilani, 2021) and shorelines (Warnasuriya et al., 2018).

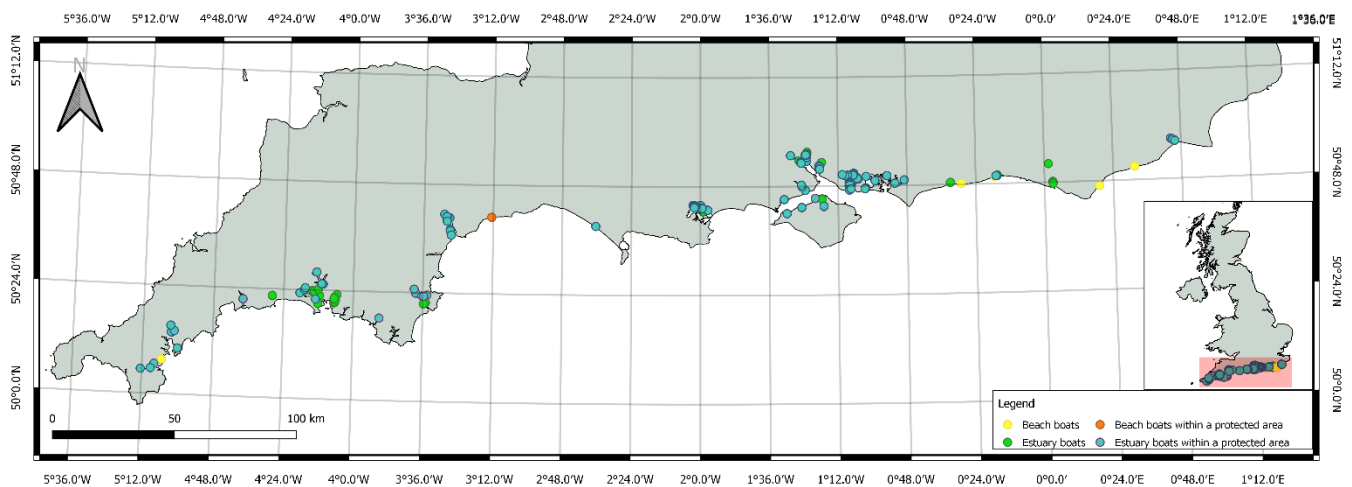


Figure 1: The area surveyed along the south coast of England from Rye to Land's End and the location of boats abandoned in estuaries (and inlets) and on beaches.

## 2. Methods

Abandoned boats were identified between Rye, East Sussex, and Land's End, Cornwall (and including the Isle of Wight), a stretch of coastline of about 1700 km in length and encompassing fourteen unitary authorities (Figure 1). The coast comprises cliff-backed rocky shores, sandy beaches (often backed by cliffs or dunes) and shingle ridges, interspersed with rias, estuaries and tidal inlets where ports, harbours and various industries are often located. The entire coastline, including estuaries and inlets up to their tidal limits, was surveyed with GE at an eye altitude of about 200 m and across the range of dates for which suitable imagery was available (between 1999 and 2004 to 2020, and up to fifteen different dates). Where abandoned boats were suspected, eye altitude was decreased to between 50 and 100 m. Here, the approximate spatial resolution, estimated from the smallest

objects or details that could be observed and including distinctive boat parts whose precise dimensions were established from a site visit to Hooe Lake (Figure 2), ranged from about 0.3 to 2 m. Because of constraints on positional accuracy resulting from the use of images from different satellites that are not orthorectified, coordinates are reported with a suitable precision (and to the nearest whole second). Where available, imagery from Google Street View, an additional feature of GE that provides interactive panoramas from positions along public streets, was inspected to gain further details about specific boats.

Boats were defined as being abandoned if being they had been in precisely (or approximately) the same position for a period of at least five years and/or met one or more of the following seven criteria: partially or completely sunk; taking on water; lack of human activity on-board (e.g., tarps and gear not moved and no evidence of renovation); plant growth or rust on the deck; damage with no attempt to fix (e.g., collapsed wheelhouse, holes in the deck); inadequate mooring; evidence of attempts to conceal (e.g., hidden under trees, located away from public access).

