# A Historical Investigation of Solent Saltmarsh as Key Coastal Nursery Habitat Areas

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# A Historical Investigation of Solent Saltmarsh as Key Coastal Nursery Habitat Areas

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# Project details

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### Further information

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# Background

Natural England requested that a desk-based review of saltmarsh habitat was undertaken for the Solent, using a combination of data sources including aerial imagery data (collected by the Environment Agency), subsequent ground-truthed data (collected by the Environment Agency and Natural England) and other local sources. This review was to help inform an investigation into the historical changes of saltmarsh in the Solent – as a key coastal nursery habitat that is vital for the vulnerable and juvenile life-stages of many invertebrate and fish species.

# A Historical Investigation of Solent Saltmarsh as Key Coastal Nursery Habitat Areas

Saltmarsh at Keyhaven Marsh © Emma Eatough. Reproduced with permission.

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# Introduction

Saltmarsh provides a wide variety of social, economic and environmental benefits to coastal environments (e.g. coastal protection, recreation, carbon sequestration and fish reproduction). Increased scientific focus on these habitats has led to greater understanding of the benefits that saltmarsh has for specialist plant and animal species (Burd, 1989).

Confined to the coastline, saltmarsh gradually raises the shoreline profile, providing a naturally formed buffer zone that increases wave friction and reduces wave attenuation by 60-80% (Moller *et al*, 2014). Subsequently, altering wave hydrodynamics and protecting coastlines from storm waves, surges, and flooding. Additionally, reduced wave energy encourages sediment deposition; if the rate of deposition is equal to the rate of sea level rise, saltmarsh can maintain their position. Saltmarsh provides important natural protection and could therefore be included into shoreline management plans and flood and coastal erosion risk management strategies.

By sequestering atmospheric carbon saltmarsh has been identified as a carbon sink. Saltmarsh in England store between 0.64 to 2.19 t C $ha^{-1}$ $yr^{-1}$ (Cannell *et al*, 1999). Therefore, saltmarsh has been recognised as an important contributor to carbon storage (blue carbon), helping mitigate climate change (Beaumont *et al*., 2014). However, Mcleod *et al* (2011) estimates that, since the 1800s, there has been a global cumulative loss in saltmarsh of 25%. Continuing decline threatens remaining saltmarsh with estimates of a further 30-40% loss in the next 100 years (Pendleton *et al*, 2012). In recent years there has been a growing interest in altering the management of land and developing restoration strategies in the hope of enhancing or re-establishing historical carbon sinks.

The carbon capturing processes within saltmarsh provides an abundance of organic carbon that is utilised by a range of secondary consumers found within the saltmarsh (Garbutt *et al*, 2017). This provides food for crustaceans, molluscs, and juvenile fish supporting a network of important wading and migratory birds as well as larger predatory fish (Adam, 1993). Saltmarsh also provides nursery grounds for commercial fish species, including seabass (Long & Mason, 1983).

There has been increasing efforts and investment into monitoring, protecting and conserving these habitats. Large areas of the Solent are encompassed within a suite of local, national, and international designations (Figure 1). Solent designations are used to protect these valuable environments by the implementation of legislations and guidance which include: Sites of Special Scientific Interest (SSSI's) from the Wildlife and Countryside Access act 1981 and strengthened by the Countryside and Rights of way Act 2000 (CRoW Act), European sites, which include Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) under the EU Habitats Directive 92/43/EEC and the EU Birds Directive 79/409/EEC, respectively and Ramsar sites from the 1971 Ramsar Convention.

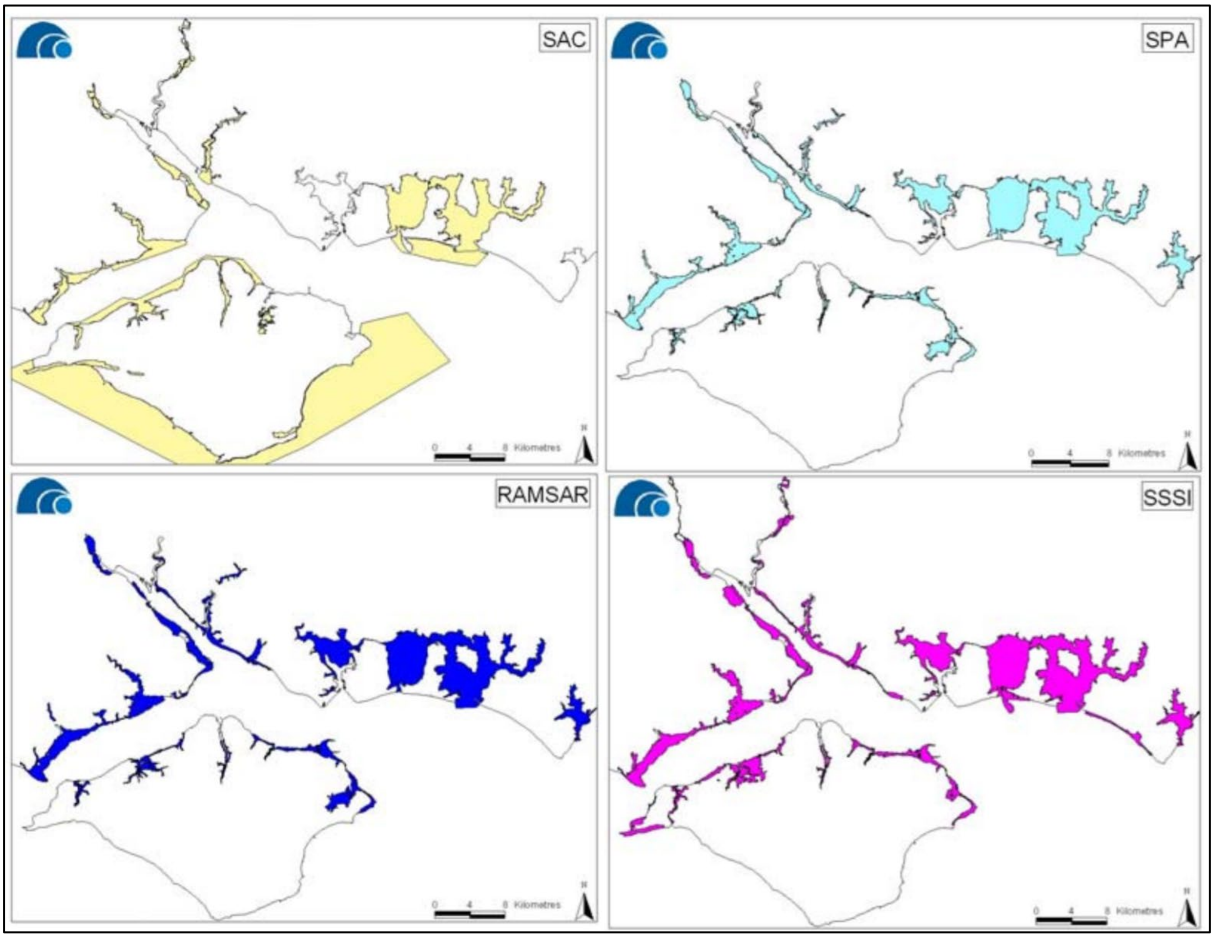


**Figure 1.** SAC, SPA, Ramsar and SSSI designations across the Solent (Cope *et al.*, 2008). Please note, Figure does not include Solent and Dorset Coast SPA because this site is designated for foraging terns only. Channel Coast Observatory, copyright New Forest District Council.
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Within the Solent, around 283km of the 387km coastline (From Hurst Spit to Selsey Bill) is protected from flooding or erosion, with most of these defences being fronted by designated sites. In the face of climate change and rising sea levels, much of the Solent's saltmarsh is subject to coastal squeeze, where sea defences inhibit the natural landward migration of intertidal habitats (Cope *et al.*, 2008). Normally, sea defences are maintained by the Environment Agency (EA) rather than by local authorities and private landowners. However, one third of the sea defences in the Solent are privately maintained which can make it more difficult to implement comprehensive and holistic approaches to defending the coastline. This is because stakeholder support is required to implement sea defence strategies and private ownership of the coastline may result in gaps in protection. For any defence schemes that result in habitat loss of European sites, suitable replacement habitat must be secured under the Habitats and Birds Directives. Managed re-alignment strategies are often the suitable option for offsetting coastal squeeze. However, the Solent is encompassed by developed residential areas, providing few opportunities for re-alignment. It is crucial that we maintain and develop remaining saltmarsh areas to prolong the lifetime and reduce the overall costs of coastal defence schemes.

## Saltmarsh Formation

Saltmarsh develops on intertidal zones within the range of normal spring tides, typically characterised by the transition of both salinity and elevation gradients (Burd, 1989). Although in

England transitional zones across both types of gradients are uncommon (92/43/EEC, 1992). A gradually inclining slope and some form of sheltering is necessary for saltmarsh due to the low wave energy required for net deposition of sediments. There is a wide range in ecological amplitude across different marsh zones (Gray and Benham, 1990). Saltmarsh is colonised by halophytic plants that colonise between the mean high-water neap up to the highest astronomical tides (HAT) (Cope *et al*., 2008; Burd, 1989), where seagrass species such as *Zostera* are able to stabilise sediments. Pioneer populations exist in conditions where a combination of wave action and saltwater inundation severely limit the growth and survivorship of plant species.

## Threats to Saltmarsh

*There are two main types of threats occurring to saltmarsh habitats, those that occur naturally and those that are anthropogenic.*

Natural types of erosion include the changing of river channels in large estuaries, causing local cycles of erosion and accretion. On a larger scale, the rate of sea level rise may be greater than the rate of sedimentation, meaning that saltmarsh can no longer sustain growth. Furthermore, the UK is adjusting to glacial isostatic tilt, whereby the south of England is gradually sinking and the north is raising (Milne *et al.,* 2006). Therefore, the natural isostatic adjustment of the UK from the last Ice-age is accelerating the rate of sea level rise in the south, adding further stress of inundation to saltmarsh in the South of England. Global warming conditions also contribute to an increase in the number of storms, which naturally erode and remove sediment from saltmarsh.

Anthropogenic threats on saltmarsh include the reclamation of saltmarsh for coastal developments, dredging activity, embanking and other engineering works. However, the use of saltmarsh for land claim has largely been reduced due to the unfavourable pressures on valuable saltmarsh species, including; red fescue (*Festuca rubra*), saltmarsh rush (*Juncus gerardii*), creeping bent-grass (*Agrostis stolonifera*) and hard-grass (*Parapholis strigosa*) (Adnitt *et al*, 2007). Light grazing of pasture animals is known to decrease the species diversity of saltmarsh; however, it has been found to benefit below ground biomass (Burd, 1989).

# Project Aims and Objectives

The aim of this project was to assess historical changes of Solent saltmarsh habitats in different areas covering the Hampshire coast, from Hurst Spit to Chichester Harbour, and the Isle of Wight.

The overall objective of the project was to source high quality data of saltmarsh habitat to a suitable resolution, enabling an assessment of the condition of saltmarsh habitat. This data would also enable an assessment of change in extent and distribution of saltmarsh habitat over time and provide data for the following attributes for saltmarsh habitat:

- Habitat extent and distribution;
- Physical structure: creeks and pans;
- Vegetation structure: zonation and sward structure;
- Vegetation composition: characteristic species and indicator of negative trend (*Spartina anglica*); and
- Other negative indicators, e.g., trampling, macroalgal blooms.

Paired with ground-truthed data from across the Solent, the report will detail the change over time in extent distribution and condition of saltmarsh habitat. An assessment of condition will be made against the attributes listed above to allow Natural England to undertake a full condition assessment of saltmarsh in the Solent. Maps will be produced detailing the extent of saltmarsh indicating where saltmarsh has been gained, lost or where there appears to be no change.

Specifically, the presence of 3 key types of Annex 1 saltmarsh coastal nursery habitats from within the Solent will be investigated. These key habitats include:

- *Salicornia* and other annuals colonising mud and sand;
- Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*); and
- *Spartina* swards (*Spartinion maritimae*).

This will allow a better understanding of the presence of this feature and inform proactive management of an incredibly important resource.

# Study area

The study area extends across 387km of South Coast, England shoreline, from Hurst Spit in Hampshire to Chichester Harbour in West Sussex (Figure 2). The study area also includes the 110km coastline of the Isle of wight. In total the study area covers 497km of coastline.

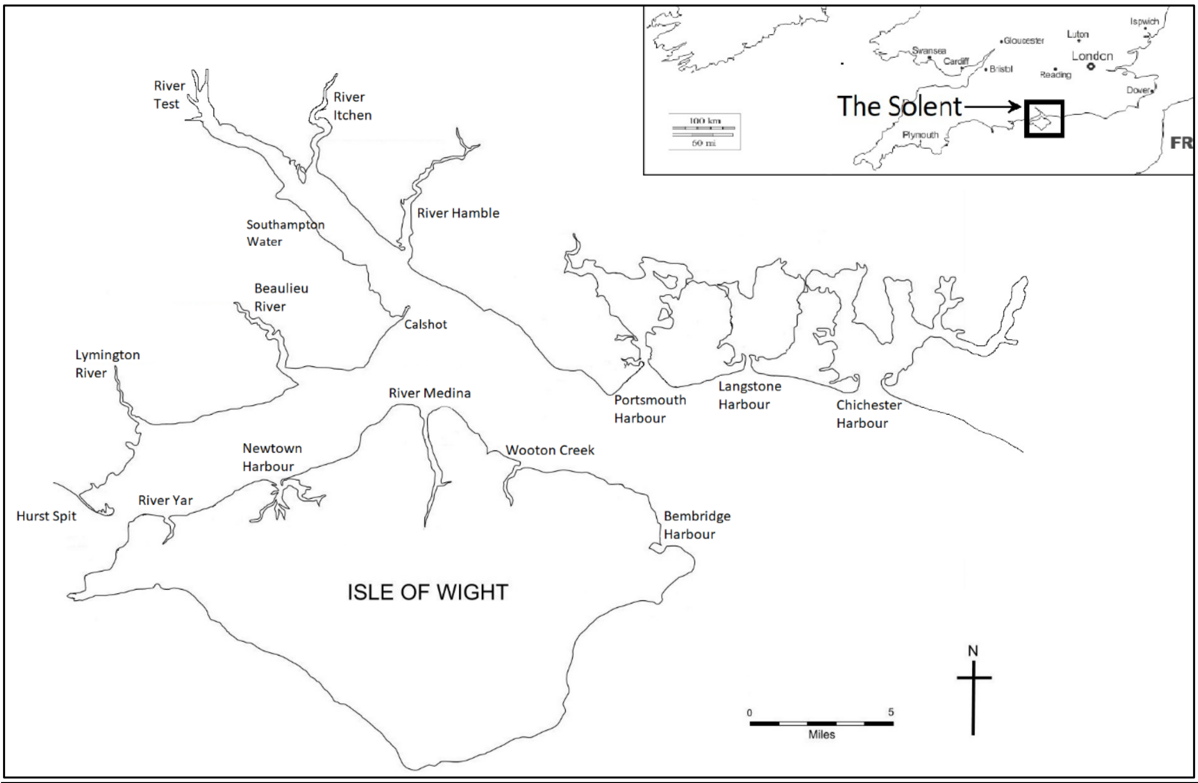


**Figure 2.** Map of the Solent and Isle of Wight.

The Solent has numerous freshwater inputs situated across all stretches of Hampshire and Isle of Wight. The freshwater inlets, particularly into Southampton Water, give rise to an important array of transition zones of brackish and freshwater communities. Burd (1989) stated that of the 66 counties, Hampshire had the 7th largest abundance of saltmarsh habitats in the United Kingdom, totalling 2660.54 hectares. At that time the south west and south of England were dominated by *Spartina* species. In 1989, it was stated that 63% of the total saltmarsh community in the south east and 46% in the south west of England were occupied by *Spartina* species (Burd,1989). Although, the south coast has seen a reduction in the area dominated by *Spartina* species by 11% (Gray *et al,* 1997).

# Methodology

The work undertaken for this project brought together work and data from various online access points, as described in greater detail below.

## Aerial photography data

Aerial photography data between 2008 and 2019 was obtained from the Channel Coastal Observatory (CCO) and Environment Agency Geomatics team.

Please note, aerial imagery assessments must be met with caution, especially older images that may need geo-rectification. Geo-rectification removes geometric distortions between sets of data points and in this example improves the accuracy of estimated saltmarsh area (Lippitt, 2020). Therefore, the use of saltmarsh extent data that is based on older historical images may display some distortion and thus estimates on saltmarsh extent may be slightly inaccurate. The seasonality and angle of photography also affects the precision of estimated saltmarsh extent. The CCO state that LiDAR data has an error tolerance of ± 5m tolerance for older aerials up to 1991 with increased accuracy to ± 0.2m for 2002 onwards.

## Saltmarsh extent Data

The Channel Coastal Observatory carried out extensive analysis as part of the Solent Dynamic Coast Project (SDCP) to quantify intertidal losses and identify potential areas for re-creation at a strategic level across the north Solent. The SDCP (Cope *et al.,* 2008) report looked at the following data to estimate loss of intertidal habitat (specifically saltmarsh) from as early as 1940 until 2002, using:

- Historical aerial photographic interpretation
- LIDAR (coastal elevation) data

The aim of this report was to build upon this historical aerial photography with two new datasets:

- 2016 and 2019 from the Environment Agency's Geomatics aerial surveys
- Natural England / Environment Agency ground-truthed data of 2016 Environment Agency Geomatics surveys

**Note*, saltmarsh extents for the Isle of Wight were only available for 2008, 2016 and 2019.

The additional datasets were added to extend the work of the SDCP to identify ongoing trends of recent years, determine whether saltmarsh was still being lost and to allow the comparison of the rates of loss. Historical saltmarsh extents, taken from the SDCP (Cope *et al.,* 2008) were used to compare against the most recent saltmarsh extents of 2008, 2016 and 2019. A summary of the available saltmarsh extent data is provided in Figure 3.

For the purpose of consistency and to allow comparison, study areas of saltmarsh were kept the same as they were in the SDCP report (Cope *et al.,* 2008). However, to gain an understanding of the areas outside of the SDCP study, a 'Broad Site Saltmarsh Extent Data Review' section has been added to those sites where saltmarsh extent data is available.

The number of saltmarsh polygons registered on ArcGIS were used to interpret the number of saltmarsh islands within each site, which was used as a proxy for saltmarsh fragmentation, growth, or loss. Paired with satellite images, an assessment of saltmarsh condition can be made. Saltmarsh species classification data was retrieved from the Environment Agency to identify the saltmarsh species zones as no ground truthing activities could take place due to covid restrictions. The zones reflect ecological communities within saltmarsh habitats required for Water Framework Directive assessment purposes. The zones within the dataset include:

- Pioneer
- *Spartina*
- Mid-low
- Upper Marsh
- Reedbeds

For the historical saltmarsh change summary in the results section, colours were assigned to characteristics of the saltmarsh: red an indicator of 'poor', amber of 'moderate', green 'good' and black where no data exists. For the saltmarsh change any suggested increase in saltmarsh was annotated green and suggested loss of saltmarsh was assigned red. This same annotation was applied for '% change' and '% change/ yr-1. For the '% of saltmarsh polygon change' colour coding was based on the evaluation of saltmarsh extent data. Red was appointed for any values where the number of polygons increased greatly, amber indicated a decrease in polygons based on an unknown reason for the change and finally green indicated a positive increase in polygons based on a growth of saltmarsh. Best case scenarios were colour coded with red indicating less than 25 years, amber between 25 and 100 years and green being greater than 100 years and/or growth in saltmarsh, black indicated no best-case scenario evaluation. Worst case scenarios were coded according to red saltmarsh reaching zero hectares within the next 30 years, amber is any case 30 to 80 years and green is any case greater than 80 years. The summary of the saltmarsh condition colour code includes an evaluation of all previous characteristics including; saltmarsh extent, the size of the saltmarsh area and subsequently the size in changes, the number of polygon change and the results from the worst and best case scenario for zero saltmarsh.

| | Year | 1940 | 1946 | 1954 | 1963 | 1965 | 1969 | 1971 | 1984 | 1991 | 2001 | 2002 | 2008 | 2016 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CHICHESTER HARBOUR | | ✓ | | | ✓ | | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ |
| East | LANGSTONE HARBOUR | | ✓ | | ✓ | | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | PORTSMOUTH HARBOUR | | ✓ | | | | | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ |
| | RIVER HAMBLE | | ✓ | | | | | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ |
| North | LOWER TEST VALLEY | | | | | | | | | | | | ✓ | ✓ | ✓ |
| | SOUTHAMPTON WATER | | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ |
| | CALSHOT | ✓ | | | | | | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ |
| | BEAULIEU RIVER | | | ✓ | | | | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ |
| | PITTS DEEP AND SOWLEY | | | | | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ |
| West | LYMINGTON RIVER ESTUARY | | ✓ | ✓ | | | | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ |
| | KEYHAVEN | | | | | | | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ |
| | HURST SPIT | | | | | | | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ |
| | YAR ESTUARY | | | | | | | | | | | | ✓ | ✓ | ✓ |
| | NEWTOWN HARBOUR | | | | | | | | | | | | ✓ | ✓ | ✓ |
| | THORNESS BAY | | | | | | | | | | | | ✓ | ✓ | ✓ |
| IoW | MEDINA ESTUARY | | | | | | | | | | | | ✓ | ✓ | ✓ |
| | KING'S QUAY SHORE | | | | | | | | | | | | ✓ | ✓ | ✓ |
| | RYDE SANDS AND WOOTTON CREEK | | | | | | | | | | | | ✓ | ✓ | ✓ |
| | BRADING MARSHES TO ST. HELEN'S LEDGES | | | | | | | | | | | | ✓ | ✓ | ✓ |

**Figure 3**. Summary of saltmarsh extent data available online. (Cope *et al.,* 2008; Environment Agency, 2020; Environment Agency, 2021)

## Storm Surge Analysis

Storm surge data were collected from the SCOPAC Storm Analysis (Wadey *et al.*, 2020) paper, to identify the frequency of storms between 1940 and 2020. The SCOPAC Storm Analysis (2020) data were adapted by using the total number of storm surges data for 1 in 1-year, 1 in 5-years, and 1 in 10-year events (calculated by fitting annual maximum values to a generalized extreme value (GEV) distribution) to show the number of storm surge events occurring within each decade. A one-way anova was used to test statistically significant differences between the means of the number of storm surges in each decade. A Tukey's pairwise comparison was used to determine if the relationship between any decades were statistically significant. Significance was determined when probability (p) was less than or equal to (≤) 0.05.

## Data analysis

Using parametric tests contained within MINITAB (MINITAB Inc ®, version 17.3.1), Regression analyses (Spearman Rank) were used to test for relationships of the rate of saltmarsh loss or gain over historical decadal timelines. Time was the independent variable. Using the regression equation, we determined the best estimate for predicting the year at which the saltmarsh will become functionally unstable, or functionally stable. We analysed the regression curves, and in some cases this provided two estimates of 'rates of saltmarsh loss', with (i) the entire historical data (1940s to present day) and (ii) using a worse-case or best-case scenario with recent decadal curves (1990 to present day). These data provided a best-case and a worse-case scenario of predicted saltmarsh loss/gain. Significance was determined when probability (p) was less than or equal to (≤) 0.05. All measurement data were log-transformed, with the suitability of the transformations scrutinised by examining residuals.

# Results

## Historically compared areas

### Chichester Harbour

Changes between 1946 and 2019 (Figures 4 and 5) revealed a 56% saltmarsh loss (Figure 5), which equates to 0.77% $yr^{-1}$ (Table 1). Changes between 1965 and 1971 indicated the greatest rate of loss, being 2.71 $yr^{-1}$. Though, changes between 2002 and 2008 highlighted an increase in saltmarsh area, 0.35% $yr^{-1}$. Since 1991 the rate of saltmarsh loss has declined to less than 1% $yr^{-1}$. There appeared to be no changes in saltmarsh extent occurring between 2016 and 2019 (Table 1).


