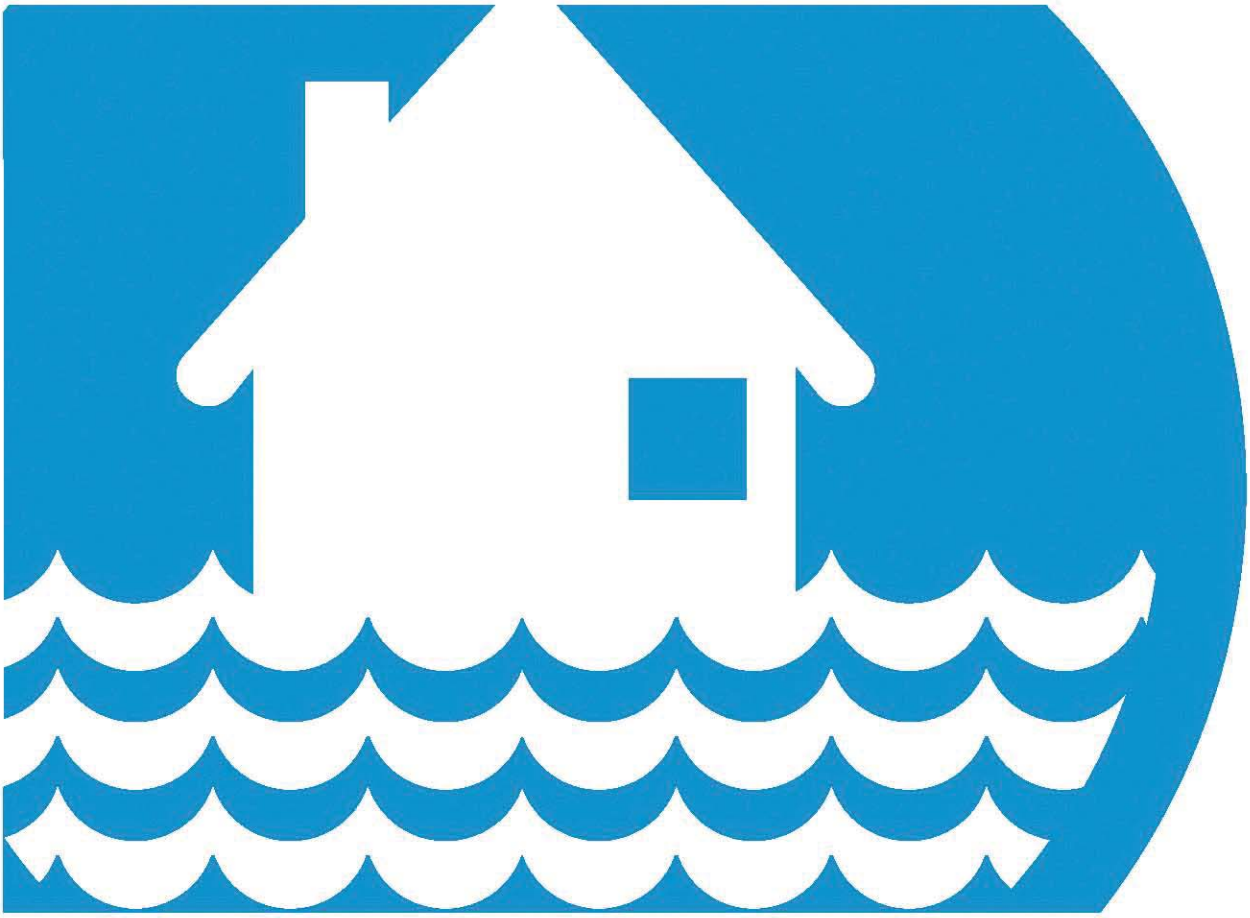
Environment Agency



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

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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.

Over the past four years, the Environment Agency has gathered aerial data and established a new baseline figure for the extent of saltmarsh in England and Wales. Aerial photography largely from 2006–2009 was used to develop a quality assured and consistent map of saltmarsh extent in England and Wales.

The last complete survey of saltmarsh extent in the UK was completed by the Nature Conservancy Council in 1989. Since then, surveys from a national perspective have been ad hoc, fragmented and localised which has made it difficult to appreciate whether saltmarsh is being gained or lost nationally. It is vital for the Environment Agency to have an accurate assessment of saltmarsh extent so that it can assess the progress it is making to meet its legal obligations for biodiversity.

The Environment Agency coordinated the mapping of saltmarsh extent in England and Wales based on the high resolution aerial photographs collected. This enabled the creation of a consistent baseline figure for the extent of saltmarsh in England and Wales, allowing future assessments to be compared with confidence. This report describes the processes involved in producing a map of saltmarsh extent and examines the consistency of approach in mapping saltmarsh to provide recommendations for future mapping.

Differences in saltmarsh mapping methodologies can be considerable. This project has compared with some caution the new national figures for saltmarsh extent in England and Wales with previous historical figures. It has identified and quantified possible sources of error, so that the extent of saltmarsh change could be estimated. This exercise suggests that the rate of saltmarsh loss at a national level has been slower than previously thought. Our improved understanding of the national rate of saltmarsh change means that the national figure for gain/loss of saltmarsh may need to be revised.

Acknowledgements

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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 Directives sites. In addition, saltmarsh is an important consideration for Flood and Coastal Risk 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, Environment Agency 2004). Accurate calculation of saltmarsh extent has therefore become an important measurement, contributing to effective planning and works for FCRM.

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.

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, Cope et al. 2007). 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 FCRM 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 BAP, WFD, in addition to ongoing responsibilities for SSSIs and Habitats and Birds Directives sites (SACs and SPAs).

With these considerations in mind, in 2006 the Environment Agency's 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 lead 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.

The resulting baseline map for England and Wales may be seen to be representative of saltmarsh extent from 2006–2009. Approximately 1 per cent of the total saltmarsh area has been mapped

[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.

using photography outside this 2006–2009 timeframe using photography stretching no further back than 2004.

1.3 Comparing new and historic data

At the beginning of the mapping programme, the steering group recommended that case studies be included to allow a degree of comparison with previous data 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 potentially be used by decision-makers or managers to compare with historic data in various locations at various scales. Without focussing on this issue, there was a risk that comparisons would be made that would be assumed to be valid. 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 crucial to highlight the issues associated with making such comparisons.

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;
- Strategy and Engagement Team in 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 1.1). 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)	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 saltmarsh programme 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 – 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. Details of the contractors' work are given below.

