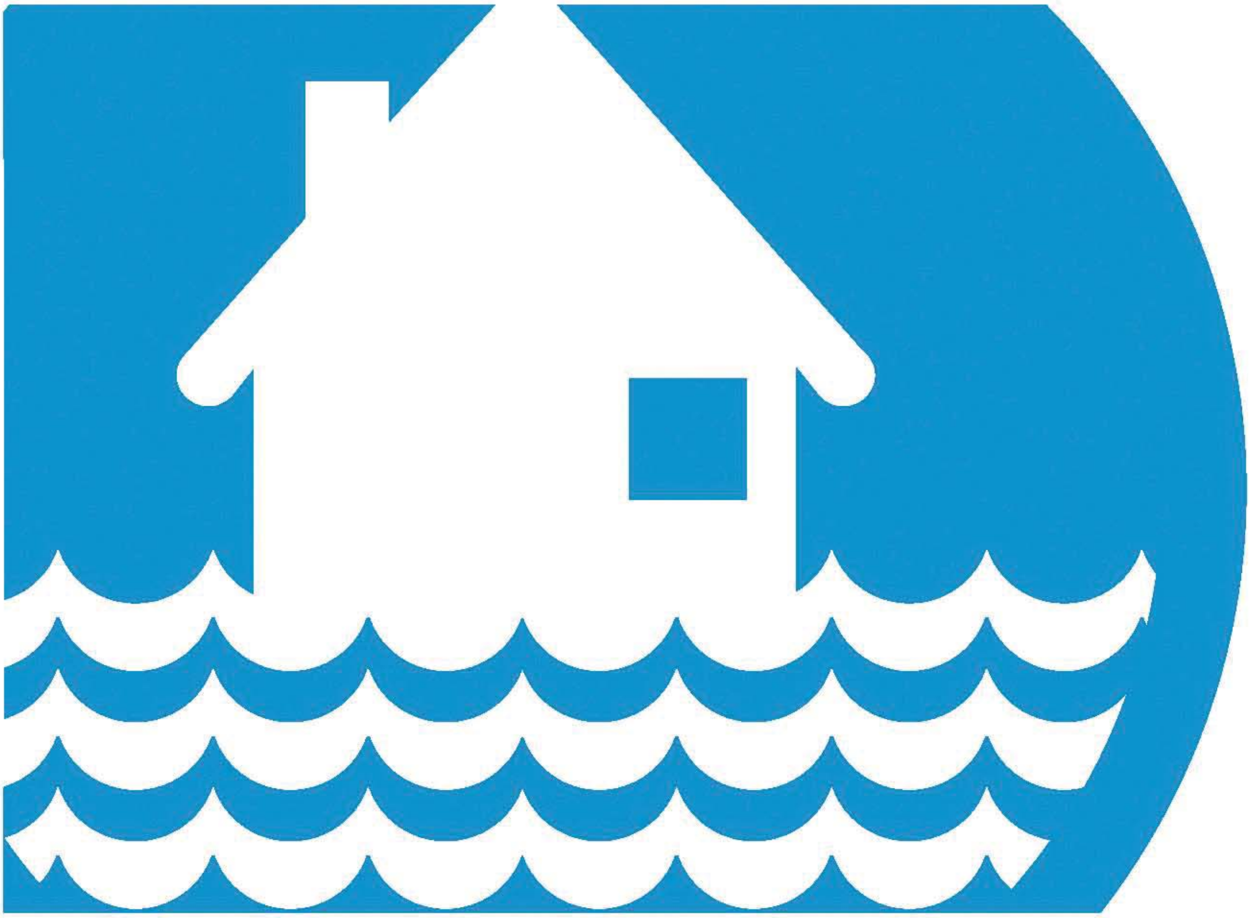

The extent of saltmarsh in England and Wales: 2006–2009

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E: enquiries@environment-agency.gov.uk.

Author(s):
Niall Phelan, Marine Monitoring Service, Environment Agency, Kingfisher House, Peterborough, PE2 5ZR

Amy Shaw, Strategy and Engagement, Flood and Coastal Risk Management, Environment Agency, Kingfisher House, Peterborough, PE2 5ZR

Adam Baylis, Research and Innovation, Evidence, Rivers House, Twerton Office, Lower Bristol Road, Bath, BA2 9ES

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Miranda Kavanagh

Director of Evidence

Executive summary

Saltmarsh provides important natural resources and ecosystem services. For example, by reducing wave energy in front of tidal defences, it provides demonstrable flood and coastal risk management benefits. It is of immense value to wildlife, supporting habitats and species of national and international significance.

The Environment Agency has legal duties through the Habitats and Birds Directives, and the Water Framework Directive, to conserve and enhance saltmarsh. It is also the lead partner for the Saltmarsh and Mudflat Biodiversity Action Plan (BAP).

The Environment Agency has gathered aerial data and established a new baseline figure for the extent of saltmarsh in England and Wales. High resolution aerial photographic images gathered largely between 2006 and 2009 have been used to develop a quality assured map of saltmarsh extent in England and Wales. This report describes the processes involved in producing a map of saltmarsh extent and examines the consistency of approach in mapping saltmarsh, providing recommendations for future mapping standards.

The last complete survey of saltmarsh extent in the UK was completed by the Nature Conservancy Council in 1989. Since then, baseline surveys have been fragmented and staggered which has made it difficult to appreciate if saltmarsh is being gained or lost at BAP reporting levels. It is important for the Environment Agency to have an accurate assessment of saltmarsh extent in order to assess the progress it is making to meet its legal obligations for biodiversity.

It should be noted that saltmarsh extent referred to in this report here excludes very low density pioneer saltmarsh vegetation termed indiscrete, which will generally be less than 5% cover. For the purposes of consistent mapping, indiscrete areas were omitted to establish a robust and repeatable mapping methodology.

It was concluded that accurate comparisons of saltmarsh extent were generally not feasible where varying data collection and survey methods were used. Differences in saltmarsh mapping methodologies through time have been considerable, so this project compared with some caution the new figures with Burd (1989) historical figures. An attempt was made to identify and quantify possible sources of error to provide some context on change. Whilst further work is required, the exercise suggests that the rate of recent saltmarsh loss at national levels has been slower than previously thought. This improved knowledge of recent national rates of saltmarsh change mean that the national estimate for yearly gain and loss may need to be revised.

Acknowledgements

The authors would like to acknowledge the steering group members, Sue Rees (Natural England), Mike Best (Environment Agency) and the late Mark Crick (JNCC) for their contributions. We would also like to thank Sarah Peaty, Oliver Crawford, Crispin Hambidge, Matthew Hill (Environment Agency), Chris Blair-Myers (Peter Brett Associates), Angus Garbutt (CEH), Nicola Rimington, Peter Rhind, Monica Jones (CCW) and all of the field survey staff for their efforts.

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1. Introduction

A number of national and international conservation objectives require accurate figures on saltmarsh extent to trace improvements or degradation in the UK. For the Environment Agency, these responsibilities include Biodiversity Action Plan (BAP) and Water Framework Directive (WFD) reporting requirements in addition to ongoing responsibilities for Sites of Special Scientific Interest (SSSI), and Habitats and Birds Directives sites. In addition, saltmarsh is an important consideration for flood risk and coastal management (FCRM). It is now widely understood that saltmarsh, in appropriate quantity and form, will reduce the construction and maintenance costs of sea defences (King and Lester 1995, Möller et al. 1999, Möller et al. 2003). Accurate calculation of saltmarsh extent has therefore become an important measurement, contributing to effective planning and works for flood and coastal risk management.

This report describes the steps and processes undertaken to produce a baseline for saltmarsh extent in England and Wales between 2006 and 2009. It presents the project’s results and some comparisons with previous extent data. These comparisons were found to be problematic and it has been concluded that they should not be used to summarise change without further contextual examinations of the historic information.

1.1 Trends in saltmarsh extent

The only national saltmarsh survey on a comprehensive scale in Great Britain was undertaken by Fiona Burd in 1989 on behalf of the Nature Conservancy Council (NCC) (Burd 1989). This study looked at constituent vegetation communities by using field survey sketches and simplified categories of the National Vegetation Classification (NVC) system (Appendix 1). It included a rough interpretation of the quantities and proportions of the main communities of the saltmarsh plus the extent. However, it is accepted that the study was undertaken using very basic methods, and also may not have captured all saltmarsh nationally. This presents difficulties in terms of using the outputs of this survey to assess change in extent over time.

Apart from the NCC survey in 1989, there have been no regular and comprehensive surveys of saltmarsh extent at national and regional scales. This has led to, in some cases, best guess generalisations on saltmarsh extent at these scales.

Comprehensive regional observations in the south and south-east of England have revealed a trend of saltmarsh loss (Burd 1992, Pye and French 1993a, Baily et al. 2002, Cooper and Cooper 2000, Cooper et al. 2001). Although trends of accretion have been observed more recently in south-east England (English Nature 2002), such trends have been significantly observed in north-west England (Hill 1987, Burd 1989, Pye and French 1993a, Huckle et al. 2004). In areas of Wales, a level of stability has been observed (Bristow and Pile 2002), while significant accretion has been shown in the Dyfi estuary in mid-west Wales (Shi 1993). On the Welsh border of the Severn estuary, saltmarshes have been shown to be generally decreasing (Allen 1990, Otto 1996), with further decreases predicted in the Severn Estuary Coastal Habitat Management Plan (CHaMP) (ABPmer 2008). CHaMPs, a science-based forecast of coastal change over 30–100 years, help fulfil legal requirements under the Habitats and Birds Directives in relation to flood risk management decisions. CHaMPs collate information on saltmarsh extent at sub-regional scales and assess likely future increases or decreases, along with other relevant habitats, for Special Areas of Conservation (SACs) and Special Protection Areas (SPAs).