**Figure. 4.** Saltmarsh extent at Chichester Harbour (Cope *et al.*, 2008).

(2008 Channel Coastal Observatory, © New Forest District Council, reproduced with permission)

**Table. 1.** Saltmarsh extent at Chichester Harbour.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 1946 | 717.3 | | | |
| 1965 | 659.1 | 1946-1965 | -8.11 | -0.43 |
| 1971 | 552.1 | 1965-1971 | -16.23 | -2.71 |
| 1991 | 346.4 | 1971-1991 | -37.26 | -1.86 |
| 2002 | 334.8 | 1991-2002 | -3.35 | -0.30 |
| 2008 | 341.8 | 2002-2008 | +2.09 | +0.35 |
| 2016 | 315.8 | 2008-2016 | -7.61 | -0.95 |
| 2019 | 315.8 | 2016-2019 | 0.00 | 0.00 |
| | | 1946-2019 | -55.97 | -0.77 |

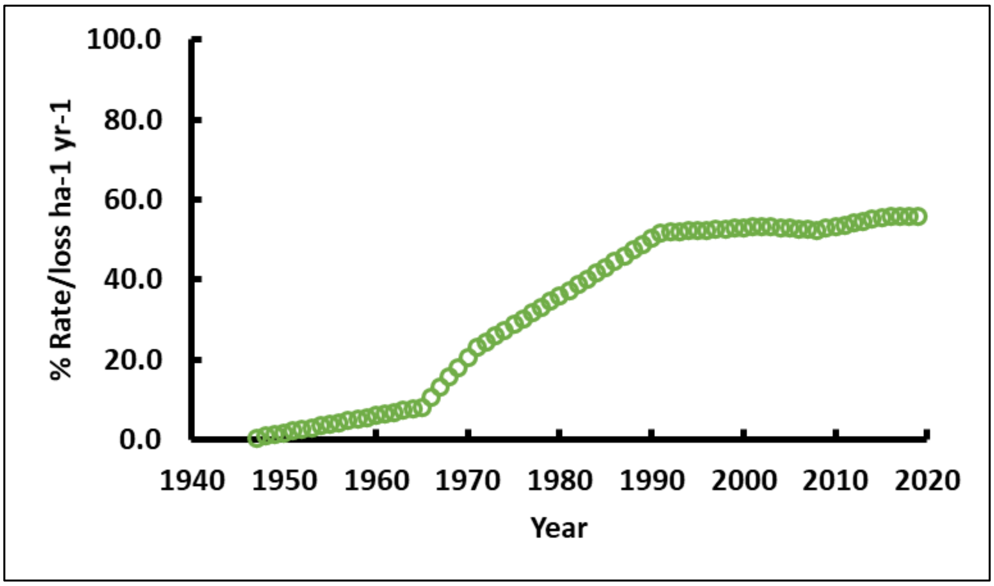


**Figure. 5.** The total percentage rate of saltmarsh loss for Chichester Harbour from 1946 to 2019.

The worst-case scenario in Chichester Harbour for loss of the saltmarsh extent is between 1946 and 2019 (Figure 6A). Using this data the total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 813.3, $p \leq 0.001$, $R^2$ = 91.9%), estimates that saltmarsh would reach zero hectares by 2054 (Table 2). The best-case scenario in Chichester Harbour is between 1990 and 2019 (Figure 6B). Using this data the rate of decline from 1990 to 2019 (Regression analysis (from 1984): $F_{1,34}$ = 107.8, $p \leq 0.001$, $R^2$ = 79.4%), estimates that saltmarsh would reach zero hectares by 2323 (Table 2). Work from the SDCP (Cope *et al.,* 2008) estimated that the best-case scenario would predict around 225 hectares of saltmarsh by 2110, whereas the worst-case scenario predicted zero saltmarsh by 2022. Therefore, the best-case for saltmarsh extent is still within the accuracy of the previous estimate. However, the worst-case scenario has been extended by 30 years.

**Table 2.** Best- and worst-case scenarios for expected zero saltmarsh at Chichester Harbour

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| **Worst-case** | **1946 - 2019** | **2054** |
| **Best-case** | **1990 - 2019** | **2323** |

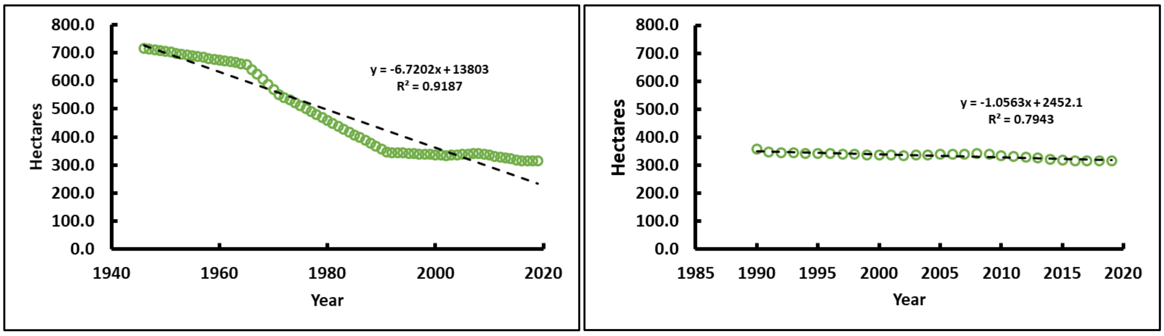


**Figure 6.** Regression analysis for saltmarsh loss in Chichester Harbour. **A)** the total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 813.3, $p \leq 0.001$, $R^2$ = 91.9%). Using these data, we estimate saltmarsh will reach zero hectares by 2054. **B)** the rate of decline from 1990 to 2019 (Regression analysis (from 1984): $F_{1,34}$ = 107.8, $p \leq 0.001$, $R^2$ = 79.4%). Using these data, we estimate saltmarsh will reach zero hectares by 2323.

### *Saltmarsh species zonation classification of 2016*

Chichester harbour is dominated by *Spartina* species which is present across much of the harbour (Figure 7). The next most dominant classification of species is those found within the mid-low and upper saltmarsh. Generally mid-low and upper saltmarsh species are found above the *Spartina* zone. However, isolated upper saltmarsh can be found surrounding the Great Deep channel in the north of Thorney Island. Reedbeds can be found in the north east of the harbour at Fishbourne and spotted lightly across the Fishbourne channel.

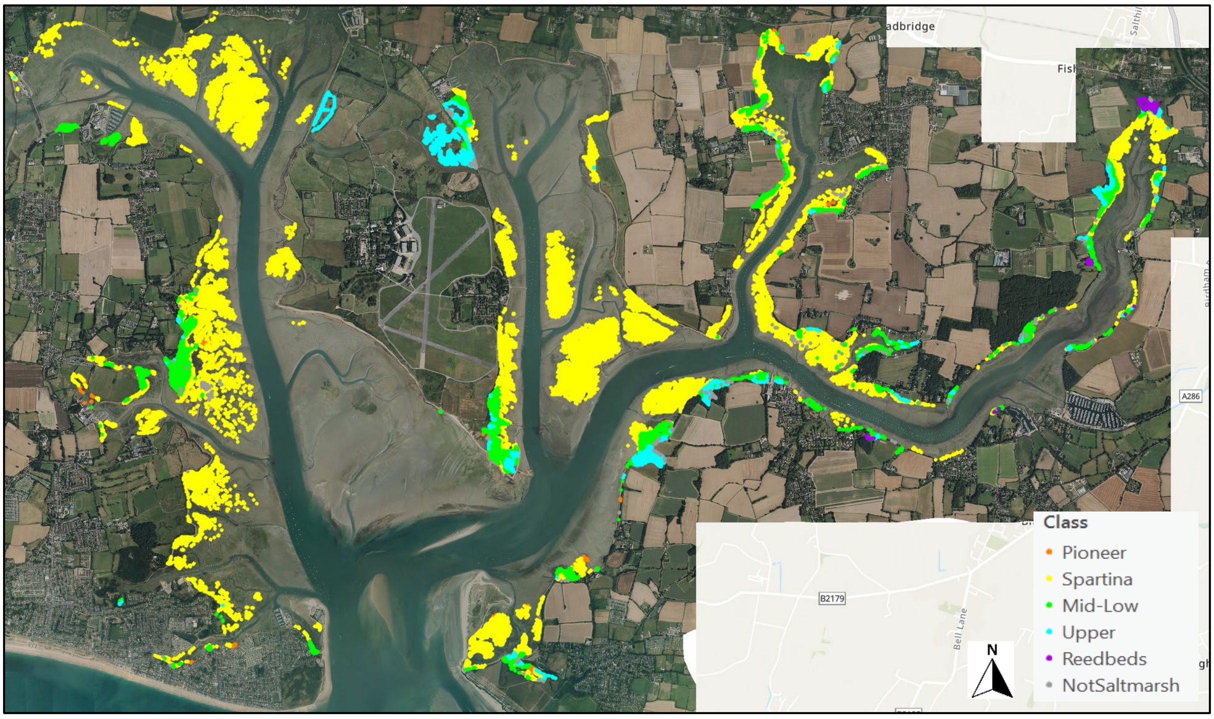


**Figure. 7.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Chichester Harbour in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figures 8a and 8b), highlight a loss of 7.61% of saltmarsh, which equates to 0.55% $yr^{-1}$ (Table 1). The dominant erosion was saltmarsh fragmentation and edge erosion, occurring all over Chichester harbour. The number of saltmarsh polygons decreased from 6338 to 5636 between 2008 and 2019, respectively. A large number of small islands on the lower lying saltmarsh have completely eroded. The west entrance of the harbour had a great loss of saltmarsh islands through edge erosion, particularly to south west Thorney Island, where *Spartina* swards islands nearly completely disappeared. The east of the harbour underwent extensive edge erosion, particularly in the upper reaches of the harbour at Fishbourne and East Chidham. Most losses of saltmarsh species occurred within the *Spartina* swards to the centre of Chichester and mid/low species along the eastern channels, this was due to the intrusion of new creeks and wider gullies, which removed large areas of saltmarsh. Gains were seen to the Reedbeds found in the north east of the harbour at Fishbourne.

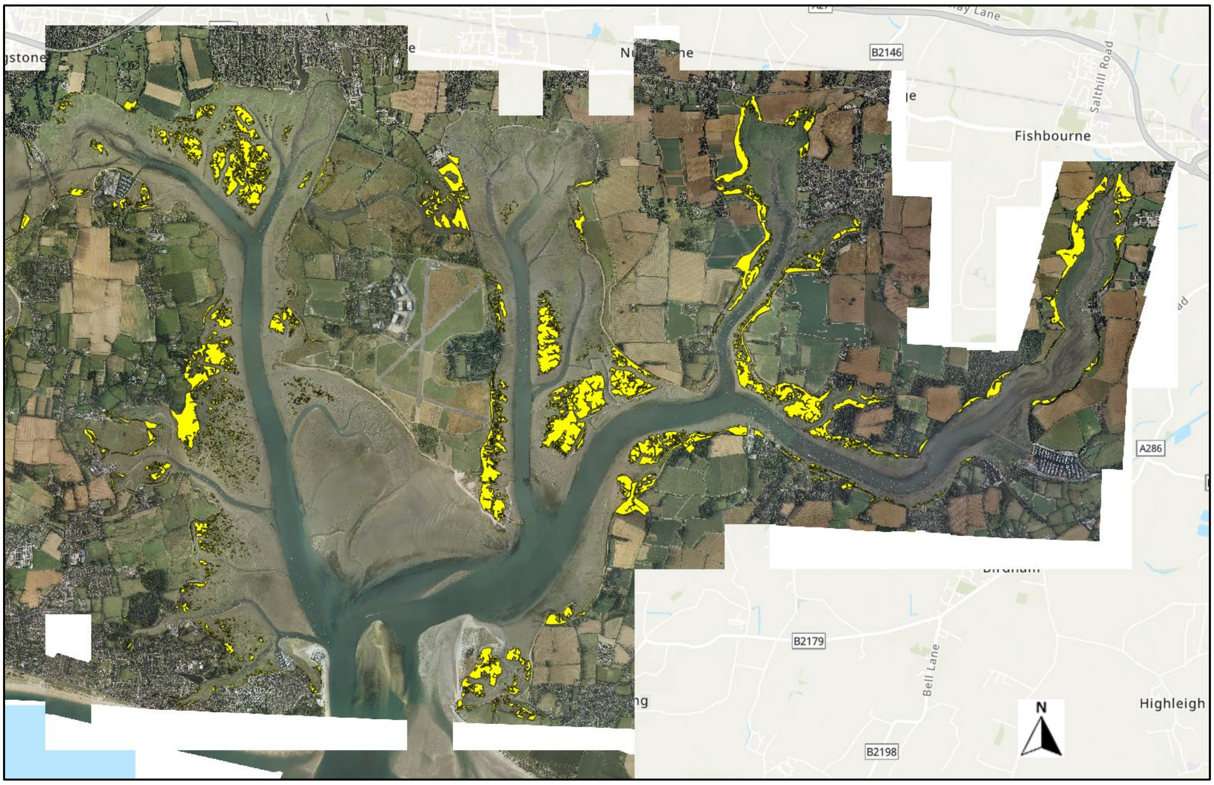


**Figure 8a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Chichester Harbour in 2008, retrieved from the Environment agency (EA, 2020).

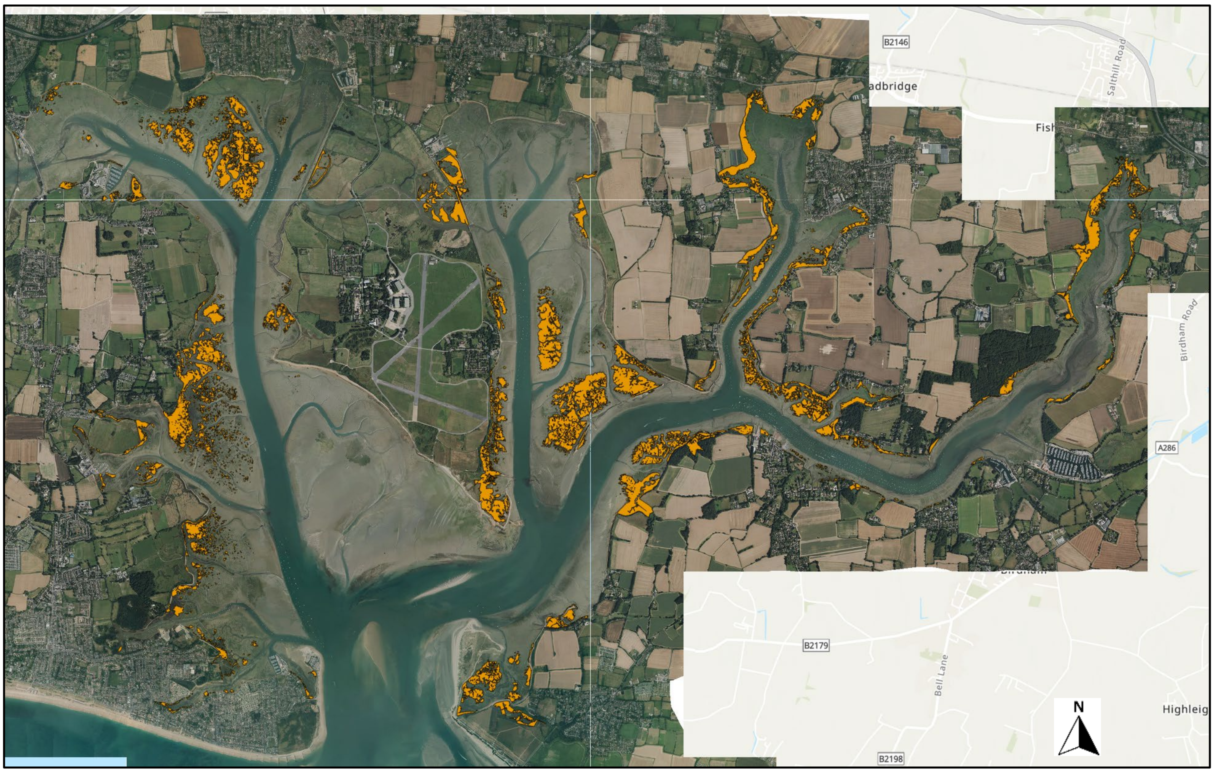


**Figure 8b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Chichester Harbour in 2016, retrieved from the Environment agency (EA, 2020).

## Langstone Harbour

Changes between 1946 and 2019 (Figures 9 and 13), indicates 85.66% saltmarsh loss, which equates to 1.17% $yr^{-1}$ (Table 3). Changes between 1963 and 1971 highlighted the greatest rate of loss, being 6.51% $yr^{-1}$ (Figure 10). Changes between 2002 and 2008 indicate a small increase in saltmarsh area, being 0.21% $yr^{-1}$. Since 1971 the rate of saltmarsh loss has declined to less than 1% $yr^{-1}$. There appeared to be no changes in saltmarsh extent between 2016 and 2019 (Table 3).

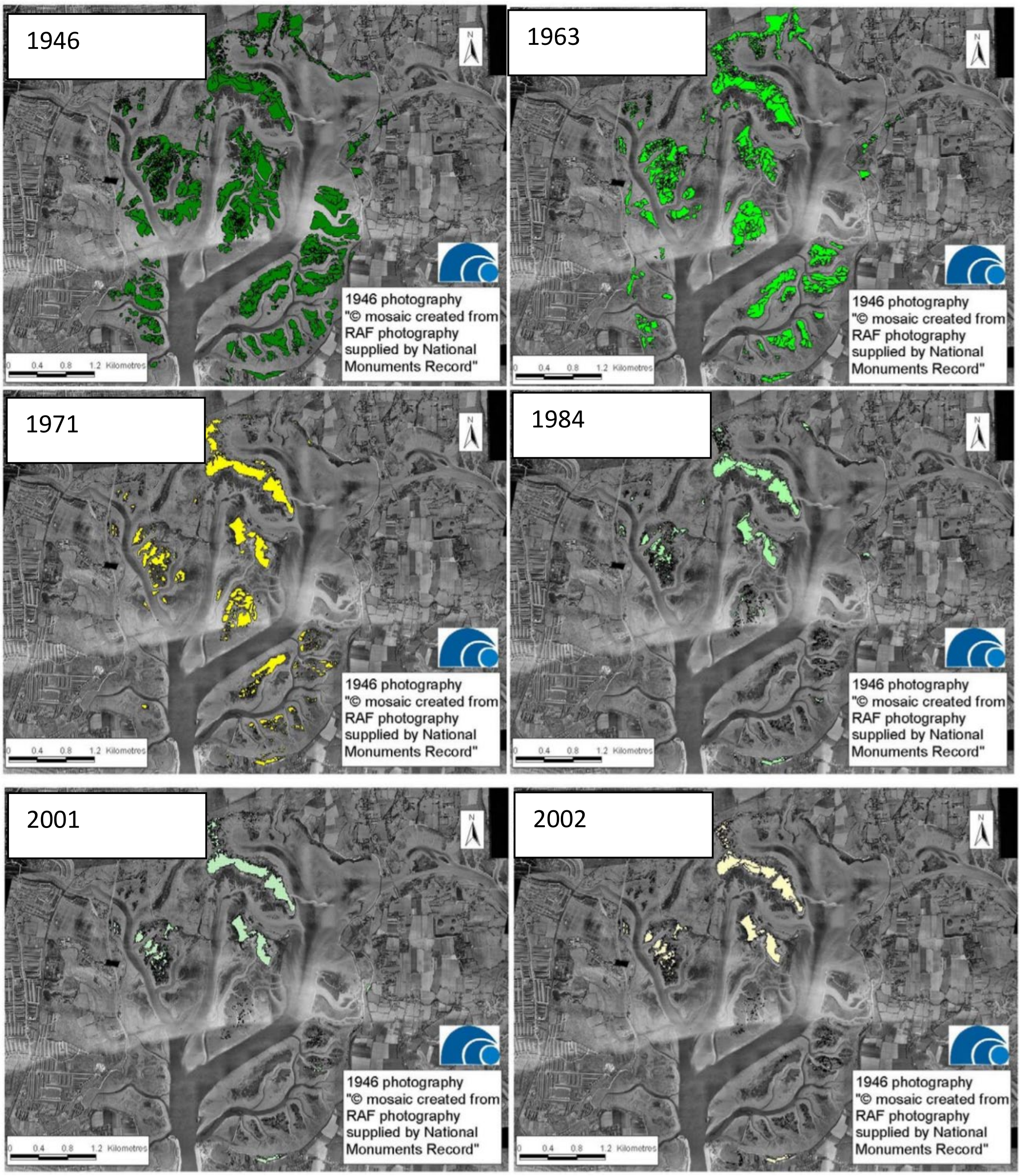


**Figure 9.** Saltmarsh extent at Langstone Harbour (Cope *et al.*, 2008).

(2008 Channel Coastal Observatory, © New Forest District Council, reproduced with permission)

**Table. 3.** Saltmarsh extent at Langstone Harbour.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| 1946 | 438 | | % Change | % Change $yr^{-1}$ |
| 1963 | 256.5 | 1946-1963 | -41.44 | -2.44 |
| 1971 | 123 | 1963-1971 | -52.05 | -6.51 |
| 1984 | 81.2 | 1971-1984 | -33.98 | -2.61 |
| 2001 | 75.3 | 1984-2001 | -7.27 | -0.43 |
| 2002 | 72.5 | 2001-2002 | -3.72 | -3.72 |
| 2008 | 73.4 | 2002-2008 | +1.24 | +0.21 |
| 2016 | 62.8 | 2008-2016 | -14.44 | -1.81 |
| 2019 | 62.8 | 2016-2019 | 0.00 | 0.00 |
| | | 1946-2019 | -85.66 | -1.17 |

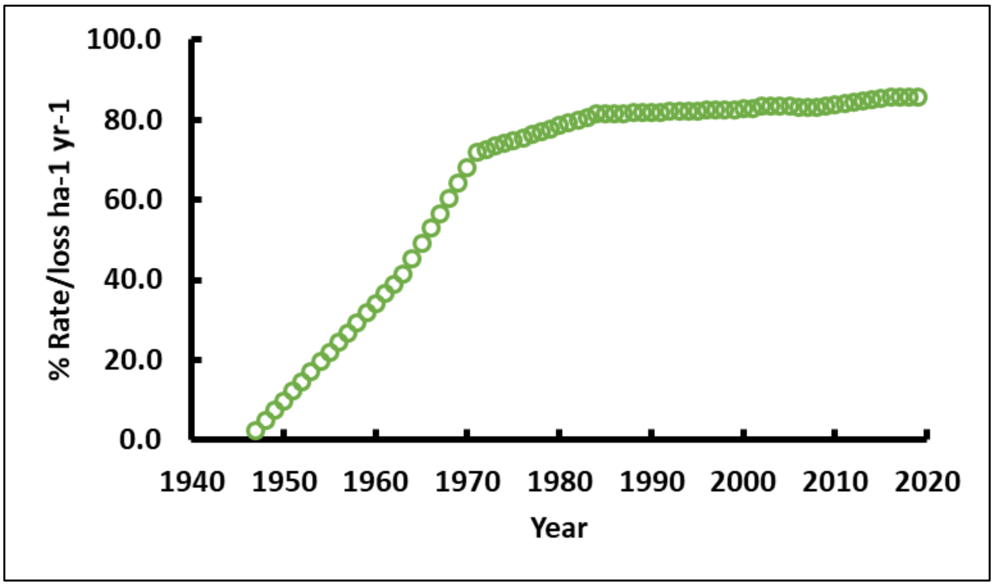


**Figure 10.** The total percentage rate of saltmarsh loss for Langstone Harbour from 1946 to 2019.

The worst-case scenario in Langstone Harbour for loss of the saltmarsh extent is between 1946 and 2019 (Figure 11A). Using this data the total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 225.7, $p \leq 0.001$, $R^2$ = 75.8%), estimates that saltmarsh would reach zero hectares by 2015 (Table 4). The best-case scenario in Langstone Harbour is between 1971 and 2019 (Figure 11B). Using this data the rate of decline from 1971 to 2019 (Regression analysis (from 1971): $F_{1,34}$ = 211.9, $p \leq 0.001$, $R^2$ = 81.8%), estimates that saltmarsh would reach zero hectares by March 2077 (Table 4). Work from the SDCP (Cope *et al.,* 2008) estimated that the best-case scenario would predict around 20 hectares of saltmarsh by 2105, whereas the worst-case scenario predicted zero saltmarsh by 2009. Therefore, the best-case for saltmarsh extent has been greatly reduced since the previous estimate. However, the worst-case scenario was extended by 6 years.

**Table 4.** Best- and worst-case scenarios for expected zero saltmarsh at Langstone Harbour.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| **Worst-case** | **1946 - 2019** | **2015** |
| **Best-case** | **1971 - 2019** | **March 2077** |

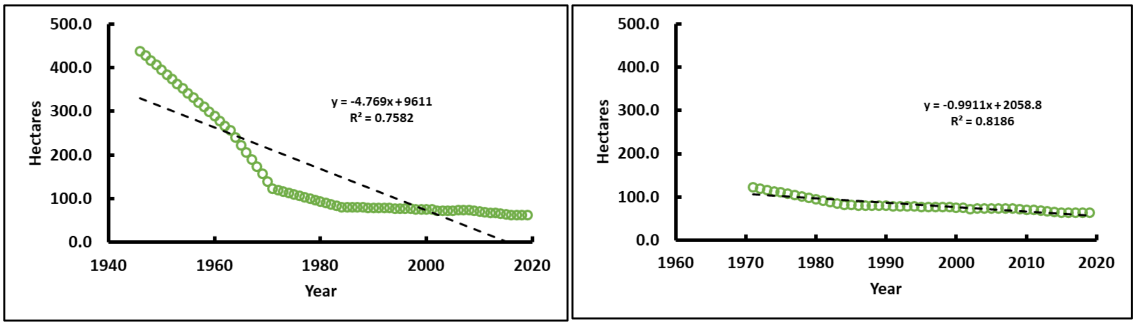


**Figure 11.** Regression analysis for saltmarsh loss in Langstone Harbour. **A)** the total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 225.7, $p \leq 0.001$, $R^2$ = 75.8%). Using these data, we estimate saltmarsh will reach zero hectares by 2015). **B)** the rate of decline from 1971 to 2019 (Regression analysis (from 1971): $F_{1,34}$ = 211.9, $p \leq 0.001$, $R^2$ = 81.8%). Using these data, we estimate saltmarsh will reach zero hectares by the April of 2077.