The construction material of each abandoned boat was noted if evident, and time series imagery and the ruler tool in GE were used to determine the date of abandonment and length to the nearest 0.1 m or 0.2 m (based on the average of available measurements over time), respectively. The former was defined as the year of first appearance of the boat if successive years of imagery were available or the middle year if annual imagery was absent (i.e., if temporal resolution was more irregular).

In many cases, identification of abandoned boats was straightforward in that a vessel would remain at a specific location and undergo decay. Boats could first appear on imagery at a particular date or be present throughout the whole time series recorded. In other cases, identification and characterisation was more complex. This is exemplified by the GE imagery of the intertidal zone of Hooe Lake, Plymouth, captured on four selected dates that illustrate the evolution in the number and condition of several boats (Figure 2). Thus, boats A and B, of 20.4 m and 9.8 m in length, respectively, are evident on the earliest imagery (December 2002). Boat A remains in the same position throughout the time series to May 2020, but has begun to list by August 2016 and exhibits considerable damage, including by fire, in the most recent image. In contrast, boat B has shifted its precise location, either because of tidal currents or intervention during the mooring or abandonment of other boats and structures, but is nevertheless classed as abandoned. Boats C and D, of lengths of 20.7 m and 17.8 m, respectively, appear in imagery dated April 2007, and while the latter is clearly abandoned and decaying, the former remains moored and appears to have undergone recent modification. A subsequent visit to the location revealed that the boat is

undergoing restoration on an intermittent basis and is, not, therefore, classified as abandoned. Boats E (32.0 m) and F (8.0 m) appeared between 2007 and 2010 and in 2016, respectively, and while the former is in poor condition and taking in water, the latter appears to be securely moored and in relatively good condition. Since boat F had been at the same location for only four years, the principal criterion for abandonment was not, therefore, met.



Figure 2: GE imagery of a region of Hooe Lake, Plymouth (50°21'22"N, 4°06'28"W), where boat abandonment has been increasing over the past twenty years. Selected dates are shown as month/year and boats labelled in each image are described in the text.

The condition of each abandoned boat identified in the most recent imagery of the coastline was categorised according to the criteria shown in Table 1, and examples of each category are illustrated in Figure 3.

Table 1: Criteria used to categorise the condition of an abandoned boat.

Condition	Criteria
Intact	Reasonable condition with minor cosmetic damage.
Damaged	Notable cosmetic or physical damage but no evidence of significant sediment or water ingress.
Partially submerged	Party below water or buried in sediment, often with notable damage.
Broken down	Completely (or almost completely) submerged and/or major damage to the whole structure.

