

Assessing historical saltmarsh change; an investigation into the reliability of historical saltmarsh mapping using contemporaneous aerial photography and cartographic data

Brian Baily · Robert Inkpen

Received: 23 July 2012 / Revised: 6 March 2013 / Accepted: 16 April 2013 / Published online: 1 May 2013
© Springer Science+Business Media Dordrecht 2013

Abstract Habitat protection, creation and management are at the forefront of nature conservation throughout the world. Many terrestrial and marine ecosystems are under pressure from a diverse range of issues including impacts associated with climate change, multiple resource use and increased development. Saltmarsh within the United Kingdom, is one such valuable habitat which has suffered significant losses over the last eighty or so years. Any environmental management practice or decision applied to these areas, should ideally be based on evidence of processes and change. One potential way of measuring saltmarsh change is by using historical maps and aerial photographs to look for patterns of growth or reduction. This research examines the process of saltmarsh mapping and compares historical aerial photographs and maps to assess their suitability for habitat change assessment. This research suggests that whilst historical aerial photography can be accessed and utilised effectively, the data presented on maps should be treated with a great deal of caution. The saltmarsh represented on the maps used in this research was noticeably different from that mapped using aerial photographs from a similar time period. Whilst this does not dismiss the use of historic maps along this part of the coast, it does suggest they should be treated with some degree of caution and will vary in their reliability.

Keywords Saltmarsh · Aerial photography · Cartography · Spartina · Habitat loss · Habitat management

Introduction

Coastal habitats and ecosystems are increasingly under threat from a variety of potential pressures including climate change, building development, pollution, erosion and recreational pressures. Mapping and monitoring of coastal habitats is now widely practised around various sites in Britain and other countries (see for example Burd 1989; Curtis and Sheehy Skeffington 1998; Gross et al. 1988; Cooper et al. 2000, 2001; Baily 2001; Van der Wal and Pye 2004; Baily and Pearson 2007; Cope et al. 2007). One important aspect of conservational management is to understand the longer-term behaviour of these systems so that managers and decision-makers may identify potential decline, estimate losses or gains and examine cyclical or other types of behaviour. A number of studies have used historical maps for coastal research around the world (French 1999; Van der Wal and Pye 2004; Baily and Collier 2010, 2011) or remote sensing (Gross et al. 1988; Gedan and Bertness 2005; Baily and Pearson 2007; Cooper et al. 2001) to examine changes in coastal ecosystems. Aerial photography and photogrammetric analysis, allows primary data to be collected from an uncontaminated data source and can ensure the same interpretation can be applied to different data sets. Aerial photographs exist widely for the British Isles and are commonly available as far back as the 1940s and beyond. Before 1945/6, the existence of vertical aerial photography is more sporadic, but archives such as the Royal Commission on the Historical Monuments of England often hold aerial photography, for some areas from the 1920s onwards.

For research wanting to go even further back in time, the only real viable option is to examine habitats as recorded on cartographic sources of evidence. Historical map data has

B. Baily (✉) · R. Inkpen
Department of Geography, University of Portsmouth,
Lion Terrace,
Portsmouth PO1 3HE, UK
e-mail: brian.baily@port.ac.uk

been collected by different organisations including the Hydrographic Office and the Ordnance Survey at a national level for many years. There also exists a plethora of other types of local cartographic outputs including estate maps and local mapping products. The inter-tidal area has often been a zone where organizational overlap occurred or a grey zone where mapping could be neglected or regarded of less importance. The reliability of maps of the coastal zone has often been questioned within the literature and any use of these data requires an understanding of some of the potential drawbacks involved (see for example Carr 1962, 1969, 1980). Ordnance Survey County series maps are widely available from the middle of the nineteenth century onwards. Beyond the 1800s, maps still exist but the quality of the intertidal mapping may be unknown. Any use of these data requires a degree of faith in the map collectors and producers. This research examines saltmarsh change at a number of sites around the Solent (Fig. 1). It examines how saltmarsh is represented on Ordnance Survey County Series maps and the policy relating to its mapping. This research uses Ordnance Survey County Series maps (1:2,500) which are widely available from the 1850s onwards to chart saltmarsh change. Early aerial photography is then compared to the saltmarsh mapping data, to compare the cartographic output with the data derived from the photography.

Saltmarsh in Britain

Saltmarshes form some of the rarest and most threatened habitats of the British Isles. These ecosystems have suffered

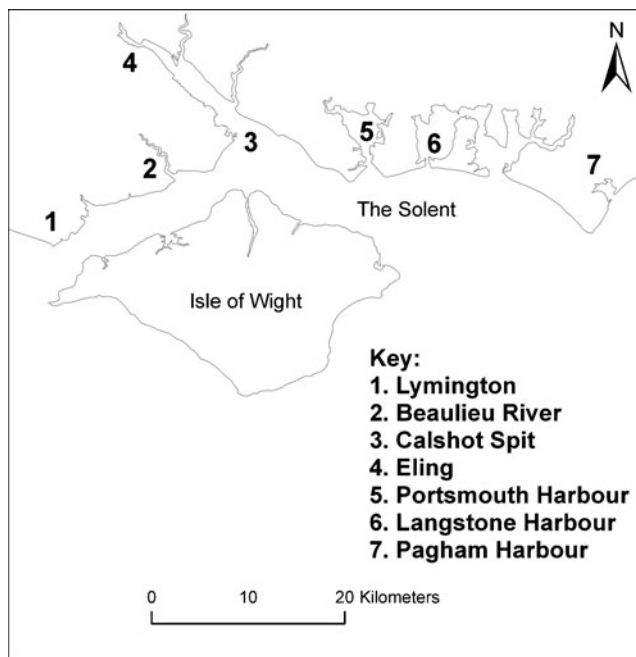


Fig. 1 A map of the Solent area highlighting the location of the selected study sites within this research

from pollution, land reclamation and erosion amongst many other issues. Successful conservational management of these important habitats requires an understanding of the development of these areas, including trends in the spatial and temporal behaviour of saltmarsh to enable long term conservation and planning. According to the 2008 National Coastal Saltmarsh report produced by the Biodiversity Action Reporting System, there are 45,820 ha of saltmarsh around the United Kingdom. These habitats are important amongst other things for sea defence, nature conservation and recreational use. In the past, the value of saltmarshes has often been undervalued and has led to urban encroachment and agricultural reclamation. More recently, the importance of saltmarshes has been recognised in relation to their value as natural habitats, their importance for the maintenance of fisheries, provision of food and raw materials, water filtering systems, carbon sequestration, coastal protection systems and recreational resources. Worldwide there have been numerous studies into saltmarsh ecology and conservation and various attempts to monitor or assess changes occurring to saltmarsh habitats (Burd 1989, 1992; Pye and French 1993; Raybould et al. 2000; Cooper et al. 2000; Van der Val and Pye 2004; Baily and Pearson 2007; Cope et al. 2007; Bromberg and Silliman 2009; Davy et al. 2009; Barbier et al. 2011). Saltmarsh around the British coasts comprises a broad range of flora and fauna including species at the land/sea boundary and species at the lower edge of the intertidal zone. Coastal saltmarshes comprise the upper, vegetated portions of intertidal mudflats, they are located in between mean high water neap tides and mean high water spring tides. Saltmarsh may be defined loosely as areas of marshland overtopped periodically by water. Barbier et al. (2011: 178) define saltmarsh as “intertidal grasslands that form in low-energy, wave protected shorelines along continental margins”. A large amount of the saltmarshes of central southern England are believed to be of recent origin and are generally less than 150 years old according to Hill (1996), with the possible exceptions of Portsmouth, Langstone, and Chichester Harbours. They are dominated by the cordgrass *Spartina anglica*, and other species such as *Salicornia* spp., sea purslane (*Halimione portulacoides*), common saltmarsh grass (*Puccinellia maritime*), red fescue (*Festuca rubra*), sea rush (*Juncus maritimus*), common reed (*Phragmites australis*), and the eelgrasses (*Zostera* spp.).