*Saltmarsh species zonation classification of 2016*

In the north-western area of Langstone Harbour saltmarshes are dominated by pioneer species (Figure 12). Whereas, the northern and central saltmarsh areas show signs of an ecologically developed saltmarsh through the presence of successive species, displaying a change in saltmarsh species from *Spartina* to mid-low and then upper saltmarsh species. Pioneer species can be found to the east of the harbour at Hayling Island Oyster Beds and in the south at The Kench, Hayling Island.

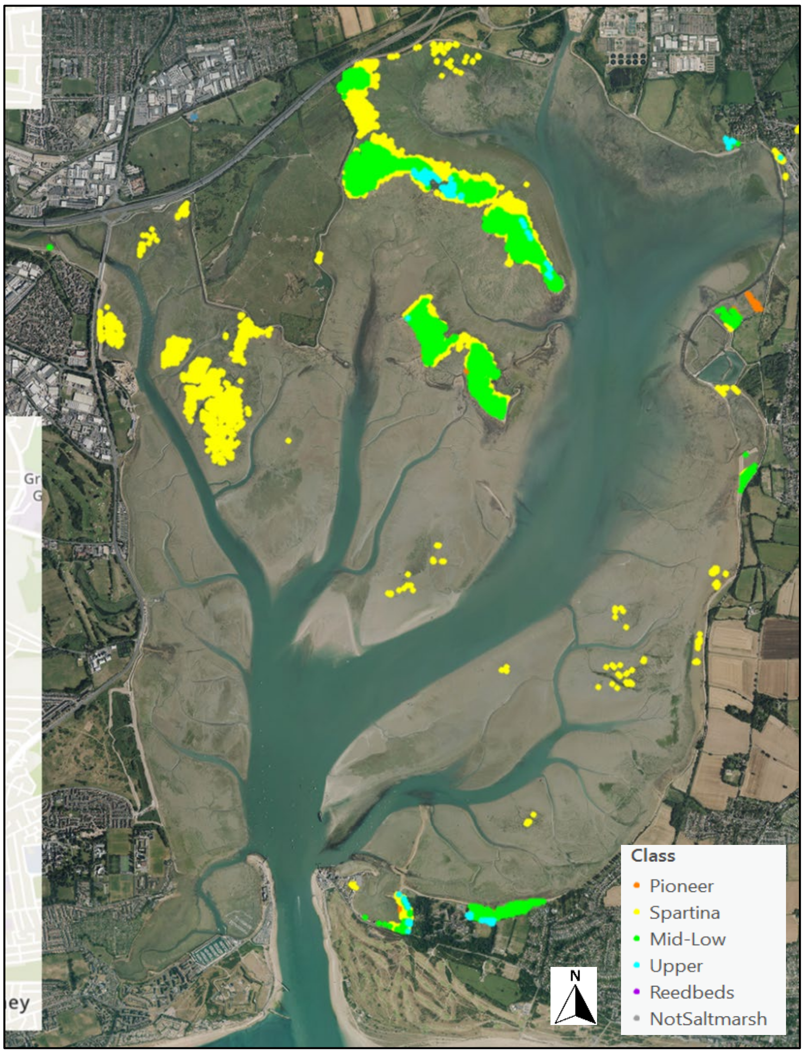


**Figure 12.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Langstone Harbour in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019, highlight a loss of 14.44% of saltmarsh, which equates to 1.54% $yr^{-1}$ (Table 3). The number of saltmarsh polygons decreased from 1406 to 699 between 2008 and 2019, respectively. The dominant erosion was edge erosion, this is visible from the reduction of saltmarsh islands in the centre of the harbour (Figures 13a and 13b). Extensive erosion occurred to the main northernly saltmarsh island, particularly to the centre (mainly upper marsh) and the north-eastern edge of the saltmarsh island (mid-low saltmarsh)., extensive edge erosion and fragmentation was identified in the saltmarsh to the south of Farlington Marshes. Finally, saltmarsh islands to the centre and south east of the harbour also suggested extensive losses.

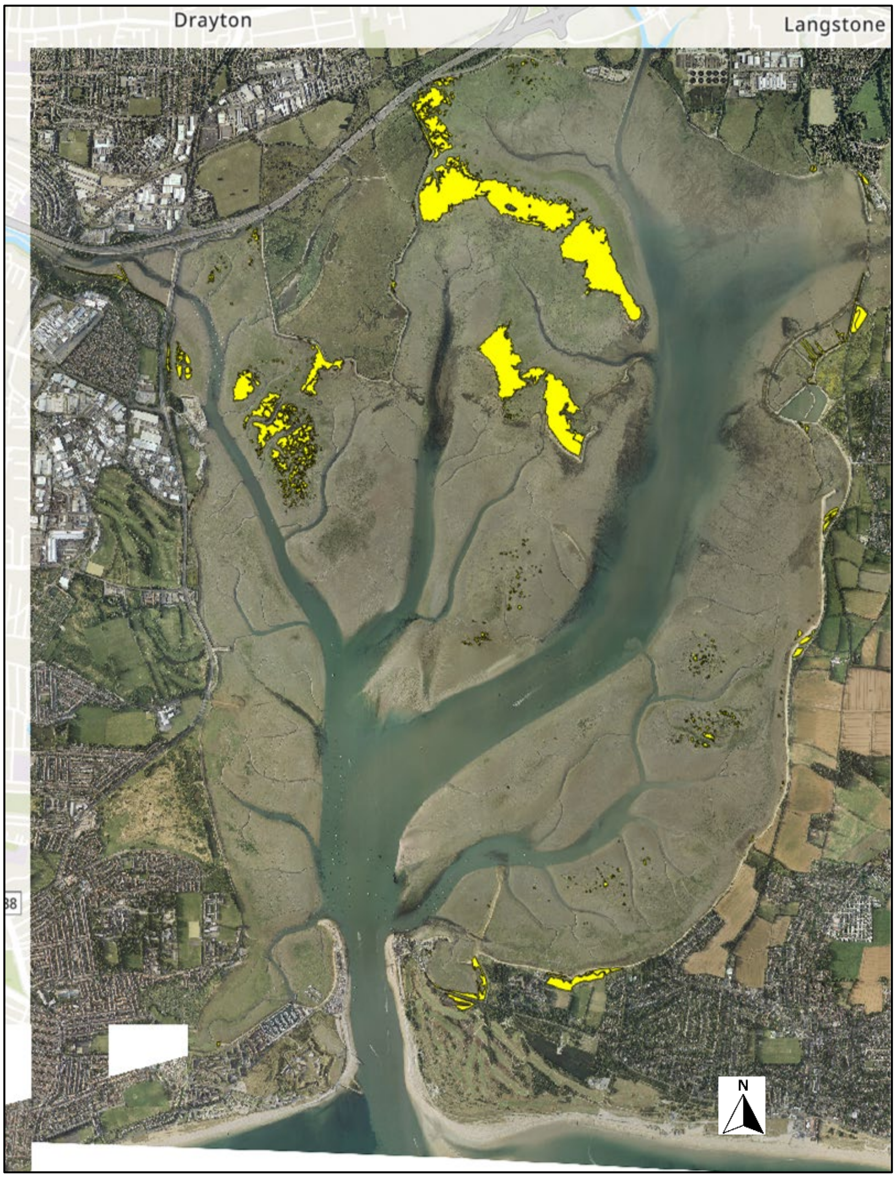


**Figure 13a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Langstone Harbour in 2008, retrieved from the Environment agency (EA, 2020).


**Figure 13b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Langstone Harbour in 2016, retrieved from the Environment agency (EA, 2020).

## Portsmouth Harbour

Changes between 1946 and 2019 (Figures 14 and 16), demonstrated an 82.18% saltmarsh loss (Figure 15), which equates to 1.13% $yr^{-1}$ (Table 5). Changes between 1971 and 1984 had the greatest rate of loss, being 5.49% $yr^{-1}$. From 2008 onwards the extent of saltmarsh in Portsmouth Harbour appears to have increased (Figure 16a). Changes between 2016 and 2019 had the greatest rate in saltmarsh gain (Figure 16b and 16c), being 1.46% $yr^{-1}$ (Table 5).

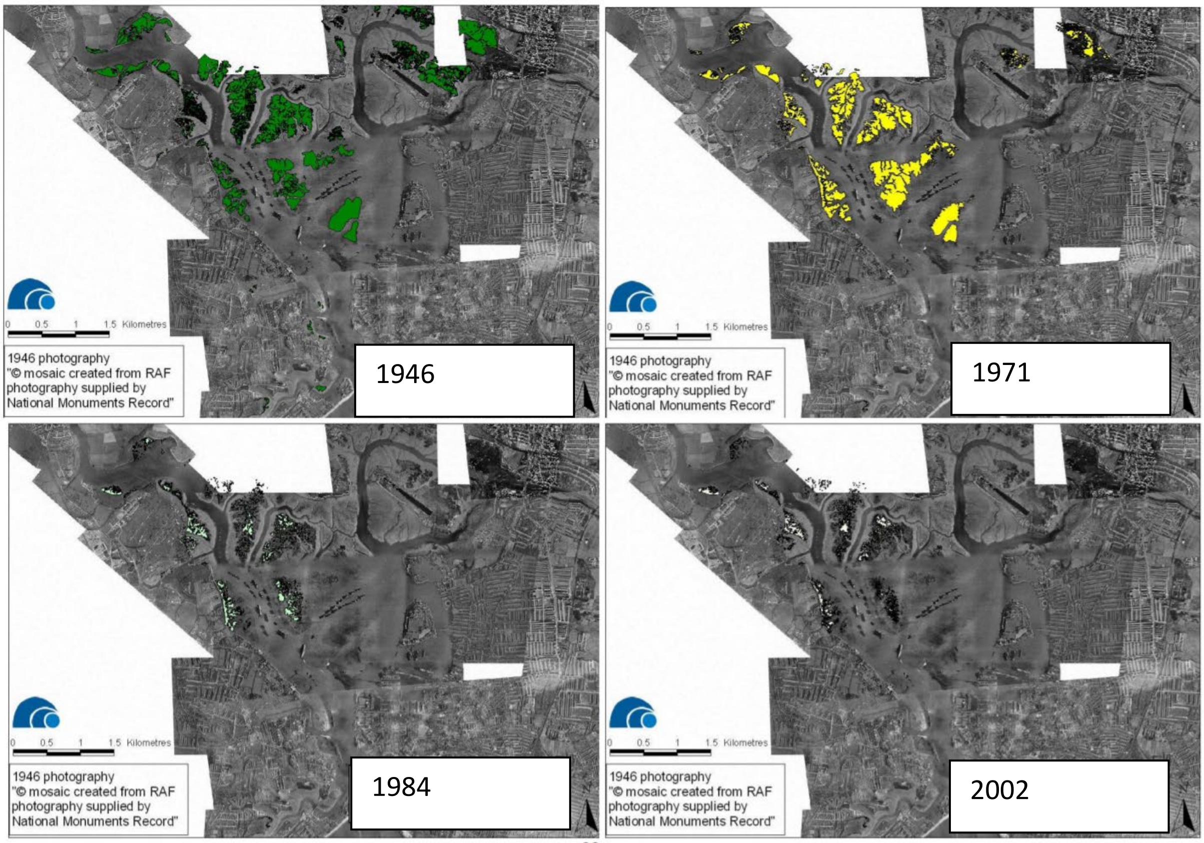


**Figure 14.** Saltmarsh extent at Portsmouth Harbour (Cope *et al.*, 2008).
(2008 Channel Coastal Observatory, © New Forest District Council, reproduced with permission)

**Table 5.** Saltmarsh extent at Portsmouth Harbour.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 1946 | 269.4 | | | |
| 1971 | 183 | 1946-1971 | -32.07 | -1.28 |
| 1984 | 52.3 | 1971-1984 | -71.42 | -5.49 |
| 2002 | 43.4 | 1984-2002 | -17.02 | -0.95 |
| 2008 | 42.6 | 2002-2008 | -1.84 | -0.31 |
| 2016 | 45.9 | 2008-2016 | +7.75 | +0.97 |
| 2019 | 48 | 2016-2019 | -4.38 | +1.46 |
| | | 1946-2019 | -82.18 | -1.13 |

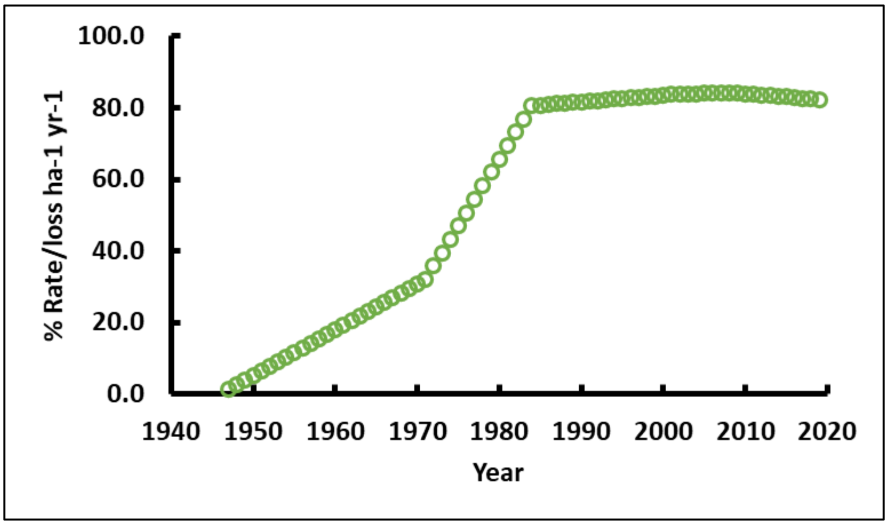


**Figure 15.** The total percentage rate of saltmarsh loss for Portsmouth Harbour from 1946 to 2019.

The worst-case scenario in Portsmouth Harbour for loss of the saltmarsh extent is between 1946 and 2019 (Figure 17A). Using this data the total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 484.1, $p \leq 0.001$, $R^2$ = 87.1%), estimates that saltmarsh would reach zero hectares by 2017 (Table 6). The best-case scenario in Portsmouth Harbour is between 1984 and 2019 (Figure 11B). Using this data the rate of decline from 1971 to 2019 (Regression analysis (from 1971): $F_{1,34}$ = 27.2, $p \leq 0.001$, $R^2$ = 44.4%), estimates that saltmarsh would reach zero hectares by 2255 (Table 6). Work from the SDCP (Cope et al., 2008) estimated that the best-case scenario would predict zero hectares of saltmarsh by 2095, whereas the worst-case scenario predicted zero saltmarsh by 2010. Therefore, the best-case for saltmarsh extent has been extended by 160 years since the previous estimate. Furthermore, the worst-case scenario was extended by 7 years.

**Table 6.** Best- and worst-case scenarios for expected zero saltmarsh at Portsmouth Harbour.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| Worst-case | 1946 - 2019 | 2017 |
| Best-case | 1984 - 2019 | 2255 |

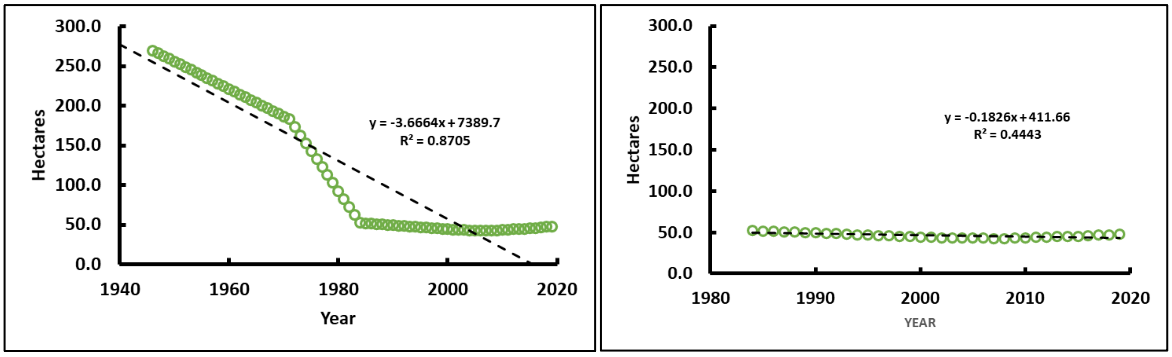


**Figure 17.** Regression analysis for saltmarsh loss in Portsmouth Harbour. **A)** the total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 484.1, $p \leq 0.001$, $R^2$ = 87.1%). Using these data, we estimate saltmarsh will reach zero hectares by 2017. **B)** the rate of decline from 1984 to 2019 (Regression analysis (from 1984): $F_{1,34}$ = 27.2, $p \leq 0.001$, $R^2$ = 44.4%). Using these data, we estimate saltmarsh will reach zero hectares by the 2255.

*Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figures 16a and 16b), indicate a gain of 12.13% of saltmarsh, which equates to 1.15% $yr^{-1}$ . Overall, the gain in saltmarsh occurred due to an increase in the size of the smaller islands on the upper areas of the marshes. Along the west coast of the harbour, above Quay Lane Boatyard, there was a large increase in the smaller saltmarsh islands. Similarly, there was a large increase in the size of the saltmarsh islands on Pewitt Island and South of Bombketch lake. Although, some erosion occurred to the southern edge of the saltmarsh islands below Bombketch lake. Between 2008 and 2019, the number of saltmarsh polygons increased from 2292 to 3637, suggesting colonisation, which could be related to the increase in saltmarsh on Pewitt Island and South of Bombketch. However, the increase in the number of polygons may also be indicative of saltmarsh fragmentation within Portsmouth Harbour. This was seen particularly to the saltmarsh in the centre of the harbour.


**Figure 16a.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Portsmouth Harbour in 2008, retrieved from the Environment agency (EA, 2020).

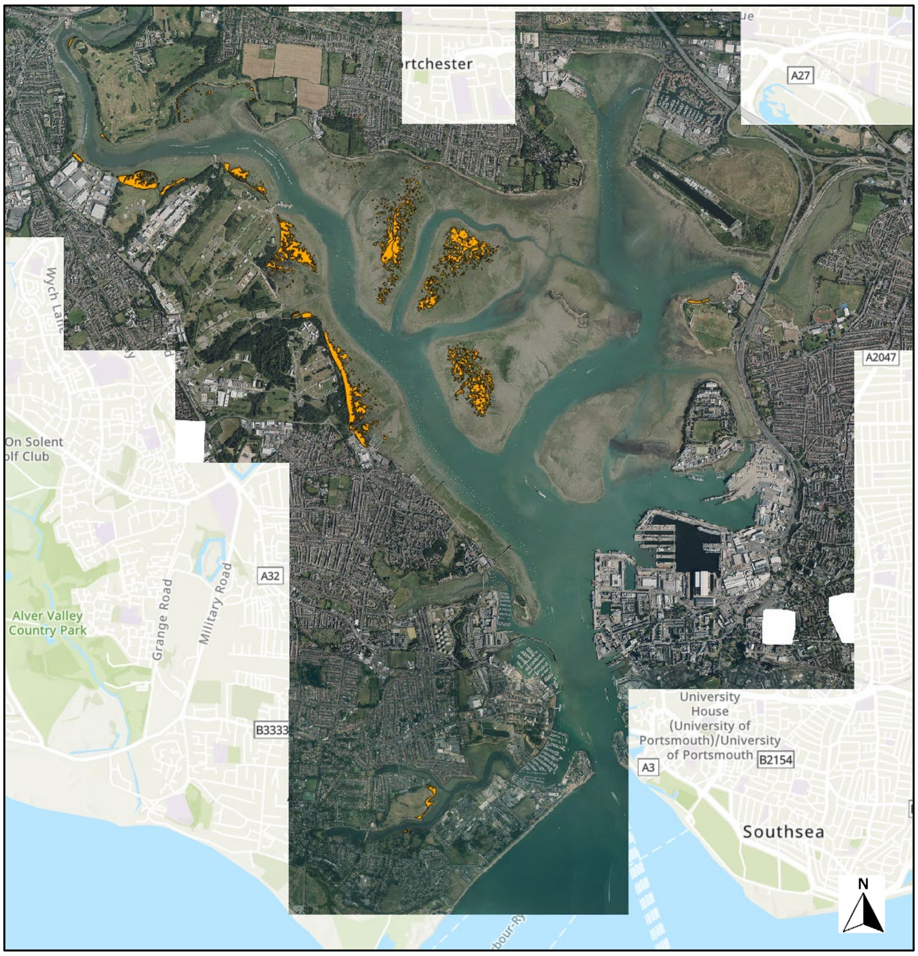


**Figure 16b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Portsmouth Harbour in 2016, retrieved from the Environment agency (EA, 2020).

## River Hamble

Changes between 1946 and 2019 (Figures 18 and 22), highlighted a 36.8% saltmarsh loss (Figure 19), which equates to 0.51% $yr^{-1}$ (Table 7). Changes between 2016 and 2019 (Figures 22a, 22b and 22c) had the greatest rate of loss, being 1.80% $yr^{-1}$. Previously, the greatest rate of loss occurred between 1971 and 1984, being a rate of 1.66% $yr^{-1}$. Changes between 2000 and 2008, indicated an 18.31% saltmarsh growth, being 2.29% $yr^{-1}$. However, following 2008 the rate of saltmarsh loss continued to decline at less than 1% $yr^{-1}$.