Although decreases in saltmarsh extent have not been shown at all regional scales, it has been accepted by government agencies and academics that saltmarsh extent has been decreasing overall in general on a UK-wide scale in recent times (Pye and French 1993b, UKBAP 2006, Environment Agency 2008).

This accepted trend at a national scale was perhaps derived primarily from the substantial losses observed in the south and south-east of England, which were viewed as decreasing at such a rate that other accreting saltmarsh systems in other parts of the UK did not mitigate these losses overall. A loss figure of 100 ha per year was estimated for England (Pye and French 1993b) and this figure has been extrapolated to a UK scale.[1]

These overall loss estimations do not provide a full picture of biodiversity losses. The nature of the new accreting communities in many regions raises questions on their biodiversity value, with the hybrid species, *Spartina anglica*, playing a major constituent role in many of these accreting areas – at least in the early pioneer stages (HR Wallingford 1996).

Historic causes of saltmarsh loss include land claim, dredging activity, embanking and other such engineering works (Doody 2008). While a significant historic landward loss may be attributed generically to land claim, recently afforded environmental assessment and conservation measures have largely eliminated this activity as a pressure on saltmarshes. More recent losses in saltmarsh extent at various locations have been attributed to other factors – coastal squeeze, isostatic tilt, sea level rise and/or increased storminess (Pye and French 1993a, HR Wallingford 1996, Cope et al. 2008).

These processes have serious implications for saltmarshes in England and Wales as a large proportion of saltmarshes are backed by seawalls, preventing the natural landward migration of marsh. While this is the most obvious impact of the presence of sea walls backing marsh, they can also have more subtle impacts on the existing saltmarsh by altering the hydrodynamics of the system (Pye 2000).

Trends of saltmarsh erosion and accretion are clearly relative to the scale and/or location at which they are viewed. Trends at one scale may inform and provide context for trends at another scale. Therefore comprehensive inventories of saltmarsh trends at both regional and national levels are not only important for conservation and flood and coastal risk management objectives, but also to enhance our understanding of saltmarsh processes.

1.2 Developing the Environment Agency mapping programme (2006–2009)

Since its formation in 1996, the Environment Agency has periodically mapped saltmarsh in various locations in England and Wales. Saltmarsh mapping by the Environment Agency has generally targeted those areas experiencing significant saltmarsh loss in the south and south-east of England (Cooper and Cooper 2000, Baily et al. 2002, Blair-Myers 2002). However, since 2006 the Environment Agency has expanded its mapping of saltmarshes to all regions. This more recent emphasis on saltmarsh mapping has been driven mainly by reporting requirements of the UK Biodiversity Action Plan (BAP) and Water Framework Directive (WFD), in addition to ongoing responsibilities for Sites of Special Scientific Interest (SSSIs) and Habitats and Birds Directives sites (SACs and SPAs).

With these considerations in mind, in 2006 the Environment Agency's Flood and Coastal Risk Management (FCRM) directorate resolved to map all remaining areas of saltmarsh in England and Wales not being mapped through other mechanisms up to 2009. This decision led to a flight and mapping programme commissioned to fill the remaining saltmarsh areas. This was followed by a national data collation and standardisation exercise.

This report describes the origins and collation of the datasets along with the high level methodology used to produce a national baseline extent map of saltmarsh in England and Wales.

[1] The 2006 Habitat Action Plan (HAP) target states that 90 per cent of the loss was in England and 10 per cent in Wales.

The resulting baseline map for England and Wales may be seen to be representative of saltmarsh extent from 2006–2009 minus indiscrete areas. Approximately 1 per cent of the total saltmarsh area has been mapped outside this 2006–2009 timeframe using photography stretching no further back than 2004.

1.3 Comparing new and historic data

At the outset of the final mapping collation, the steering group recommended that case studies be included in reporting to allow a degree of comparison with previous datasets on extent. It was acknowledged that making comparisons with prior estimates was problematic. It was however accepted that some degree of context was required with the delivery of the baseline maps. As the project progressed it was also accepted that the updated extent data would be used by decision-makers or managers to make comparisons with historic data in various locations at different scales. At regional and national scales, work was required to attempt to make new data comparable with historic extent data. Examining the feasibility of making these comparisons was therefore deemed to be an important addition to this project. It was also thought essential to highlight the issues associated with making such comparisons.

Further work was undertaken to attempt an error correction based on perceived flaws in Burd's (1989) output. This error correction was largely driven by expert judgement. For this reason, CCW requested that it be omitted from this report due to possible bias but is available upon request.

1.4 Definition of saltmarsh extent for the purpose of this report

The primary focus of this project was to produce a saltmarsh extent change figure for England and Wales, based on a consistent and repeatable methodology using aerial images as the main data source. As is explained in more detail in section 2.4 and section 2.6.2, this means that it was necessary to exclude low density, non discrete pioneer saltmarsh vegetation. This was partially due to the transience of this vegetation and the difficulty to map it consistently. Creeks were generally mapped to approximately 1.5-2m in width. Narrower creeks were generally included within the extent feature. Inner pans were generally mapped if greater than $150m^2$. It is expected that in the future, standards for mapping will be adopted that will allow greater compatibility across reporting responsibilities. It is also hoped that created saltmarsh extent layers can be used as a starting point to fulfil other reporting responsibilities where broader information is required.

2. Methodology

This section describes the flight and mapping programmes which enabled a full national picture of saltmarsh extent in England and Wales to be obtained. These programmes were coordinated by various Environment Agency departments including:

- Regional Coastal Monitoring Programmes (RCMPs);
- Marine Monitoring Service (MMS) under its WFD work (MMS-WFD);
- Strategy and Engagement Team in Flood and Coastal Risk Management (FCRM).

The final collation was undertaken by MMS.

2.1 Flight and mapping programmes

Table 2.1 summarises the geographical spread of the three programmes across the Environment Agency's regions (Figure 2.1). The FCRM programme formed the gap filling exercise which allowed full national collation (see section 1.2). Details of the three programmes are given below. In the final collation, 99 per cent of the total saltmarsh area used the imagery captured within the 2006-2009 timeframe. The origin of the remaining 1 per cent saltmarsh area, which consisted mainly of 2004 imagery, is described in section 2.3.4.

Figure 2.1: Environment Agency Regions as of 2010

Table 2.1: Geographical spread of the saltmarsh mapping programmes from 2006–2009

Region	Programme		
	Regional Coastal Monitoring Programmes (RCMPs)	Marine Monitoring Service (MMS-WFD)	Flood and Coastal Risk Management (FCRM)
North West	X	X	
North East		X	X
South West	X	X	
Southern	X		
Anglian	X	X	X
Thames		X	
Wales		X	X

2.1.1 Regional Coastal Monitoring Programmes (RCMPs)

RCMPs are regional partnerships of local authorities, Coastal Groups and the English regions of the Environment Agency. They have 'a collective vision to develop a long-term, region-wide coastal process monitoring and analysis programme'.[2] RCMPs now exist for all the regions of England, though they are at different stages of development. The Environment Agency is responsible for programme coordination for all the RCMPs.

The four RCMPs that provided data for this project carry out aerial monitoring relative to their region's specific requirements. As a result, the South West and South East (Environment Agency Southern) RCMPs provided both imagery and habitat maps for this exercise. In Anglian Region only flight imagery was provided and mapping of saltmarsh extent was carried out by the MMS-WFD and FCRM programmes (see Table 2.1). In addition, the North West RCMP specifically commissioned aerial photography and mapping of saltmarsh within the 2006–2009 timeframe, which was incorporated into this collation.

2.1.2 Marine Monitoring Service – Water Framework Directive (MMS-WFD) saltmarsh monitoring

WFD monitoring in transitional and coastal (TraC) waters is largely represented by a 'surveillance' programme of water bodies as defined in the Directive (2000/60/EC). WFD surveillance water bodies are spread throughout the country and are selected to represent different typologies. The relevant biological elements of a surveillance water body are monitored to determine the level of deviation from reference conditions. There are 57 surveillance water bodies in England and Wales out of a total of 233 water bodies.

MMS is responsible for carrying out WFD monitoring in TraC waters and, under the terms of its monitoring programme for angiosperms, is committed to mapping saltmarsh in surveillance water bodies at least once in every river basin planning cycle (six years).

[2] http://www.channelcoast.org/southeast/programme_aims

2.1.3 FCRM gap filling programme

The FCRM flight and mapping programme was created to enable completion of mapping of the remaining areas of saltmarsh not covered by the other programmes. Essentially this required contributing to the mapping of saltmarsh extent in Wales, North East and Anglian Regions. This work was carried out in consultation with MMS and the RCMPs. Natural England and the Joint Nature Conservation Committee (JNCC) were consulted throughout the collation process and a steering group met and communicated regularly at the collation stage.

2.2 Procedures and coverage for each programme

An idealised high level flow chart for saltmarsh mapping using the methodology adopted for this programme is shown in Appendix 2.