The saltmarshes around many parts of the British coastline are generally showing a trend of retreat across a variety of different geographical locations (Baily and Pearson 2007). This retreat and decline appear to be in contradiction to the earlier rapid expansion of saltmarsh which occurred towards the end of the nineteenth century onwards (Olivier 1925). Much of the saltmarsh along the south coast of England are the perennial saltmarsh grasses. *Spartina townsendii* was first recorded in the 1870s and still exists

in some areas. *Spartina anglica* was first recorded in Lymington in the 1892 and spread rapidly to other areas. *Spartina anglica* emerged as a result of the hybridization between the indigenous *Spartina maritima* and the eastern American *Spartina alterniflora*. *Spartina alterniflora* was introduced to Hythe around 1870 from the east coast of America where it crossed with the native species to produce *Spartina anglica* and the sterile *Spartina townsendii* (Gray et al. 1991). In evidence given to the Royal Commission on Coastal erosion in 1909, Lord Montague of Beaulieu drew attention to the rapid spread of *Spartina* across the Hampshire coast. *Spartina* was seen as a valuable tool in land reclamation and indeed thousands of plants were exported to other countries including Ireland, Trinidad, Germany and New Zealand (PRO FT1/54). The rapid expansion initially of the hybrid *Spartina townsendii*, was discussed by Stapf (1913:13) ‘*S. townsendii* has in a comparatively short time conquered thousands of acres of bare mud land’. Oliver (1925:74) notes “Its spread from the point where it was originally discovered has been continuous and remarkable”. Gray et al. (1991) note that the *Spartina townsendii* and *Spartina anglica* are often confused in earlier studies due to the difficulty in separating them. What is beyond doubt is that the rapid growth of these two cord grasses radically changed the intertidal habitat of many areas from the end of the nineteenth century onwards. Goodman and Braybooks (1959) note that by 1913 the *Spartina spp.* had invaded every estuary and harbour from Chichester to Poole and was also established on the Isle of Wight.

After an initial period of rapid expansion of the saltmarsh areas, there began to appear sporadic reports of the die-back of these species and a reduction in saltmarsh. According to Goodman and Braybooks (1959:652), one of the worst affected areas was the Lymington estuary which had lost around 30 ha. This decline has continued along the south coast with a recent study using aerial photography showing loss of saltmarsh in nearly all of the sites examined (Baily and Pearson 2007; Cope et al. 2007). The spatial and temporal pattern of loss varies between sites, but some areas such as Langstone Harbour near Portsmouth have seen a decline of large areas of saltmarsh amounting to the loss of 83.4 % between 1946 and 2002 (Cope et al. 2007). This pattern reflects those recorded in other areas including the Stour estuary which has been reduced by an estimated 59 % with major losses being recorded in the estuaries of the Orwell (46 %), Hamford (29 %), and Blackwater (22 %) between 1974 and 1998 (Cooper et al. 2001). Rather than stabilizing, there is increasing evidence that the rate of erosion of the saltmarsh has increased since the 1970s (see for example Bradbury 1995). The loss of the saltmarsh is related to both natural and anthropogenic factors. Natural factors may be related to the phenomenon referred to as *Spartina* die-back (Goodman and Braybooks 1959; Gray et

al. 1991); indeed, Bray et al. (2004) suggest that the trend toward net loss almost certainly correlates with the commencement of erosion and dieback of *Spartina anglica*. Other potential factors include changes in sea level rise, climate or wave regime (Cooper et al. 2001; Van der Wal and Pye 2004; Boorman 1992), coastal squeeze (Morris et al. 2004), herbicide use (Mason et al. 2003) and herbivation (Paramor and Hughes 2004).

There have been numerous attempts to map the decline of saltmarshes around Britain using ground survey, historic maps and charts and aerial photographs. Although specific rates and amounts of loss vary, the common theme running through many of these studies is one of saltmarsh decline or change, often at an increasing rate. The spatial and temporal variation of the rate of loss is thus apparent from these studies, although clearly some variation may be attributable to the varying reliability of secondary data sources, particularly maps, and the difficulty of measuring the rate of change along complex erosional fronts. Nevertheless, there is clear consensus that the saltmarsh is receding in many areas.

Cartographic historical coastal evidence

Around the coastline of the United Kingdom there is a generally accessible historical archive of aerial photography available for many coastal areas (RCHME, Swindon; RCHMS Edinburgh, for example). Most regions appear to have photography available from the 1940s onwards with some having photography back to the 1920s or earlier. As has been discussed previously, many of the changes in saltmarsh composition and distribution went through a major period of change from the 1870s onwards. Therefore, when attempting to map these early changes it becomes necessary to employ historical maps. As with any other data source, historical cartographic data contains errors which need to be assessed and understood before they are used. According to Hooke and Kain (1982), there are three broad areas of potential errors in the use of cartographic data for environmental change research. The first of these occurs during the collection of information itself and is related to data collection instruments and surveying and mapping skills. In the case of saltmarsh, these may include factors such as whether the saltmarsh was surveyed or sketched, which of course may be related to practicality and accessibility. A second potential source of error may occur in the subsequent transfer of information from the field data set to the cartographic medium. This will include the original edition of the map but may also well include subsequent revisions or partial revisions. Again with reference to saltmarsh, this could be the problem of partial revision or of no revision at all between dates. In relation to saltmarsh

data, it is important to understand the extent to which revision took place and the extent of copying of earlier data.

One further potential main error source is related to the handling and storage of the documents themselves. All hardcopy sources whether maps or aerial photographs are subject to distortions, through the production and storage process including paper shrinkage and stretching. In particular, this affects the accuracy of planimetric features and needs to be recognized as a potential source of error. Procedures are available for identifying and estimating errors in cartographic sources and are described by amongst others (Maling 1989; Thieler and Danforth 1994 and Jenny 2006). The three main sources of error whilst not ruling out the use of cartographic evidence for saltmarsh change analysis should be understood, incorporated and recognised in any study of saltmarsh change. Many of these errors can be estimated or measured and included in any study. However, with coastal features it is also important to understand the reasons behind the survey to prevent misinterpretation of the reliability of a particular source.