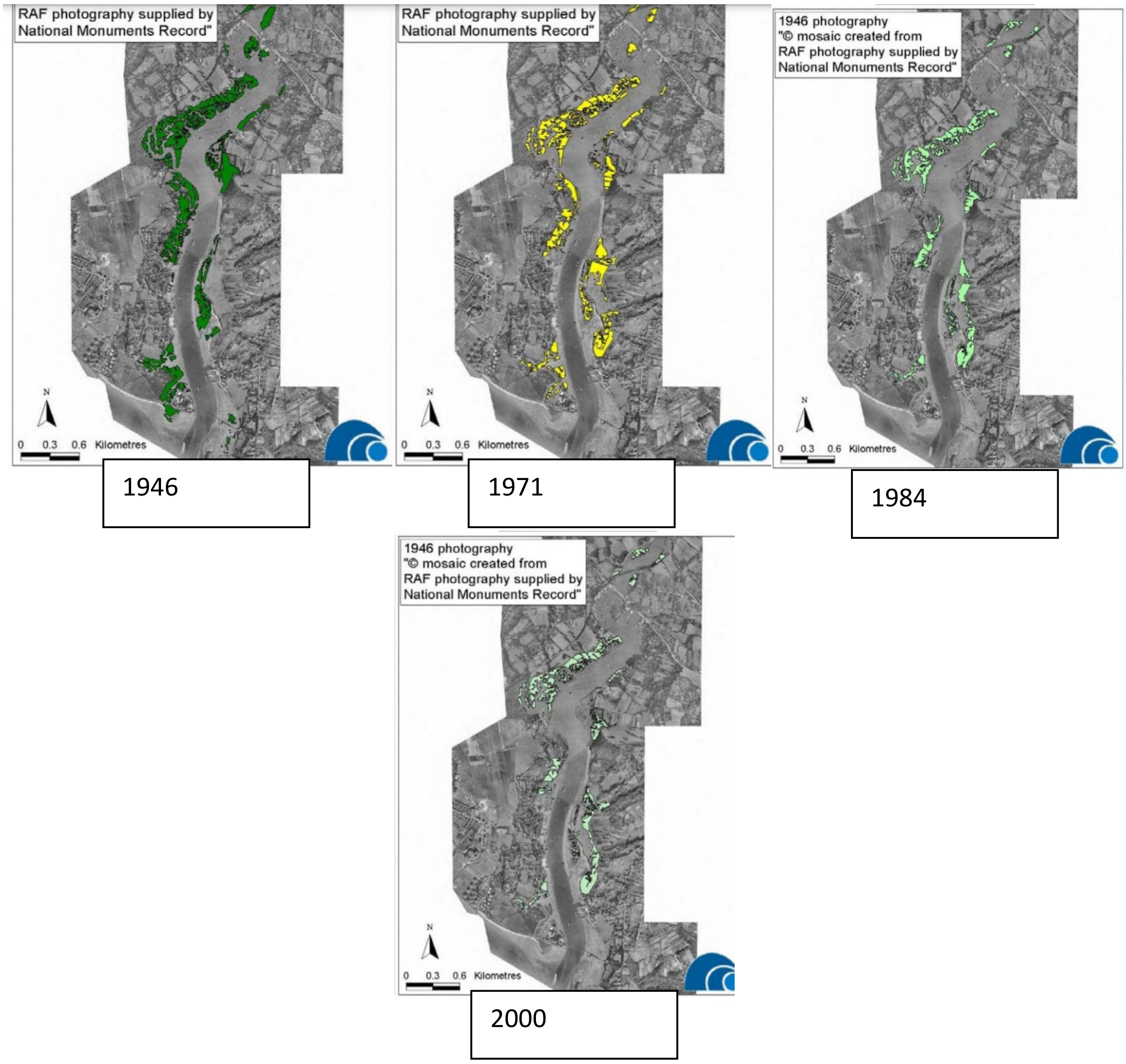


**Figure 18.** Saltmarsh extent at River Hamble (Cope *et al*., 2008).
(2008 Channel Coastal Observatory, © New Forest District Council, reproduced with permission)

**Table 7.** Saltmarsh extent at River Hamble.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 1946 | 61 | | | |
| 1971 | 49.1 | 1946-1971 | -19.51 | -0.78 |
| 1984 | 38.5 | 1971-1984 | -21.59 | -1.66 |
| 2000 | 35.7 | 1984-2000 | -7.27 | -0.45 |
| 2008 | 43.7 | 2000-2008 | +18.31 | +2.29 |
| 2016 | 40.7 | 2008-2016 | -6.86 | -0.86 |
| 2019 | 38.5 | 2016-2019 | -5.41 | -1.80 |
| | | 1946-2019 | -36.80 | -0.51 |

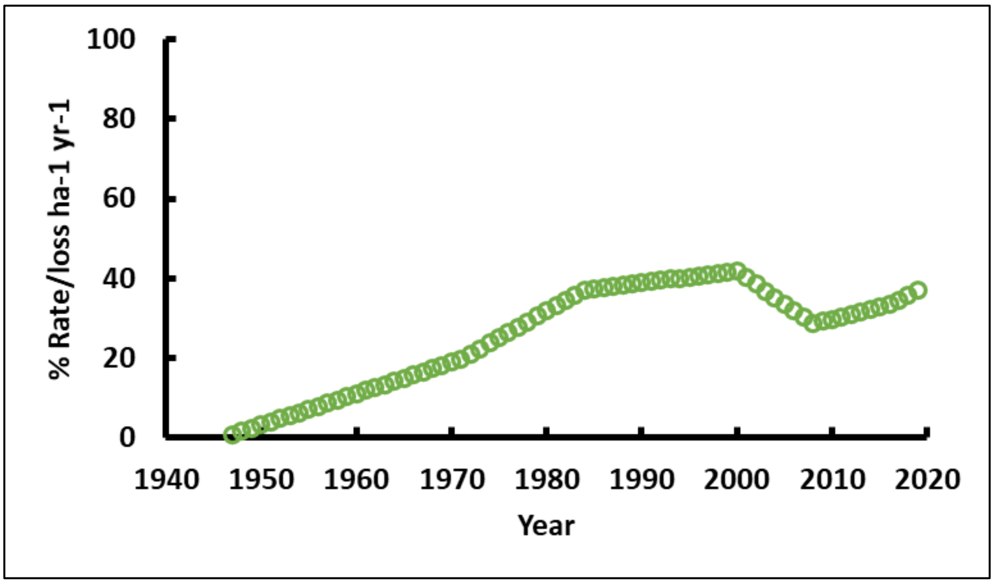


**Figure 19.** The total percentage rate of saltmarsh loss for River Hamble from 1946 to 2019.

The worst-case scenario in River Hamble for loss of the saltmarsh extent is between 1946 and 2019 (Figure 20). Using this data the total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 185.3, $p \leq 0.001$, $R^2$ = 72%), estimates that saltmarsh would reach zero hectares by 2130 (Table 8). No best-case scenario has been produced for this report as the data showed no appropriate change in rate. Work from the SDCP (Cope et al., 2008) estimated that the best-case scenario would predict 17 hectares of saltmarsh by 2110, whereas the worst-case scenario predicted zero saltmarsh by 2075. Therefore, the updated estimate for zero saltmarsh is later than the previous worse-case scenario but does not extend as far as the previous best-case estimate.

**Table 8.** Worst-case scenario for expected zero saltmarsh at River Hamble.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| Worst-case | 1946 - 2019 | 2130 |

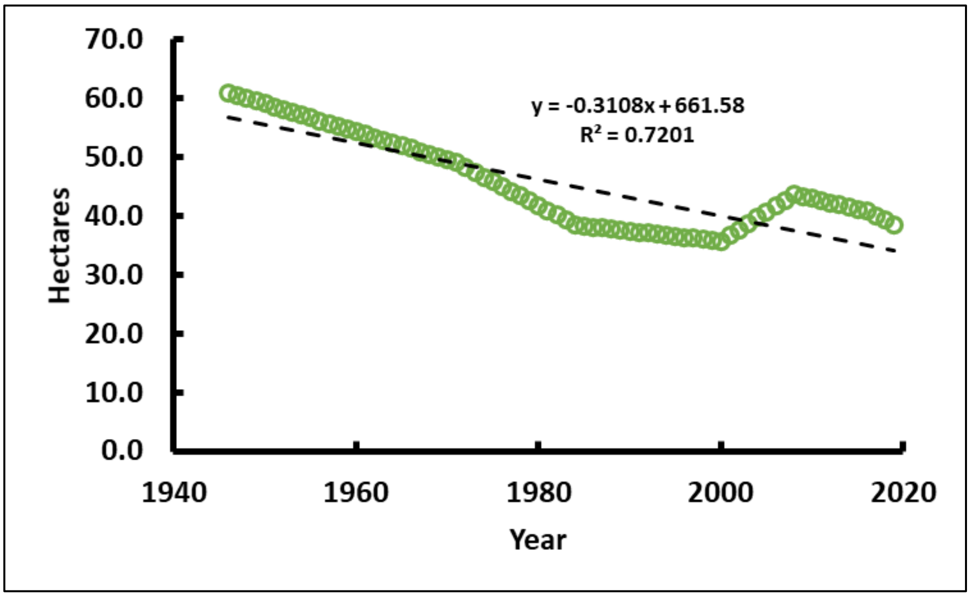


**Figure. 20.** Regression analysis for saltmarsh loss in River Hamble. The total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 185.3, $p \leq 0.001$, $R^2$ = 72%). Using these data, we estimate saltmarsh will reach zero hectares by 2130.`

*Saltmarsh species zonation classification of 2016*

The River Hamble is dominated by Reedbeds and mid-low saltmarsh species (Figure 21). The largest cluster of mid-low species within the Hamble is found at the Salterns Boatyard, which has a band of reedbeds on the inner reaches of the marsh. A dense patch of reedbeds can be found on the west shore of central Hamble area. The northern reaches of the River Hamble are dominated by upper saltmarsh species and reedbeds. Mid-low saltmarsh species decrease in presence with distance from the river mouth.

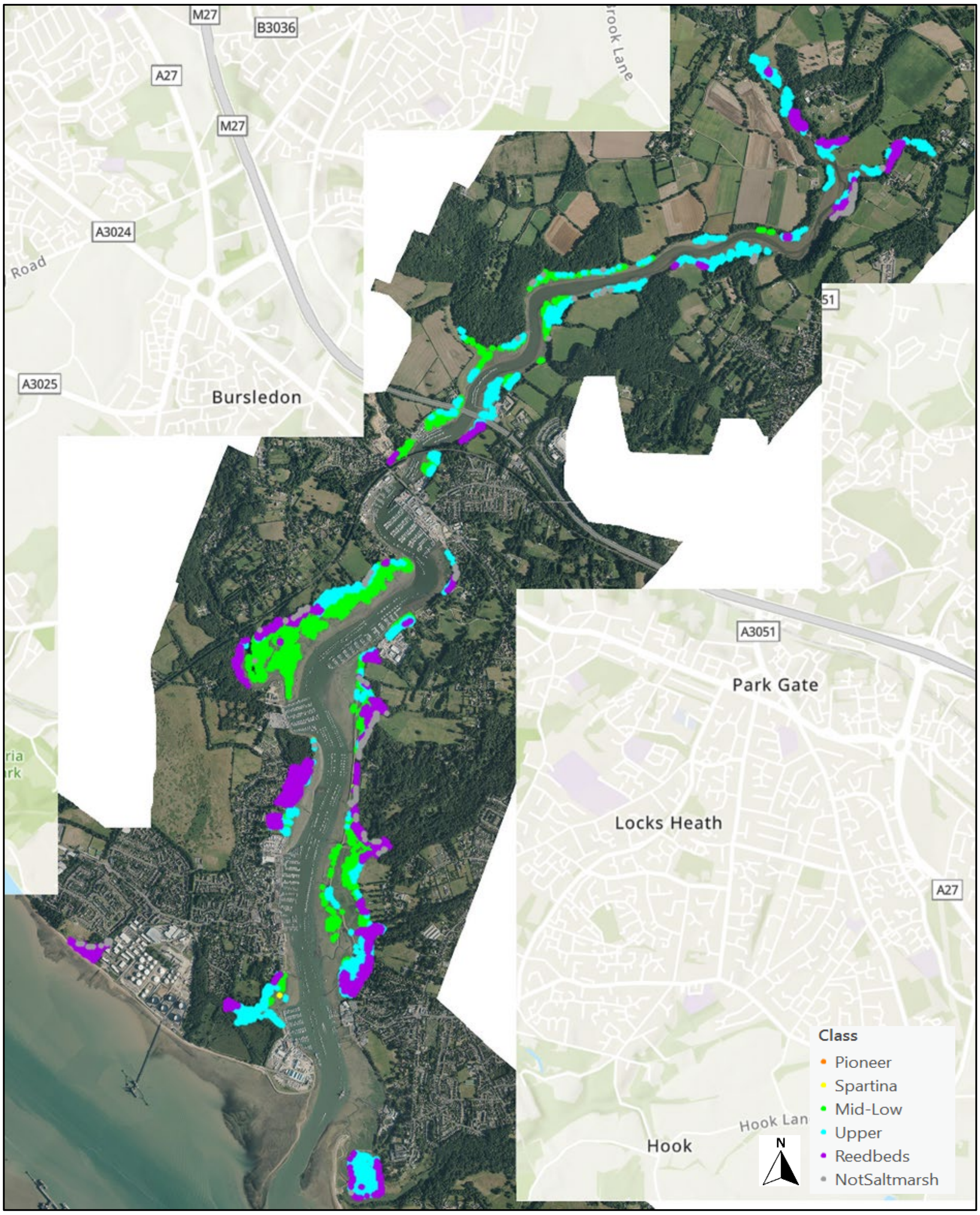


**Figure 21.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of the River Hamble in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019, show a net loss of 12.37% of saltmarsh, which equates to 1.12% $yr^{-1}$. Edge erosion is the dominant natural process occurring within the River Hamble, which has seen greatest losses to the mid-low saltmarsh species. Some reclamation has occurred in the south at Hamble Common, which is mainly upper marsh species. Fragmentation of saltmarsh has also occurred and may be a main contributor to the loss of saltmarsh, as the number of saltmarsh polygons increased from 296 to 638, between the years 2008 and 2019.

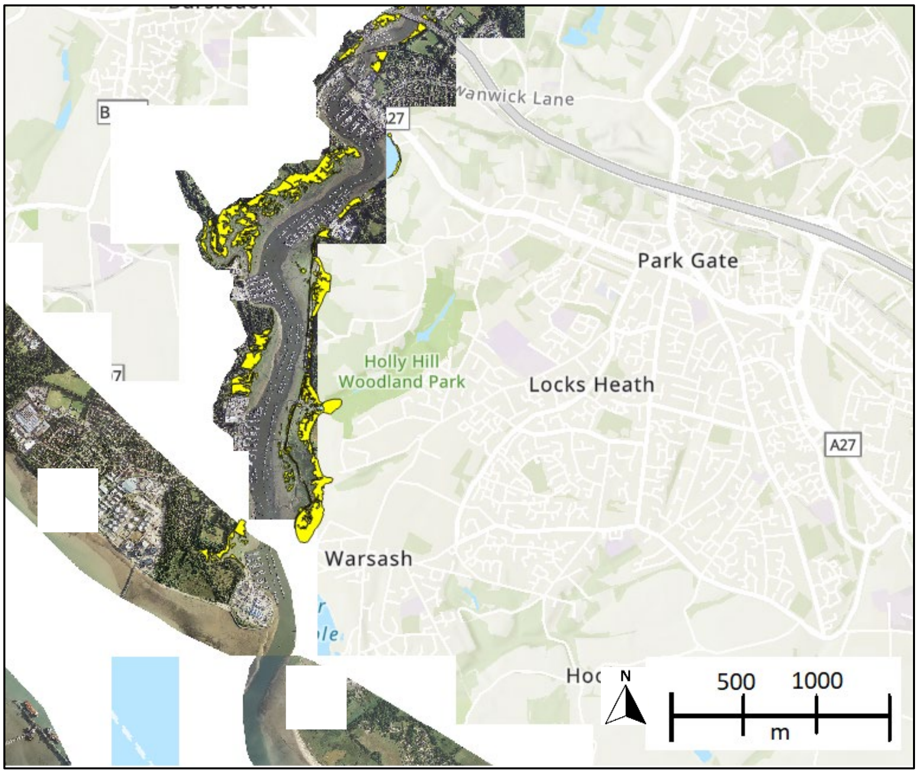


**Figure 22a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the River Hamble in 2008, retrieved from the Environment agency (EA, 2020).


**Figure 22b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the River Hamble in 2016, retrieved from the Environment agency (EA, 2020).

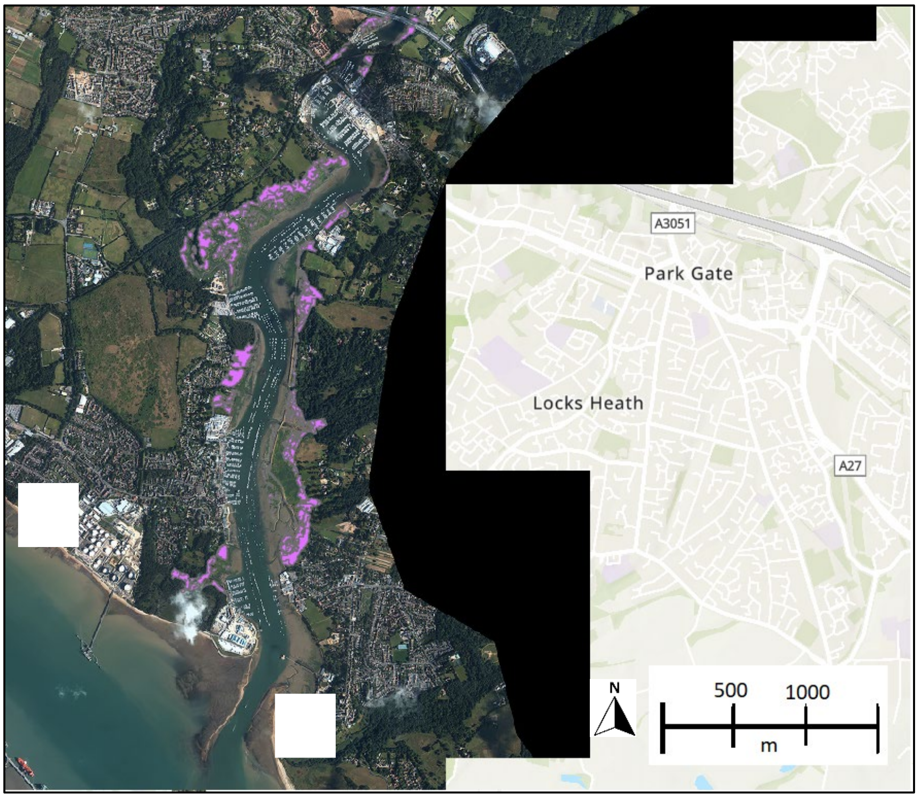


**Figure 22c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the River Hamble in 2019, retrieved from the Environment agency (EA, 2020).

*Broad Site Saltmarsh Extent Data Review*

From looking at The River Hamble as a whole between 2008 and 2019 there was a net loss of 7.8% of saltmarsh (Figures 23a, 23b and 23c), which equates to 0.7% $yr^{-1}$ . The lower section of the River Hamble (below Bridge Road, A27) contains the largest amount of saltmarsh and between 2008 and 2019 lost 13.5% of saltmarsh. Whereas, the saltmarsh north of Bridge Road indicated a gain in 5.7% of saltmarsh (0.9 hectares). Edge erosion is the dominant natural process occurring within the River Hamble. The greatest gain in saltmarsh within the River Hamble occurred at the most northern point of the Hamble at Steeple Court Manor, with the greatest increases of upper saltmarsh species and reedbeds.

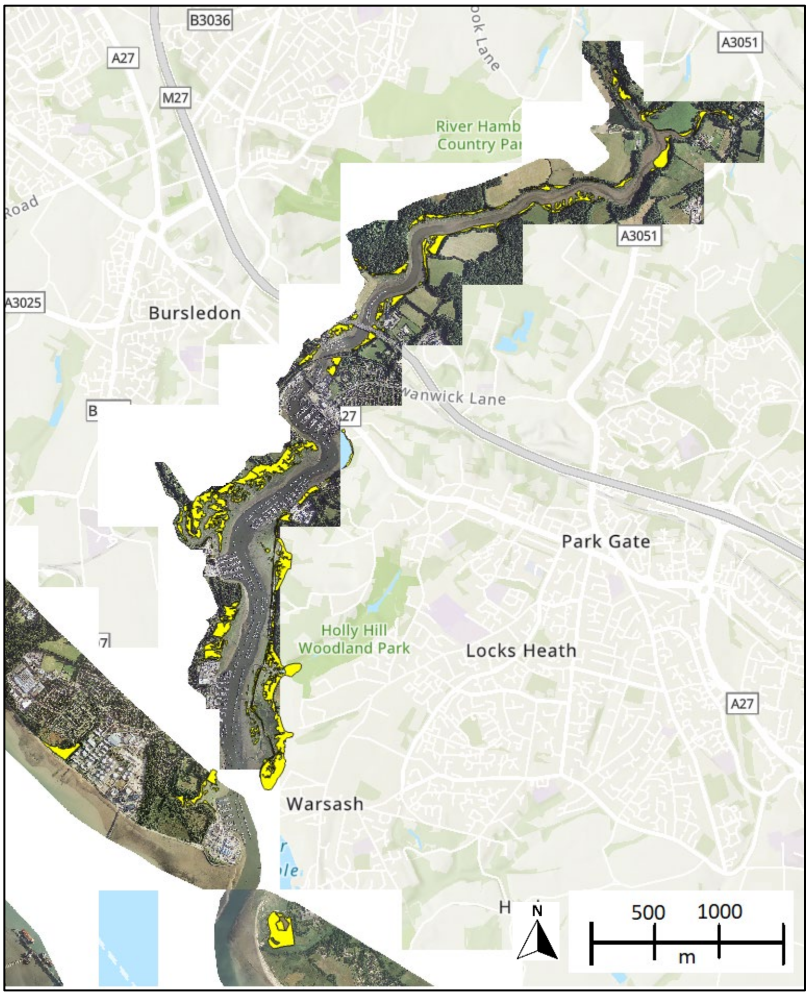


**Figure 23a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the River Hamble in 2008, retrieved from the Environment agency (EA, 2020).

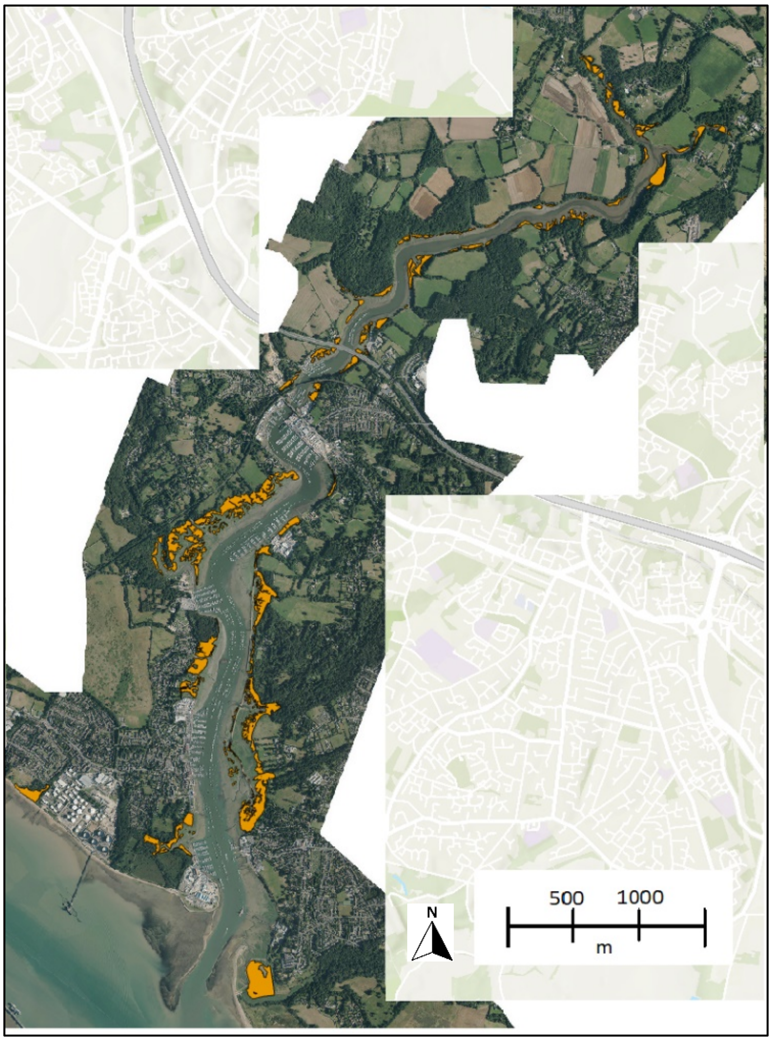


**Figure 23b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the River Hamble in 2016, retrieved from the Environment agency (EA, 2020).

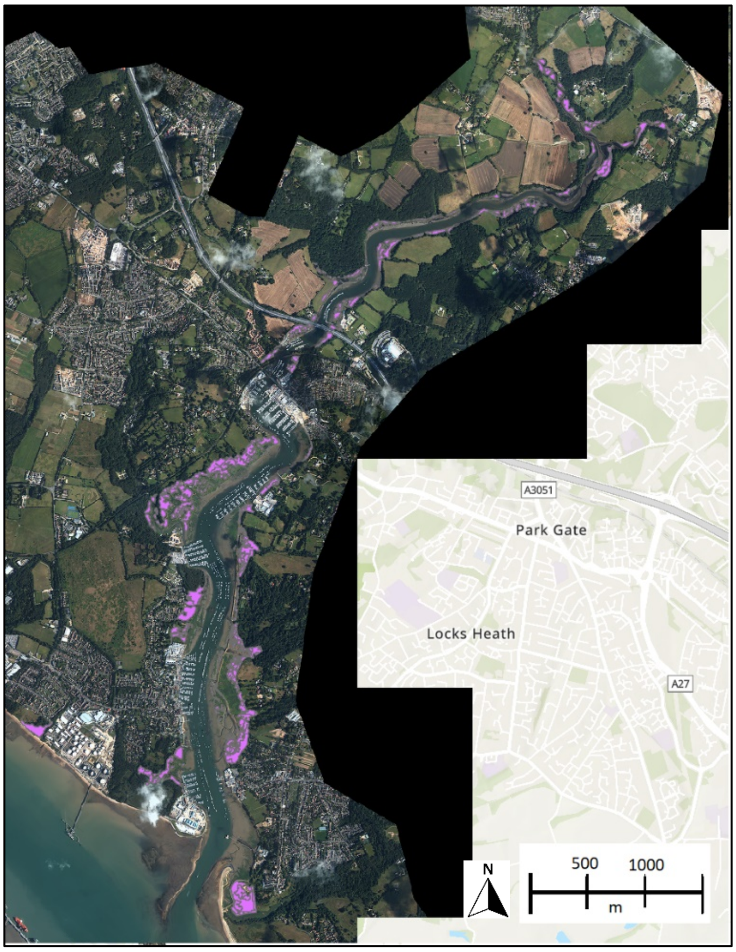


**Figure 23c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the River Hamble in 2019, retrieved from the Environment agency (EA, 2020).

### Lower Test Valley

Changes between 2008 and 2019 (Figures 25a, 25b and 25c), revealed a 19.21% saltmarsh loss (Figure 24), which equates to 1.75% $yr^{-1}$ (Table 9). Changes between 2008 and 2016, had the greatest rate of loss, being 2.51 % $yr^{-1}$ . Saltmarsh extent between 2016 and 2019, had a gain of saltmarsh, being 0.15% $yr^{-1}$. There were no historical satellite images available for the Lower Test site prior to 2008.