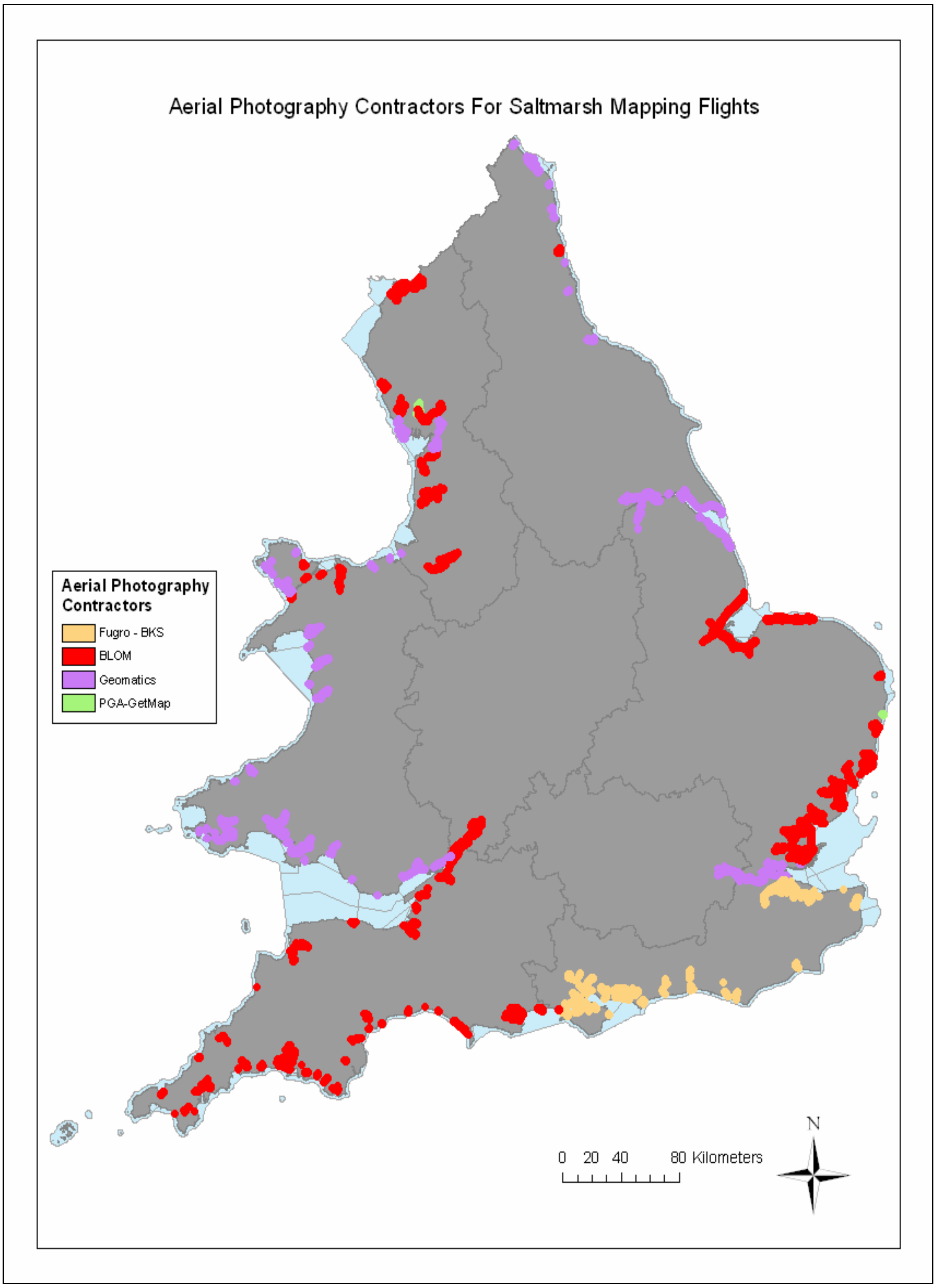


Figure 2.2: Geographical spread of aerial photography contractors

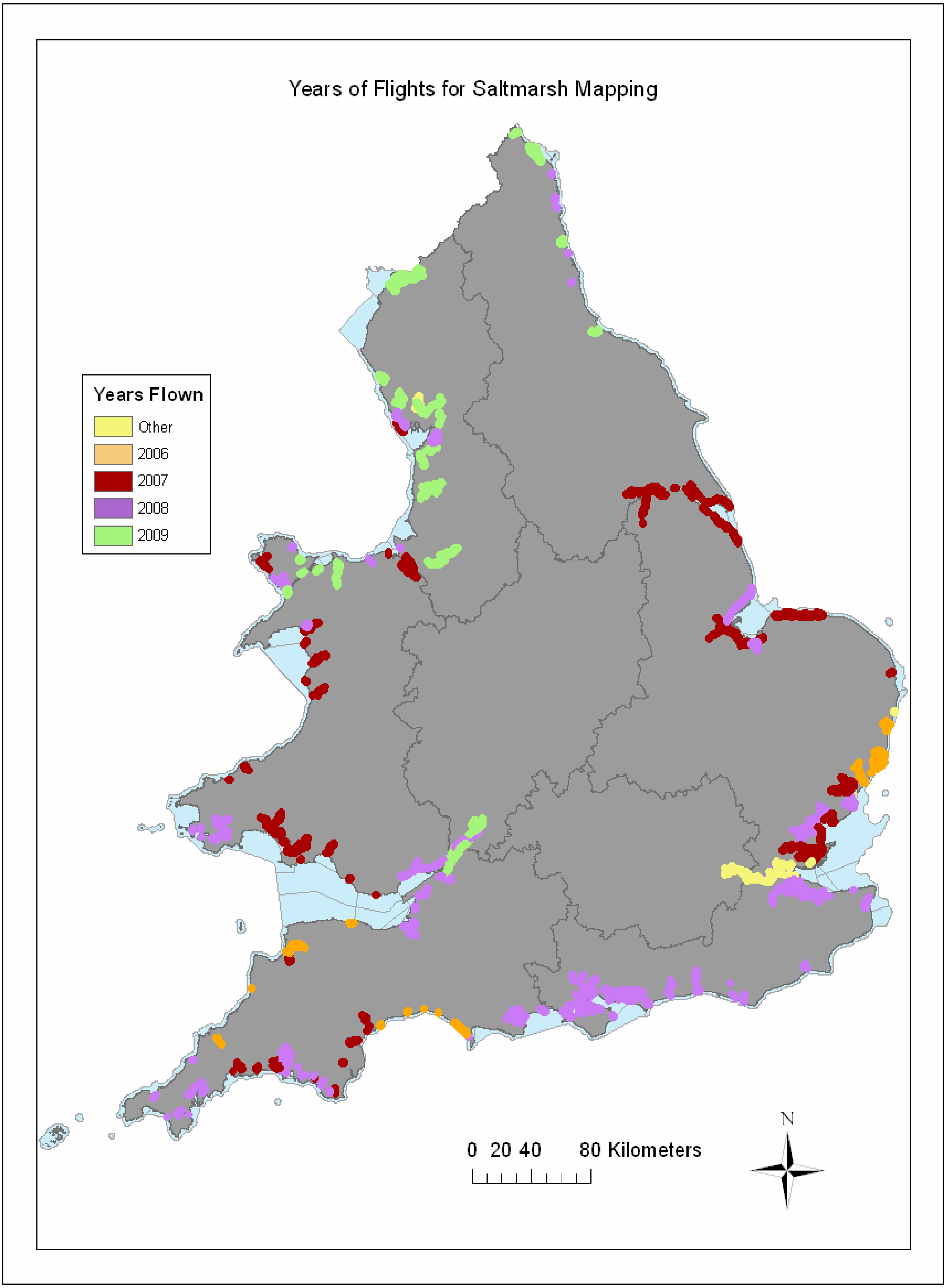


Figure 2.3: Geographical spread of years flown for the saltmarsh mapping programme

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		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) defines saltmarsh as:

> '*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 was to define saltmarsh as any discrete marsh, or reed bed, subject to tidal inundation from saline waters. It was

[3] http://www.ukbap.org.uk/ukplans.aspx?id=33

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 swaths 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.

To ensure consistency of repeatability, it was decided that non-discrete pioneer would not be included in the final extent map.

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 with 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		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	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 are designed to achieve faster and more consistent mapping with the available technology and the scale under consideration.

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 5m2 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 Saltmarsh Programme

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 for datasets in the collation 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.

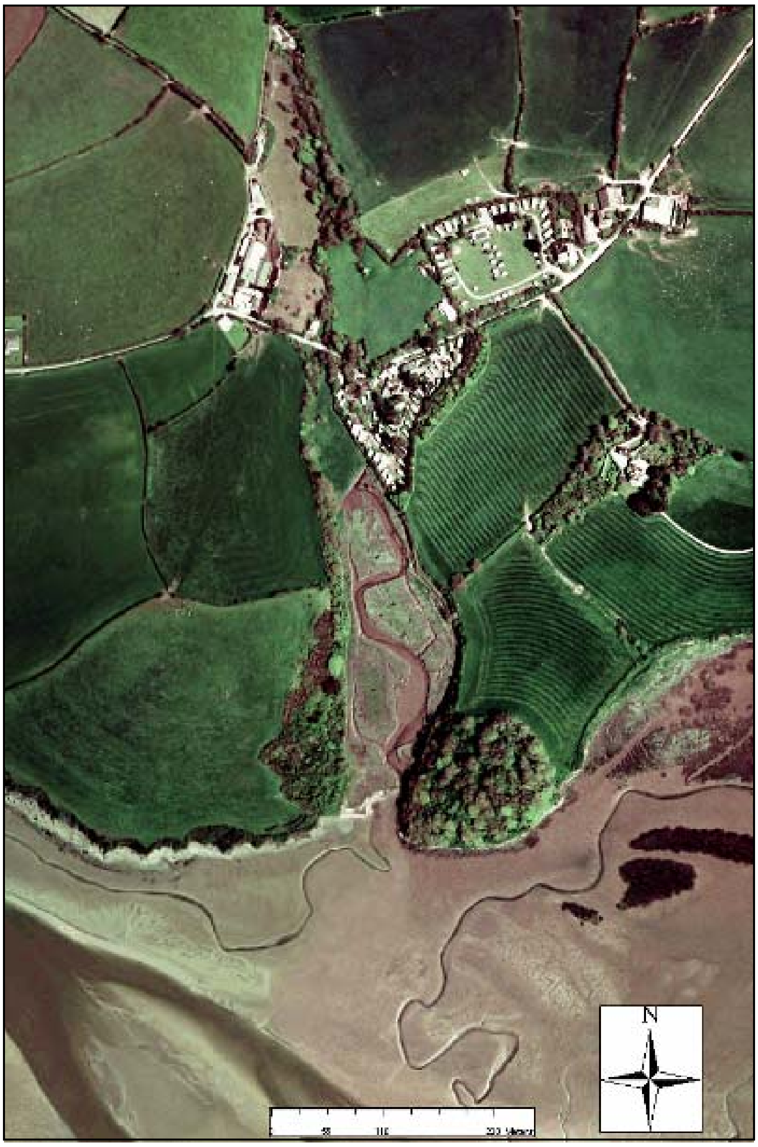


Figure 2.5: Test area of the Camel estuary

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. But 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. The extent according to WFD water bodies is given in Appendix 5.

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 the first repeatable baseline of saltmarsh extent in England and Wales within a geographical information (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, it became clear that no conclusions could be drawn from the 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 therefore 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 and its findings integrated into this report.