Mapping saltmarsh and the inter-tidal zone

Before the advent of aerial photography and photogrammetric mapping the collection of survey data in the inter-tidal area presented a great challenge to the Ordnance Survey and other mapping bodies. Previous research on tidal line mapping within the coastal zone has shown how these features were often surveyed but at other sketched on the maps (Baily and Collier 2010). An evolving process of the formalisation of Ordnance Survey coastal mapping policy began in the 1840s and was finally completed in 1868. The Ordnance Survey Act 1841, paragraph 1 required Justices of the Peace to appoint meresmen to assist the Master General and Board of Ordnance in *Examining, ascertaining and marking out the reputed boundaries of each County, City, Borough, Town, Parish* (House of Commons 1841). Before 1868, the measurement of these boundaries did not include the extra parochial places including the foreshore and areas of saltmarsh, which were not included in any parish. However, in 1868 came the passing of the Poor Law Amendment Act and all the remaining extra parochial places were included for civil parochial purposes in the next adjoining parish as the parish boundary was now extended to the low water line. The Poor Law Amendment and a judgement by the Lord Chancellor (Lord Cranworth), who in 1854 legally recognised the high and low water mark of an ordinary or average tide as the boundary of the foreshore, altered the approach of the Ordnance Survey mapping of the intertidal area, as it now became necessary for the Ordnance Survey to include areas of the foreshore within the rating area. In the survey of 1878, the Ordnance Survey carried

parish boundaries to the low water mark of ordinary tides, as this line now represented the seaward extent of the city, parish and town etc. This theoretically now included areas of saltmarsh above the low water line.

Saltmarsh features on maps are presented in several different ways. The earliest Ordnance Survey maps show marsh areas represented by a series of symbols, which prior to 1869, were hand drawn and then later stamped onto the original plates. Earlier saltmarsh is represented on maps as shown in Fig. 2. This is often, although not always, given the ‘saltings’ label. The older saltmarsh often has a different symbol to the later marshes, which emerged as *Spartina* spp. spread across the south coast. The older saltmarsh is also bounded by a solid or dotted line and often given the label ‘Saltings’ or ‘Salterns’, whereas the other saltmarsh is often unbounded and simply represented by a stamped symbol (Fig. 3). These symbols were originally hand drawn on maps but were later changed to a more automated stamping approach

Data capture of the saltmarsh cover on historical maps

Historical analysis of natural systems often involves the use of data such as aerial photographs or historical cartographic outputs. The use of these data and sources often involves specialized techniques such as georeferencing, classification or vectorization (Fig. 3). The maps used in this research are those which are available for download from the Edina Historical Digimap service and produced by the Landmark Information Group. The maps used in this research are the Ordnance Survey County Series maps at a scale of 1: 2,500, First edition (1868–69); First revision (1876–1898); Second Revision (1909–1912) and the Third revision (1932–1945) (Fig. 4). The dates given in the results section are for the

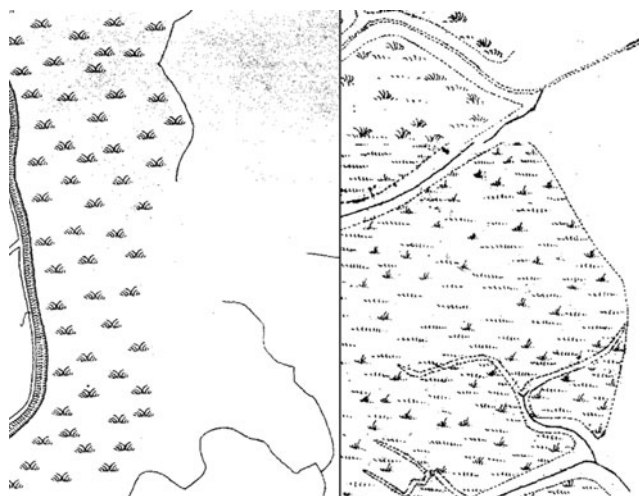


Fig. 2 Showing the different symbols and borders used for areas of saltings (*right*) and the newly formed saltmarsh (*left*)

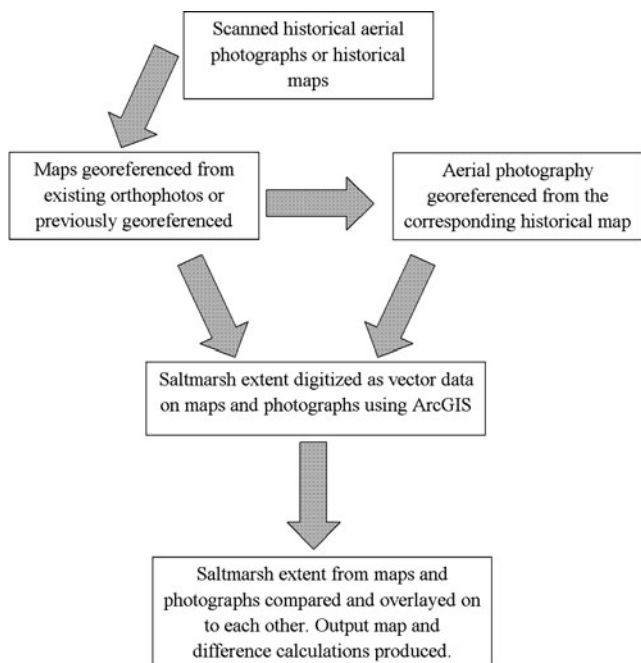


Fig. 3 A flow chart diagram demonstrating the methodological process followed in this research

publication date of the map. The maps available from Edina Digimap are already georeferenced and therefore it is possible to vectorize the saltmarsh from these without any manipulation. To ensure consistency, these maps were also then used to georeference the historical aerial photographs.

As most of the saltmarsh areas shown on the maps did not have boundary lines, the lines digitized used the edges of the symbols shown on the maps (Fig. 5). The areas of saltmarsh were digitized using a head up digitizing technique using ArcGIS 10. The Calshot Spit area (Fig. 5)



Fig. 4 A section of one of the Ordnance Survey County Series map available from Edina (Reproduced with the permission of the Landmark Information Group, Using: EDINA Historic Digimap Service)

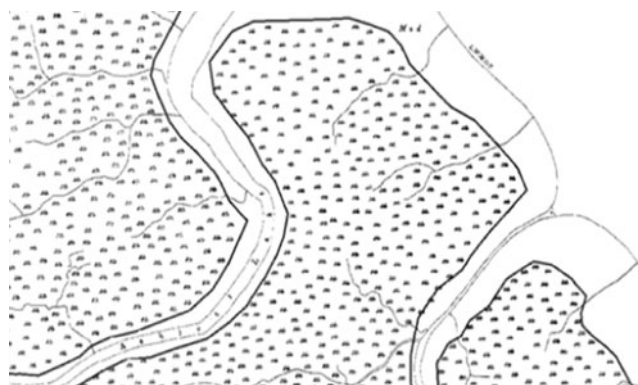


Fig. 5 The digitized vector outline from the County Series First revision (1897) (Reproduced with the permission of the Landmark Information Group, Using: EDINA Historic Digimap Service)

exemplifies the problems in using the historical maps for saltmarsh mapping for this particular location. In the County Series First Edition, the saltmarsh represented appears to be only patchy. However, following the growth of the hybrid *Spartina townsendii* and *anglica* it can be seen by the first revision of (1897) that many of the areas of saltmarsh have expanded greatly. The smooth curves and lack of outline may suggest that this area has been sketched and not surveyed in detail. The later second revision and third revisions, show little if any change, with the earlier digitised vector fitting the later saltmarsh mapping exactly. This suggests that the saltmarsh has either not changed at all or that the same lines have simply been reused. The saltmarsh was mapped for the various dates available for the different study sites. The areas of coverage were then calculated for each site for every epoch.