**Table 9.** Saltmarsh extent at Lower Test Valley.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 2008 | 58.8 | | | |
| 2016 | 47 | 2008-2016 | -20.07 | -2.51 |
| 2019 | 47.5 | 2016-2019 | +1.05 | +0.15 |
| | | 2008-2019 | -19.21 | -1.75 |

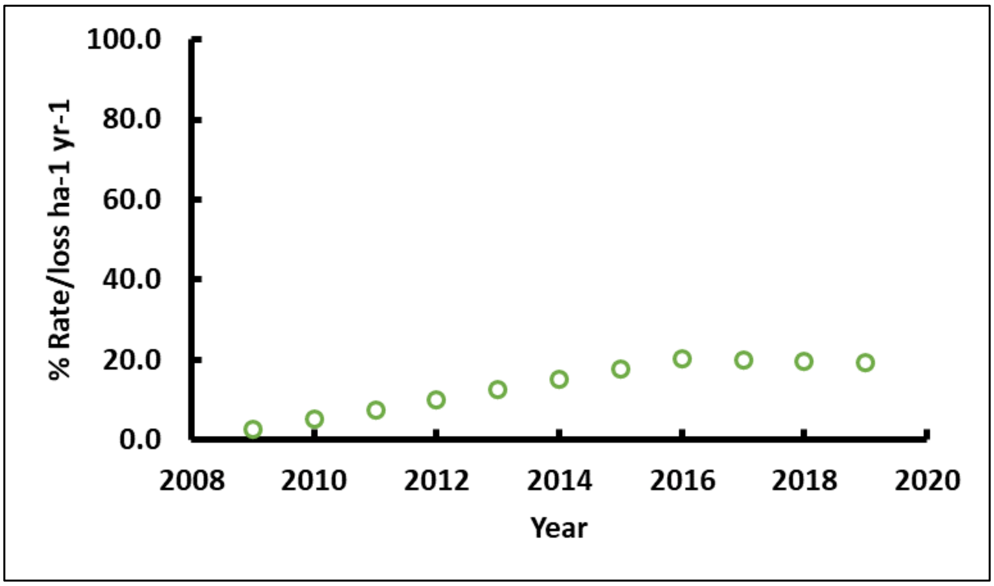


**Figure 24.** The total percentage rate of saltmarsh loss for Lower Test Valley from 2008 to 2019.

The worst-case scenario in Lower Test Valley for loss of the saltmarsh extent is between 2008 and 2019 (Figure 24). Using this data the total rate of decline from 2008 to 2019 (Regression analysis (all years): $F_{1,78}$ = 137.4, $p \leq 0.001$, $R^2$ = 93.2%), estimates that saltmarsh would reach zero hectares by 2059 (Table 10). No best-case scenario has been produced for this report as the data showed no appropriate change in rate. There were no saltmarsh data for Lower Test Valley in the SDCP report (Cope *et al*., 2008), therefore no comparisons in estimates could be made.

**Table 10.** Worst-case scenario for expected zero saltmarsh at Lower Test Valley.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| **Worst-case** | **2008 - 2019** | **2059** |

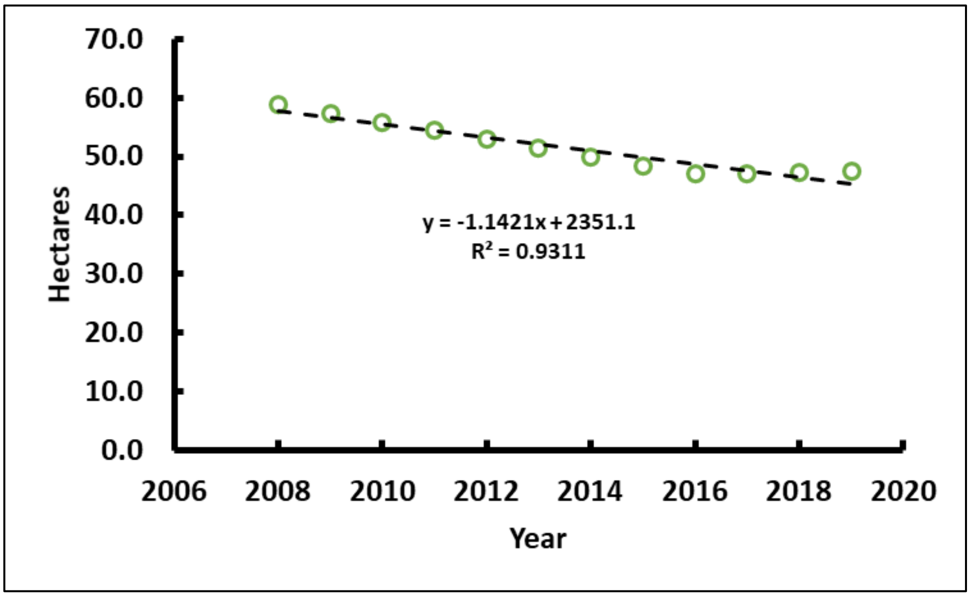


**Figure. 25.** Regression analysis for saltmarsh loss in Lower Test Valley. **A)** the total rate of decline from 2008 to 2019 (Regression analysis (all years): $F_{1,78}$ = 137.4, $p \leq 0.001$, $R^2$ = 93.2%). Using these data, we estimate saltmarsh will reach zero hectares by 2059.

*Saltmarsh species zonation classification of 2016*

The Lower Test Valley marshes are dominated by a mixture of upper saltmarsh species and reedbeds (Figure 26). The north-east Test river is dominated by reedbeds, whereas below the southern Test river are upper saltmarsh species.

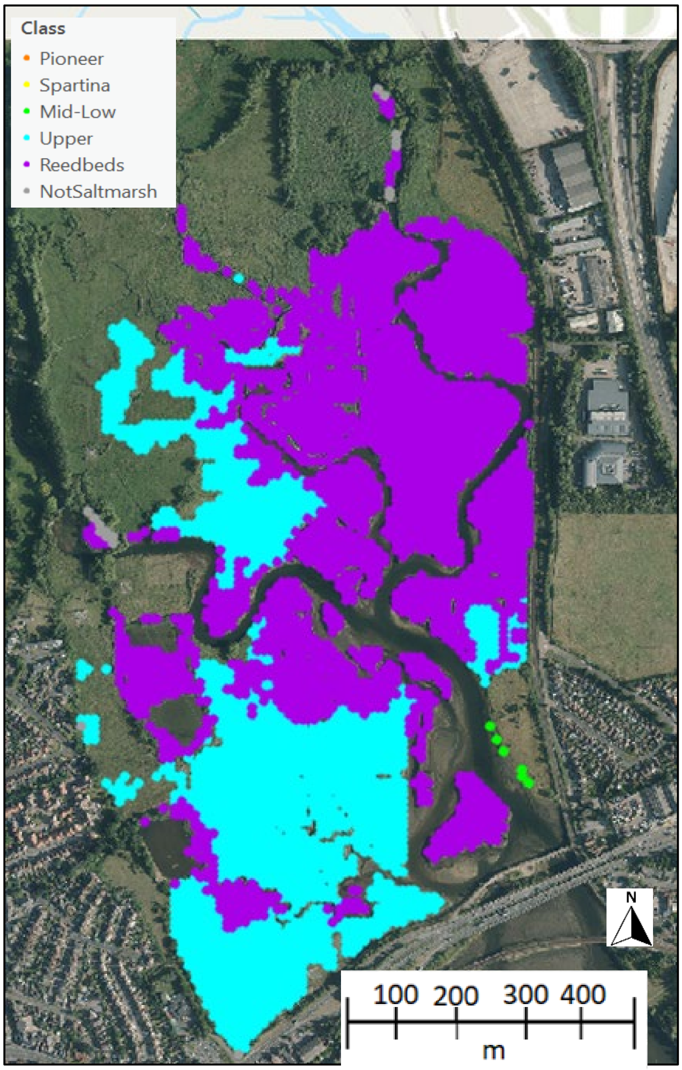


**Figure 26.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Lower Test Valley in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figures 27a, 27b and 27c), revealed a net loss of 19.21 % of saltmarsh, which equates to 1.75% $yr^{-1}$ (Table 9). The main erosion process is edge erosion of inner streams, particularly in the south west of the Test Valley, mainly to the upper saltmarsh species. Saltmarsh fragmentation is also occurring within the Lower Test area, as the number of saltmarsh polygons increased from 39 to 102, between the years 2008 and 2019.Saltmarsh grew in the north east of the marsh, west of Test Valley Business Centre. Saltmarsh species were detected on the island north of Redbridge Causeway, which may be a historical inaccuracy in the 2008 data, as satellite images show no change in the saltmarsh species.

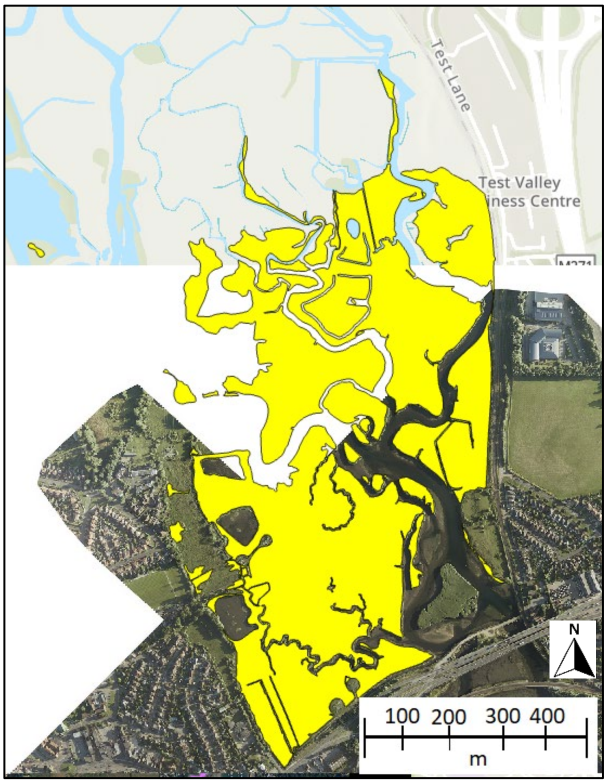


**Figure 27a.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the Lower Test Valley in 2008, retrieved from the Environment agency (EA, 2020).

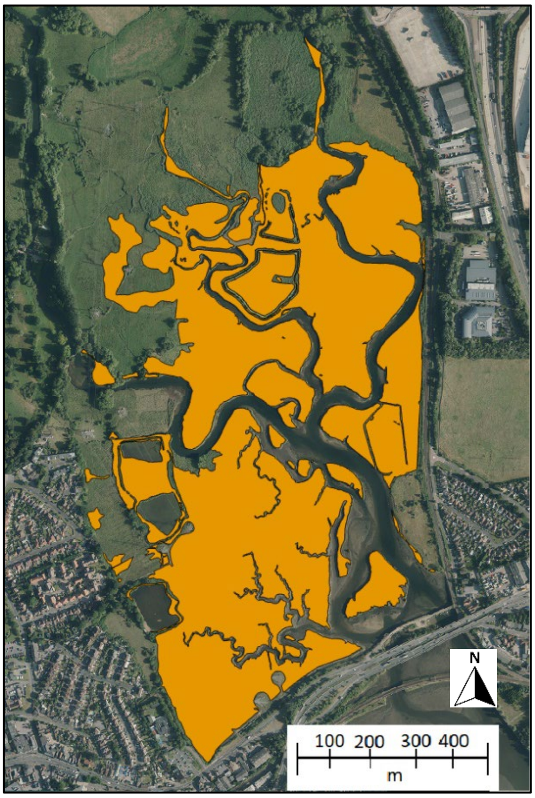


**Figure 27b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Lower Test Valley in 2016, retrieved from the Environment agency (EA, 2020).


**Figure 27c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Lower Test Valley marshes in 2019, retrieved from the Environment agency (EA, 2020).

## Southampton Water

Changes between 1946 and 2019 (Figures 28, 32a, 32b and 32c), show a 65.07% saltmarsh loss which equates to 0.93% $yr^{-1}$ (Table 11). Changes between 1963 and 1971 revealed the greatest rate of loss, being 2.91% $yr^{-1}$. Changes between 2001 and 2008, and 2016 and 2019 had zero saltmarsh loss (Figures 32a, 32b and 32c). Since 1984 the rate of saltmarsh loss has declined to less than 1% $yr^{-1}$.

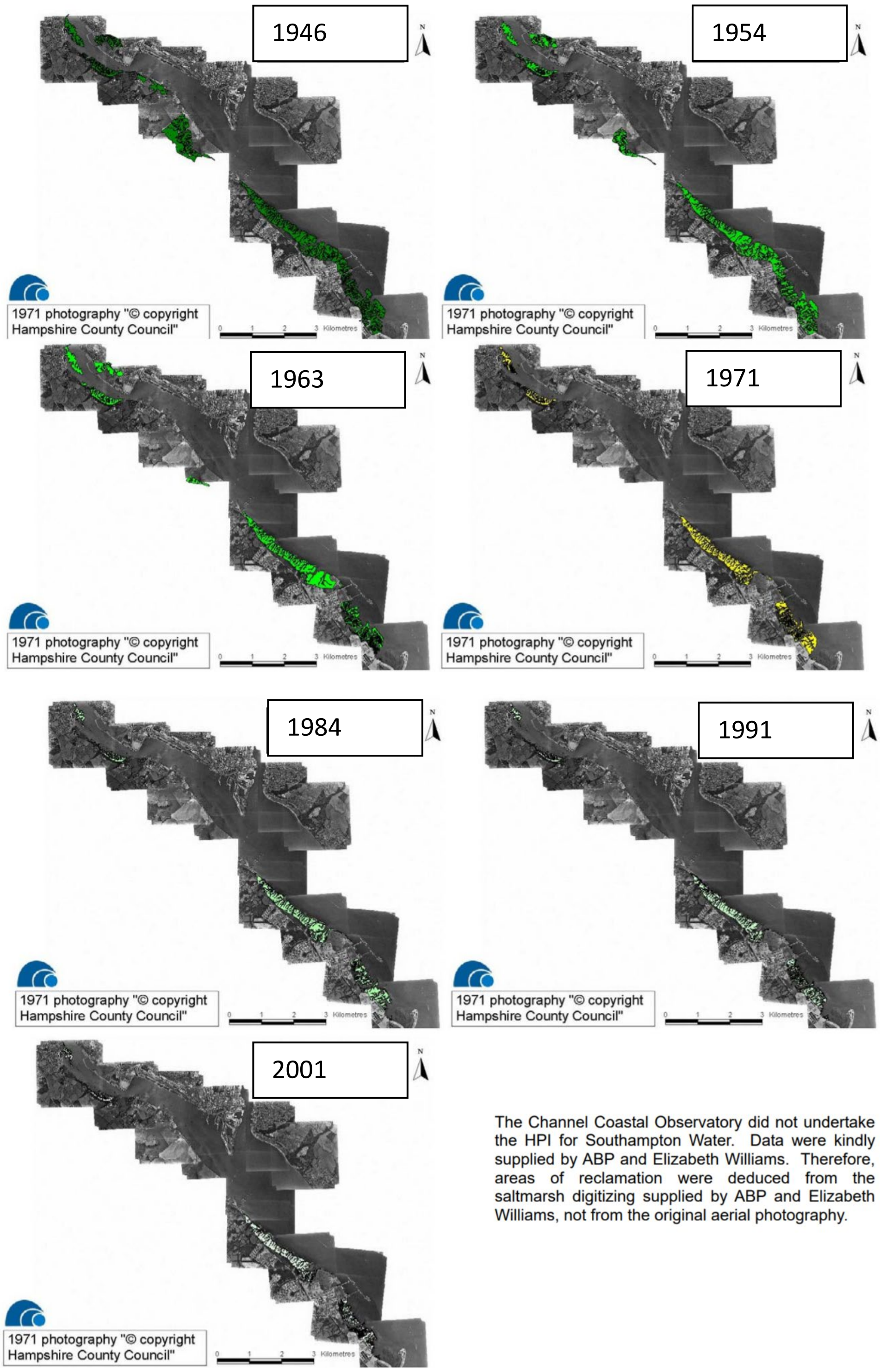


**Figure 28.** Saltmarsh extent at Southampton Water (Cope *et al*., 2008).

(2008 Channel Coastal Observatory, © New Forest District Council, reproduced with permission)

**Table 11.** Saltmarsh extent at Southampton Water.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 1946 | 440.6 | | | |
| 1954 | 342.8 | 1946-1954 | -22.20 | -2.77 |
| 1963 | 262.3 | 1954-1963 | -23.48 | -2.61 |
| 1971 | 201.2 | 1963-1971 | -23.29 | -2.91 |
| 1984 | 178.2 | 1971-1984 | -11.43 | -0.88 |
| 1991 | 172.1 | 1984-1991 | -3.42 | -0.49 |
| 2001 | 160.8 | 1991-2001 | -6.57 | -0.66 |
| 2008 | 160.8 | 2001-2008 | 0.00 | 0.00 |
| 2016 | 153.9 | 2008-2016 | -4.29 | -0.54 |
| 2019 | 153.9 | 2016-2019 | 0.00 | 0.00 |
| | | 1946-2019 | -65.07 | -0.93 |

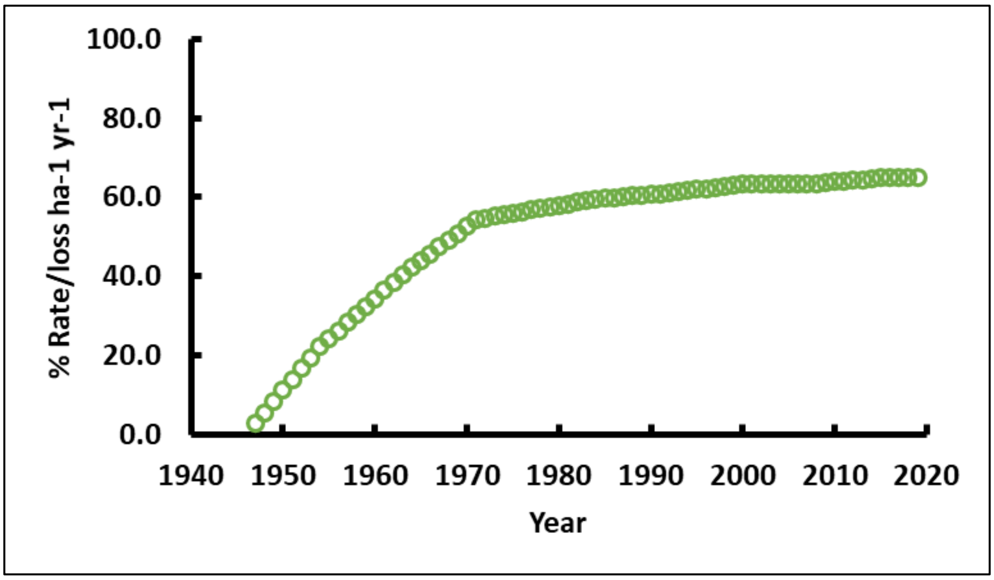


**Figure 29.** The total percentage rate of saltmarsh loss for Southampton Water from 1946 to 2019.

The worst-case scenario in Southampton Water for loss of the saltmarsh extent is between 1946 and 2019 (Figure 30A). Using this data the total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 223.12, $p \leq 0.001$, $R^2$ = 75.6%), estimates that saltmarsh would reach zero hectares by June 2050 (Table 12). The best-case scenario in Southampton Water is between 1971 and 2019 (Figure 30B). Using this data the rate of decline from 1971 to 2019 (Regression analysis (from 1971): $F_{1,34}$ = 731.4, $p \leq 0.001$, $R^2$ = 94%), estimates that saltmarsh would reach zero hectares by 2176 (Table 12). Work from the SDCP (Cope et al., 2008) estimated that the best-case scenario would predict around 95 hectares of saltmarsh by 2110, whereas the worst-case scenario predicted zero saltmarsh by 2054. Therefore, the estimated saltmarsh loss of the SDCP is still within a valid accuracy (Cope *et al.,* 2008).

**Table 12.** Best and worst-case scenarios for expected zero saltmarsh at Southampton Water.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| **Worst-case** | **1946 - 2019** | **June 2050** |
| **Best-case** | **1971 - 2019** | **2176** |

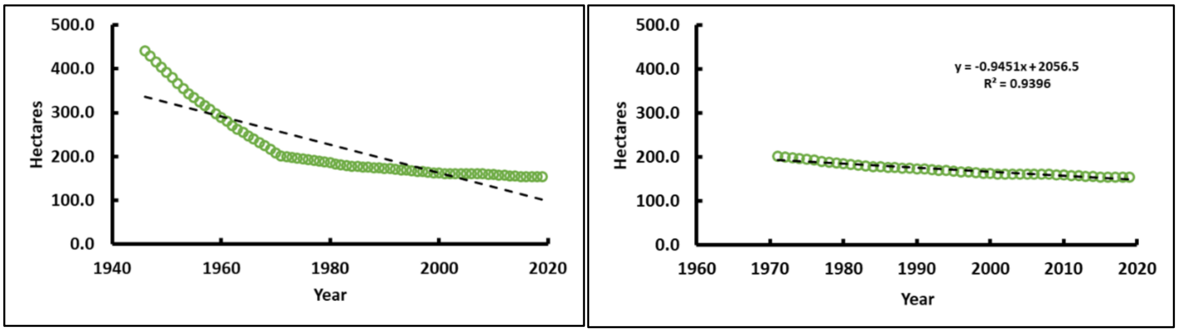


**Figure 30.** Regression analysis for saltmarsh loss in Southampton Water. **A)** the total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 223.12, $p \leq 0.001$, $R^2$ = 75.6%). Using these data, we estimate saltmarsh will reach zero hectares by mid-2050. **B)** the rate of decline from 1971 to 2019 (Regression analysis (from 1971): $F_{1,34}$ = 731.4, $p \leq 0.001$, $R^2$ = 94%). Using these data, we estimate saltmarsh will reach zero hectares by 2176.

*Saltmarsh species zonation classification of 2016*

In the most northern reaches of Southampton Water the saltmarshes are dominated by large islands of upper marsh species and some reedbeds (Figure 31). At Bury marsh there are scattered islands of mid-low saltmarsh species, dissected by channels and creeks.

The centre of the region is dominated by a thick band of mid-low saltmarsh species, with a thin layer of *Spartina* species on the outermost reaches of the marsh. At the upper reaches of the marsh are a band of upper saltmarsh species and scattered reedbeds.

In the southern reaches of Southampton Water, *Spartina* and mid-low saltmarshes species are most dominant. At the south, in front of Fawley Power Station, are a cluster of pioneer species. Behind the docks are a dense cluster of reedbeds.

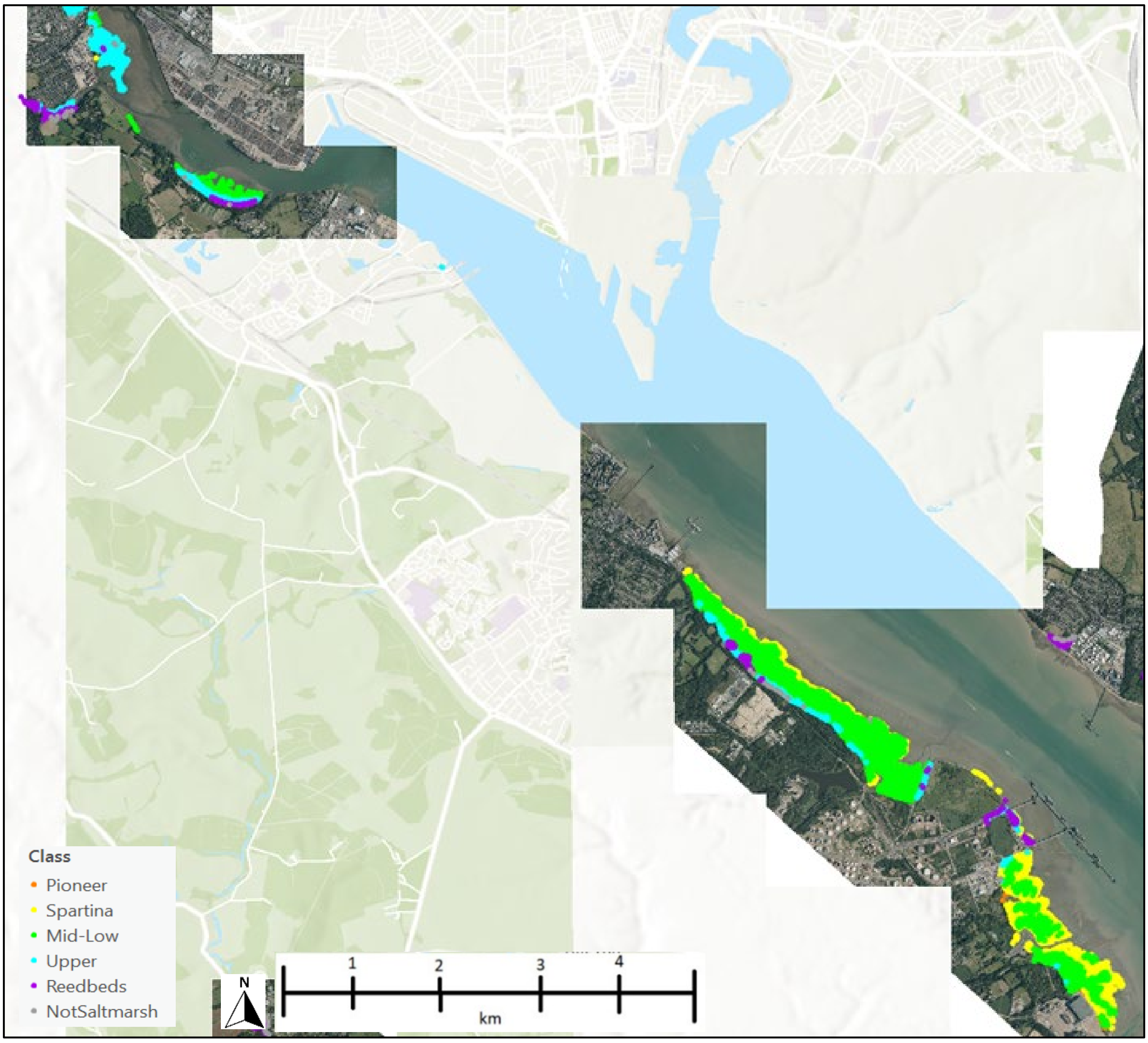


**Figure 31.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Southampton Water in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

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*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019, show a net loss of 4.29% of saltmarsh, which equates to 0.39% $yr^{-1}$. Saltmarsh in Southampton Water is exposed to wave attack and thus edge erosion of the outer marshes is the dominant form of loss, resulting in the loss of *Spartina* species and into the mid-low saltmarsh species. There is some internal dissection occurring, stemming from channels reaching into saltmarshes and removing mid-low saltmarsh species. This is supported by the increase in the number of saltmarsh polygons between 2008 and 2019, from 664 to 912,Small areas of upper saltmarsh species, close to the shoreline, appeared to grow in extent and improved in connectivity between 2008 and 2019.