The correction factor method used was based on expert judgement, examining a balance of bias and overall extent miscalculation at a national level. It is not plausible to use the correction factors to make comparisons at a local or regional scale.

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 (CCW) 2009 saltmarsh dataset which drew largely on their 2003 intertidal habitat surveys.

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 (see section 4.2).

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 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

The CCW 2009 saltmarsh extent output was chosen to examine another collation that used a combination of methods to achieve a full national figure. This dataset was provided by CCW for this project and although no report is available for this dataset a large portion of it is based on the CCW (2006) CCW Phase 1 Intertidal survey dataset (unpublished). It is also supported by a range of other unpublished data also held by CCW. 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[1]	7927.63
Environment Agency (2006–2009)	6950.16
Difference	-12.3%

Note: [1] Phases I and II plus OS data

The methods used in the CCW assessment are based on recent field survey sketching with Ordnance Survey (OS) data. The OS marsh datasets group includes freshwater marsh and saltmarsh in one category. This is probably the reason for the difference between the Environment Agency survey and the CCW survey. In addition there is no temporal record of the mapped output.

4.2 Further examination: Environment Agency (2006–2009) and NCC (Burd,1989)

An in-depth comparison of the Environment Agency (2006–2009) inventory with the NCC (Burd1989) survey data enabled initial observations on the validity of the 100 ha loss per year prediction on which UKBAP relies for management and reporting purposes.