Results from the cartographic digitizing

Vector data was digitized for all the saltmarsh areas where the coverage was available. The coverages were then calculated (Table 1). It can be seen from these data that where coverage is available, that the areas have witnessed an increase in saltmarsh coverage as suggested by the literature. For example, the Beaulieu River area has seen an increase from 87.85 hectares (ha) in 1869 to 198.19 ha in 1909 representing a 56 % increase (Fig. 6). Similarly, the area near Calshot Spit shows only 4.86 ha in the 1869 edition, which then peaks at 159.42 ha (nearly a 33 fold increase) in 1897 and falls slightly to 150.63 ha in 1932 (Fig. 7). This pattern of increase is followed for Portsmouth Harbour, Langstone Harbour and Eling. Some sites such as Lymington do not show any saltmarsh at all for the earlier maps, even though it is recorded that saltmarsh existed in these areas. Other sites such as Portsmouth and Langstone harbours, seem to only record sporadic patches of marsh,

Table 1 Showing the results from the vectorization of the saltmarsh as recorded on the OS County series maps from selected study sites

| Site | Coverage first edition circa 1868–9 | Coverage circa 1876–98 | Coverage circa 1909–12 | Coverage circa 1932–1945 |
|--------------------|-------------------------------------|------------------------|---------------------------------------|--------------------------|
| Beaulieu River | 87.8449 ha | 96.9952 ha | 198.1856 ha | No maps available |
| Lymington | No saltmarsh shown | No saltmarsh shown | No saltmarsh shown | 253.41 ha |
| Calshot spit | 4.8636 ha | 159.4150 ha | 151.5360 ha | 150.6266 ha |
| Portsmouth Harbour | No saltmarsh shown | 13.9148 ha | 15.1605 ha | 16.3535 ha |
| Langstone Harbour | 12.1663 ha | 19.2418 ha | 15.3904 ha | 65.1317 ha |
| Pagham Harbour | 23.9342 ha | No change | Harbour enclosed | No saltmarsh shown |
| Eling | 37.8667 ha | 33.7857 ha | 43.1126* ha *One map tile unavailable | 44.8358 ha |

even though it was probably more widespread than this. Pagham Harbour is slightly different to the other areas, in that the harbour was reclaimed for a time. There is evidence on the first edition map of saltmarsh existing, which then disappears as the harbour is enclosed. On the next map (1932), where the harbour is again open, there is no saltmarsh recorded. The extent of the saltmarsh mapping does appear to vary between sites possibly due to accessibility and practicality issues.

Data capture from the historical aerial photography

It is clear from the mapping and discussion so far, that the saltmarsh was mapped to a varying level of detail by the Ordnance Survey. The maps clearly show areas of saltmarsh and change occurring. In reality, the rapid changes caused by the spread of *Spartina* would have made it particularly

difficult to keep up with the spread of saltmarsh along the south coast. To gauge an understanding of the reliability of early saltmarsh mapping, it is possible to use early aerial photography from similar areas, to match the extent to which the saltmarsh on the maps matched the coverage on the aerial photographs. Until the 1950s, the majority of the Ordnance Survey data was collected using ground survey techniques. Methods for the collection of data in the field were clearly laid out in a series of publications and Ordnance Survey instructions (Close 1912; Ordnance Survey 1932, 1948; PRO OS 45/8). The development of photogrammetric stereo plotting increasingly led to more data being collected using photogrammetric techniques. Historical aerial photography has long been used in the study of coastal change (see for example Oliver 1925; Fuller 1973). Aerial photography has the principal advantage of being a data source where the researcher is not reliant upon the previous interpretation of others. Aerial photography exists

Fig. 6 Showing the rapid change in saltmarsh areas between the maps of 1869 and 1909 for the Beaulieu area. (Reproduced with the permission of the Landmark Information Group, Using: EDINA Historic Digimap Service)

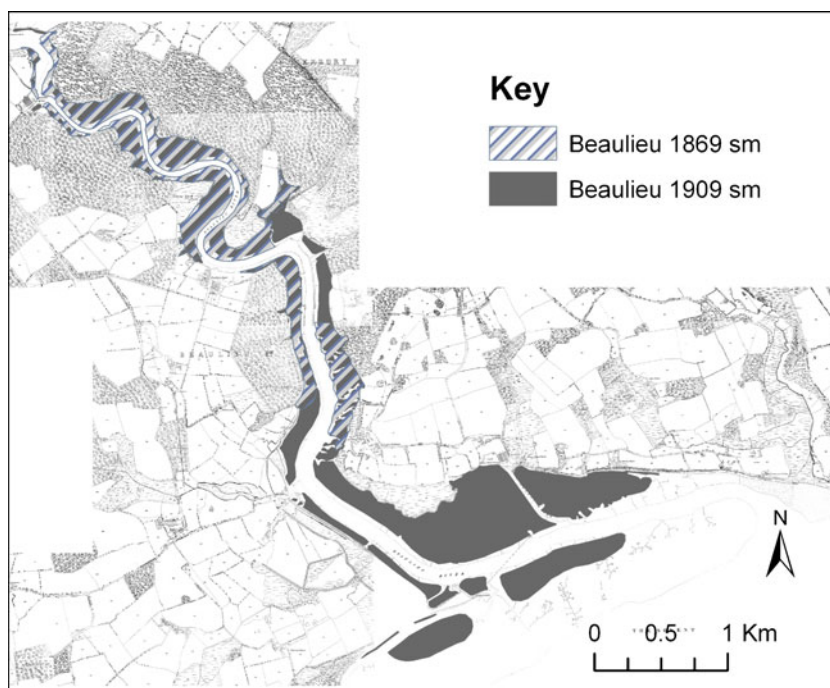
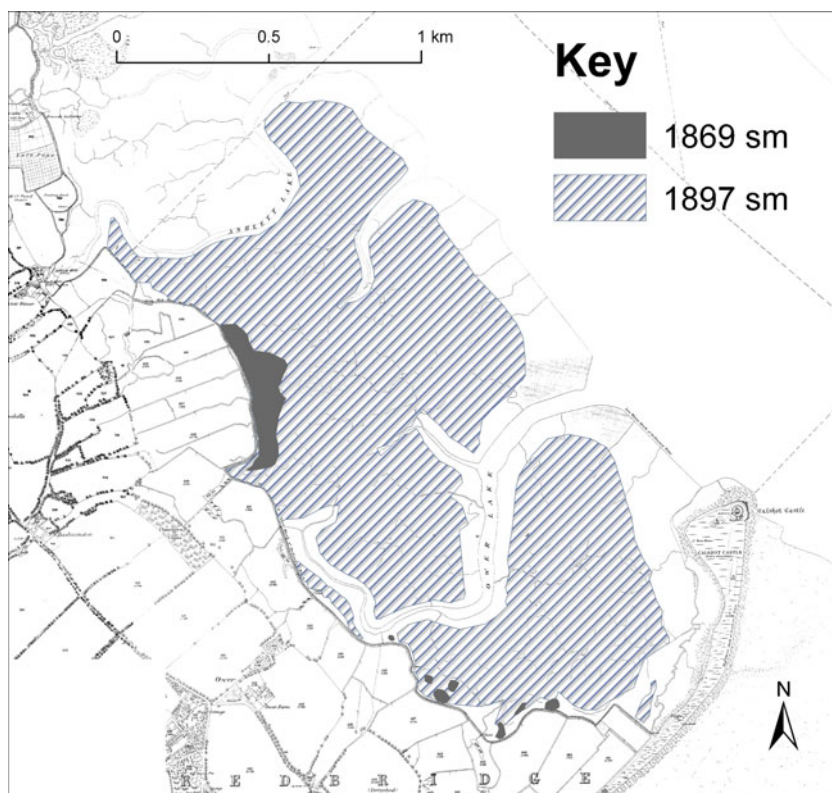