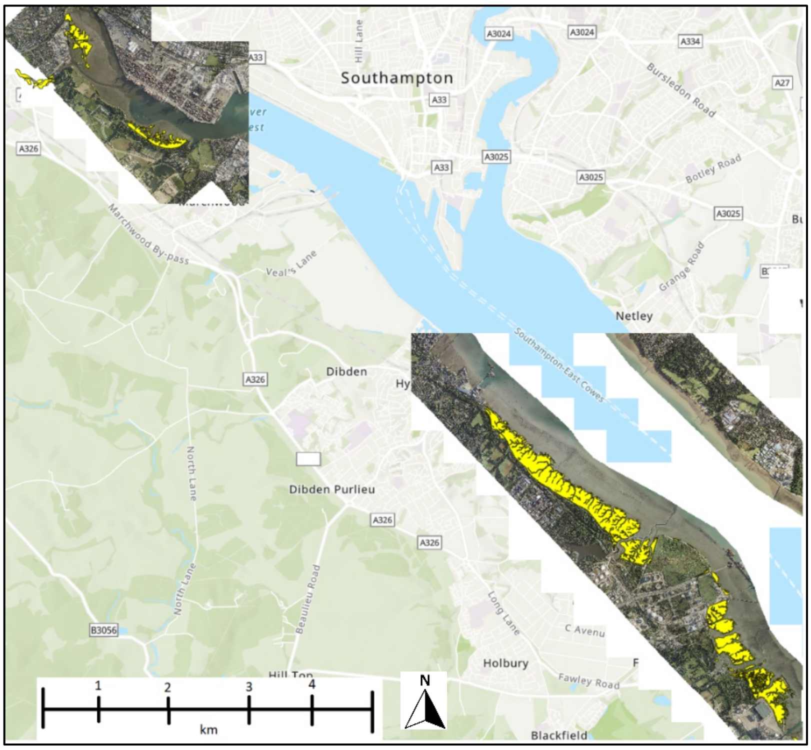



**Figure 32a.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Southampton Water in 2008, retrieved from the Environment agency (EA, 2020).

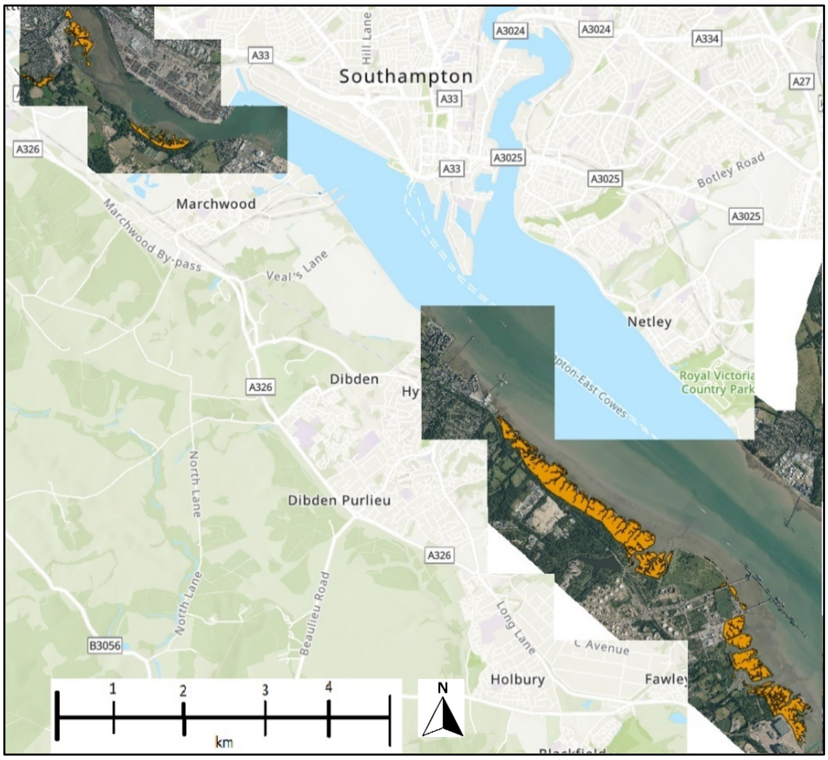



**Figure 32b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Southampton Water in 2016, retrieved from the Environment agency (EA, 2020).


**Figure 32c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Southampton Water in 2019, retrieved from the Environment agency (EA, 2020).

## Calshot Marsh

Changes between 1946 and 2019 (Figures 33 and 37), show an 82.2% saltmarsh loss (Figure 34), which equates to 1.13% $yr^{-1}$ (Table 13). Changes between 1971 and 1984 revealed the greatest rate of loss, being 3.56 $yr^{-1}$. From 2008 onwards the extent of saltmarsh in Calshot Marsh had increased. Changes between 2016 and 2019 had the greatest rate in saltmarsh gain, being 1.46% $yr^{-1}$.

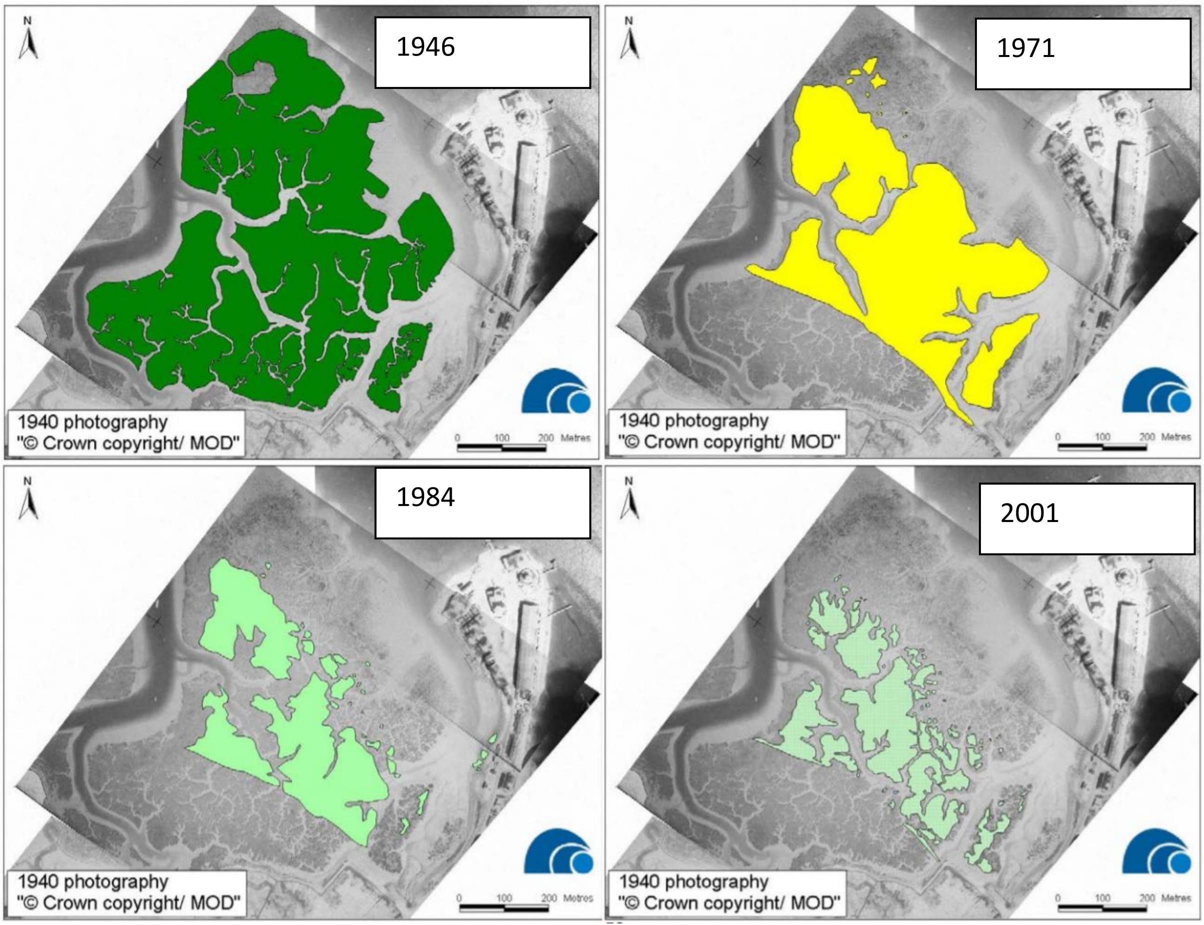



**Figure 33.** Saltmarsh extent at Calshot Marsh (Cope *et al.*, 2008).
(2008 Channel Coastal Observatory, © New Forest District Council, reproduced with permission)

**Table 13.** Saltmarsh extent at Calshot Marsh.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 1940 | 34.8 | | | |
| 1971 | 20.1 | 1940-1971 | -42.24 | -1.36 |
| 1984 | 10.8 | 1971-1984 | -46.27 | -3.56 |
| 2001 | 9.4 | 1984-2001 | -12.96 | -0.76 |
| 2008 | 7.3 | 2001-2008 | -22.34 | -3.19 |
| 2016 | 7.9 | 2008-2016 | +7.59 | +0.95 |
| 2019 | 7.4 | 2016-2019 | -4.38 | -1.46 |
| | | 1940-2019 | -78.74 | -1.00 |

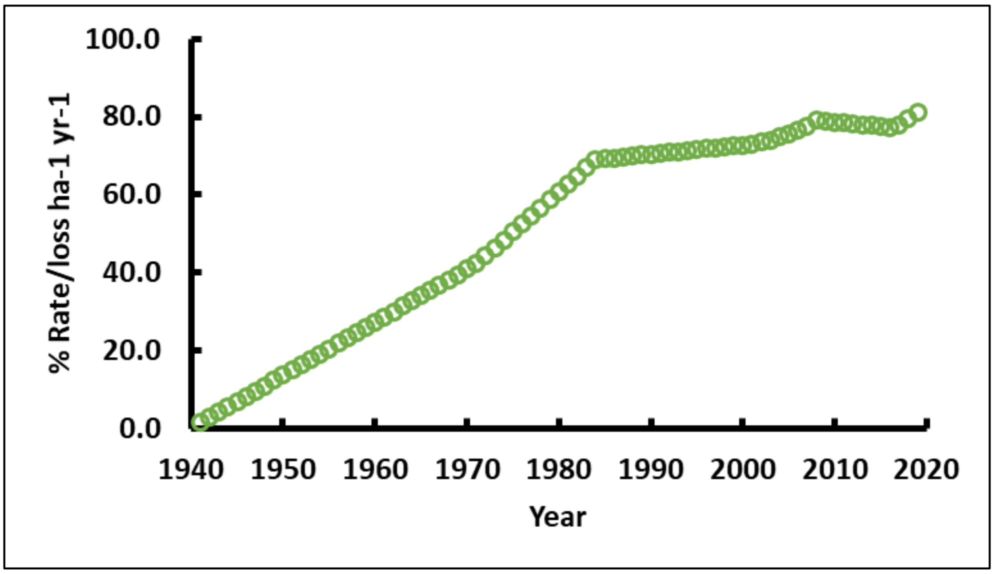



**Figure 34.** The total percentage rate of saltmarsh loss for Calshot Marsh from 1940 to 2019.

The worst-case scenario in Calshot Marsh for loss of the saltmarsh extent is between 1940 and 2019 (Figure 35A). Using this data the total rate of decline from 1940 to 2019 (Regression analysis (all years): $F_{1,78}$ = 1074.4, $p \leq 0.001$, $R^2$ = 93.2%), estimates that saltmarsh would reach zero hectares by June 2027 (Table 14). The best-case scenario in Calshot Marsh is between 1984 and 2019 (Figure 35B). Using this data the rate of decline from 1984 to 2019 (Regression analysis (from 1971): $F_{1,34}$ = 402.4, $p \leq 0.001$, $R^2$ = 92.2%), estimates that saltmarsh would reach zero hectares by April 2083 (Table 14). Work from the SDCP (Cope et al., 2008) estimated that the best-case scenario would predict around 5 hectares of saltmarsh by 2055, whereas the worst-case scenario predicted zero saltmarsh by 2014. Therefore, both previous estimates of saltmarsh loss of the SDCP have been extended.

**Table 14.** Best and worst-case scenarios for expected zero saltmarsh at Calshot Marsh.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| Worst-case | 1940 - 2019 | Mid 2027 |
| Best-case | 1984 -2019 | April2083 |

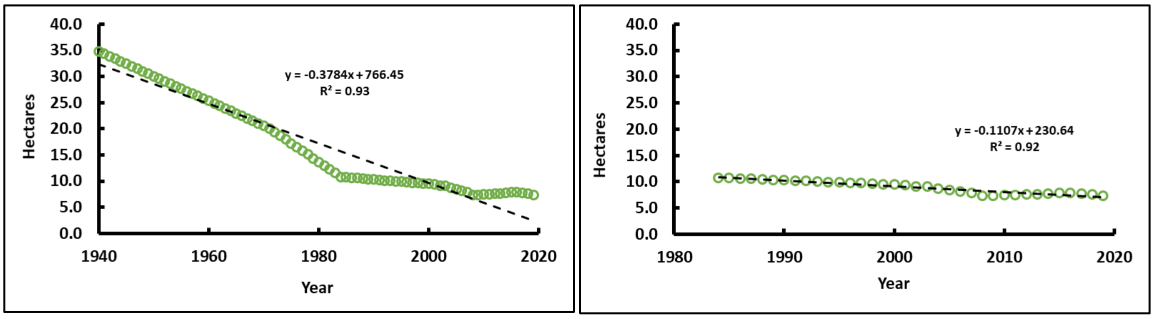



**Figure 35.** Regression analysis for saltmarsh loss in Calshot Marsh. **A)** the total rate of decline from 1940 to 2019 (Regression analysis (all years): $F_{1,78}$ = 1074.4, $p \leq 0.001$, $R^2$ = 93.2%). Using these data, we estimate saltmarsh will reach zero hectares by mid-2027. **B)** the rate of decline from 1984 to 2019 (Regression analysis (from 1984): $F_{1,34}$ = 402.4, $p \leq 0.001$, $R^2$ = 92.2%). Using these data, we estimate saltmarsh will reach zero hectares by the first quarter of 2083.

*Saltmarsh species zonation classification of 2016*

Calshot Marsh saltmarsh are mainly dominated by *Spartina* species that extend from the shoreline (Figure 36). Shore-side of the public footpath is a thin band of mid-low saltmarsh species. Bankside of the public foot path the saltmarsh is a combination of mixed mid-low and upper saltmarsh species.

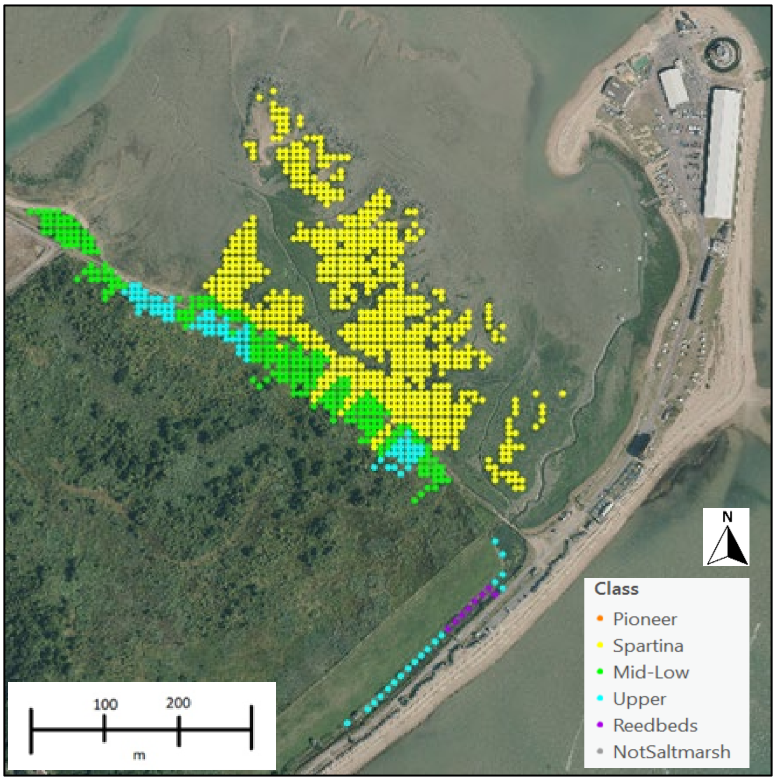



**Figure 36.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Calshot Marsh in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figures 37a, 37b and 37c), show a net gain of 1.4% of saltmarsh, which equates to 0.13% $yr^{-1}$ . The gain in saltmarsh area occurred near to shore where existing mid-low and *Spartina* species increased in size and thus connectivity. However, a great amount of saltmarsh was lost due to edge erosion to the *Spartina* islands closest to the Solent channel. This may be supported by the loss of saltmarsh polygons seen at Calshot Marsh between 2008 and 2019, from 183 to 78.

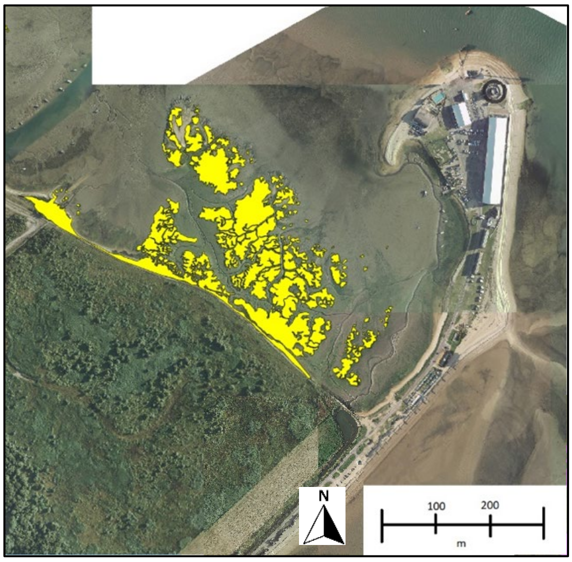



**Figure 37a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Calshot Marsh in 2008, retrieved from the Environment agency (EA, 2020).


**Figure 37b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Calshot Marsh in 2016, retrieved from the Environment agency (EA, 2020).


**Figure 37c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Calshot Marsh in 2019, retrieved from the Environment agency (EA, 2020).

*Broad Site Saltmarsh Extent Data Review*

A review of the aerial photography of the Calshot Marsh shows no obvious change in species composition between the 2008, 2016 and 2019 datasets (Figures 38a, 38b and 38c). However, the datasets from Natural England and the Environment Agency ground-truthed data showed a net gain of 27.3% of saltmarsh, which equates to 2.48% $yr^{-1}$. The greatest area of accretion of saltmarsh (according to the ground-truthed data) occurred behind the public footpath.

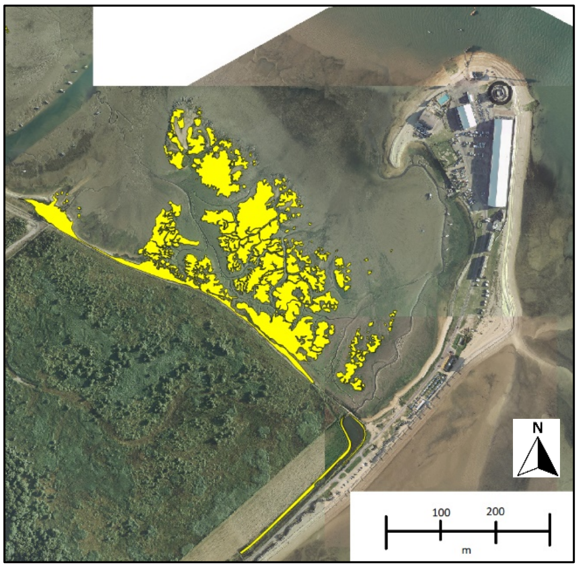



**Figure 38a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Calshot Marsh in 2008, retrieved from the Environment agency (EA, 2020).

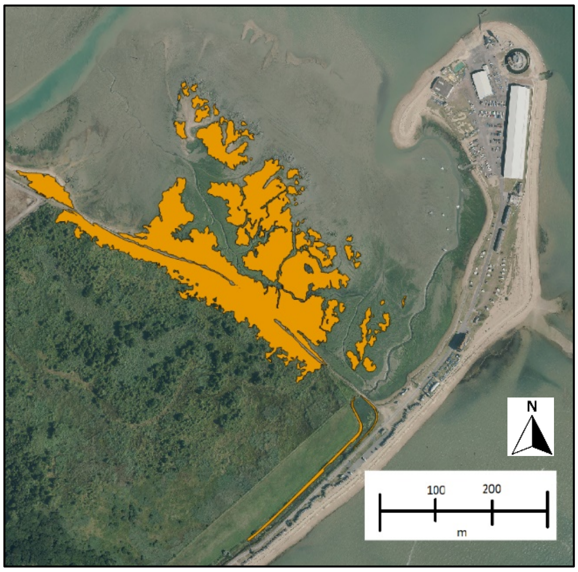



**Figure 38b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Calshot Marsh in 2016, retrieved from the Environment agency (EA, 2020).

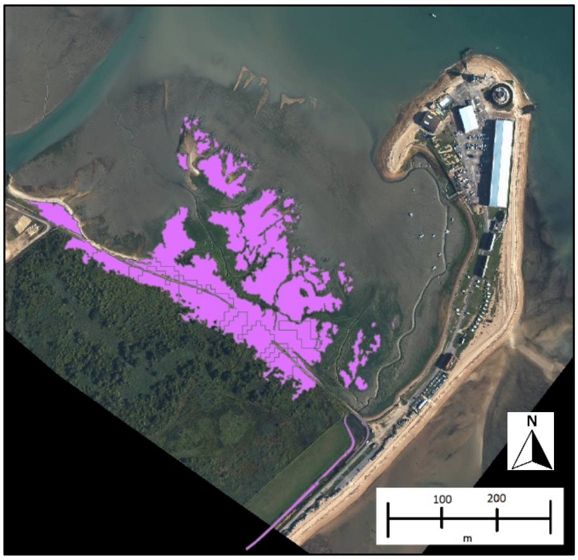



**Figure 38c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Calshot Marsh in 2019, retrieved from the Environment agency (EA, 2020).

## Beaulieu River Estuary

Changes between 1954 and 2019 (Figures 39 and 43), revealed a 42.66% saltmarsh loss (Figure 40), which equates to 0.88% $yr^{-1}$ (Table 15). Changes between 1984 and 2001 had the greatest rate of loss, being 2.02% $yr^{-1}$. Changes between 2016 and 2019 had the smallest rate of loss, being 0.02% $yr^{-1}$. Since 2001 the rate of saltmarsh loss has declined to less than 1% $yr^{-1}$.