Figures 2.2 and 2.3 show the geographical coverage of the contractors and the years in which the flights were undertaken respectively.

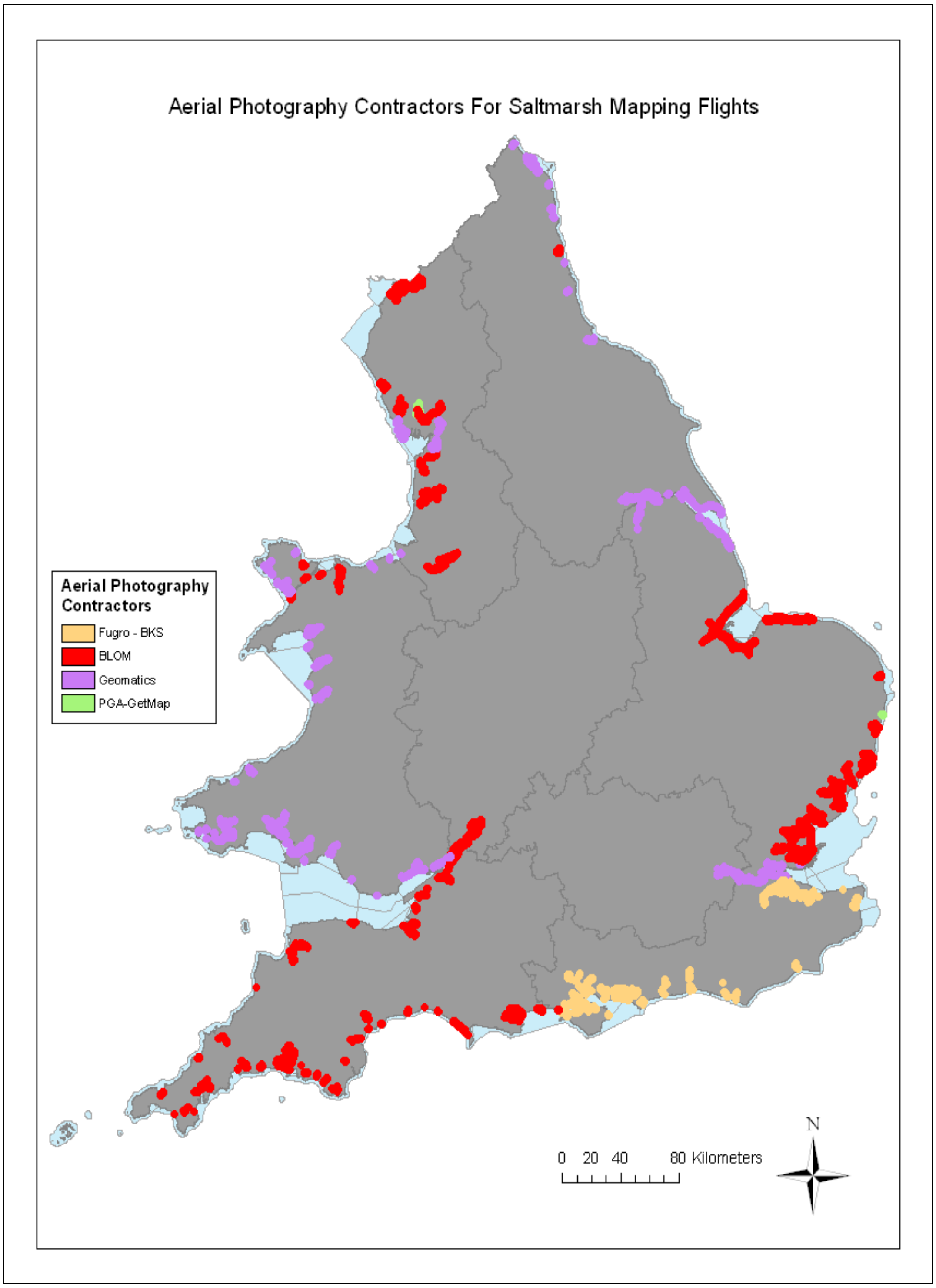

Figure 2.2: Geographical spread of aerial photography contractors

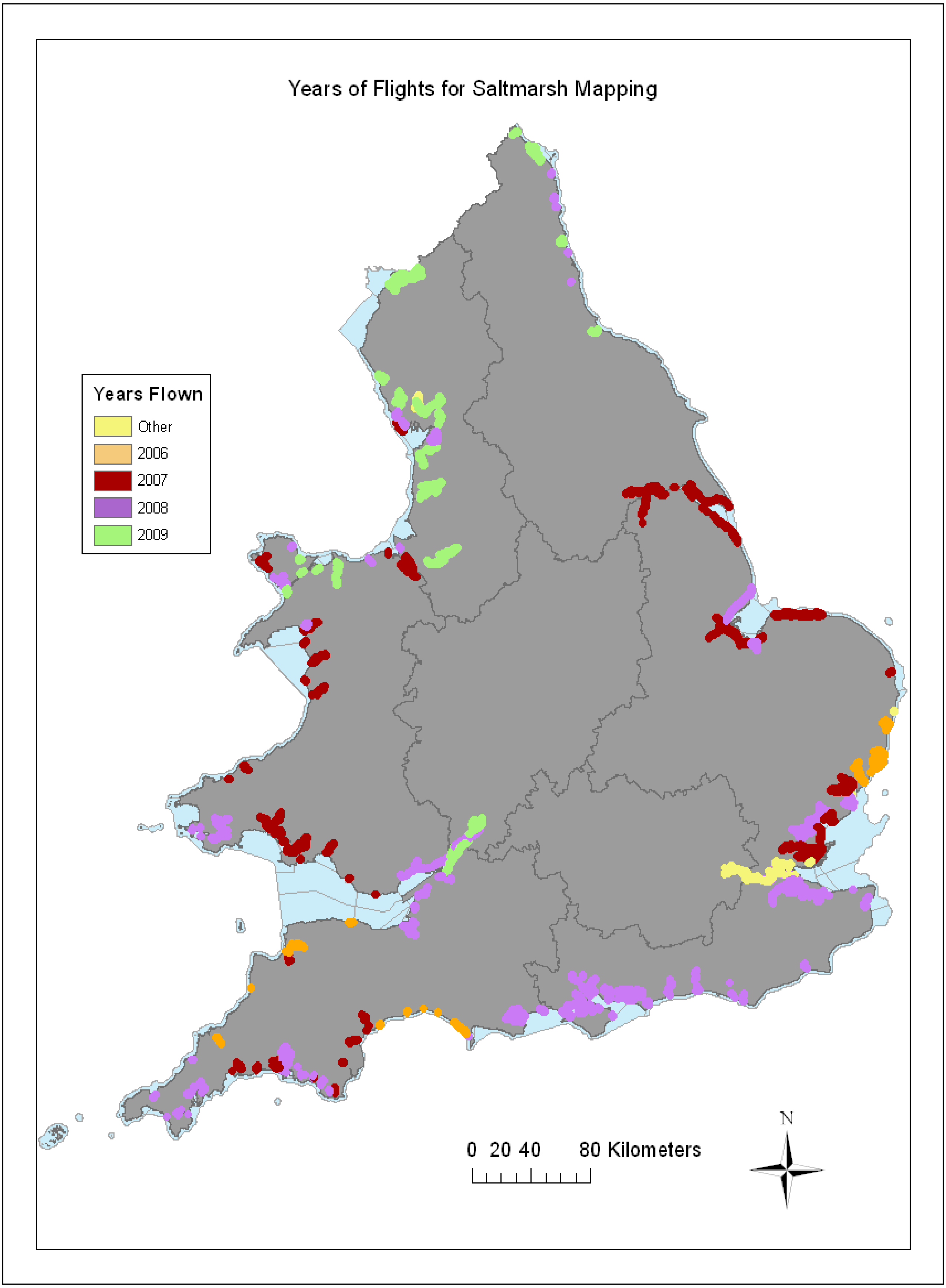

Figure 2.3: Geographical spread of years flown for the saltmarsh mapping programme

2.3 Imagery acquisition

The capture of aerial imagery for the Environment Agency (2006–2009) survey was undertaken by two chartered aerial surveyors (Fugro-BKS and BLOM Aerofilms) and the Environment Agency's own internal Geomatics Group. Table 2.2 summarises the utilisation of these three aerial surveyors by the three programmes.

Table 2.2: Aerial surveyors used by the three programmes

Programme	Flight surveyor		
	Fugro-BKS	BLOM Aerofilms	Geomatics Group
MMS-WFD		X	X
RCMPs	X	X	X
FCRM	X	X	

Each of the surveyors had a slightly different specification for the work undertaken (Table 2.3).

Table 2.3: Flight specifications and output formats for the flight mapping programmes

Specification	Fugro-BKS	BLOM Aerofilms	Geomatics Group
Camera type	Analog	Digital	Digital
Flying height	±750 to ±1150 m	±1200 to ±1300 m	±750 to ±850 m
Image resolution	10 cm	10 cm	10 cm
Tidal state	Varied	± 2 hours	± 2 hours
Near infrared (NIR) capture	No	Yes	Yes
Orthophoto positional accuracy	N/A	±1 m / ±0.5 m	RMSE 10 cm
Utilised file type	.ecw	.tif / .ecw	.tif
Utilised resolution for saltmarsh mapping	10 cm	10 cm/25 cm	10 cm

Note: RMSE = root mean square error

2.3.1 Fugro-BKS

Fugro-BKS was commissioned by the Southern Region RCMP. While the imagery used in this programme was acquired between 2006 and 2009, there was an almost complete flight programme in 2008.