Fig. 7 Map showing the change in saltmarsh coverage for the area around Calshot spit for the maps published in 1869 and 1897. (Reproduced with the permission of the Landmark Information Group, Using: EDINA Historic Digimap Service)



for most of England and Wales back to the 1940s and sporadically for many other sites far beyond this. The aerial photographs were obtained from the Royal Commission on Historical Monuments of England and Wales at Swindon (RCHME). Three main areas were identified for comparison, which had good quality vertical aerial photography. The sites selected were the north of Langstone Harbour east of Portsmouth (site 6 on Fig. 1), the area of saltmarsh near Lymington behind Hurst Castle Spit (site 1 on Fig. 1) and the area near Calshot Spit along Southampton Water (site 3 on Fig. 1). The search results showed that English Heritage in Swindon held photography for all three sites taken at a similar period to the mapped data. Photography for Langstone Harbour was obtained for 1929, Lymington for 1924 and for Calshot Spit for 1924–7 and 1941. Photographs were purchased for all three sites and were then scanned using a Vexcel Ultrascan 500 photogrammetric scanner. The photographs were then georeferenced to the Ordnance Survey National grid using Erdas Imagine 11 software. The Langstone Harbour/Lymington and Calshot County series 3rd Edition maps were downloaded from Edina Digimap and were used for the control images for the geocorrection process (Fig. 8). Using the georeferenced map from Edina to create the georeferenced images helped to reduce spatial errors between the two data sets (maps and photos), although the absolute spatial inaccuracy would be higher. A combination of ground control check points and visual comparison were used to ensure the best possible fit

between the two data sets. Typically, the georeferencing suggested an RMSE error of between 5 and 6 m from the map to the photograph. Since this study is mainly comparing the level of detail of survey of the saltmarsh this level of error was considered sufficient.

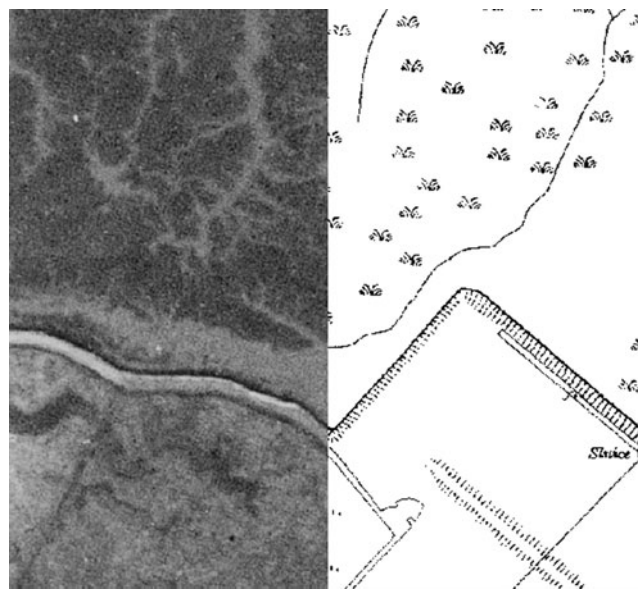


Fig. 8 Georeferenced image draped on to the original Calshot County series map (3rd edition, 1932). (Historic map reproduced with the permission of the Landmark Information Group, Using: EDINA Historic Digimap Service; Aerial photography Copyright English Heritage, Swindon)

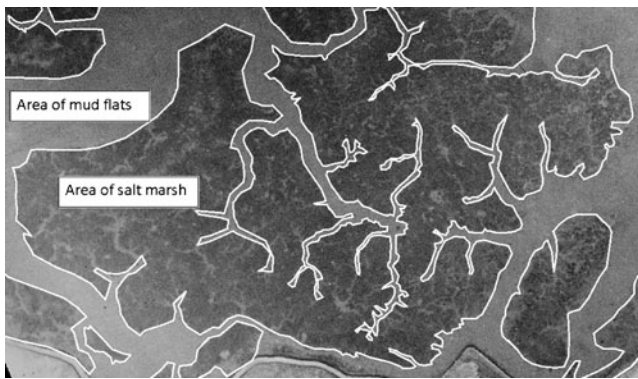
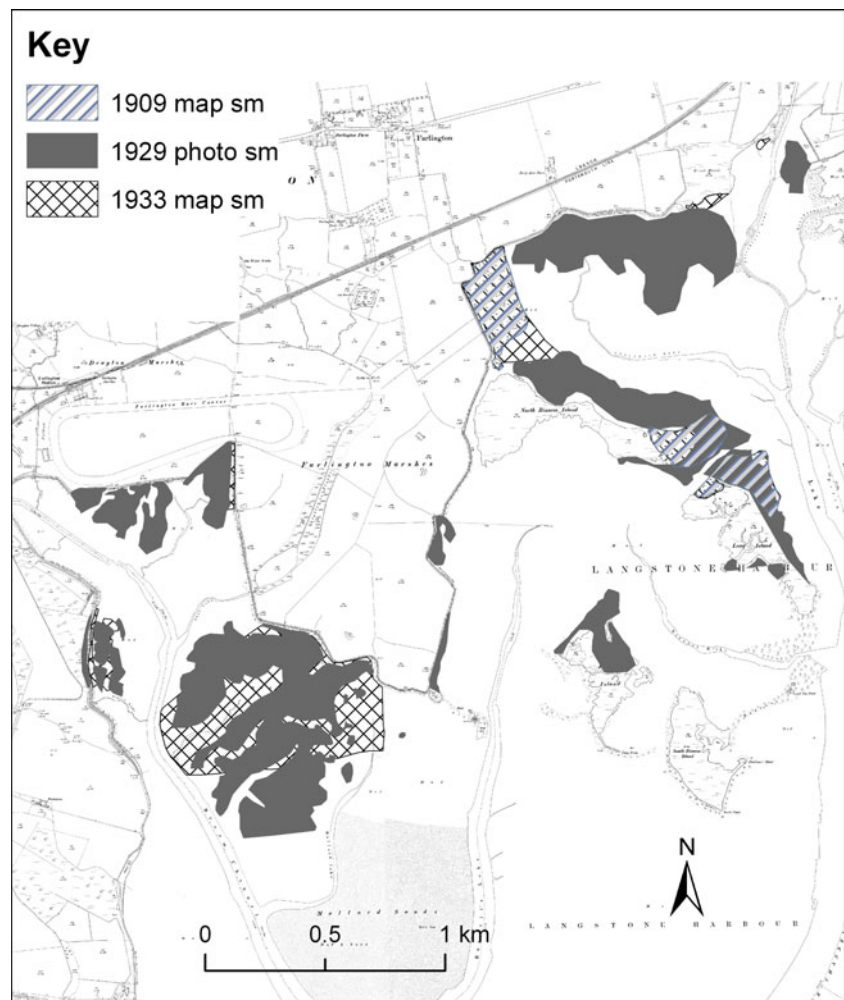


Fig. 9 Calshot saltmarsh digitizing for the 1924 photography showing the level of detail and quality of photography. (Reproduced with the permission of English Heritage, Swindon)

Once the images had been georeferenced, it was then possible to digitize areas of saltmarsh from the georeferenced images. It should be noted that the historical photographs are only panchromatic images but the imagery was of a sufficient quality to enable an approximate estimate of saltmarsh extent for both areas to be determined.