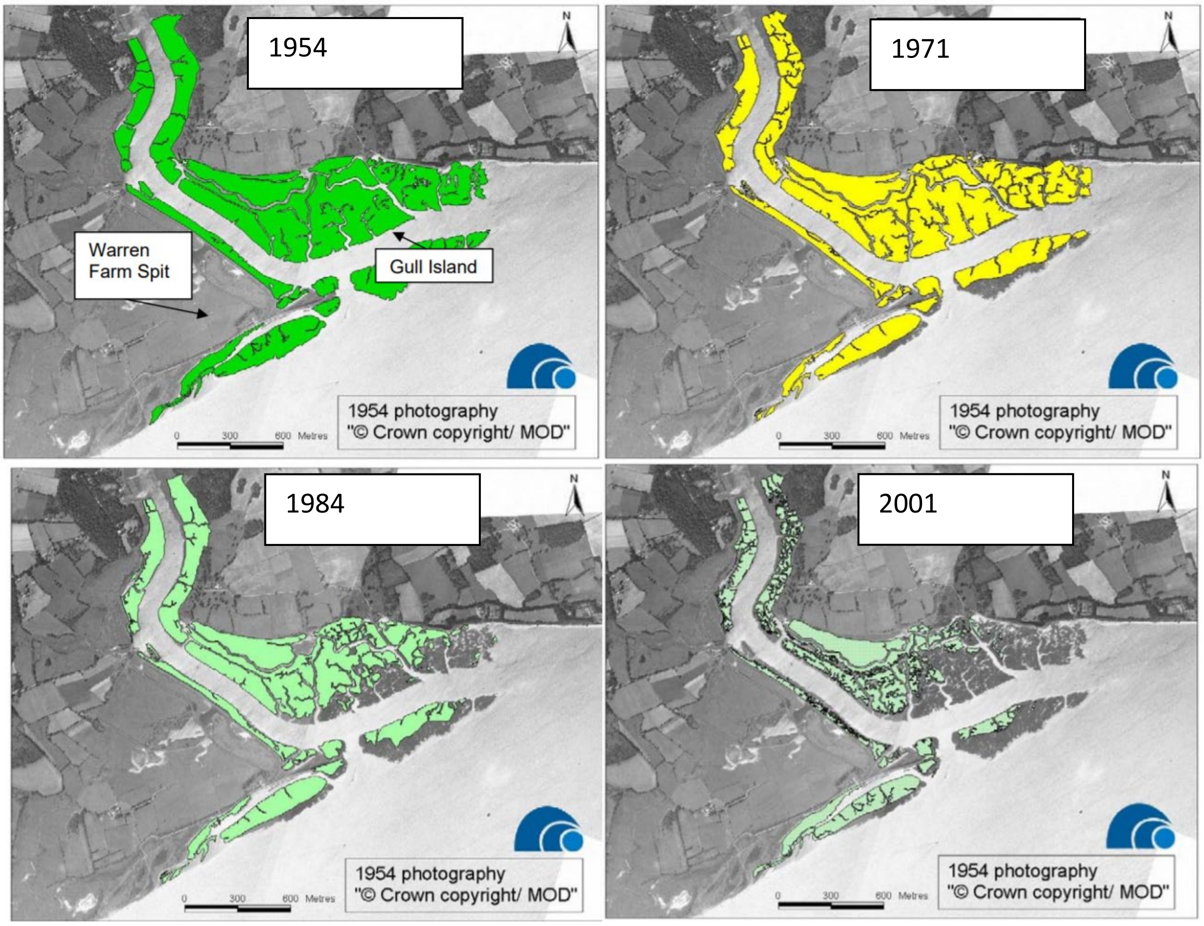



**Figure 39.** Saltmarsh extent at Beaulieu River Estuary (Cope *et al*., 2008).
(2008 Channel Coastal Observatory, © New Forest District Council, reproduced with permission)

**Table 15.** Saltmarsh extent at Beaulieu River Estuary.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| 1954 | 149.8 | | % change | % change $yr^{-1}$ |
| 1971 | 136.2 | 1946-1971 | -9.08 | -0.53 |
| 1984 | 107.9 | 1971-1984 | -20.78 | -1.60 |
| 2001 | 70.9 | 1984-2001 | -34.29 | -2.02 |
| 2008 | 66.8 | 2001-2008 | -5.78 | -0.83 |
| 2016 | 64 | 2008-2016 | -4.19 | -0.60 |
| 2019 | 63.9 | 2016-2019 | -1.60 | -0.02 |
| | | 1946-2019 | -42.66 | -0.88 |

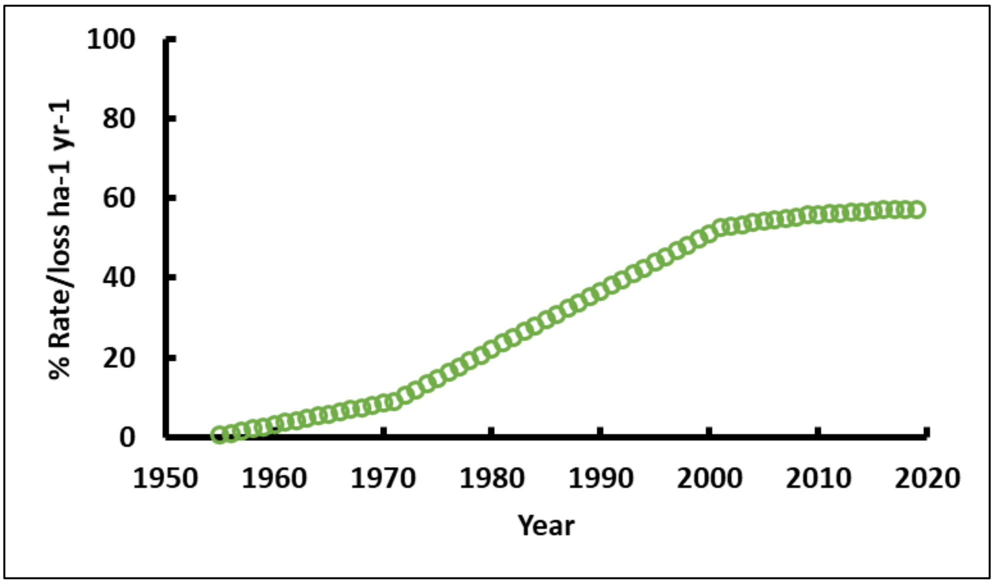



**Figure 40.** The total percentage rate of saltmarsh loss for Beaulieu River Estuary from 1954 to 2019.

The worst-case scenario in Beaulieu River Estuary for loss of the saltmarsh extent is between 1954 and 2019 (Figure 41A). Using this data the total rate of decline from 1954 to 2019 (Regression analysis (all years): $F_{1,78}$ =2152.2, $p \leq 0.001$, $R^2$ = 97.1%), estimates that saltmarsh would reach zero hectares by 2051 (Table 16). The best-case scenario in Beaulieu River Estuary is between 2001 and 2019 (Figure 41B). Using this data the rate of decline from 2001 to 2019 (Regression analysis (from 1971): $F_{1,34}$ = 382.2, $p \leq 0.001$, $R^2$ = 95.7%), estimates that saltmarsh would reach zero hectares by 2178 (Table 16). Work from the SDCP (Cope et al., 2008) estimated that the best-case scenario would predict around zero hectares of saltmarsh by 2090, whereas the worst-case scenario predicted zero saltmarsh by 2034. Therefore, both previous estimates of saltmarsh loss of the SDCP have been extended, with best-case scenario being extended by 88 years (Cope *et al.,* 2008).

**Table 16.** Best and worst-case scenarios for expected zero saltmarsh at Beaulieu River Estuary Marshes.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| **Worst-case** | **1954 - 2019** | **2051** |
| **Best-case** | **2001 - 2019** | **2178** |

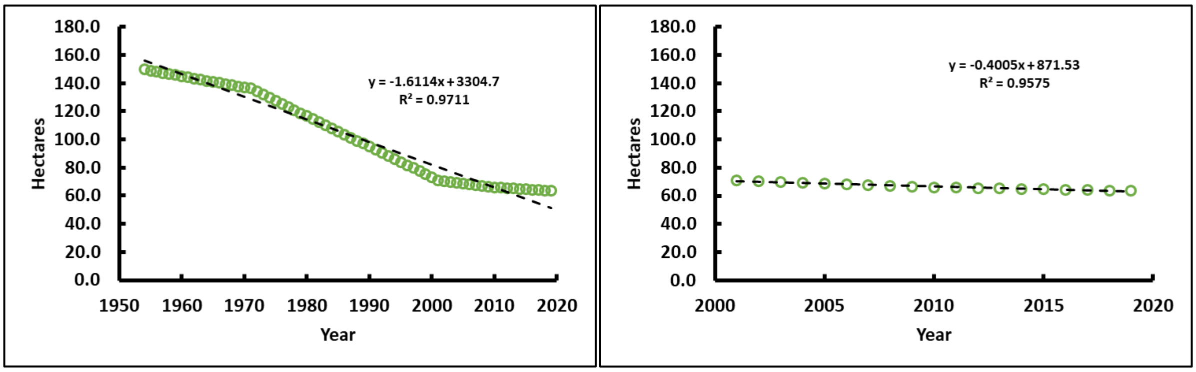



**Figure 41.** Regression analysis for saltmarsh loss in Beaulieu River Estuary. **A)** the total rate of decline from 1954 to 2019 (Regression analysis (all years): $F_{1,78}$ =2152.2, $p \leq 0.001$, $R^2$ = 97.1%). Using these data, we estimate saltmarsh will reach zero hectares by 2051**. B)** the rate of decline from 2001 to 2019 (Regression analysis (from 2001): $F_{1,34}$ = 382.2, $p \leq 0.001$, $R^2$ = 95.7%). Using these data, we estimate saltmarsh will reach zero hectares by the 2178.

### *Saltmarsh species zonation classification of 2016*

The Beaulieu estuary demonstrates vertical succession throughout the River (Figure 42). The lower estuary is dominated by *Spartina* and mid-low saltmarsh species. Mid-low saltmarsh species dominate a large area of the reclaimed zone at St Margaret's Creek. Saltmarsh south of the reclaimed saltmarsh at St Margaret's Creek are dominated by *Spartina* species. Behind Warren Farm Spit/ Gull island are an extensive area of mid-low saltmarsh species. Below Needs Ore cottages is a band of *Spartina* marshes. Around Warren Beach Cottage are ponds of upper saltmarsh and reedbeds. Upper saltmarsh species are more prevalent in the northern reaches of the Beaulieu than in the south. A dense patch of pioneer saltmarsh species is found just north of Buckler's Hard Yacht Harbour. The upper most reach of the Beaulieu River is occupied by a dense patch of reedbeds.

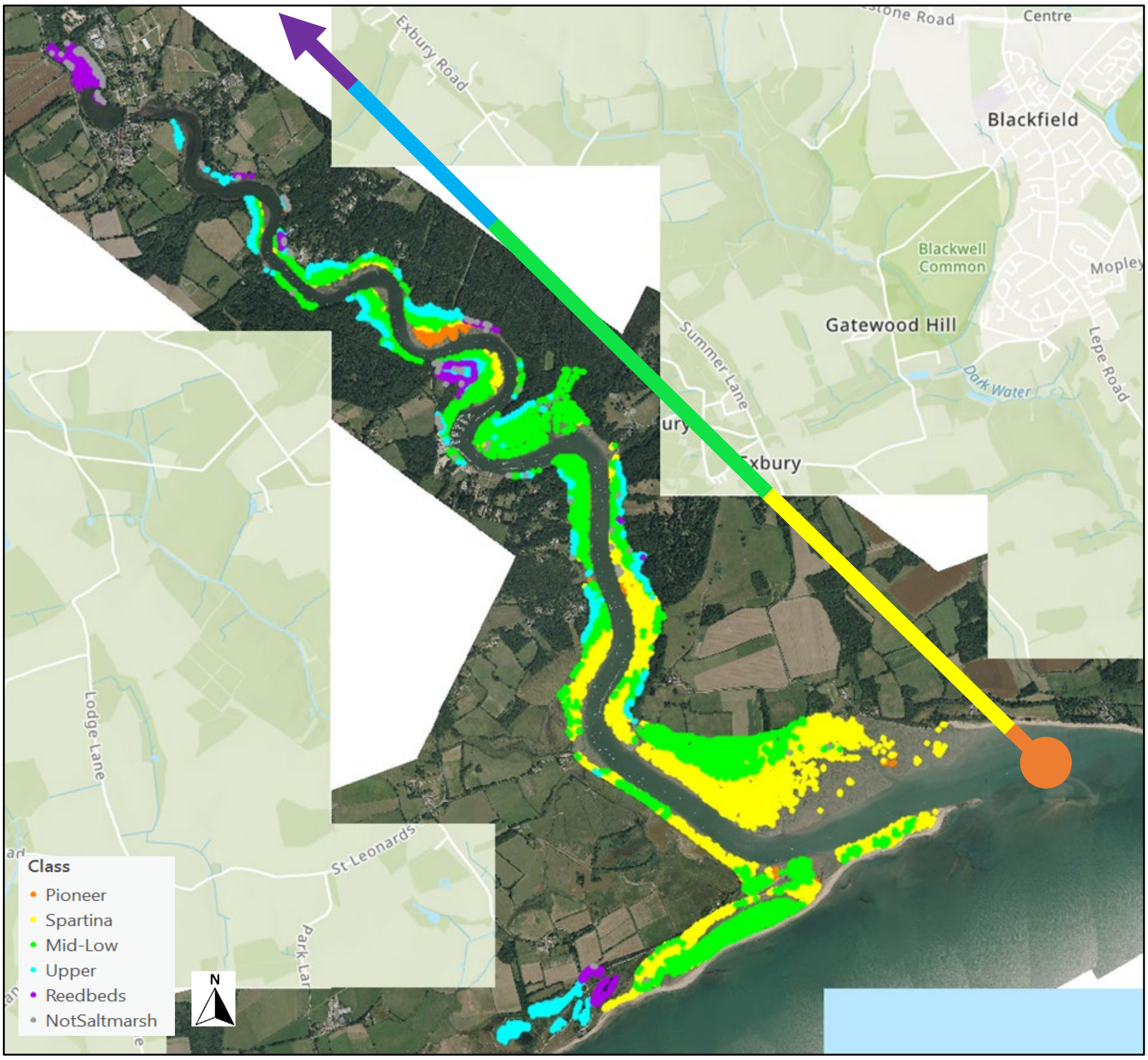



**Figure 42.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of the Beaulieu River in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 43a, 43b and 43c), had a net loss of 4.5% of saltmarsh, which equates to 0.41% $yr^{-1}$. Within the Beaulieu river estuary, the number of saltmarsh polygons increased from 652 to 2174, between 2008 and 2019, respectively. Saltmarsh fragmentation is the dominant process occurring within the Beaulieu River Estuary, particularly to the *Spartina* swards. However, reclamation of mid-low saltmarsh species has occurred to the north side of the Beaulieu channel due to increased connectivity of the marshes. Although, linear patterns of erosion are present on the reclaimed area of the saltmarsh, presumably man-made, which has contributed to a large amount of saltmarsh loss at the Beaulieu Marshes. However, this may be an inaccuracy with 2008 data which is therefore contributing to the net losses within the Beaulieu.

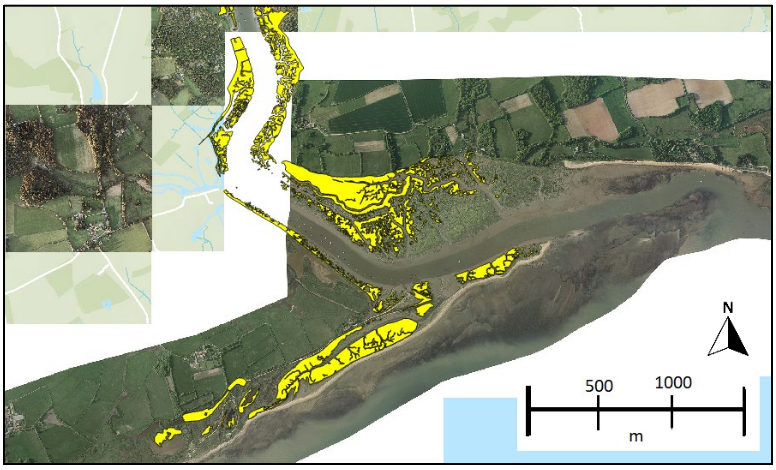



**Figure 43a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Beaulieu River Estuary in 2008, retrieved from the Environment agency (EA, 2020).


**Figure 43b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Beaulieu River in 2016, retrieved from the Environment agency (EA, 2020).

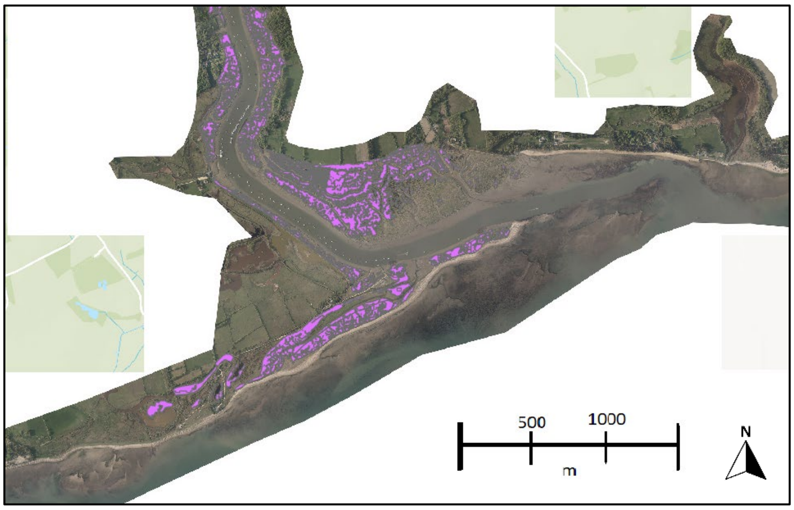



**Figure 43c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Beaulieu River in 2019, retrieved from the Environment agency (EA, 2020).

*Broad Site Saltmarsh Extent Data Review*

The saltmarsh extent between 2008 and 2019 (Figure 44a, 44b and 44c) had a net loss of 4.2% of saltmarsh, which equates to 0.38% $yr^{-1}$. Previously, saltmarsh extent of the Beaulieu River estuary Did not include the extent of saltmarsh within the mid and upper reaches of the estuary. Changes between 2008 and 2019 indicated large losses of saltmarsh due to internal dissection and edge erosion. No changes were documented within the uppermost reach of the estuary, where the reedbeds are present. Gains in saltmarsh extent were seen around the Buckler's Hard Yacht Harbour and further up the estuary.

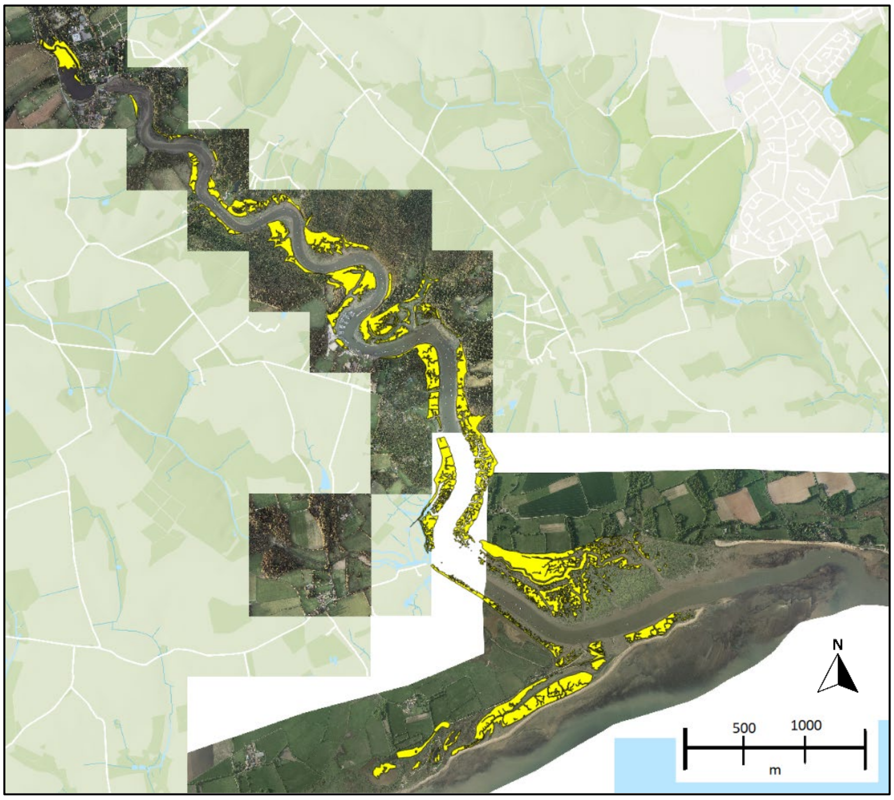



**Figure 44a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Beaulieu River Estuary in 2008, retrieved from the Environment agency (EA, 2020).

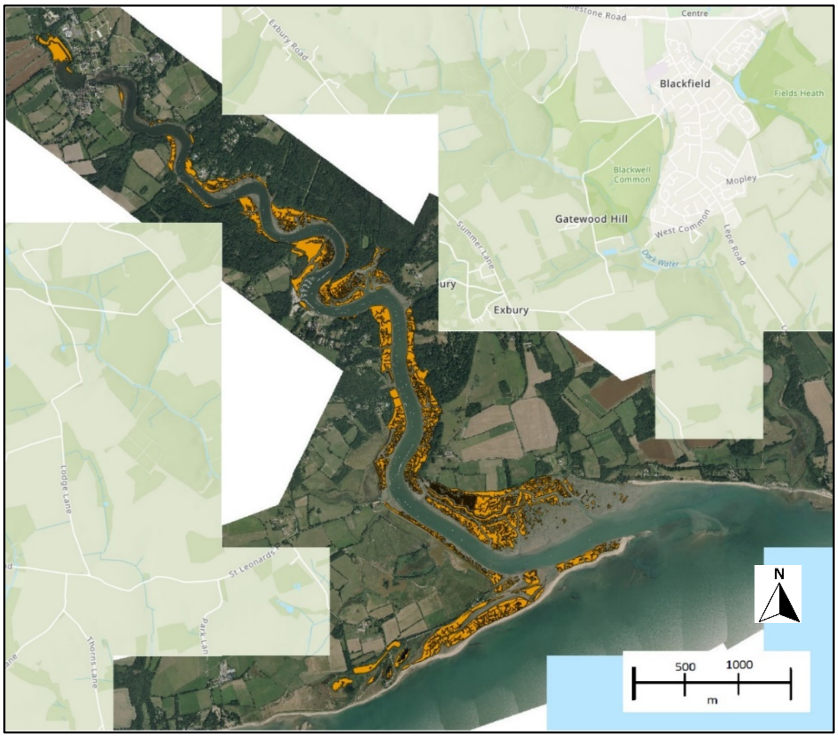



**Figure 44b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Beaulieu River in 2016, retrieved from the Environment agency (EA, 2020).

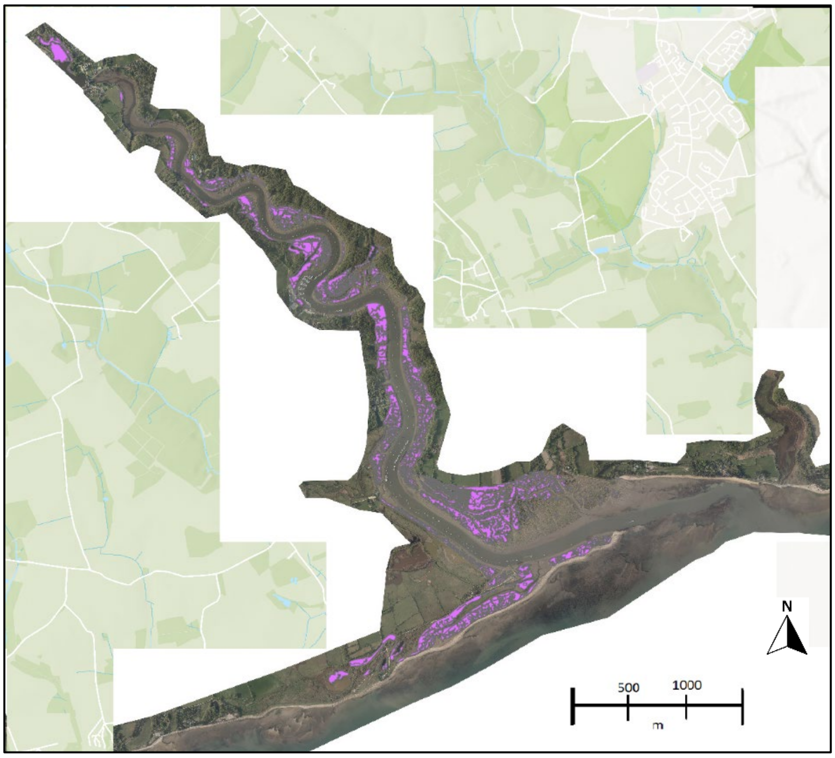



**Figure 44c.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Beaulieu River in 2019, retrieved from the Environment agency (EA, 2020).