2.3.2 BLOM Aerofilms

BLOM Aerofilms completed the aerial photography and post-processing of the imagery for the whole of the Anglian and South West Environment Agency Regions. The imagery used in this programme was acquired between 2006 and 2009.

2.3.3 Geomatics Group

Geomatics Group completed the aerial photography for the majority of Wales and North West Regions. The imagery used in this programme was acquired between 2006 and 2009. As this was a flight programme specifically for saltmarsh mapping, the flight coverage was planned by MMS, with the remaining planning and execution undertaken by Geomatics Group.

2.3.4 Use of imagery outside of 2006–2009 timeframe

A small proportion of the aerial photography (approximately 1 per cent) to complete the national saltmarsh extent map was acquired outside the 2006–2009 timeframe (see section 2.4.7). This was due to a number of factors including:

- the availability of high quality mapping of saltmarsh for a proportion of the Lower Thames from 2004;
- failure to capture all the saltmarsh from the flight programmes.

The main water bodies which used aerial photography outside of this timeframe were:

- Thames Lower;
- Benacre Broad;
- Wyre;
- Leven;
- Kent.

2.4 Saltmarsh mapping from aerial imagery

2.4.1 Defining saltmarsh

There are various ways of defining saltmarshes. The UK Biodiversity Action Plan (UKBAP) states that:

> '*Coastal saltmarshes in the UK comprise the upper, vegetated portions of intertidal mudflats, lying approximately between mean high water neap tides and mean high water spring tides. For the purposes of this action plan, however, the lower limit of saltmarsh is defined as the lower limit of pioneer saltmarsh vegetation (but excluding seagrass Zostera beds) and the upper limit as one metre above the level of highest astronomical tides to take in transitional zones*.'[3]

The definition of saltmarsh across the various Environment Agency reporting requirements was discussed by the steering group. It was agreed that there can be difficulty in defining plants and communities strictly as saltmarsh as a number of saltmarsh plants can also occur across freshwater marsh and saltmarsh. In addition there can frequently be a fuzzy boundary between the two, which is perhaps impossible to define.

With these considerations in mind, it was decided that the most pragmatic solution for this mapping exercise was to define saltmarsh as *'any discrete marsh, grassland or reed bed, subject to tidal*

[3] http://www.jncc.defra.gov.uk/Docs/UKBAP_BAPHabitats-08-CoastSaltmarsh.doc

inundation from saline waters'. It was also accepted that this would prove difficult in the delineation of boundaries in some cases, which would have to be examined again in the future.

Another problem in defining saltmarsh is in the extent mapping of saltmarshes containing large swathes of 'non-discrete' pioneer saltmarsh.[4] The term 'non-discrete' pioneer was used because it does not appear as contiguous vegetation on aerial photography; Figure 2.4 shows an example from the Dee estuary. As noted above to ensure consistency of repeatability, non-discrete pioneer was not included in the final extent map. Non-discrete areas however will be considered in future mapping exercises.

Figure 2.4: Area of the Dee Estuary containing non-discrete saltmarsh (i.e. low density Salicornia species)

2.4.2 Saltmarsh mapping using aerial photography

The recent availability of high resolution digital aerial photography has made the mapping of saltmarsh extent easier than before with minimal ground truthing required to verify extent boundaries in most cases. But as seen from the flow chart in Appendix 2, ground truthing of some kind is recommended. Although the simultaneous capture of near infrared (NIR) assists in the identification and differentiation of certain vegetation, it is not critical for an acceptable extent output.

2.4.3 Mapping contractors

A number of different mapping contractors were used by the different mapping programmes to interpret the aerial photography; the spread of contractors is shown in Tables 2.4 and 2.5. Details of their work are given below.

For future reference, an idealised set of mapping rules is given in Appendix 2.

[4] The saltmarsh pioneer zone is located in the lower intertidal area consisting of open plant communities where one or more of *Spartina*, *Salicornia or Aster* species grow. This zone is covered by all tides except the lowest neap tides.

Table 2.4: Mapping undertaken for each programme

Programme	Mapping contractor		
	Peter Brett Associates/Hyder	MMS	Geomatics Group
MMS-WFD		X	
FCRM			X
RCMP	X		X

Table 2.5: Geographical spread of mapping undertaken by mapping contractors

Region	Mapping contractor		
	Peter Brett Associates/Hyder	MMS-WFD	Geomatics Group
North West		X	X
North East		X	X
South West	X	X	
Southern	X		
Anglian		X	X
Thames		X	
Wales		X	X

2.4.4 Mapping undertaken by Peter Brett Associates/Hyder

All saltmarsh mapping in Southern (South East RCMP) and South West Regions was funded through the relevant RCMP programme. The consultants undertaking the mapping were Hyder and Peter Brett Associates. Both contractors mapped the aerial photography manually and used the Integrated Habitat System (IHS)[5] – a habitat mapping system originally developed by Somerset Records Centre. IHS categories that qualify as saltmarsh are listed in Appendix 3.

During the initial stages of saltmarsh mapping work, the saltmarsh plant community categories were divided further resulting in a higher degree of separation. This tended to occur when new communities were encountered. In addition, saltmarsh was a subset of a number of categories. These categories are listed in Table 2.6 and at the bottom of the table in Appendix 3.

2.4.5 Mapping undertaken by MMS (WFD)

MMS interpreted the aerial photographs using object-oriented software which processes imagery to create boundaries between logical areas (using both shape patterns and spectral signatures) in imagery. These outputs can be used as a template to produce final mapping outputs (they may require manual editing), thus minimising manual mapping time.

[5] http://ihs.somerc.co.uk/

Definiens Developer 7.0 software was used by MMS for this part of the work. Shape and compactness parameters were set at 0.1 and 0.5 respectively and the scale factor was set at 50. ‘Multi-resolution’ and ’region-grow’ functions were also utilised, which merged the smaller areas together by merging the polygons with a similar spectral value. This had the result of removing all the creeks below a threshold of approximately 1 m and reduced the number of polygons at the edges of the saltmarsh. Imagery was initially processed with the outputs of this process, exported to shapefile format and then utilised by a photointerpreter to create the appropriate extent boundaries.

Landward saltmarsh boundary definition was determined by visual interpretation of the images and aided by use of a modelled highest astronomical tide (HAT) dataset. Additional digitising took place at a screen scale of 1:500. On the seaward boundary both discrete and non-discrete areas of pioneer were mapped. Only discrete areas of pioneer were used for the purposes of the extent map.

Due to the need for efficiency and the need to repeatedly revise saltmarsh extent, MMS developed the following rules for mapping saltmarsh:

1. Only map saltmarsh that exceeds 5 m^2 unless otherwise directed.
2. Only map internal parts of a saltmarsh that exceed 150 m^2 unless otherwise directed.
3. Do not map creeks less than 1.5 m wide.

These three rules were designed to achieve faster and more consistent mapping with the available technology and the scale under consideration. As reviews are expected for these standards in the future, please contact the author for updates.

While not all the saltmarsh mapped by MMS conforms fully to Rule 3 on creek width, it is anticipated that this will be phased in during mapping revisits such that all saltmarsh eventually conforms to all three rules. Rule 3 is not deemed critical for deriving accurate figures for saltmarsh extent on regional scales but has been adopted to ensure consistency.

2.4.6 Mapping undertaken by Geomatics Group

The Geomatics Group also used Definiens Developer 7.0 software to interpret the aerial photographs. Shape and compactness parameters were set at 0.1 and 0.5 respectively and the scale factor set at 50. These parameters allowed the software to run efficiently while maintaining a good level of detail in the segmentation.

The polygons generated from the segmentation process were exported to shapefile format and each polygon was assigned attributes based on the average pixel values (red, green and blue, RGB) and the shape of the polygons. These attributes are used in the classification process to query the data and to automate the process of assigning each polygon a class.

Landward saltmarsh boundary definition was in the most part determined by visual interpretation of the image data and use of a HAT modelled dataset. This was digitised to a scale of 1:1000 on-screen to allow for a compromise of high level of detail in the final product and efficient digitisation.

The occurrence of sparse vegetation in the seaward boundary made it difficult to apply automated methods – even with NIR data. It was also agreed with MMS that only discrete areas of saltmarsh should be mapped for standardisation.

Agreement on standardisation between MMS and Geomatics also resulted in an agreement to standardise outputs using the following rules:

- To only map saltmarsh that exceeds 5m^2 unless otherwise directed
- To only map internal parts of a saltmarsh that exceed 150m^2, unless otherwise directed.

Geomatics also adopted a simplification process to reduce the file size of the polygons and to remove complex creek systems that were very narrow in nature. This served to reduce the complexity of the maps and to achieve greater consistency across mapping approaches.

2.4.7 Mapping of imagery outside the 2006–2009 timeframe

Both MMS and Geomatics had to undertake some mapping using imagery outside the 2006–2009 timeframe. The areas requiring additional mapping using imagery outside of the 2006-2009 timeframe included the upper areas of the Leven, an area of Benacre Broad, the Wyre and a small area of Kent. These areas utilised imagery from the 2001 GetMapping suite of imagery licensed to the Environment Agency.