Fig. 10 A map showing the area of Langstone Harbour saltmarsh digitized from the map from 1909 to 1933 and the area digitized from the aerial photography for 1929. (Reproduced with the permission of the Landmark Information Group)



Once the images had been georeferenced and checked for accuracy, the areas of saltmarsh were digitized using the same head up digitizing method as was used to digitize the map data. The level of detail captured in the digitizing process can be seen in Fig. 9 for the salt marsh near Calshot Spit. All vegetation mapping from remote sensing or ground survey contains some form of interpretive error. Using the methods described in this study, it is clear that any digitizing of natural features such as saltmarsh, will always contain some form of interpretive error particularly in terms of boundary definition. This research used panchromatic photography which meant that potentially it could have been difficult to distinguish between saltmarsh areas and areas of other types of vegetation. This could to an extent be coped with by using the texture of the vegetation and knowledge of saltmarsh patterns. However, all of the areas for comparison in this research were a contrast between mudflats and areas of saltmarsh so misclassification because of species recognition was not an issue. Similarly, because of the quality of the photography the identification and definition of the precise boundaries to saltmarsh areas was somewhat restricted. This research is, however, looking

Fig. 11 A map showing the area of Calshot Spit saltmarsh digitized from the map from 1932 and the area digitized from the aerial photography for 1924. (Reproduced with the permission of Landmark Information Group, Using: EDINA Historic Digimap Service)

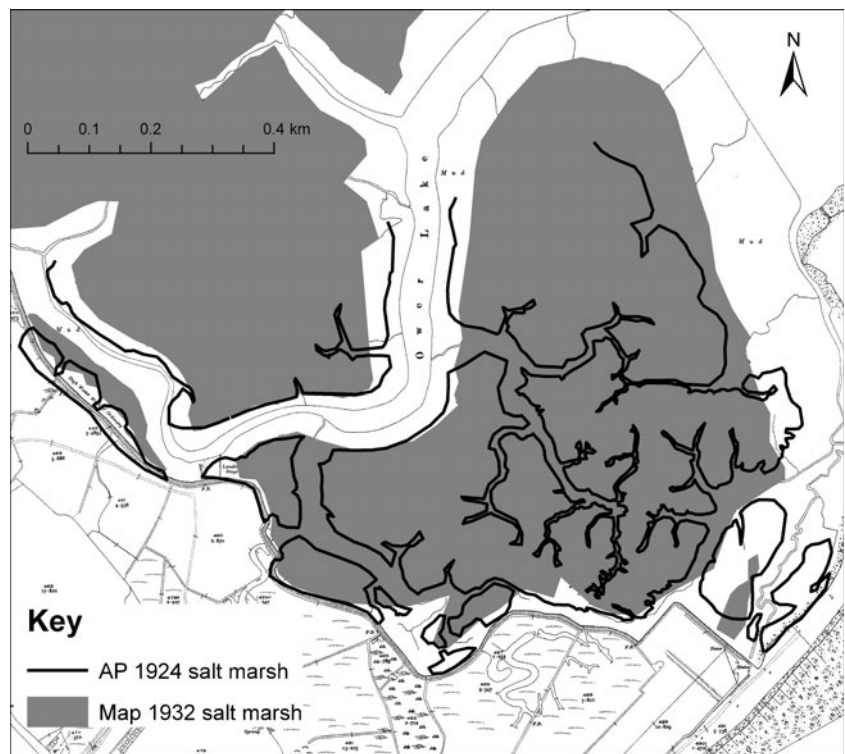
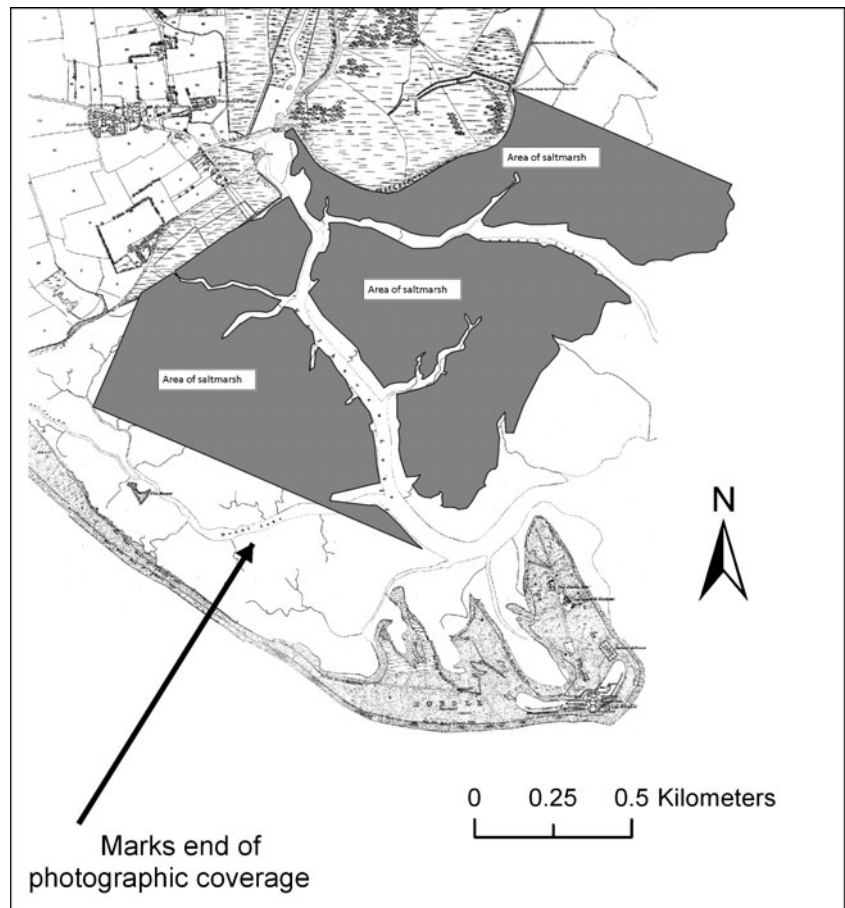


Fig. 12 Saltmarsh digitized from the 1924 aerial photography of the Lymington area. (Reproduced with the permission of Landmark Information Group, Using: EDINA Historic Digimap Service)



at broad differences across large areas so the precise definition of boundaries to specific features is likely to have a relatively small impact on the overall interpretation of the results. However, any research looking at changes in the boundaries of specific mapped features between dates it will be important to determine estimates of error associated with the use of photography and maps of different dates. The planimetric accuracy of the border mapping, using either photograph or maps, will depend partly on the quality of the ground control and ground truthing which can be quantified. Using ground truthing as the basis, it would then be possible to assess the precision of interpreting vegetation boundaries. Error terms can be derived from this testing relative to the ground truthed boundaries and an estimation of accuracy derived. The accuracy of the vegetation border data collection will also be related to the scale of the photography used which again can be quantified using ground truth and interpreter comparisons and then scaled up to in relation to the areas being researched.