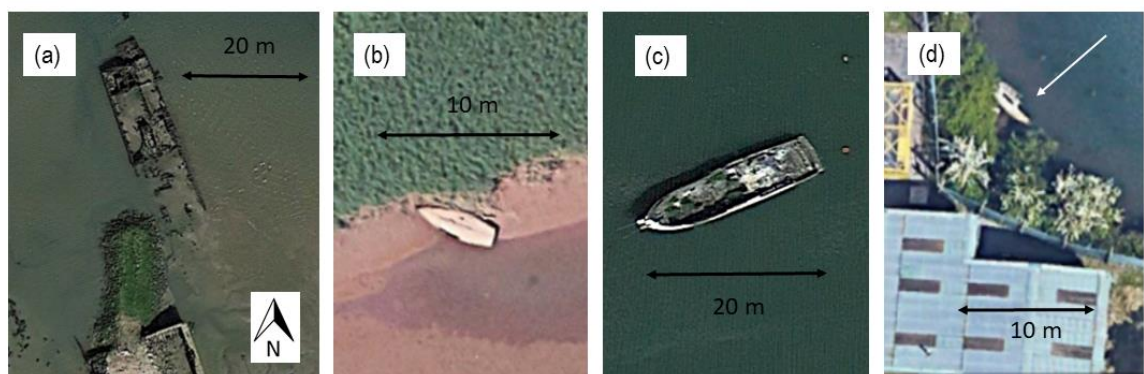


Figure 3: GE images of (a) A broken down boat in Tipner Lake, Portsmouth ( $50^{\circ}49'38.29''\text{N}$ ,  $1^{\circ}05'18.86''\text{W}$ ), (b) an abandoned boat, hull facing upwards, in reasonable condition (intact) on the Exe Estuary ( $50^{\circ}40'53.81''\text{N}$ ,  $3^{\circ}28'03.65''\text{W}$ ), (c) a damaged but floating boat on the Itchen Estuary



(50°55'08.46"N, 1°23'05.17"W), and (d) a partially submerged and concealed boat in a creek off Southampton Water (50°53'39.19"N, 1°25'35.00"W).

### 3. Results and Discussion

#### 3.1. Spatial distribution of abandoned boats

Overall, 266 abandoned boats were identified along the southern coast of England from GE imagery, with the vast majority overlooked by the existing Wrecks Areas UK EEZ database (Admiralty Maritime Data Solutions, 2020). This figure is equivalent to an average of one abandoned boat for every 6.4 km of shoreline. However, the geographical distribution of the boats, shown in Figure 1, reveals a high degree of spatial variation. Specifically, the majority of boats ( $n = 257$ ) were encountered on or in the intertidal mudflats and saltmarshes of estuaries and tidal inlets, with just nine boats found above the high water line of (mainly) shingle beaches. This distribution results in significant fractions of abandoned boats being located within protected sites, including 60.4% in Ramsar Wetlands of International Importance and 68.7% in Sites of Special Scientific Interest (SSSI). Presumably, the relatively high density of boats in mudflats and saltmarshes reflects limited public accessibility (especially where the shoreline is industrialised) and ready concealment (and in particular amongst saltmarsh vegetation), as well as the ability of fine, accreting sediment to immobilise large structures.

Many of the boats on intertidal flats were also encountered in distinct clusters of up to twelve boats (with clusters defined as at least two boats within 100 m of each other). The majority of clusters were observed in the sheltered intertidal flats of estuaries and embayments around Portsmouth, Southampton, Poole and Plymouth (Figure 1). In some cases, clusters appeared to develop over a period of time through mooring aggregation, and as exemplified in Figure 4. Here, boats abandoned before 1999 in the Itchen Estuary (and illustrated in 2004) were subsequently used for the mooring and abandonment of newer vessels, resulting in the development of a dense cluster (and illustrated in 2016).

Scattered clustering occurs when there is a growth of abandoned boats at a particular locality that are not moored together. This type of clustering is evident in Hooe Lake, Plymouth (Figure 2), and at Lytchett Bay in Poole Harbour (Figure 5) and has been reported in studies of the east coast of England (Turner and Rees, 2016) and the Pacific and Caribbean territories of the US (Lord-Boring, et al., 2004). Such locations are perceived to be convenient and acceptable because they evade any punishment or other repercussions; consequently, they attract successive abandonments by the

same or different owners over a period of time. These locations often attract the dumping of other structures that may or may not be related to boating activities (and as exemplified in Figure 5).

Event clustering is the sudden, mass abandonment of multiple boats at the same time resulting from an incident. Mass abandonment has been reported in US territories because of extreme weather events (Lord-Boring et al., 2004) but this is unlikely in the UK. More important here might be closures of boating facilities or the withdrawal or replacement of a particular type of vessel. As an example, a cluster of abandoned boats observed in Forton Lake, Portsmouth Harbour (Figure 6), was attributed to an event that pre-dated GE imagery. Specifically, multiple boats were left when a boatyard closed down in 1959, with additional boats being abandoned within the cluster since (Karmy, 2009).



Figure 4: GE imagery showing the evolution of a cluster of abandoned boats on the Itchen Estuary ( $50^{\circ}54'57''\text{N}$ ,  $1^{\circ}22'55''\text{W}$ ) between (a) 2004 and (b) 2016.