The 1989 survey concluded that England and Wales had 39,248 ha of saltmarsh. With UKBAP loss estimates of 100 ha per year, approximately 37,248 ha of saltmarsh would be expected to remain. Instead the Environment Agency (2006–2009) survey found 40,522 ha of saltmarsh. This is 8.1 per cent more saltmarsh than expected, and taken at face value, would equate to 64 ha per year of accretion.

An attempt was therefore made to eliminate the issue of methodological differences to allow a fairer comparison of actual change by:

- comparing and evaluating methodologies;
- applying a correction factor to the 1989 survey.

4.2.1 Summaries of the survey approaches

In summary, the Environment Agency (2006–2009) method was as follows:

- High resolution aerial photography was captured between 2006 and 2009 for nearly all English and Welsh saltmarsh.
- Identification of saltmarsh for flight capture used comprehensive datasets giving a complete coverage in nearly all areas.
- Mapping was undertaken by three main parties commissioned by the Environment Agency.
- Photointerpreters used a defined set of criteria and GIS tools to map saltmarsh using manual and semi-automated techniques.
- Ground truthing to some extent was used in all programmes.

In summary, NCC (Burd1989) survey method was as follows:

- Field survey data were collected between 1981 and 1989, covering the saltmarsh of Great Britain.
- In some areas, the survey drew on existing surveys, one of which dated back as far as 1974. Areas of known change within the 1974 survey were re-surveyed during the 1981–1989 period.
- The survey relied on existing knowledge by local teams to highlight the areas of saltmarsh data to be surveyed.
- For each of the areas, a surveyor visited the site and drew a 'sketch map' (often with little reference to OS maps).
- Back at the office a dot grid was used on the sketch map to calculate the area of the habitat. These sketch maps were then scaled up to match OS map scales.

4.2.2 Applying a correction to make the results comparable

Given the time resources and constraints of attempting such a task, the application of a correction factor to align the NCC (Burd 1989) study with the Environment Agency (2006-2009) study could only be done by expert judgement. However the aim of this exercise was to potentially improve on historic estimates of loss which themselves were expert judgement assessments with even less information to hand. With this in mind, it was thought appropriate to pursue this means of revising national loss estimates.

As noted above, it is more likely that nationwide historical estimates will be an underestimate of extent rather than an overestimate. This is due to an inevitable failure to capture all areas of saltmarsh in every location with the limited resources and technology available historically. However, there are also more complex considerations. These are outlined below and a consequent correction applied.

Table 4.4 highlights the differences between the NCC (Burd 1989) and the Environment Agency (2006–2009) surveys. The final column suggests a correction factor that could be applied to the 1989 survey to eliminate the issue and allow a fair comparison. For example, a correction factor of +1 per cent means that findings of the 1989 survey should be increased by 1 per cent before comparing them with those from the 2009 survey.

In most cases the correction factors are not based on hard data but instead were estimated through discussions with the authors of both surveys. A wide range of correction factors are examined in section 4.2.4. The estimates here allow a focus on the most likely range. (Note that these issues would have a cumulative impact on extent estimates.)

Table 4.4: Differences between results and correction factor

Issue	NCC (Burd 1989) survey	Environment Agency (2006–2009) survey	Correction based on expert judgement
High tide mark	The surveyors used local evidence such as wrack marks (lines of debris deposited at high tide along the beach) to identify the highest recent tide level. This defined the landward limit of any saltmarsh habitat.	The photointerpreters used the HAT level in each area to mark the landward extent of any saltmarsh data. Often this was higher than recent high tides.	+0.5% to +1% Certainly a factor but only applies in a few areas where the high tide mark is not well-defined.
Access to sites	The surveyors could not access all the sites they had identified. The final report describes a figure of 0.8% of identified sites that could not be accessed. There may have been other sites that were not identified (see below).	The aerial photography covered all of the coast.	+0.5% to +1% Assuming 0.8% of sites = 0.8% of total area
Survey sites	The survey relied on local knowledge to identify sites of known saltmarsh area. This means there could have been some areas of saltmarsh about which the surveyors were simply unaware.	The inventory of saltmarsh location prior to flying integrated multiple national and local sources of data.	+1% to +2% There will certainly have been sites that were missed, but local knowledge is likely to have identified all the major sites.
Mapping	The surveyors drew 'sketch maps' while on site – often without reference to OS maps. These sketch maps could also be a source of operator bias. A fundamental problem with this mapping approach was highlighted by Andre and Rogers (2006), who showed that estimating distances of 5–90 m visually (solid triangles) resulted in underestimates of the actual distance by 15–25%.	Aerial photography and a strictly defined process were used to map the areas of saltmarsh.	+1% to +2% The 1989 survey cited this factor as the likely largest source of error. It probably led to an underestimate of total saltmarsh extent by Burd for the NCC (Burd 1989) survey as the surveyors would have problems seeing far enough at ground level.

Issue	NCC (Burd 1989) survey	Environment Agency (2006–2009) survey	Correction based on expert judgement
Pioneer areas	Local surveyors were able to identify pioneer areas on the ground.	Pioneer areas proved problematic for identification by aerial photography so were formally excluded.	0% The total pioneer area was measured in the Environment Agency (2006–2009) survey for Southern and South West Regions. It only accounted for 10 ha and therefore is probably insignificant compared to the overall totals.
Measuring total area	The 1989 survey measured the area of each habitat using dot grids. This could be a source of error, but it is not known if this increased or decreased the estimate.	The area was calculated using GIS-based tools.	-1% to +1% There are probably some errors from using this technique. However they would lead to both underestimates and overestimates, meaning that the net effect of all the errors is probably small.
Total			+2% to +7% (sum of maximums and minimums for each factor)

4.2.3 What has been the annual change in saltmarsh using this approach?

Three pieces of information are needed to estimate a figure for the annual change in saltmarsh:

- **Environment Agency (2006–2009) aerial survey total without saltmarsh creation schemes.** Before 1991 there were no records of managed realignment schemes. Since this date there have been many schemes which are estimated to have produced an additional 1,000 ha of saltmarsh. However, only 458 ha would have been mature enough to be picked up by the Environment Agency (2006–2009) aerial survey. Therefore the Environment Agency (2006–2009) total without saltmarsh creation is 40,522 – 458 = 40,064 ha.