2.5 Ground truthing

A flow chart showing the role of ground truthing in the process of extent mapping is shown in Appendix 2, which also includes confirmation of the idealised rules to follow in any future mapping programmes.

As discussed above, the availability of high resolution digital aerial photography has enabled greater accuracy in the mapping of saltmarsh, with high quality extent products possible with only minimal ground truthing in many cases. But as seen in the high level flow chart, ground truthing of some kind is recommended over wide areas of consideration to obtain ample confidence in the output.

Risk-based ground truthing was generally employed throughout the various mapping programmes in this project with only areas of low confidence (identified through the mapping process) being visited. The methods used for ground truthing by the various programmes are described below.

2.5.1 Regional Coastal Monitoring Programmes (RCMPs)

RCMPs provided mapped saltmarsh outputs for the Southern and South West Regions and undertook ground truthing on the basis of a need to differentiate communities and not just extents. Validation of saltmarsh took place after mapping had taken place and was performed only when areas of very low confidence were noted. It is currently estimated that ground truthing took place in 1–5 per cent of the saltmarsh areas (Blair-Myers C, personal communication).

2.5.2 MMS-WFD

Each WFD saltmarsh area under consideration required a field survey to satisfy the needs of the Directive which requires the species diversity of the marsh of the water body to be quantified. The design of this field survey accounted for the majority of the ground truthing needs for the extent mapping. Under the survey design, surveyors are required to:

- walk transects 500 m to 2 km apart, depending on marsh size;
- note the beginning and end of saltmarsh – defined by a 5 per cent threshold of saltmarsh extent;
- use quadrats to sample every major community along the transect;
- make an inventory of all saltmarsh species found in the water body, including those not found in the quadrats.

The survey strategy rarely targeted areas that were specific ground truthing requirements for photointerpretation. However, low confidence areas identified during the interpretation process were flagged and in some cases examined by Environment Agency field surveyors.

2.5.3 FCRM

Ground truthing of FCRM saltmarsh extents was undertaken by Green Lane Ecology. This ground truthing was undertaken specifically to help define the landward and seaward boundaries of a limited number of areas, in addition to acting as a way of verifying the quality of the interpretation. In uncertain cases, quadrat sampling was carried out and the percentage cover of saltmarsh species recorded. The quadrats here simply mark the base of the sea wall.

In summary the following work was undertaken by surveyors:

- Make a transect from the seaward to landward boundaries using a 5 per cent cover of saltmarsh species as the limit of saltmarsh extent.
- Lay a tape down along a transect line and record 2 × 2 m quadrat data in five equidistant places along the tape. If the percentage cover of saltmarsh plants is not 5 per cent at the correct point along the tape (that is, the 5 per cent zone was not straight), move landwards or seawards away from the tape until a point was reached at which cover is 5 per cent.
- Use GPS readings to mark the boundaries of extents and quadrats.
- Calculate the mean distances and standard deviations of ground data points to the interpreted boundary.

2.6 Final collation of the three mapping outputs

As set out in section 2.4.1, saltmarsh for the purposes of this project was defined as any discrete marsh or reed bed subject to tidal inundation from saline waters. To ensure all collated datasets adhered to this definition as much as possible, a number of tasks were necessary to standardise the data.

The main standardisation work was undertaken on saltmarsh outputs from Southern and South West Regions which were mapped using the IHS system. The main standardisation tasks for these datasets were to:

- aggregate and re-categorise IHS data to capture saltmarsh as defined in this project;
- remove areas defined as ‘non-discrete’.

These two tasks were undertaken by Peter Brett Associates.

2.6.1 Re-categorisation of IHS data

The IHS covers all habitats and contains a total of 460 habitat categories, of which saltmarshes constitute 26. There are also five categories of which saltmarsh is a subset (Table 2.6). This meant that the RCMP outputs in Southern and South West Regions required a degree of merging and manual editing to conform to the project definitions of saltmarsh.

Table 2.6: IHS categories that have saltmarsh as a subset [1]

IHS code	Category name
GN33	Coarse transitional neutral grassland
GN42	Grazing marsh pasture [*Alopecurus bulbosus* sub-community]
EM11	Reed beds
EM1Z	Other swamp vegetation
EM13	*Bolboscheoenus maritimus* dominant community

Note: [1] See also Appendix 3.

2.6.2 Removal of non-discrete pioneer from outputs

The other standardisation task required for the IHS saltmarsh outputs was to remove areas of non-discrete pioneer from the final outputs. This required a revision of the outputs through manual editing. The reasons for this requirement are detailed below.

Classifying large swathes of non-discrete pioneer offers the potential for large variations in mapping between interpreters as non-discrete or low density stands of pioneer saltmarsh can be very difficult to see on an aerial photograph. In addition, this type of habitat can be subject to considerable seasonal variation.

Non-discrete pioneer has been so termed because it does not appear as contiguous vegetation on aerial photography. The underlying substrate will generally provide the dominant colouration on the image.

Non-discrete pioneer generally appears very slight on aerial photography and, even with skilled photointerpretation, substantial ground truthing is required to ensure high confidence in a correct classification. In addition, non-discrete pioneer saltmarsh viewed from imagery cannot be strictly linked with vegetation abundance in the field as differing quality imagery and conditions may provide a different view. It was therefore decided not to include these areas as part of an extent map. However, it was accepted that non-discrete pioneer could be mapped as additional information when possible.

This decision meant that there would be differences between the three source outputs used in the collation. However this was only relevant to the IHS Peter Brett Associates/Hyder outputs for Southern and South West Regions. A revision of these outputs was therefore commissioned by FCRM for the final collation, which effectively removed the non-discrete pioneer.

2.6.3 Field attribute information

To ensure that the final output could be repeated and reused, a comprehensive attribution was given to all polygons with full metadata provided. The final field attribute structure was agreed between the steering group members prior to finalisation and can be seen in Appendix 4. Flight line information provided by the RCMPs enabled a full inventory of the Southern and South West Region outputs where this information was missing from the delivery for the final collation.

2.6.4 Outputs

The dataset is available as an ArcGIS shapefile with each polygon containing a full trace of the sources used to produce it. This shapefile is available under licence from the Environment Agency and can be provided at national or regional scales.

2.7 Testing consistency across mapping approaches

To explore variation in extent estimation between the mapping methods, a test area was mapped independently and verified for extent with all three methods. While MMS and Geomatics both utilised object-oriented classification software to enable more rapid saltmarsh mapping, the RCMP outputs were all hand digitised without the aid of analysis software.

The case study area chosen was the section of the Camel estuary shown in Figure 2.5. However, this test area did not have difficult transitional zones for interpretation and it is recommended that future work is undertaken to explore variations in interpretation in these more difficult areas.

Figure 2.5: Test area of the Camel estuary

The results showed a significant similarity in extent calculation as seen in Table 2.7 and 2.8, and Figure 2.6. The small variations in interpretation approaches were explained on further examination; in particular, areas of grassland in the northern part of the area caused confusion in defining boundaries. This confirmed the need for the ground truthing survey to be integrated into mapping for high accuracy maps. Even so, differences in extent estimation were thought to be insignificant and the levels of accuracy were deemed acceptable.

Table 2.7: Area calculated by the three independent mapping exercises

Interpreter	Area of test (ha)	% similarity to mean
MMS	1.96	98.9
Geomatics	1.94	97.9
Peter Brett	2.03	97.5

Table 2.8: Outputs from test of similarity in area between the three independent mapping exercises

Interpreter	% similarity in area
MMS – Geomatics	98.98
MMS – Peter Brett	96.55
Peter Brett Associates – Geomatics	95.56

Figure 2.6: Interpretation output from the test area of the Camel estuary

3. Results

Table 3.1 shows the first repeatable baseline of saltmarsh extent in England and Wales based on a clear set of mapping rules. The amount of saltmarsh, as defined by this project, found to be present in England and Wales (2006–2009) is 40,522 ha.

Table 3.1: Extent figures by Environment Agency regions

	Area (ha)
By Environment Agency region:	
Anglian [1]	15255.75
North East	476.06
North West	12018.88
South West [1]	2574.03
Southern	2707.31
Thames	539.54
By country:	
Wales	6950.16
England	33571.57
England and Wales	40521.73

Note: [1] For the purposes of simplification, saltmarsh from Midland's region was divided between these regions.

4. Analysis of change

The standards and technology available for this assessment have enabled a more repeatable baseline of saltmarsh extent in England and Wales within a GIS layer. However, the project identified a need to examine previous efforts to assess saltmarsh extent across wide areas and to compare these estimates with the new figures.

After the mapping work had been completed and examinations of historic assessments were made, it became clear that no conclusions could be drawn from initial comparisons due to the risks and dangers in making potential observations of change based on different methodologies. Following discussion of the initial comparison findings (see section 4.1), the Environment Agency commissioned further work.

This work focused on the NCC survey (Burd 1989) in order to achieve a plausible comparison between the two inventories at a national level (see section 4.2). The work was undertaken by the Environment Agency's Evidence team. The correction factor method used was based on expert judgement, examining a balance of bias and overall extent miscalculation at a national level. As a coarse correction it was not deemed plausible to use the correction factors at a local or regional scale. The outputs are available upon request.