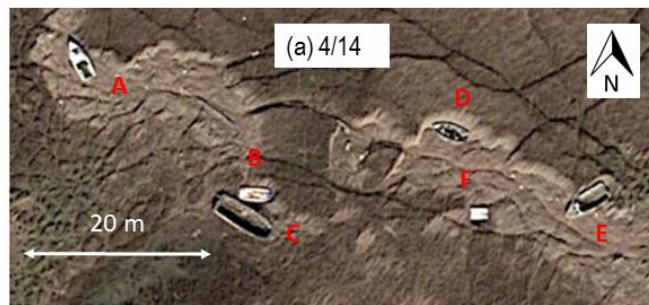


Figure 5: GE image of a cluster of abandoned boats (A to E) in Lytchett Bay (50°43'53"N, 2°02'10"W).  
Note the presence of an additional, rectangular structure (F) that has been dumped at the location.

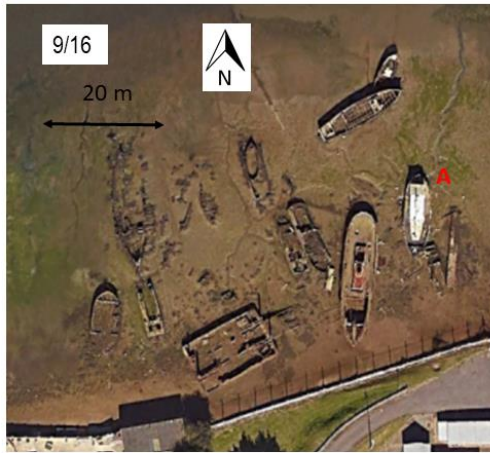


Figure 6: GE image of a cluster of abandoned boats in Forton Lake, Portsmouth Harbour (50°48'11"N, 1°07'57"W). Most boats, including those partly submerged in the sediment, were abandoned following the closure of a boatyard in 1959, but boat A appeared in 2015.

### 3.2. Characteristics of boats and dates of abandonment

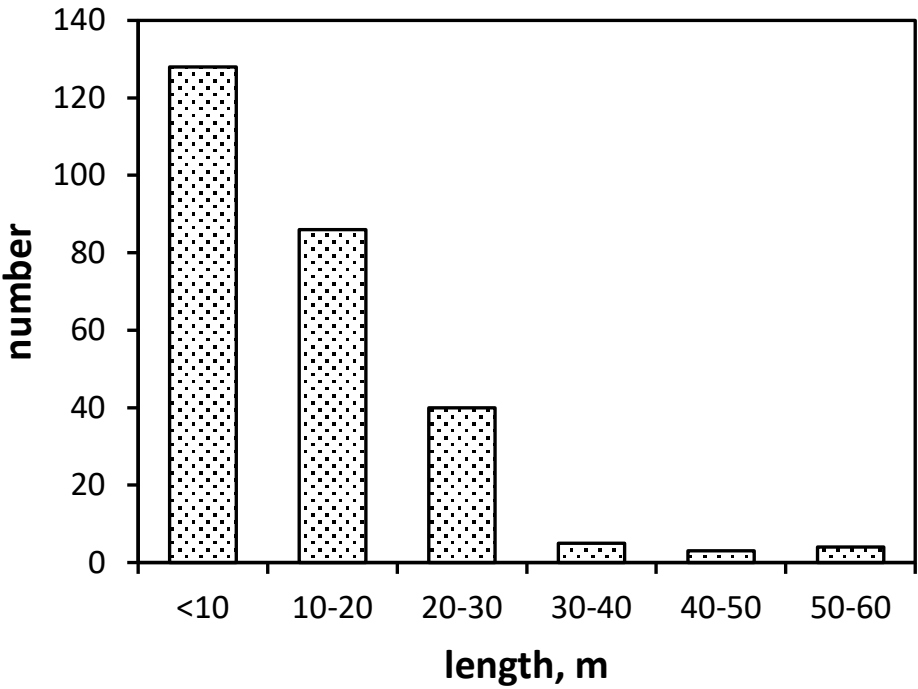
The size distribution of the abandoned boats identified in the present study is shown in Figure 7. Length ranged from 2.6 m to 60 m, with mean and median values of 13.4 m and 10.5 m, respectively, and frequency exhibited a reduction with increasing length. Regarding boat condition, and according to our criteria, 190 were broken down, 43 were damaged, 31 were partly submerged and two were intact. Amongst the abandoned boats, 95 could be defined in terms of their material of construction. Thus, based on colour, texture, panelling and decay, and, where available, imagery generated by Google Street View, 90 were identified as being of timber construction and five were identified as being of steel construction.