- **NCC (Burd 1989) survey total corrected to reduce methodological/resource differences.** It is very difficult to provide a precise figure for this with the data available. However, Table 4.4 gives an estimate of the likely range of this correction factor (+2 to +7 per cent). Using this correction factor, the total is likely to be somewhere in the range 40,033 to 41,995 ha.

- **Time period over which change occurred.** The 1989 survey collected data between 1981 and 1988. The Environment Agency (2006–2009) aerial survey collected data between 2006 and 2009. Taking the mid-points of these ranges gives an average time period of 23 years.

Based on this information, the likely range of saltmarsh can be calculated as follows:

$$\frac{\text{(2006–2009 aerial survey total – saltmarsh created) – (1989 survey total} \times \text{correction factor)}}{\text{Time over which change occurred}}$$

Application of this formula suggests that the likely annual saltmarsh change for England and Wales was between +1 and -83 ha per year. This suggests that the net effect of saltmarsh change in England and Wales is probably negative. However, it is probably less severe than the original predictions of 100 ha loss.

4.2.4 Use of different correction factors

The greatest source of uncertainty in this analysis is the correction factor. A much wider range of correction factors were also examined and the results are shown in Figure 4.1.

This graph highlights why using data collected through different methodologies makes it extremely difficult to estimate annual saltmarsh change. The final figure is highly sensitive to any artefacts in the methodology which cause it to underestimate or overestimate compared with another methodology. For example, the range from +5 per cent to -5 per cent takes the annual estimate from +123 ha per year to -47 ha per year.

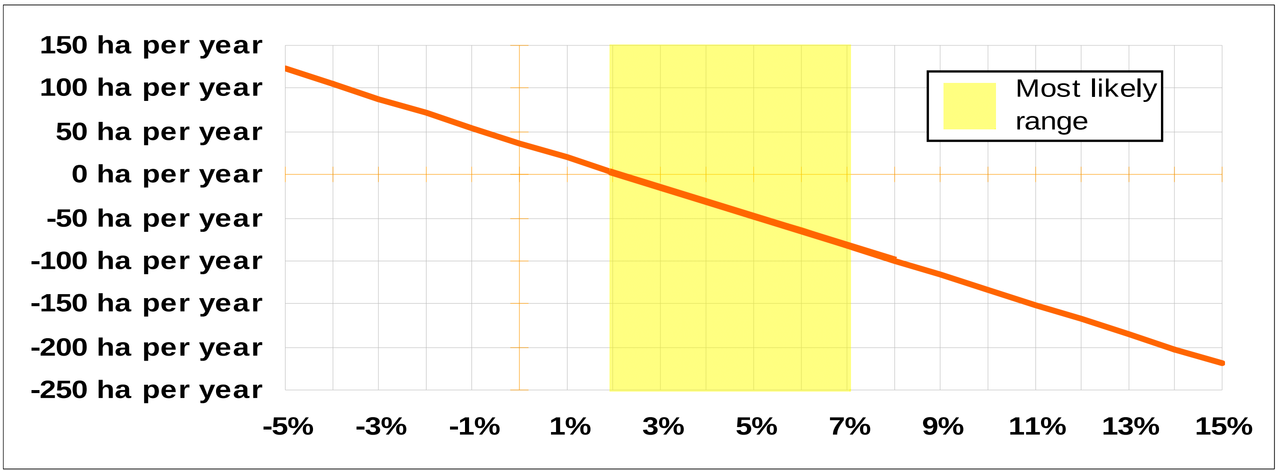


Figure 4.1: Impact of different correction factors on annual saltmarsh loss/gain

4.2.5 Are the results supported by other studies?

To provide evidence on the reliability of the differences between the Environment Agency (2006–2009) survey and the NCC (Burd 1989) survey, results were compared with some select local studies of saltmarsh change over time within the interval of the studies.

For each study, the total saltmarsh change was adjusted to estimate the change over a 20-year period to allow a comparison with the results of the national surveys. None of the studies covered exactly the same time period but they are all within the time interval of the NCC and Environment Agency surveys.

A similar direction and magnitude of change was found in all cases. As none of the specific locations showed unexpected results, it is less likely that differences observed are due to fundamental errors in either of methods used but that they are due to cumulative methodological differences.

Cooper et al. (2001)

This study compared three different surveys over a 25-year period from 1973 to 1998. It concluded that approximately 1,000 ha of saltmarsh had been lost in Essex during this period. Assuming the rate of loss was constant, then 800 ha was lost over a 20-year period.

The major estuaries in Essex are the Blackwater, Deben, Crouch, Foulness and Roach. The majority of saltmarsh is found in these areas. When the data for these estuaries are compared with the data from the NCC (Burd 1989) and the Environment Agency (2006–2009) surveys, there is a 674 ha loss. The direction and magnitude of change are similar in both cases, indicating erosion of 35–40 ha per year.

There has been a number of managed realignment sites in Essex since the early 1990s which may have impacted on the rate of loss. However, they will not impact on the direction of change as they are not extensive enough to have reversed the total loss.

Baily and Pearson (2007)

This paper discusses a study of saltmarsh area in central southern England from Hurst Castle Spit in Hampshire to Pagham Harbour in west Sussex using aerial photography from 1971, 1984 and 2001. It showed an overall loss in the area of 645 ha. Assuming the rate of loss was constant over that period, then 431 ha would have been lost in a 20-year period.

Comparison of major estuaries from the NCC (Burd 1989) and the Environment Agency (2006–2009) surveys for this area shows a 584 ha loss.

Thus the direction and magnitude of change are similar in both cases and the evidence consistently shows saltmarsh eroding in the Solent area at a rate of 20–30 ha per year.

More detailed analysis of the sites also shows that all the sites are eroding apart from Pagham Harbour; this is the same for both analyses. However, the study by Bailey and Pearson concludes that the increase in Pagham Harbour is minimal (<5 ha), while the NCC (Burd 1989) vs. Environment Agency (2006–2009) analysis suggests that the increase was about 70 ha.

Environment Agency Anglian Coastal Monitoring Programme (2007)

This study (Environment Agency 2007) used aerial photography taken in 1992 and 2006 to look at saltmarsh change in the Wash. The study concluded that 1,021 ha were gained during the 14 years of the study period. Assuming the rate of loss was constant during this period, then during a 20-year period there would be a gain of 1,459 ha.

Comparison of the NCC (Burd 1989) and the Environment Agency (2006–2009) survey data shows a 1,244 ha gain.

The direction and magnitude of change is the same in both cases. The evidence consistently shows saltmarsh accreting at a rate of 62–73 ha per year.