4.1 Initial comparison with other baselines

An initial analysis provided a high level assessment of change by comparing the findings of the Environment Agency (2006–2009) survey with the findings of the following studies:

- the survey of saltmarsh extent in Great Britain carried for NCC by Fiona Burd (Burd 1989);
- a comparative study of south east saltmarshes by Cooper et al. (2001);
- a Countryside Council for Wales (2009) saltmarsh dataset comprising Phase 2 NVC survey data (1990–2003), Phase 1 intertidal survey data (1996–2004) and a small amount of data derived from Ordnance Survey maps.

4.1.1 NCC (Burd 1989)

The NCC (Burd) 1989 survey was chosen as it is the only comprehensive attempt to detail all of the saltmarsh extent in England and Wales. The assessment had known limitations and it is assumed that saltmarsh extent was generally considerably underestimated due to the constraints of the method available at the time; this assumption was noted recently in a conference presentation by Angus et al. (2011) in relation to Scotland's coasts. The results of the comparison are summarised in Table 4.1. It was not deemed feasible to make any initial observations of change without further examination.

Table 4.1: Comparison of estimated overall saltmarsh extent between NCC (Burd 1989) and Environment Agency (2006–2009) inventory

	NCC (Burd 1989) (ha)	Environment Agency (2006–2009) (ha)	Difference
England	32500.13	33571.57	+3.2%
Wales	6747.74	6950.16	+2.9%
Scotland	6089.33	Not applicable	Not applicable

4.1.2 Cooper et al. (2001)

Cooper et al. (2001) was chosen because it investigated losses in a well-studied part of England (Essex) and over a wide area. Table 4.2 shows the main locations from the study that were geographically comparable with the Environment Agency (2006–2009) survey. Please note that in all cases boundary definitions for estuaries will be slightly different and this may result in added comparison inaccuracies in some cases.

The study used aerial photography as its mapping method, but it is thought that the scope of photography may not have captured all the saltmarsh in the study areas compared to the Environment Agency (2006–2009) inventory. Therefore it was again assumed that observations of change would not be valid without further in-depth examination. However, this required a comparison with the original spatial data which was not possible in the time available.

Table 4.2: Comparison of extent estimates from Cooper et al. (2001) and Environment Agency (2006–2009) inventory

	Total area (ha)			
	Cooper et al.			Environment Agency (2006–2009)
	1973	1988	1998	
Orwell	99.5	69.5	53.7	58.96
Stour (Essex)	264.2	148.2	107.4	114.16
Hamford Water	876.1	765.4	621.1	674.81
Blackwater and Colne	1671.7	1482.9	1378.5	1373.80
Dengie	473.8	436.5	409.7	449.30
Crouch	467.1	467.1	307.8	425.84
Thames (Lower)	443.7	–	–	407.08
Medway	843.8	–	–	763.38
Swale	377	–	–	462.89

4.1.3 CCW 2009 saltmarsh dataset

This report was revised to incorporate issues brought forward by CCW in the initial comparisons of the two datasets. The CCW 2009 saltmarsh extent output was originally chosen to examine a collation that used a combination of methods to achieve a full national figure. It should be noted that this dataset was not intended to be a baseline for a particular point in time, but was collected in the first instance to update the Welsh saltmarsh extent layer as seen on the Defra MAGIC and Marine Resource atlas websites.

The 2009 dataset provided by CCW for this project comes from three main sources. The majority of the extent data collated by CCW (> 90%) were derived from Phase 2 NVC Saltmarsh Surveys carried out between 1990–2003, with a smaller proportion of the saltmarsh polygons being derived either from the CCW Phase 1 Intertidal Survey (1996 - 2004) (7.6%) or being estimated and digitised from OS 1:50,000 maps in 2003 (<2%). Table 4.3 shows a comparison of its results with those of this project.

Table 4.3: Comparison of CCW intertidal saltmarsh maps and Environment Agency (2006–2009) inventory

Survey	Extent (ha)
CCW 2009 saltmarsh dataset	7927.63
Environment Agency (2006–2009)	6950.16
Difference	-12.3%

Due to the differing approaches, direct comparison of the two data sets in their existing form was concluded to be inappropriate and it was recommended that further work be carried out to make the data sets more comparable. The key differences in the two datasets are summarised as:

a) More detailed mapping of creeks and pans by the EA dataset

b) Differences in interpretation of what constitutes saltmarsh

c) Temporal considerations

d) Exclusion of discrete pioneer saltmarsh in the EA mapping output

e) Other differences in scale and mapping approach

5. Discussion

Two key areas for discussion were identified as requiring detailed consideration in this report. These were:

- sources of inconsistency in the Environment Agency (2006–2009) survey;
- the exercise undertaken to apply a correction to the NCC (Burd 1989) work to make a comparison more valid.

5.1 Sources of inconsistency in the Environment Agency (2006–2009) survey

5.1.1 Variations in scales and levels of detail of extent mapping

Scale inconsistencies in saltmarsh extent mapping can arise when:

- the level of detail applied by an interpreter in the mapping of creeks varies;
- internal features are mapped at various levels of detail or are not mapped at all;
- variations in mapping detail as manifested through the on-screen scale of mapping, the settings and the types of software used to obtain an initial mapped product.

Rules on defining creek width for mapping purposes were not consistent across the country. The differences are summarised below:

- In south and south west regions, no minimum creek width for mapping was specified.
- In other regions, methods were employed to attempt a standardisation. However, the rules were applied in the latter stages of the project using automated methods and therefore consistency cannot be guaranteed.

Creek width rules have only relatively a small impact on extent figure estimations unless all creeks are considered as part of the saltmarsh extent. This may be considered appropriate for some reporting purposes and has been pointed out by CCW as preferable due to the creeks being integral to the marsh (P. RHind *pers. comm. 2012*). Comparison of the three mapping approaches, which had only slight variation in creek width mapping standards (approximately 1.5- 3m) in a typical area of marsh showed that the methodological differences in this instance were not significant for the mapping of definable areas of marsh.

Although there was some scale variation in the outputs, the level of variation is thought to be insignificant for estimates of extent at national, regional or in some cases even local levels. Nonetheless, resolving these differences in scale consideration is important for consistency and efficiency, and it is recommended that the rules set out in Appendix 3 are examined for future versions (see section 6.2.4).

5.1.2 Defining saltmarsh through photointerpretation

A large proportion of saltmarsh in this mapping collation was defined with no ground truthing information. However, this should not be an issue in the majority of areas because:

- high resolution RGB aerial photography with, in many cases, NIR photography allows saltmarsh to be easily distinguished from other types of vegetation;
- most transitional areas, which can lead to confusion in vegetation type delineation, have been eliminated from the marshes of England and Wales through the building of seawalls.

In cases where distinguishing saltmarsh from other types of vegetation proves to be difficult, it is accepted that ground truthing should take place. However, the resource constraints of the various programmes meant that this was not always the case for this survey. The level of ground truthing afforded to different saltmarsh areas will have depended on the resources available to the programme in question.

Defining saltmarsh according to perceived plant communities presents a number of difficulties. One of these difficulties is that similar reed bed communities may be difficult to define as either being saltmarsh or freshwater marsh. In this work, this issue was somewhat overcome by using:

- OS tidal limits to delineate tidal from non tidal areas;
- a modelled HAT boundary.

However, the final collation still contained some questionable areas as some coastal reed beds behind beach ridges or sea defences may be at a lower elevation than HAT. Provided assessors are aware of this issue, then this potential classification inaccuracy will not be carried through into the assessments of change.

Low confidence areas where ground truthing has not taken place need to be targeted in future work. In general, ground truthing offers the greatest benefit for defining saltmarsh communities (that is, beyond extent to community or zone level). In the vast majority of cases, no ground truthing information is required when mapping saltmarsh extent with high resolution aerial photography.

For the purposes of boundary delineation, saltmarshes were defined in WFD guidance as having a boundary where there was less than 5 per cent saltmarsh species in a quadrat. This rule has not been adopted in other circumstances and a standard for defining transitional areas needs to be finalised. It is possible that this method of defining boundaries for WFD may be revised in the future.

The seaward boundary presented difficulties for interpreting extent boundaries. A decision was made to not include areas of saltmarsh in the aerial photography that appeared ‘fuzzy’ and could only be defined with low confidence. These were generally low density areas of pioneer vegetation. Saltmarsh extents were therefore restricted to what appears to be discrete.

This approach reduces the influence on variations in extent of:

- the time of year;
- the skills of the photointerpreter;
- the quality of the imagery.

However, it is not a perfect solution as what appears to be discrete will also still be influenced to some degree by these factors.

In a number of areas, data were also collated on non-discrete areas of pioneer vegetation but these data are not included in this mapping output.

6. Conclusions and recommendations

6.1 Conclusions

The outputs of this work enable a comprehensive inventory of saltmarsh extent in England and Wales, providing the foundation for an enhanced view of perceived overall losses and gains at a national level. While the confidence in making observations on historic changes is somewhat limited due to methodological differences, future assessments of change will be able to provide significantly greater confidence of losses/gains at a national level.

Having accurate extent figures of saltmarsh loss or gain reduces certain environmental and reporting risks for the Environment Agency and other agencies. Of particular relevance to the Environment Agency, these outputs:

- enable broad-scale and local-scale pictures to be created of the extent of some of our most important coastal flood risk management assets;
- enhance our ability to take appropriate steps to avoid the deterioration of sites protected under European legislation;
- help us to fulfil our obligations to further the conservation and enhancement of these protected sites;
- contribute to the future assessment of ecological status for marine angiosperms for WFD;
- act as a benchmark to implementing the UK saltmarsh BAP objectives in England and Wales. Any measures in the future will rely on this baseline to make observations of change.