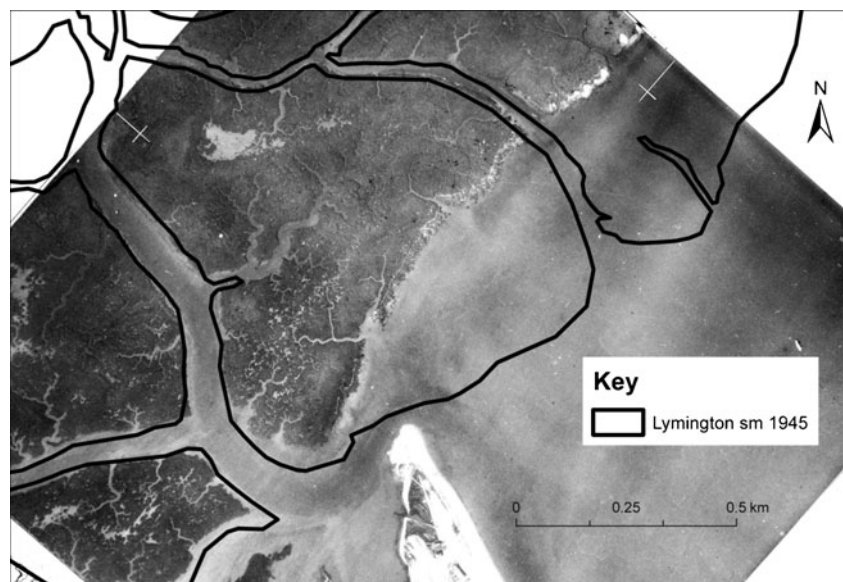
The data captured from the aerial photography was then compared to the data captured from the historical maps for the Langstone Harbour, Lymington and Calshot Spit areas. At Langstone, a visual comparison reveals that the areas shown on the various editions of the map bear very little resemblance to the areas of saltmarsh identified on the aerial photographs. They are different in the area covered and the spatial distribution (Fig. 10). Figure 10 shows the clear differences between the estimates of saltmarsh cover from an historical map and aerial photography. The Calshot Spit area show more similarity in spatial extent but does also show a noticeable difference in detail and exact extent. This area is relatively accessible and suggests that the saltmarsh on the historical map was probably sketched (Fig. 11). The most strikingly different results are obtained from the

Lymington photography where no saltmarsh is represented until the 1945 map edition but where the 1924 photography shows a well established swathe of saltmarsh (Fig. 12). A comparison of the 1945 map revision, with earlier 1941 aerial photography matches relatively well although the seaward extent of the saltmarsh is considerably different (Fig. 13). This suggest that the data was collected much earlier or/and that rapid erosion of the saltmarsh has taken place here.

Discussion

This research has shown that for the southern English coastline the reliability of mapped saltmarsh on Ordnance Survey County series maps needs to be treated with caution. The instructions to surveyors certainly infer that post-1868, that areas above the low water mark would be mapped and included on plans. However, the instructions do not give specific details concerning the quality and accuracy of saltmarsh mapping unlike the instructions rigorously offered for tidal line mapping. It is easy to understand the practical difficulties of manually surveying saltmarsh features on the ground, in particular areas unconnected to the shoreline would have been difficult and often hazardous to map. The rapid growth of saltmarsh along the south coast would have been difficult to keep up with alongside all the other changes which were occurring on the land at the time and required the attention of the Ordnance Survey. The extent to which the Ordnance Survey would have considered the rapidly changing saltmarsh as a priority mapping target must also be questioned. It would appear likely that in some areas the older native saltmarsh may have been mapped in some areas such as Eling and Calshot along Southampton Water in a

Fig. 13 The outline of saltmarsh from the 1945 map revision overlaid on to the 1941 aerial photography. (Reproduced with the permission of English Heritage, Swindon)



reasonable amount of detail. However, the rapid spread of *Spartina spp.* would have been very difficult to keep recording accurately due the speed of the changes. It would appear that the newer invasive hybrid species, which formed areas of saltmarsh in Langstone Harbour, may have been sketched from the shoreline to give an indication of coverage, but intended to represent the detailed extent of the vegetative coverage. This would also explain why several areas have not been mapped at all. At Calshot, the initial surveys appear a little more detailed, although subsequent map revisions appear to reuse the existing data. The coverage here is much nearer the overall extent, but again lacks the detail of ground survey and was also probably sketched. A similar picture emerges at Lymington where the early aerial photography shows a well established area of saltmarsh which does not appear until the later 1945 revision and is not shown at all on the 1909 revision. The reasons for this are partly related to policy, but also related to the practicalities of mapping in the field. The offshore areas are inaccessible, potentially dangerous and were changing at a very fast rate. Constant revision of these areas would not have been feasible or desirable. The maps give an impression of what is in the area but do not attempt to offer a detailed ecological mapping of saltmarsh. Given the rapid changes on land during this period, it would not have been possible for the Ordnance Survey to constantly revise the rapidly changing vegetation.

The comparison of historical mapping coverage with aerial photography highlights the differences that exist between the two data sources. The saltmarsh on the historical maps is often only represented by stamped symbols and has not border or outline. Therefore, whilst these maps can give an indication of coverage they do not appear to be of sufficient quality to allow analysis of vegetation change rates. The contemporaneous aerial photography in contrast although not available for all areas, offers a data set which allows modern techniques to accurately capture the data. The availability of historic maps from Edina allows relatively accurate georeferencing of historical photography. From this data source it can be seen that there were large areas of saltmarsh omitted from the Ordnance Survey maps. The majority of these appear to be the newer areas of saltmarsh which had colonised the areas rapidly and in many places have subsequently retreated. The historical data collection does allow the coverage to be determined with some accuracy although as discussed previously the fact that the photography is panchromatic may lead to interpretational issues.

In conclusion, it can be seen from this study that the use of Ordnance Survey County Series historical maps for the analysis of saltmarsh change should be treated with caution. Whilst many areas clearly give an indication of coverage, this may over or under-represent the real vegetative areas. This may be important when calculating habitat loss over longer periods.

Although this research concentrates on the southern coastline of England, the rapid changes which took place in saltmarsh cover have been replicated elsewhere around the world. As reliable coastal habitat management often requires accurate data on trends and changes, it would seem advisable that where possible, data is collected from archival aerial photography which is widely available for many sites.