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 can not be guaranteed.

These creek width rules have minimal impact on estimations of extent figures and therefore are not considered to significantly impact the accuracy of the extent estimations. Comparison of the three mapping approaches in a typical area of marsh showed that the methodological differences were generally insignificant 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 was deemed to be 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.

5.2 Comparison of NCC (Burd 1989) survey with Environment Agency (2006–2009) survey

The NCC (Burd 1989) survey estimated the total saltmarsh habitat in England and Wales as 39,248 ha. With an expected habitat loss of 100 ha per year, an extent of 37,248 ha would be expected to remain 20 years later. However, the Environment Agency (2006–2009) survey identified 40,522 ha of saltmarsh. The comparison in this report of the findings from the NCC (Burd 1989) and the Environment Agency (2006–2009) surveys to independent local studies found the same direction and magnitude of change in all the localities examined.

With respect to the original annual 100 ha loss figures predicted by Pye and French (1993b), the changes in extent observed are due to either or both of the following:

- There are differences in methodology which mean that the NCC (Burd 1989) survey underestimated saltmarsh habitat compared with the Environment Agency (2006–2009) aerial survey.
- Saltmarsh is not eroding at a rate of 100 ha per year as current UK targets suggest.

The analysis of change (section 4.2.3) suggests that the annual saltmarsh change estimate figures used for this project are very sensitive to changes in methodology – especially given their importance.

- If the methodology overestimates by 5 per cent, then annual change is a 47 ha loss.
- If the methodology underestimates by 5 per cent, then annual change is a 123 ha gain.

The analysis of methods suggests that a major part of observed differences will be down to methodology rather than actual change. Undertaking this exercise has also indicated that there are serious risks in using surveys with different methodologies to measure change.

However, it is important to review the 100 ha per year loss figure in light of the latest evidence. A range of correction factors were examined to account for the differences in the surveys. These ranged from -5 per cent to +15 per cent correction to the NCC (Burd 1989) data to align with the Environment Agency (2006–2009) survey.

Based on the analysis of the methodology, a correction factor based on expert judgement of the factors identified was applied. This correction was somewhere between +2 per cent and +7 per cent of the NCC (Burd 1989) survey. These values show annual change as being between +1 and -83 ha per year, suggesting that the current target may be too high. The mid-point in this range is roughly -40 to -50 ha per year. If this were the true figure, then England and Wales would have lost 920 ha in the past 23 years. It is important to note that these are national rates of change and should not be used to determine local or regional rates of change.

6. Conclusions and recommendations

6.1 Conclusions

The outputs of this work enable a comprehensive inventory of saltmarsh extent in England and Wales, providing 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 eliminates significant risk 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;
- greatly 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 this project has 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 learnt 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 should avoid problems with differing interpretations.

Regular mapping of saltmarsh extent should occur at least every six years in line with the river basin management plan cycle of the WFD. 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 the same person. However, more recent streamlined 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.

References & Bibliography

ABPmer, 2008. *Severn Estuary Coastal Habitat Management Plan*. Interactive CD produced on behalf of the Environment Agency.

Allen, J.R.L,. 1990. The Severn Estuary in southwest Britain: its retreat under marine transgression, and fine-sediment regime. *Sedimentary Geology*, 66, 13-28.

Andre, J. and Rogers, S., 2006. Using verbal and blind-walking distance estimates to investigate the two visual systems hypothesis. *Perception and Psychophysics*, 68, 353-361.

Angus, S., Hansom, J.D. and Rennie A., 2011. 'Oir-thìrean na h-Alba ag Atharrachadh: habitat change on Scotland's coasts'. In *The Changing Nature of Scotland* (ed. S.J. Marrs, S. Foster, C. Hendrie, E.C. Mackey and D.B.A. Thompson). Edinburgh: TSO.

Baily, B. and Pearson, A., 2007. Change detection mapping and analysis of salt marsh areas of central southern England from Hurst Castle Spit to Pagham Harbour. *Journal of Coastal Research*, 23(6), 1549-1564.

Baily, B., Pearson, A., Collier, P. and Fontana, D., 2002. Mapping the intertidal vegetation of the harbours of southern England for water quality management. *Journal of Coastal Conservation*, 8, 77-86.

Best, M., Massey, A. and Prior, A., 2007. Developing a saltmarsh classification tool for the European water framework directive. *Marine Pollution Bulletin*, 55, 205-214.

Blair-Myers, C., 2002. North Kent Marshes Saltmarsh Survey 2002. Report for the Environment Agency

Bristow, C.S. and Pile, J., 2002. *South Wales estuaries Carmarthen Bay: evolution of estuarine morphology and consequences for SAC management.* CCW Science Report 528. Bangor: Countryside Council for Wales.

Burd, F., 1989. *The saltmarsh survey of Great Britain: an inventory of British saltmarshes*. Nature Conservatory Council, Research and Survey in Nature Conservation no. 42. Peterborough: Nature Conservancy Council.

Burd, F., 1992. *Erosion and vegetation change on the saltmarshes of Essex and north Kent between 1973 and 1988*. Research and Survey in Nature Conservation No. 42. Peterborough: English Nature.

CCW, 2006. *CCW Phase 1 Intertidal survey dataset* (unpublished)

Cooper, N. and Cooper, T., 2000. *Saltmarsh change within the Suffolk estuaries between 1971, 1986 and 1998.* Report to the Environment Agency Anglian Region.

Cooper, N. Cooper, T. and Burd, F., 2001. 25 years of saltmarsh erosion in Essex: Implications for coastal defence and nature conservation. *Journal of Coastal Conservation*, 7, 31-40.

Cope, S.N., Bradbury, A.P. and Gorczynska, M., 2008. *Solent Dynamic Coast Project. Summary report.* A report by Channel Coast Observatory for New Forest District Council. Available from: http://www.newforest.gov.uk/index.cfm?articleid=6652&articleaction=nthslnt&CFID=41455035&CFTOKEN=52483683 [Accessed March 2011].

Department for Environment, Food and Rural Affairs (Defra), 2005. *Making Space for Water: Taking forward a new Government strategy for flood and coastal erosion risk management in England.* London: Defra.

Doody, P., 2008, *Saltmarsh Conservation, Management and Restoration.* Dordrecht and London: Springer.

Environment Agency, 2007. *The Wash coastal trends analysis.* Bristol: Environment Agency.