The current figure for saltmarsh rate of change is estimated to be -100 ha per year and was put forward in 1992 as a forecast for the next 20 years. Although some analyses from the project outputs have indicated that the rate of change may be lower than -100 ha per year, annual losses cannot be assumed to stay at this level forever. This is because climate change – and specifically accelerated sea level rise – will impact on the rate of change of saltmarsh in the future.

6.2 Recommendations for future work

A number of recommendations and lessons learned have arisen as a result of this work. These are discussed below.

6.1.1 Mapping change over time

Future mapping of saltmarsh extent should be undertaken using this extent map as the baseline as this would avoid problems with differing interpretations. Non-discrete areas should also be considered using accepted alternative levels of confidence in their mapping. Further studies are planned to examine how various reporting requirements can be integrated better.

Regular mapping of saltmarsh extent should occur at least every six years in line with the river basin management plan cycle of the Water Framework Directive. The exact process would need to be agreed, but it should link in with the national framework of coastal monitoring.

Because adopting this approach could lead to complex saltmarsh maps, creeks under a certain width and internal saltmarsh factors (for example, small saltpans) need to be eliminated to decrease mapping time for repeat exercises. Adopting these standards may reduce the complexity of the GIS files generated from these tasks.

If future remapping takes place utilising previous extent maps, high accuracy orthorectifications and/or alignments with previous imagery releases will be necessary to enable the remapping to take place as smoothly as possible. While most of the mapping in this project used Definiens professional software, it is anticipated that this software will no longer be needed now that a baseline of saltmarsh extent has been created.

6.1.2 Further delineation of habitats

Saltmarsh extent can be a misleading indicator of biodiversity – particularly in recent times with the prolific spread of *Spartina anglica,* which has been extensive in many areas.

Further delineation of habitats, as in the original 1989 survey has not been explored in this particular project. However, further delineation of saltmarsh habitats (by photointerpretation) has taken place for the Environment Agency's Southern and South West Regions as well as for parts of the Thames using the Integrated Habitat System, which is designed to be a more mapping-relevant system to the National Vegetation Classification. Ground truthing was minimal in these regions and so habitat differentiation relied almost solely on a photointerpreter's skills. Precise and consistent delineation of habitats as defined by NVC and IHS have yet to be shown to be repeatable through photointerpretation alone because of the continuum in which most of these habitats exist and the inability to distinguish certain saltmarsh habitats with aerial photography. Hyperspectral classification approaches present some similar issues with repeatability of habitat delineation within saltmarsh habitat.

While these facts do not invalidate the maps that are created, strong caveats should be raised if change analyses are made beyond basic extents or communities where very apparent communities are visible from a vertical viewpoint.

If habitat delineation work is to continue, it is recommended that work is undertaken to examine the scales at which consistent community change can be detected from aerial image mapping. Aspects of this are currently being examined as part of WFD status classification by MMS.

6.1.3 Ground truthing

Ground truthing was not as widespread throughout this study as it could have been. There was very little risk-based ground truthing, for example, examining transition zones to determine a best estimation of a boundary. However, the recent availability of handheld GPS units at significantly lower prices means that more accurate ground truthing could be pursued in any future mapping work.

A standardised approach to ground truthing is required which maximises the joint expertise of both the mapper and the field surveyor. Until recently, the two tended to have a close association, if not be the same person. However, more recent streamlined, widespread mapping strategies have not allowed this to be the case and processes for this aspect of saltmarsh extent mapping should therefore be examined further.

6.1.4 A standardised approach to saltmarsh mapping

The rules developed in this project arose partly as a result of trial and error in the mapping process and can be seen in Appendix 2. The lessons learned from this project on the practicality of applying certain rules in saltmarsh mapping to enable greater consistency should be revisited for formalisation in the future.

The development of a protocol for saltmarsh mapping could be easily drafted for potential adoption by the Environment Agency and conservation agencies. Such a protocol should not focus on the technology to be utilised but on the parameters and scales that would need to be adhered to.

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List of abbreviations

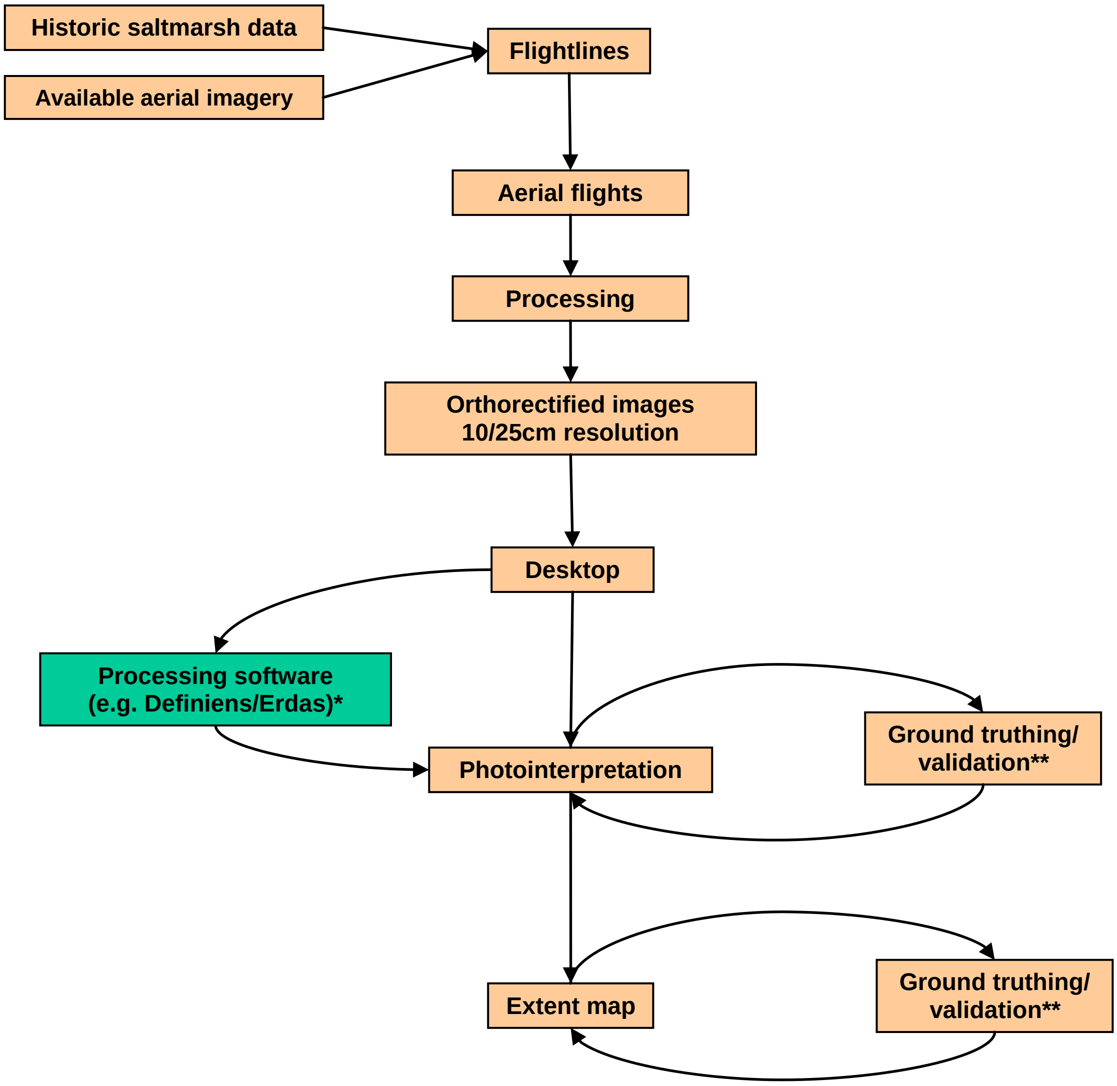
BAP	Biodiversity Action Plan
CCO	Channel Coast Observatory
CHaMP	Coastal Habitat Management Plan
CCW	Countryside Council for Wales
FCRM	Flood and Coastal Risk Management
HAT	Highest Astronomical Tide
IHS	Integrated Habitat System
JNCC	Joint Nature Conservation Committee
MMS	Marine Monitoring Service
NCC	National Conservancy Council
NIR	Near Infrared
NVC	National Vegetation Classification
OS	Ordnance Survey
RCMP	Regional Coastal Monitoring Programme
RGB	Red Green Blue
RMSE	Root Mean Square Error
SAC	Special Area of Conservation
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
TraC	Transitional and Coastal
UKBAP	UK Biodiversity Action Plan
WFD	Water Framework Directive

Appendix 1: NVC survey classification categories

Saltmarsh survey community	**NVC communities**
1. Spartina	SM4 *Spartina maritima*
	SM5 *Spartina alterniflora*
	SM6 *Spartina anglica*
2a. Salicornia/Suaeda	SM7 *Arthrocnemum perenne*
	SM8 Annual Salicornia
	SM9 *Suaeda maritima*
2b. Aster	SM11 *Aster tripolium* var. discoideus
	SM12 Rayed *Aster tripolium*
3a. Puccinellia	SM1O Transitional low marsh vegetation
	SM13 *Puccinellia maritima* – *P.maritima* sub-comm.
3b. Halimione	SM14 *Halimione portulacoides* – *H.portulacoides* sub-comm. – *Juncus maritimus* sub-comm. – *P.maritima* sub-comm.
4a. Limonium/Armeria	SM13 Puccinellia maritima – Limonium/Armeria sub-comm.
4b. Puccinellia/Festuca	SM13 *Puccinellia maritima* – *Glaux maritima* sub-comm. – Plantago/Armeria sub-comm. – turf fucoid sub-comm.
	SM16 *Festuca rubra* – tall *F.rubra* sub-comm.
	SMI7 *Artemisia maritima*
4c. *Juncus gerardii*	SM16 *Festuca rubra* – *P.maritima* sub-comm. – *Juncus gerardii* sub-comm. – Festuca/Glaux sub-comm. – *Leontodon autumnalis* sub-comm.