References

- Baily B (2001) Analysis of beach mapping techniques and their application to the investigation of the spatial and temporal variations in the morphological behaviour of shingle beaches. PhD Thesis. University of Portsmouth
- Baily B (2011) Tidal line surveying and Ordnance Survey mapping for coastal geomorphological research. *Surv Rev* 43(321):252–268. doi:10.1179/003962611X13055561708263, ISSN 0039–6265
- Baily B, Collier P (2010) The development of the photogrammetric mapping techniques of tidal lines by the Ordnance Survey. *Cartogr J* 47(3):262–269. doi:10.1179/000870410X12786821061530, ISSN 0008–7041
- Baily B, Pearson AW (2007) Change detection mapping and analysis of saltmarsh areas of central southern England from Hurst Castle Spit to Pagham Harbour. *J Coast Res* 23(6):1549–1564
- Barbier EB, Hacker SD, Kennedy C, Koch EW, Stier AC, Silliman BR (2011) The value of estuarine and coastal ecosystem services. *Ecol Monogr* 81(2):169–193
- Boorman LA (1992) The environmental consequences of climatic change on British saltmarsh vegetation. *Wetl Ecol Manag* 2:11–21
- Bradbury A (1995) Western Solent saltmarsh study. In: Saltmarsh Management for Flood and Coastal Defence. Proceedings of Research Seminar organised by Sir William Halcrow and Partners and the National Rivers Authority
- Bray MJ, Carter DJ, Hooke JM (2004) Coastal sediment transport study. Volume 3: Hurst castle spit to Chichester Harbour entrance. Report to SCOPAC. University of Portsmouth, Portsmouth
- Bromberg K, Silliman BR (2009) Patterns of salt marsh loss within coastal regions of North America: pre-settlement to present. In: Silliman BR, Grosholz T, Bertness MD (eds) Human impacts on salt marshes: a global perspective. University of California Press, Berkeley, pp 253–266
- Burd F (1989) The saltmarsh survey of Great Britain. An inventory of British saltmarshes. Research and Survey in Nature Conservation No. 17. Nature Conservancy Council, Peterborough
- Burd F (1992) Erosion and vegetation change on the saltmarshes of Essex and North Kent between 1973 and 1988. Nature Conservancy Council, Research and survey in nature conservation, report No. 42
- Carr AP (1962) Cartographic record and historical accuracy. *Geography* 47:135–144
- Carr AP (1969) The growth of Orford Spit: cartographic and historical evidence from the sixteenth century. *Geogr J* 135:28–39
- Carr AP (1980) The significance of cartographic sources in determining coastal change. In: Cullingford RA, Davidson DA, Lewin J (eds) Timescales in geomorphology. Wiley and Sons, Chichester, pp 69–78
- Close CF (1912) Instructions to examiners and field revisers. Ordnance Survey, Southampton
- Cooper N J, Skrzypczak T, Burd F, (2000) Erosion of the Saltmarshes of Essex between 1988 and 1998. Report to the Environment Agency, Coastal Geomorphology Partnership
- Cooper NJ, Cooper T, Burd F (2001) Twenty five years of saltmarsh erosion in Essex: implications for coastal defence and nature conservation. *J Coast Conserv* 7:31–40

- Cope S, Gorczynska M, Webbon R (2007) Aerial photography report: langstone harbour. Report for the Southeast Strategic Regional Coastal Monitoring Programme
- Curtis TGF, Sheehy Skeffington M (1998) The salt marshes of Ireland: an inventory and account of their geographical variation. *Biol Environ: Proc R Irish* 98B(2):87–104
- Davy AE, Figueroa E, Bakker J (2009) Human modification European salt marshes. In: Silliman BR, Grosholz T, Bertness MD (eds) Human impacts on salt marshes: a global perspective. University of California Press, Berkeley, pp 311–336
- French PW (1999) Managed retreat: a natural analogue from the Medway estuary, UK. *Ocean Coastal Manag* 42:49–62
- Fuller R (1973) The assessment of coastal habitat resources from aerial photography mapping and assessment of saltmarsh vegetation resources. Coastal Ecology Research Paper No. 3. The Nature Conservancy, Norwich
- Gedan KB, Bertness MD (2005) Reconstructing New England salt marsh losses using historical maps. *Estuaries* 28(6):823–832
- Goodman PJ, Braybrouks JM (1959) Investigations into 'Die-Back' in *Spartina Townsendii*. The Present Status of *Spartina Townsendii* in Britain. *J Ecol* 47(3):651–677
- Gray AJ, Marhsall DF, Raybould AF (1991) A century of evolution in *Spartina anglica*. *Adv Ecol Res* 21:1–62
- Gross MF, Klemas V, Levasseur JE (1988) Remote sensing of biomass of salt marsh vegetation in France. *Int J Remote Sens* 9(3):397–408
- Hill MI (1996) Saltmarsh. In: Barnes JH, Robson CF, Kaznowska SS, Doody JP, Davidson NC (eds) Coast sand Seas of the United Kingdom. Region 9 Southern England: Hayling Island to Lyme Regis. Joint Nature Conservation Committee, Peterborough
- Hooke JM, Kain RJP (1982) Historical change in the physical environment; a guide to sources and techniques. Butterworth Scientific, London
- House of Commons (1841) Ordnance survey: a bill. To authorize and facilitate the completion of a survey of Great Britain and the Isle of man. 24 May 1841. House of Commons Parliamentary papers Online (2005) Proquest Information
- Jenny B (2006) Analysis of the planimetric accuracy of historical maps with digital tools. Proceedings of the first international workshop Digital Approaches to Cartographic Heritage, Thessaloniki, Greece, 18–19 May 2006. National Center for Maps and Cartographic Heritage, Thessaloniki. ISBN: 960-7999-18-5, 87–91
- Maling DH (1989) Measurements from maps: principles and methods of cartometry. Pergamon Press, Oxford
- Mason CF, Underwood GJC, Baker NR, Davey PA, Davidson Hanlon A, Long SP, Oxborough K, Paterson DM, Watson A (2003) The role of herbicides in the erosion of the salt marshes in eastern England. *Environ Pollut* 122:41–49
- Morris RKA, Reach IS, Duffy MJT, Collins TS, Leafe RN (2004) On the loss of saltmarshes in south-east England and the relationship with *Nereis diversicolor*. *J Appl Ecol* 41:787–791
- Oliver FW (1925) *Spartina Townsendii*: its mode of establishment, economic uses and taxonomic status. *J Ecol* 13(1):74–91
- Ordnance Survey (1932) Instructions to field revisers 1/2500 scale. His Majesty's Stationery Office, London
- Ordnance Survey (1948) Instructions for 1:1250 Field and Office Examination and Revision (The Green Book). Ordnance Survey, Southampton
- Paramor OAL, Hughes RG (2004) The effects of bioturbation and herbivory by the *Nereis diversicolor* on loss of saltmarsh in South-east England. *J Appl Ecol* 41:449–463
- PRO FT1/54 *Spartina townsendii*. The National Archives, Kew
- PRO OS 45/8 OS 307 Instructions to Surveyors. The National Archives, Kew
- Pye K, French PW (1993) Erosion and accretion processes on British Saltmarshes. Volumes 1–5. Cambridge Environmental Research Consultants Ltd, Cambridge
- Raybould AF, Gray AJ, Hornby DD (2000) Evolution and current status of saltmarsh grass *Spartina anglica* in the Solent. In: Collins MB, Ansell K (eds) Solent science—A Review. Elsevier Science, Amsterdam, pp 299–302
- Stapf O (1913) Distribution and ecology of *Spartina Townsendii* Proceedings of Bournemouth. *Nat Sci Soc* 5
- Thieler ER, Danforth WW (1994) Historical shoreline mapping (I): improving techniques and reducing position errors. *J Coast Res* 10(3):549–5
- Van Der Wal D, Pye K (2004) Patterns, rates and possible causes of saltmarsh erosion in the Greater Thames area (UK). *Geomorphology* 61:373–391