Environment Agency, 2008. *Conserving and enhancing biodiversity: our legal obligations, policy drivers and targets*. Operational Instruction 635_08. Bristol: Environment Agency.

English Nature, 2002. *North Kent Coastal Habitat Management Plan.* Peterborough: English Nature.

Hill, M.I., 1987. Vegetation change in communities of *Spartina anglica* C.E. Hubbard. In *Saltmarshes of northwest England.* Contract Surveys No. 9. Peterborough: Nature Conservancy Council.

HR Wallingford, 1996. Saltmarsh change in England and Wales – its history and causes. R & D Technical Report W12. Bristol; Environment Agency.

Huckle, J.M., Marris, R.H. and Potter, J.A., 2004. Spatial and temporal changes in saltmarsh distribution in the Dee estuary, NW England, determined from aerial photographs. *Wetlands Ecology and Management*, 12(5), 483-498.

King, S.E. and Lester, J.N., 1995. The value of salt marsh as a sea defence. *Marine Pollution Bulletin*, 30(3), 180-189.

Möller, I., Spencer, T., French J.R., Leggett, D.J. and Dixon M., 1999. Wave transformation over salt marshes: a field and numerical modelling study from north Norfolk, England. *Estuarine, Coastal and Shelf Science*, 49(3), 411-426.

Möller, I., Spencer, T. and French, J.R., 2003. *Wave attenuation over saltmarshes: implications for flood defence management.* Saltmarsh Management Handbook series. Bristol: Environment Agency.

Otto, S., 1996. *Sea level rise and saltmarsh erosion with special reference to the Severn Estuary, SW Britain*. Publication No. 96/1. Reading: Kimberley Services.

Pye, K., 2000. Saltmarsh erosion in southeast England: mechanisms, causes and implications. In *British Saltmarshes* (ed. B.R. Sherwood, B.G. Gardiner and T. Harris), pp. 359-396. Cardigan: Forrest Press.

Pye, K. and French, P.W., 1993a. *Erosion and Accretion Processes on British Saltmarshes.* Volumes 1–5. Cambridge: Cambridge Environmental Research Consultants.

Pye, K. and French, P.W., 1993b. *Targets for coastal habitat re-creation.* English Nature Science. Peterborough: English Nature.

Shi, Z., 1993. Recent saltmarsh accretion and sea level fluctuations in the Dyfi Estuary, central Cardigan Bay, Wales, UK. *Geo-Marine Letters*, 13, 182-188.

UKBAP, 2006. *The UK Biodiversity Action Plan: Highlights from the 2005 reporting round.* London: Defra. Available from: http://www.ukbap.org.uk/library/Reporting2005/UKBAPReport05.pdf [Accessed March 2011].

List of abbreviations

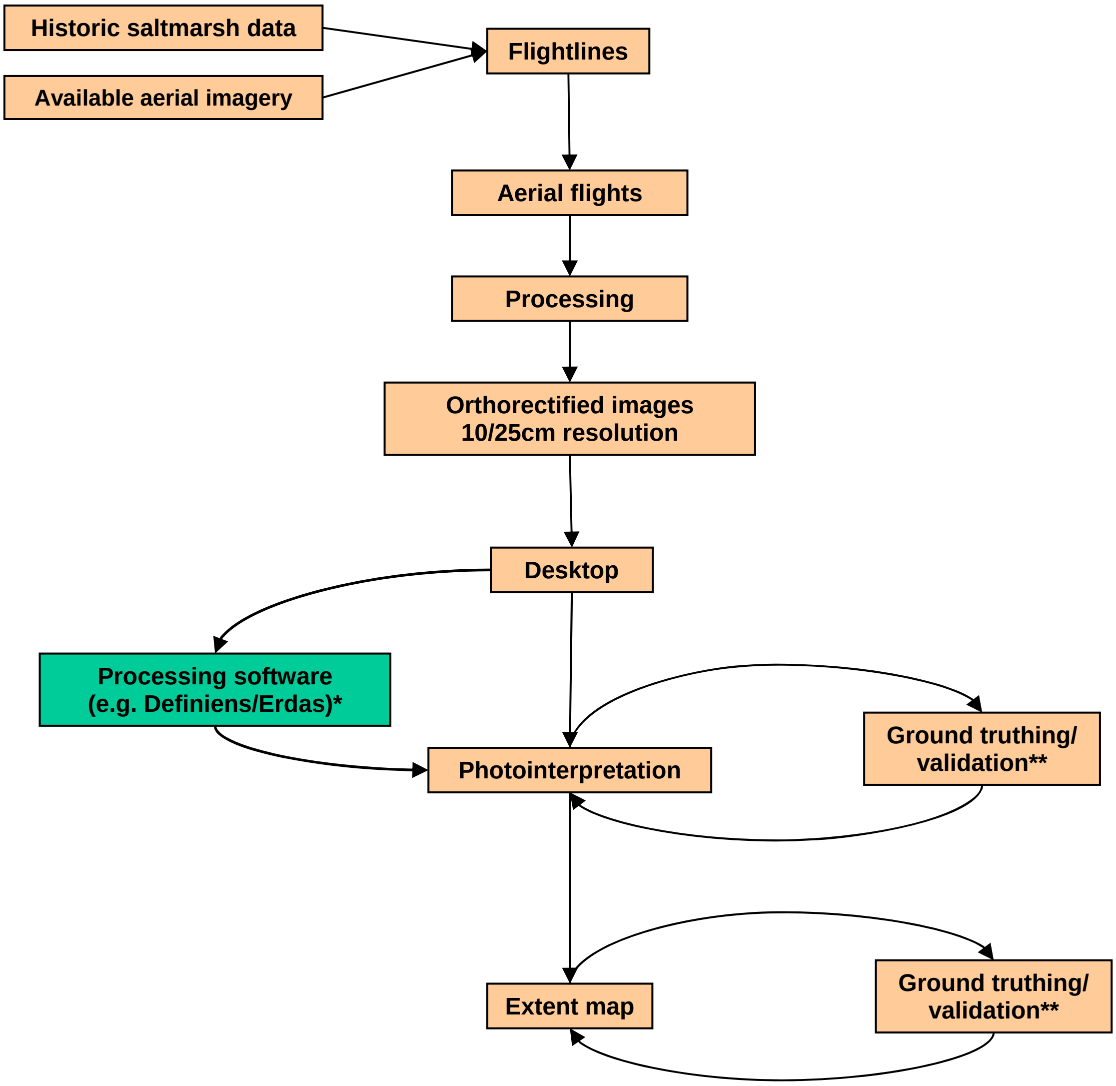
BAP	Biodiversity Action Plan
CCO	Channel Coast Observatory
CHaMP	Coastal Habitat Management Plan
CCW	Countryside Council for Wales
FCRM	Flood and Coastal Risk Management
HAT	Highest Astronomical Tide
IHS	Integrated Habitat System
JNCC	Joint Nature Conservation Committee
MMS	Marine Monitoring Service
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, FCERM and MMS data: Y = Yes, N = No. MMS data take priority, then FCERM, 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: Saltmarsh extent according to WFD water bodies for Environment Agency (2006–2009) survey