Saltmarsh survey community	NVC communities
4d. *Juncus maritimus*	– *Carex flacca* sub-comm.
	SM15 *Juncus maritimus/Triglochin maritima*
	SM18 *Juncus maritimus* – *J.maritimus*/Oiachenalii sub-comm. – *Festuca arundinacea* sub-comm.
5a. Agropyron (Elymus) 5b. *Suaeda fruticosa*	SM24 *Elymus pycnanthus* SM28 *Elymus repens* SM25 *Suaeda vera* drift line – *E.pycnanchus* sub-comm. – *H.portulacoides* sub-comm.
6. Upper marsh swamps	S4 *Phragmites australis*
	S19 *Eleocharis palustris*
	S20 *Scirpus lacustris* ssp. tabernaemontani
	S21 *Scirpus maritimus*
7i. Shingle/dune transition	SM21 *Suaeda vera/Limonium binervosum* – typical sub-comm. – *Frankenia laevis* sub-comm.
	SM22 *H.portulacoides/F.laevis*
7ii Freshwater transition	MG11 *F.rubra/A.stolonifera/P.anserina* – *Lolium perenne* sub-comm. – *Atriplex hastata* sub-comm. – *Honkenya peploides* sub-comm.
7iii. Grassland transition	MG12 Coarse *Festuca arundinacea* – *Lolium perenne/Holcus lanatus* sub-comm. – *Oenanthe lachenalii* sub-comm.

Appendix 2: Idealised work flow



Provisional rules for mapping saltmarsh

1. Only map saltmarsh that exceeds 5 m^2 unless otherwise directed.

2. Only map internal parts of a saltmarsh that exceed 150 m^2 unless otherwise directed.

3. Do not map marsh that is not in discrete formations on the imagery used. Fuzzy areas are not reliable or consistent enough to warrant mapping.

4. Do not map creeks less than 1.5 m in width.***

Figure A.1: Recommended work flow to conform to the method implemented in the national collation

Notes: * Utilisation of processing software to aid mapping is an optional step.
** Ground truthing may be undertaken to: (a) inform photointerpretation; (b) to edit the extent map; or (c) in both stages. This will depend on the overall aims of the mapping, the level of confidence required in the photointerpreted product, and the resources available.
*** Not all saltmarsh extents conformed to this rule, but where they did not, they were mapped to a higher level of detail.

Appendix 3: IHS classification categories

IHS code	IHS short description	EUNIS	Corine	NVC
LS3	Coastal saltmarsh (PHT)	A2.5		
LS31	Salicornia [Glasswort] and other annuals colonising mud and sand (AN1)	A2.551	15.11	SM8+SM9
LS311	Salicornia [Glasswort] colonising mud and sand (TT	A2.5513		SM8
LS312	Suaeda colonising mud and sand (TT)	A2.5512		SM9
LS313	*Aster tripolium* colonising mud and sand (TT)	A2.556	15.322	
LS31Z	Other annual colonising mud and sand			
LS32	Spartina swards [Cord grass] [Spartinion] (AN1)	A2.5541	15.21	SM4-6
LS321	*Spartinion maritimae* swards (TT)			SM4-5
LS32Z	Other Spartina swards (TT)			SM6
LS33	Atlantic salt meadows [*Glauco-Puccinellietalia maritimae*] (AN1)	A2.54	15.3	SM9+SM10+ SM11+SM12 +SM13+SM1 4
LS331	Transitional low-marsh (TT)	A2.548	15.323	SM9+SM10
LS332	*Puccinellia maritima* mid-marsh (TT)	A2.541	15.32	SM13
LS333	*Atriplex portulacoides* mid-marsh (TT)	A2.545		SM14
LS334	*Aster tripolium* low-marsh (TT)	A2.556 A2.557		SM11+SM12
LS3341	Rayed [*Aster tripolium*] pioneer saltmarshes	A2.556		SM12
LS3342	[*Aster tripolium*] var. [discoides] pioneer saltmarshes	A2.557		SM11
LS33Z	Other Atlantic salt meadows (IC)			
LS34	Mediterranean salt meadows [*Juncetalia maritima*] (AN1)	A2.53		SM15+SM16 +SM18

IHS code	IHS short description	EUNIS	Corine	NVC
LS341	*Festuca rubra* upper salt-marsh community (TT)	A2.53A A2.53B		SM16
LS342	*Juncus maritimus* upper salt-marsh community (TT)	A2.535		SM18
LS343	*Juncus maritimus–Triglochin maritima* salt-marsh community (TT)	A2.536		SM15
LS34Z	Other Mediterranean salt meadows (IC)			
LS35	Inland salt meadows [Sarcocornetea] (AN1)			
LS36	Mediterranean and thermo-*Atlantic halophilous* scrubs [*Sarcocornetea fruticosi*] (AN1)			
LS37	*Elytrigia atherica* upper-marsh (TT)			SM24+MG12
LS3Z	Other saltmarsh (IC)			
GN33	Coarse transitional neutral grassland			MG12
GN42	Grazing marsh pasture [*Alopecurus bulbosus* sub-community]			
EM11	Reed beds (PHT)	C3.21 D5.1		S4
EM1Z	Other swamp vegetation (IC)	C3.2		S15+S23
EM13	*Bolboscheoenus maritimus* dominant community (TT)	C3.22.		S21

Appendix 4: Field attributes in GIS extent outputs

Column heading	Description
Area	This is the area in m2.
Hectares	This is the area in hectares (ha).
NIR_Used	This tells you whether infrared imagery was used to help define these data.
Year	This is the year of the flight to capture the imagery.
Month	This is the month of the flight to capture the imagery.
UK_Region	This is the region in which the saltmarsh lies.
EA_WB_ID	This is the water body ID based on the transitional and coastal water body of 2008 as an identifier for the water bodies.
EA_Area_CD	This is the regional short identifier and is as follows: AN = Anglian, CY = Wales, NE = North East England, NW = North West England, TH = Thames, SO = Southern and SW = South West.
Alt_Name	This column contains an additional name if the shapefile is split due to an administrative boundary; for example, Dee (England) and Dee (Wales).
WB_Name	This is the name of the water body.
Interprete	This is the photointerpreter responsible for mapping the saltmarsh; for example, MHILL + OCA shows that a combination of mapping was undertaken between Matthew Hill and Oliver Crawford-Avis
Used_Final	This is whether the shapefile is used in the final shapefile combining IHS, FCRM and MMS data: Y = Yes, N = No. MMS data take priority, then FCRM, then IHS; this is done to prevent any overlap of the data.
AP_Source	The company that flew the photography for the saltmarsh mapping. Note: Environment Agency and Geomatics are the same organisation.

Appendix 5: Initial comparison findings

Please note that the figures here cannot be used for assessments of change as the methodologies and coverage differences vary considerably.

Case study 1: NCC (Burd 1989)

The tables below compare the findings of the NCC (Burd 1989) survey and the Environment Agency (2006-2009) survey, which are as geographically correct for comparison as possible in the given time. In some places this required aggregating figures.

Table A.1: Estimation of overall saltmarsh extent by NCC (Burd 1989) and Environment Agency (2006–2009) inventory

Country	NCC (Burd 1989) (ha)	Environment Agency (2006-2009) (ha)
England	32500.13	33571.57
Wales	6747.57	6950.16
Scotland	6089.33	Not applicable

Table A.2: Estimation of overall saltmarsh extent by NCC (Burd 1989) according to the regional units of the study

Region	NCC (Burd 1989) (ha)
North West England	8692.78
West Midlands	2122.16
South West England	2647.67
Southern England	2874.33
South East England	2161.27
East Anglia	8819.24
East Midlands	4222.79
North East England	959.89
North Wales	2220.12
Dyfed Powys	1278.91
South Wales	3248.54

Table A.3: 1989 survey saltmarsh extent figures put into the equivalent Environment Agency regions

Environment Agency Region	NCC (Burd 1989) adapted regional figures	NCC (Burd 1989) (ha)	Environment Agency (2006–2009) (ha)	Difference
Anglian	East Midlands + East Anglia + Humber	13689.89	15255.75	+10.3%
Southern	Southern – S Thames	2796.66	2707.31	-3.3%
North West	North West +Cheshire	10557.19	12018.88	+12.2%
North East	North East – Humber	312.03	476.06	+34.5%
South West	South West + Gloucestershire	2905.42	2574.03	-12.9%
Thames	Thames	454.58	539.54	+15.7%
Wales	Wales	6747.57	6950.16	+2.9%

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