Local databases and historical accounts of shipwrecks and other underwater structures mention a few of the larger foreshore boats identified in the present study with abandonment dating back to 1945 (Langley and Small, 1988; The SHIPS Project, 2021). However, and despite GE imagery available since 1999 in some areas, the earliest date of recording across the entire coastal region surveyed was 2004. The year of abandonment since this date is shown in terms of cumulative frequency in Figure 8 and reveals a steady increase in the number of boats that averages 8.4 per year and a

269 relationship between cumulative frequency and year of abandonment that is defined by linear  
270 regression with statistical significance. Note that this figure is not offset by boat recovery as none of  
271 the abandoned vessels identified were removed from their locations during the time period  
272 surveyed.

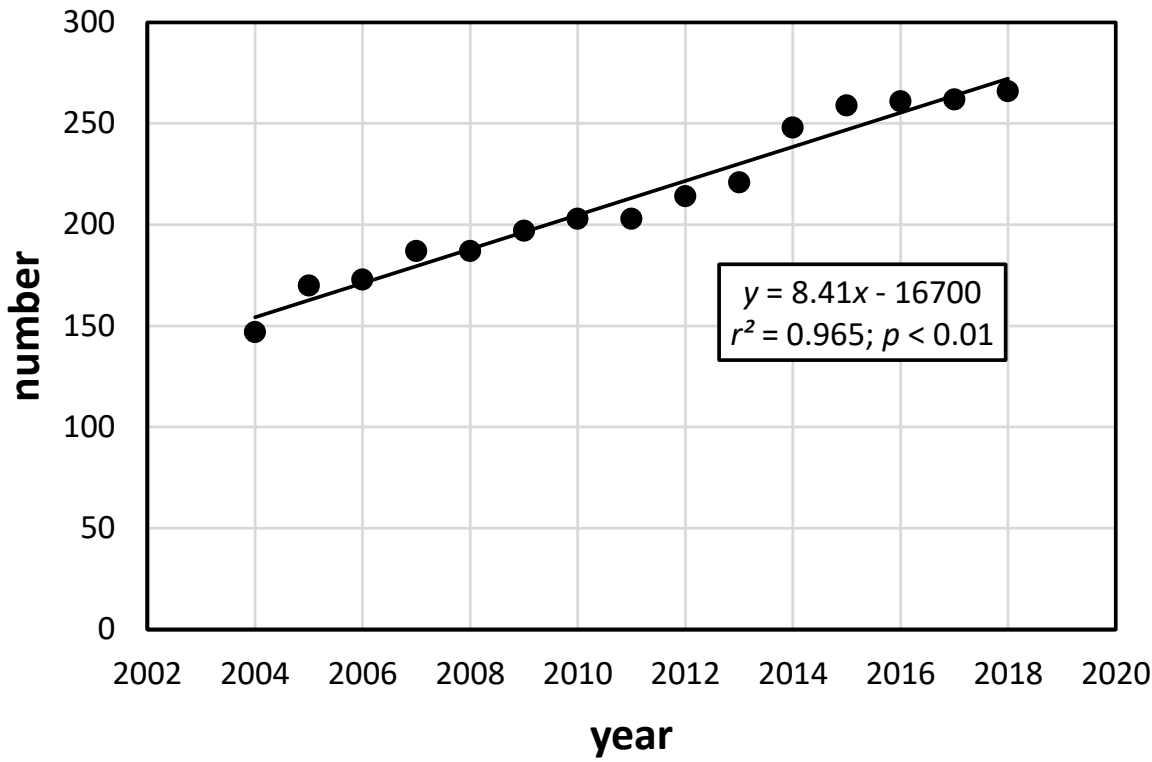
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276 Figure 7: Size distribution of the abandoned boats identified along the south coast of England.