Region	Water body name	Area (ha)	Region	Water body name	Area (ha)
Anglian	ALDE & ORE	424.4	Anglian	Humber Middle	458.5
Anglian	Benacre Broad	20.1	Anglian	Humber Upper	280.3
Anglian	BLACKWATER & COLNE	1373.8	Anglian	NENE	12.0
Anglian	Blackwater Outer	281.0	Anglian	Norfolk North	335.0
Anglian	BLYTH (S)	88.1	Anglian	Orwell	59.0
Anglian	BURE & WAVENEY & YARE & LOTHING	13.3	Anglian	STIFFKEY/ GLAVEN	1246.6
Anglian	BURN & MOW & OVERY & NORTON	1147.3	Anglian	STOUR (ESSEX)	114.2
Anglian	CROUCH	772.8	Anglian	Suffolk	202.0
Anglian	DEBEN	261.5	Anglian	WASH INNER	3149.9
Anglian	Essex	476.9	Anglian	Wash Outer	1154.0
Anglian	Great Ouse	573.1	Anglian	WELLAND	508.6
Anglian	HAMFORD WATER	674.9	Anglian	WITHAM	93.3
Anglian	Harwich Approaches	65.2	Anglian	Yorkshire South / Lincolnshire	567.1
Anglian	Humber Lower	903.1			
North West	DUDDON	622.8	North East	ALN	40.9
North West	ESK (W)	163.7	North East	BLYTH (N)	11.7
North West	Kent	1050.2	North East	COQUET	21.3
North West	Leven	417.2	North East	Farne Islands to Newton Haven	30.0
North West	Lune	396.3	North East	Holy Island & Budle Bay	251.0
North West	MERSEY	895.8	North East	Tees	88.6
North West	Morcambe Bay & Duddon Sands	1157.2	North East	Tweed	26.1
North West	Ribble	2382.8	North East	Tyne and Wear	3.6
North West	Solway	2795.7	North East	WANSBECK	0.6
North West	Wyre	331.9	North East	WEAR	2.4

Region	Water body name	Area (ha)	Region	Water body name	Area (ha)
South West	AVON	14.4	South West	HELFORD	2.7
South West	AXE	13.7	South West	KINGSBRIDGE	0.3
South West	BRISTOL AVON	48.7	South West	LOOE	5.3
South West	Bristol Channel Outer South	57.4	South West	Lyme Bay East	2.5
South West	CAMEL	52.7	South West	OTTER	14.3
South West	Carrick Roads Inner	67.2	South West	PLYMOUTH SOUND	276.9
South West	CHRISTCHURCH HARBOUR	64.1	South West	POOLE HARBOUR	508.9
South West	Cornwall North	0.2	South West	River Parrett	234.4
South West	Dart	22.6	South West	Salcombe Harbour	0.0
South West	Dorset / Hampshire	5.3	South West	Severn Middle	379.3
South West	ERME	28.7	South West	Severn Upper	76.3
South West	Exe	70.6	South West	St Austell	0.1
South West	Fleet Lagoon	26.5	South West	Taw / Torridge	213.8
South West	FOWEY	13.6	South West	TEIGN	27.2
South West	GANNEL	15.0	South West	YEALM	3.2
South West	HAYLE	13.3			
Southern	ADUR	21.0	Southern	Old Mill Ponds	2.6
Southern	ARUN	10.3	Southern	OUSE	1.9
Southern	BEAULIEU RIVER	108.4	Southern	Pagham Harbour	103.9
Southern	Bembridge Harbour Lagoon	1.8	Southern	Portsmouth Harbour	44.0
Southern	Chichester Harbour	296.0	Southern	ROTHER	36.0
Southern	CHICHESTER HARBOUR EAST	25.7	Southern	Solent	106.1
Southern	CUCKMERE	10.6	Southern	SOUTHAMPTON WATER	265.1
Southern	Great Deep	7.9	Southern	Sowley Marsh	2.6
Southern	Kent North	0.8	Southern	STOUR (KENT)	118.4
Southern	Langstone Harbour	70.3	Southern	Sussex	1.1
Southern	Langstone Oysterbeds	1.1	Southern	SWALE	462.7
Southern	LYMINGTON	108.7	Southern	WALLINGTON	1.1
Southern	MEDINA	12.5	Southern	WESTERN YAR	44.4
Southern	MEDWAY	763.2	Southern	Whitstable Bay	3.3
Southern	NEWTOWN RIVER	75.4	Southern	WOOTTON CREEK	0.2

Region	Water body name	Area (ha)	Region	Water body name	Area (ha)
Thames	Thames Lower	406.8	Wales	GLASLYN	536.2
Thames	Thames Middle	132.7	Wales	Holyhead Strait	56.6
Wales	ALAW	31.4	Wales	LOUGHOR	954.1
Wales	Anglesey North	55.6	Wales	Loughor Outer	1049.5
Wales	ATRO	70.5	Wales	MAWDDACH	307.7
Wales	BRAINT	16.3	Wales	Menai Strait	70.9
Wales	Bristol Channel Inner North	3.5	Wales	Milford Haven Inner	256.6
Wales	Bristol Channel Outer North	8.3	Wales	Milford Haven Outer	41.5
Wales	CEFNI	101.3	Wales	NEATH	182.7
Wales	CLYWD	44.5	Wales	NYFER	8.0
Wales	Conwy	196.6	Wales	OGMORE	9.9
Wales	Cymyran Bay	10.1	Wales	Severn Lower	650.2
Wales	Dee	2571.5	Wales	Teifi	14.9
Wales	DYFI & LERI	512.6	Wales	TYWI & CYWYN & GWENDRAETH	1134.0
Wales	DYSYNNI	17.6	Wales	Usk	67.3
Wales	FFRAW	3.0	Wales	Wye	11.5
Wales	FORYD BAY	75.8			

Appendix 6: 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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