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Figure 8: Cumulative frequency distribution of date of boat abandonment along the south coast of England. The regression (solid line) is defined by the parameters annotated.

### **3.3. Environmental impacts of boat abandonment**

Although GE is useful tool for the remote identification of abandoned boats, it is not able to provide information on the significance of the problem. In the UK, for example, intervention from the Environmental Agency will only take place if there is an immediate or visible navigation or pollution threat. The latter is generally restricted to leaking oil (Turner and Rees, 2016), with impacts associated with human safety, habitat loss and access to the shoreline not generally considered. A longer-term pollution risk to the environment that is also overlooked by the authorities is the gradual loss of antifouling hull paint particles into intertidal sediments (Rees et al., 2021; Hopkinson et al., 2021). On older boats, antifouling paints may contain substances based on mercury, lead and tributyltin that have been restricted or banned for decades (Lagerström et al., 2017; Turner, 2022). Empirical evidence in the literature suggests that antifouling paint particles based on various contemporary and historical formulations are toxic to many marine plants and animals at environmentally realistic concentrations (Soroldoni, et al., 2018; 2020; Muller-Karanassos et al., 2019). In this regard, some of the areas surveyed in the present study would appear to be at particular risk. For instance, Lytchett Bay (Figure 6) is both an SSSI and a Ramsar Site and had the highest concentration of abandoned boats across southern England (27 on about 1 km<sup>2</sup> of mudflats). According to the Dorset Wildlife Trust (2021), the area is crucial for wading birds, fish, invertebrates and amphibians and is also a destination for migrant birds which rely on invertebrates inhabiting the mud for food.

## **4. Conclusions**

GE provides a convenient and novel means of remotely assessing the scale and evolution of a pervasive problem that has thus far received very little systematic or scientific attention. The findings of this study across a 1700-km coastline of southern England reveal that boats are most commonly abandoned in the intertidal zone of estuaries and inlets and, for a number of reasons, abandonment is often observed in distinct clusters. Although the precise environmental impacts of abandoned boats will require in situ monitoring, GE can help to identify sensitive or remote areas at risk and regions where abandonment is rapidly increasing in order to assist with any decision- and policy-making and guide intervention strategies.

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315

### 316 **Declarations**

317

### 318 **Availability of data and materials**

319 The full dataset for the current study is available from the corresponding author on reasonable  
320 request.

321 Not applicable

### 322 **Ethical approval**

323 Not applicable

### 324 **Consent to participate**

325 Not applicable

326 **Author contribution** MP: methodology, formal analysis, investigation, resources, data curation,  
327 writing—original. AT: conceptualization, methodology, formal analysis, investigation, writing —  
328 original draft, writing—review and editing, visualization, supervision, and project administration.

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331 **Consent for publication** Not applicable

332 **Competing interests** The authors declare no competing interests

333

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337 [portal/items/a46e1c0d912d459fbaf723c347ee9b78?geometry=-](https://datahub.admiralty.co.uk/portal/apps/sites/#/marine-data-portal/items/a46e1c0d912d459fbaf723c347ee9b78?geometry=-76.201%2C41.509%2C160.928%2C72.502)  
338 [76.201%2C41.509%2C160.928%2C72.502](https://datahub.admiralty.co.uk/portal/apps/sites/#/marine-data-portal/items/a46e1c0d912d459fbaf723c347ee9b78?geometry=-76.201%2C41.509%2C160.928%2C72.502) (Accessed: 23/02/21)

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