## Pitts Deep and Sowley

Changes between 1971 and 2019 (Figures 45 and 49), had a 91.52% saltmarsh loss (Figure 46), which equates to 1.41% $yr^{-1}$ (Table 17). Changes between 2001 and 2008, revealed the greatest rate of loss, being 5.97% $yr^{-1}$. Changes between 2016 and 2019 had the smallest rate of loss, being 0.63% $yr^{-1}$. Changes between 2016 and 2019 had zero saltmarsh loss.

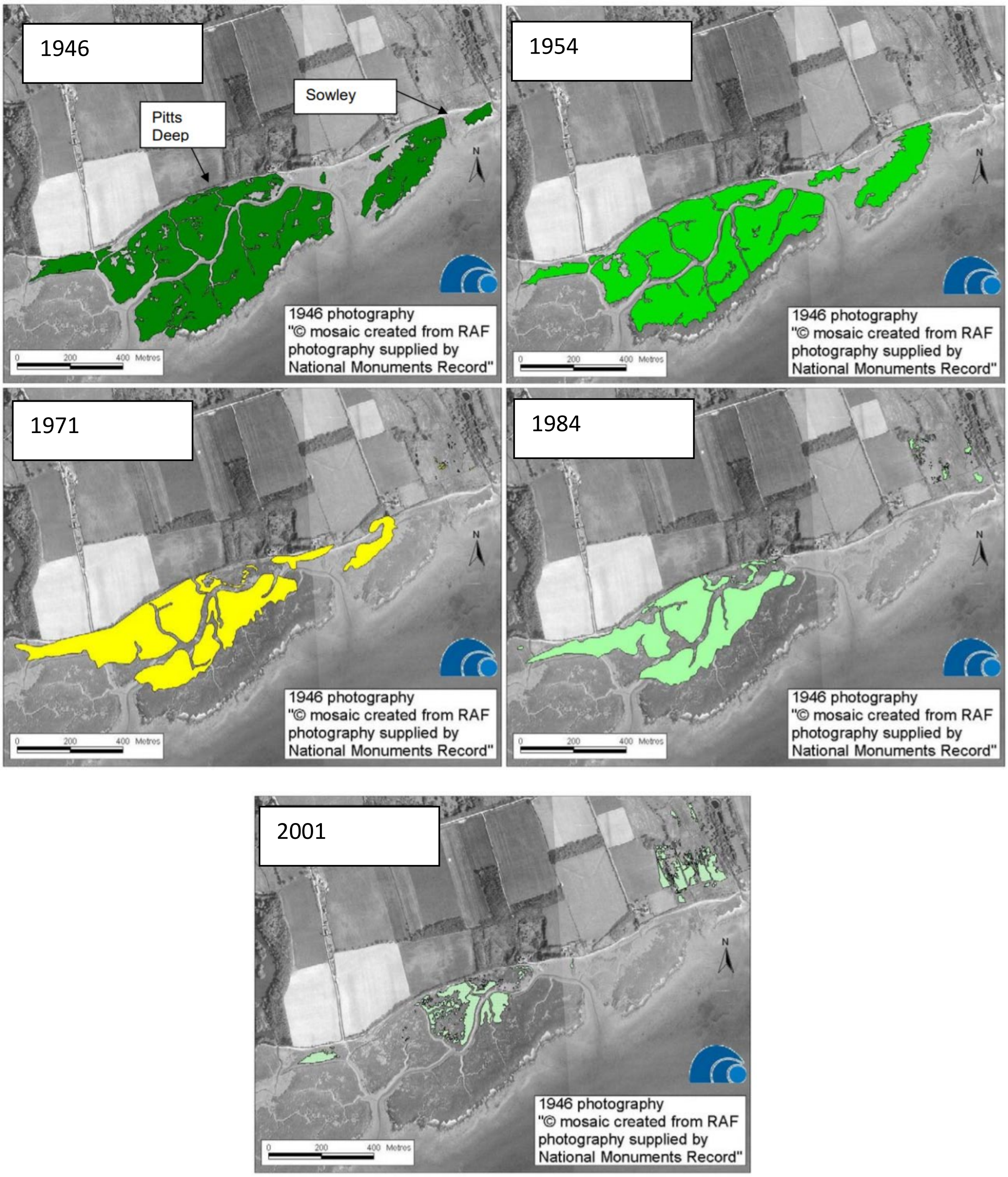



**Figure 45.** Saltmarsh extent at Pitts Deep and Sowley (Cope *et al.*, 2008).

(2008 Channel Coastal Observatory, © New Forest District Council, reproduced with permission)

**Table 17.** Saltmarsh extent at Pitts Deep and Sowley.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| 1954 | 33 | | % Change | % loss $yr^{-1}$ |
| 1971 | 21.6 | 1954-1971 | -34.55 | -2.03 |
| 1984 | 16.1 | 1971-1984 | -25.46 | -1.96 |
| 2001 | 6.7 | 1984-2001 | -58.39 | -3.43 |
| 2008 | 3.9 | 2001-2008 | -41.79 | -5.97 |
| 2016 | 2.8 | 2008-2016 | -28.21 | -3.53 |
| 2019 | 2.8 | 2016-2019 | 0.00 | 0.00 |
| | | 1954-2019 | -91.52 | -1.41 |

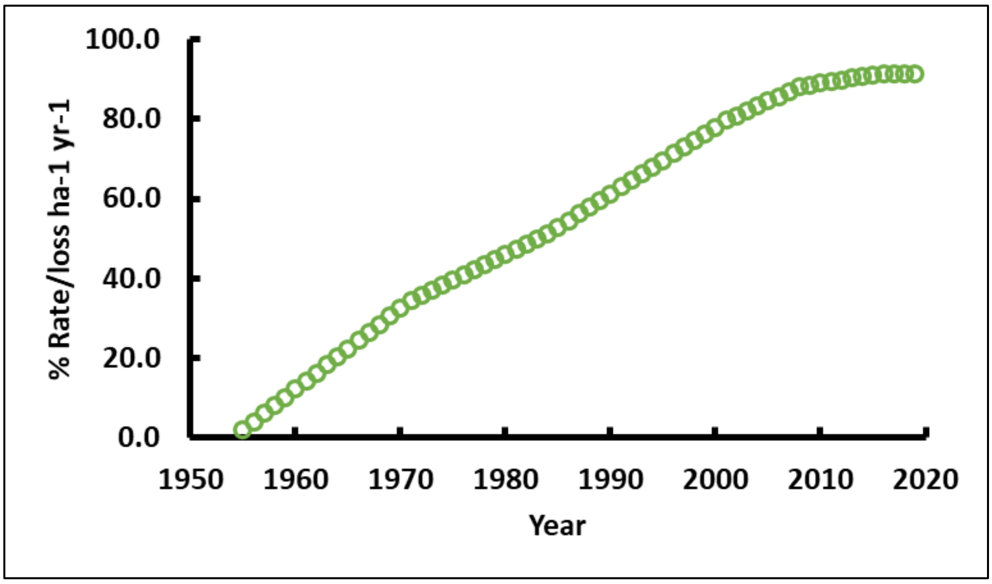
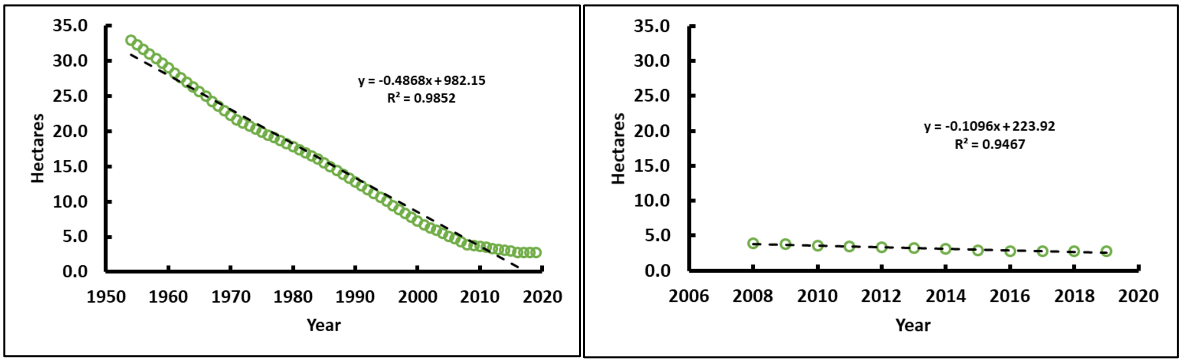



**Figure 46.** The total percentage rate of saltmarsh loss for Pitts Deep and Sowley from 1954 to 2019.

The worst-case scenario in Pitts Deep and Sowley for loss of the saltmarsh extent is between 1971 and 2019 (Figure 47A). Using this data the total rate of decline from 1971 to 2019 (Regression analysis (all years): $F_{1,78}$ = 4277.7, $p \leq 0.001$, $R^2$ = 98.5%), estimates that saltmarsh would reach zero hectares by 2019 (Table 18). The best-case scenario in Pitts Deep and Sowley is between 2008 and 2019 (Figure 47B). Using this data the rate of decline from 2008 to 2019 (Regression analysis (from 1971): $F_{1,34}$ = 151.6, $p \leq 0.001$, $R^2$ = 93.8%), estimates that saltmarsh would reach zero hectares by 2045 (Table 18). Work from the SDCP (Cope et al., 2008) estimated that the best-case scenario would predict around zero hectares of saltmarsh by 2017, whereas the worst-case scenario predicted zero saltmarsh by 2010. Therefore, both previous estimates of saltmarsh loss of the SDCP have been extended, however the ecological function of the saltmarsh at this site may now be extinct due to the small size of the remaining saltmarsh (Cope *et al.,* 2008).

**Table 18.** Worst-case scenario for expected zero saltmarsh at Pitts Deep and Sowley.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| **Worst-case** | **1954 - 2019** | **2019** |
| **Best-case** | **2008 - 2019** | **2045** |



*Saltmarsh species zonation classification of 2016*

Pitts deep is dominated by islands of *Spartina* species (Figure 48). The shore has a band of upper saltmarsh species and some mid-low saltmarsh species. To the west of the shore a small cluster of pioneer species behind the sandy bank. Due to the lack of species and sophistication of saltmarsh, it could be argued that this area of saltmarsh is functionally collapsed.


**Figure 48.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Pitts Deep and Sowley marshes in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 49a, 49b, 49c), had a net loss of 39.3% of saltmarsh, which equates to 3.6% $yr^{-1}$. This is the greatest rate of saltmarsh loss across the Solent. This is a high annual rate of loss for the size of the remaining marsh. The exposed seaward edge of the marsh is particularly vulnerable to wave attack. Therefore, the dominant erosive processes are edge erosion, occurring to the remaining *Spartina* marshes. This is supported in the reduction of saltmarsh polygons from 120 to 112, between 2008 and 2019, respectively. Small internal dissection occurs throughout the remaining marsh, heightening the vulnerability of the remaining marsh to edge erosion. Sowley has completely disappeared except for a few clusters of small *Spartina* marsh, however so little remained it was not documented in the classification zones.

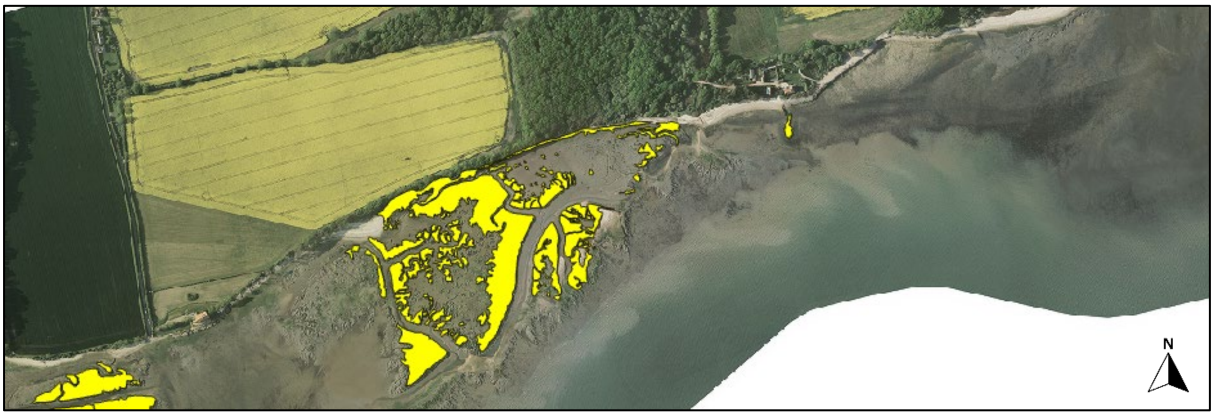



**Figure 49a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Pitts deep and Sowley in 2008, retrieved from the Environment agency (EA, 2020).


**Figure 49b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Pitts Deep and Sowley in 2016, retrieved from the Environment agency (EA, 2020).

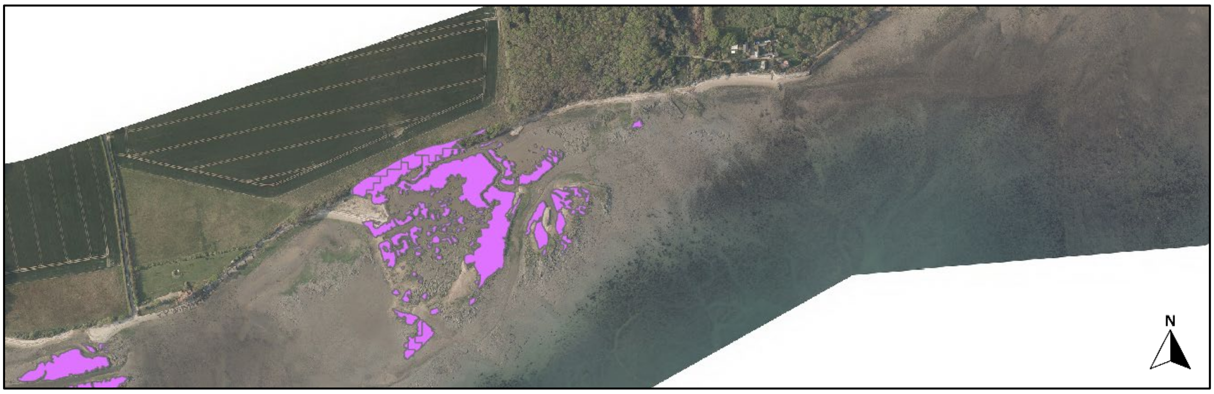



**Figure 49c.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Pitts Deep and Sowley in 2019, retrieved from the Environment agency (EA, 2020).

### Lymington River Estuary

Changes between 1971 and 2019 (Figure 50), had a 67.71% saltmarsh loss (Figure 51), which equates to 0.92% $yr^{-1}$ (Table 19). Changes between 1984 and 2001, revealed the greatest rate of loss, being 4.52% $yr^{-1}$. Changes between 2016 and 2019 had the smallest rate of loss, being 0.63% $yr^{-1}$.

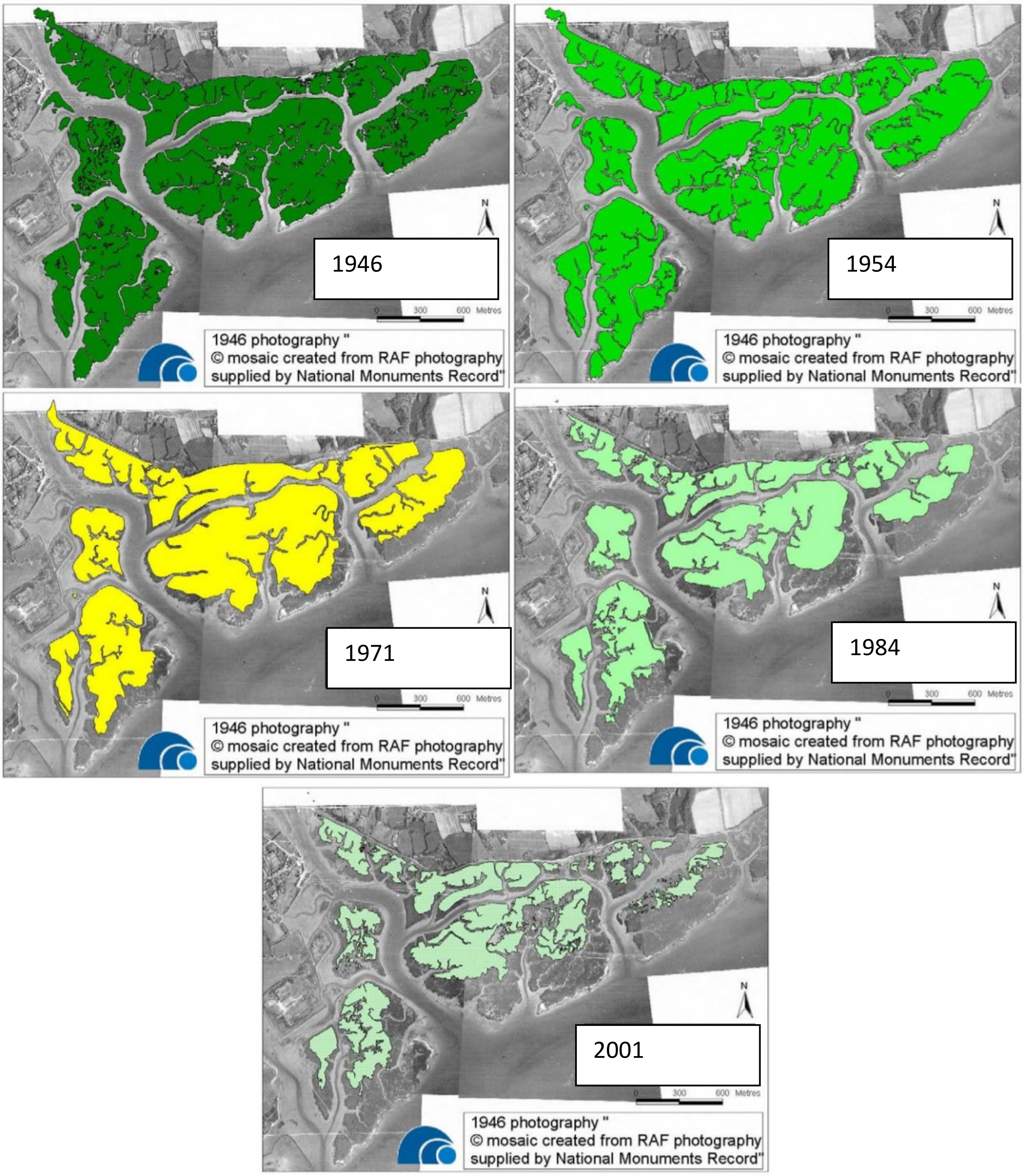



**Figure 50.** Saltmarsh extent at Lymington River Estuary (Cope *et al.*, 2008).
(2008 Channel Coastal Observatory, © New Forest District Council, reproduced with permission)

**Table 19.** Saltmarsh extent at Lymington River Estuary.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| 1946 | 266.3 | | % Change | % loss $yr^{-1}$ |
| 1954 | 248.7 | 1946-1954 | -6.61 | -0.94 |
| 1971 | 207.7 | 1954-1971 | -16.49 | -2.36 |
| 1984 | 162.2 | 1971-1984 | -21.91 | -3.13 |
| 2001 | 110.9 | 1984-2001 | -31.63 | -4.52 |
| 2008 | 100 | 2001-2008 | -9.83 | -1.40 |
| 2016 | 90 | 2008-2016 | -10.00 | -1.43 |
| 2019 | 86 | 2016-2019 | -4.44 | -0.63 |
| | | 1956-2019 | -67.71 | -0.92 |

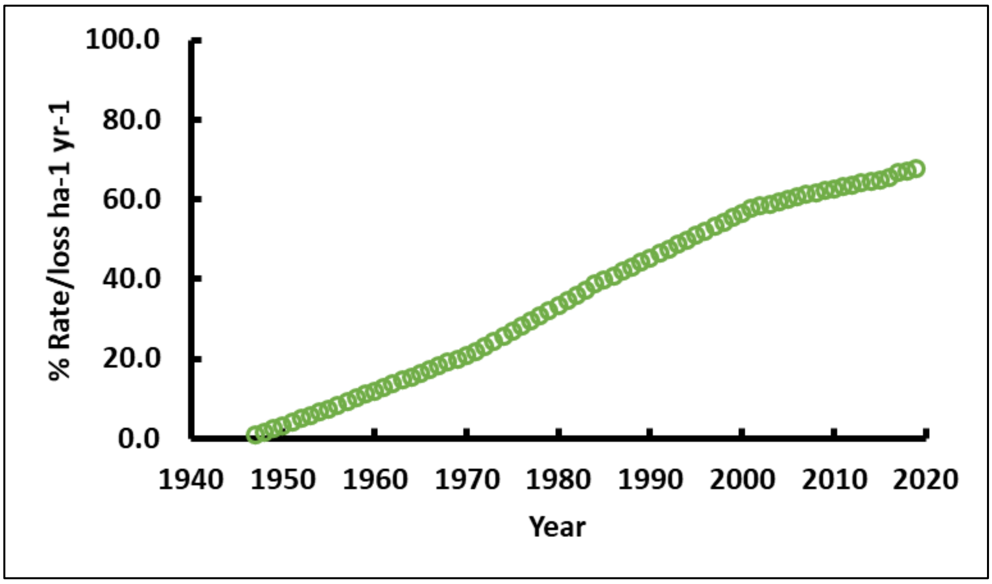



**Figure 51**. The total percentage rate of saltmarsh loss for Lymington River Estuary from 1946 to 2019.

The worst-case scenario in Lymington for loss of the saltmarsh extent is between 1946 and 2019 (Figure 52). Using this data the total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 7837.8, $p \leq 0.001$, $R^2$ = 99.1%), estimates that saltmarsh would reach zero hectares by April 2045 (Table 20). Lymington's current rate of loss is consistent and linear and thus a best-case scenario could not be worked out. Work from the SDCP (Cope et al., 2008) estimated that the worst-case scenario would predict around zero hectares of saltmarsh by 2052, whereas the worst-case scenario predicted zero saltmarsh by 2038. Therefore, the current estimate of saltmarsh loss fits perfectly between the best-case and worst-case estimates of the SDCP (Cope *et al.,* 2008).

**Table 20.** Worst-case scenario for expected zero saltmarsh at Lymington.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| **Worst-case** | **1946 - 2019** | **April 2045** |

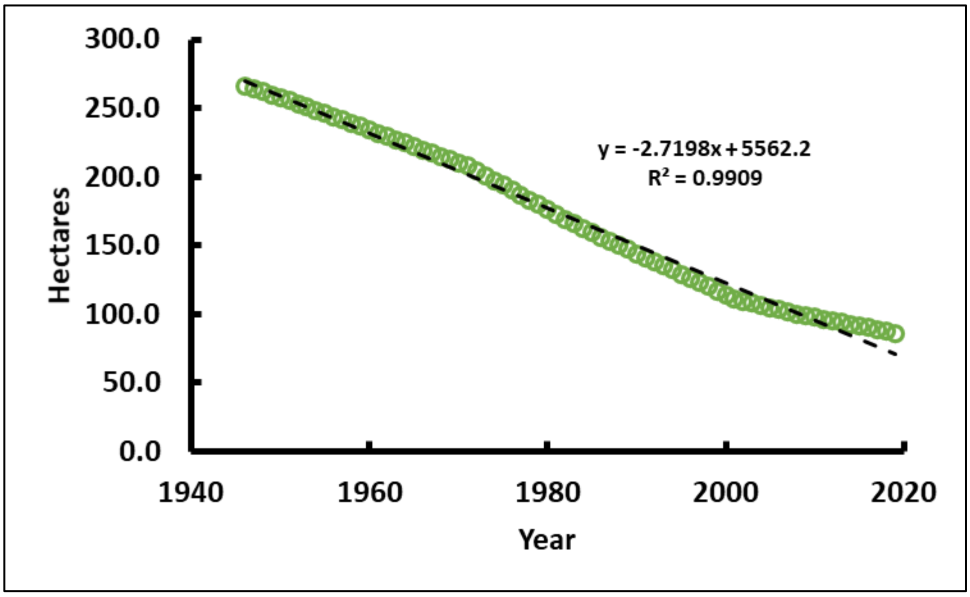



**Figure 52.** Regression analysis for saltmarsh loss in Lymington River Estuary. **A)** the total rate of decline from 1946 to 2019 (Regression analysis (all years): $F_{1,78}$ = 7837.8, $p \leq 0.001$, $R^2$ = 99.1%). Using these data, we estimate saltmarsh will reach zero hectares by April 2045.

### *Saltmarsh species zonation classification of 2016*

Lymington marshes are dominated almost entirely by *Spartina* species (Figure 53). At East Lake there are a collection of pioneer species, scattered at the lower water marks of the marsh. Mid-low species surround the channels on the east of East Lake. Small clusters of pioneer species are found all over the northern parts of the marshes. South of Crooked Lake Pioneer species are present near the raised banks**.** Mid-low saltmarsh species can be found on the higher reaches of the marsh behind the raised bank at Crooked Lake. Upper and mid-low saltmarsh species are present in the reclaimed area behind the old cliff line.

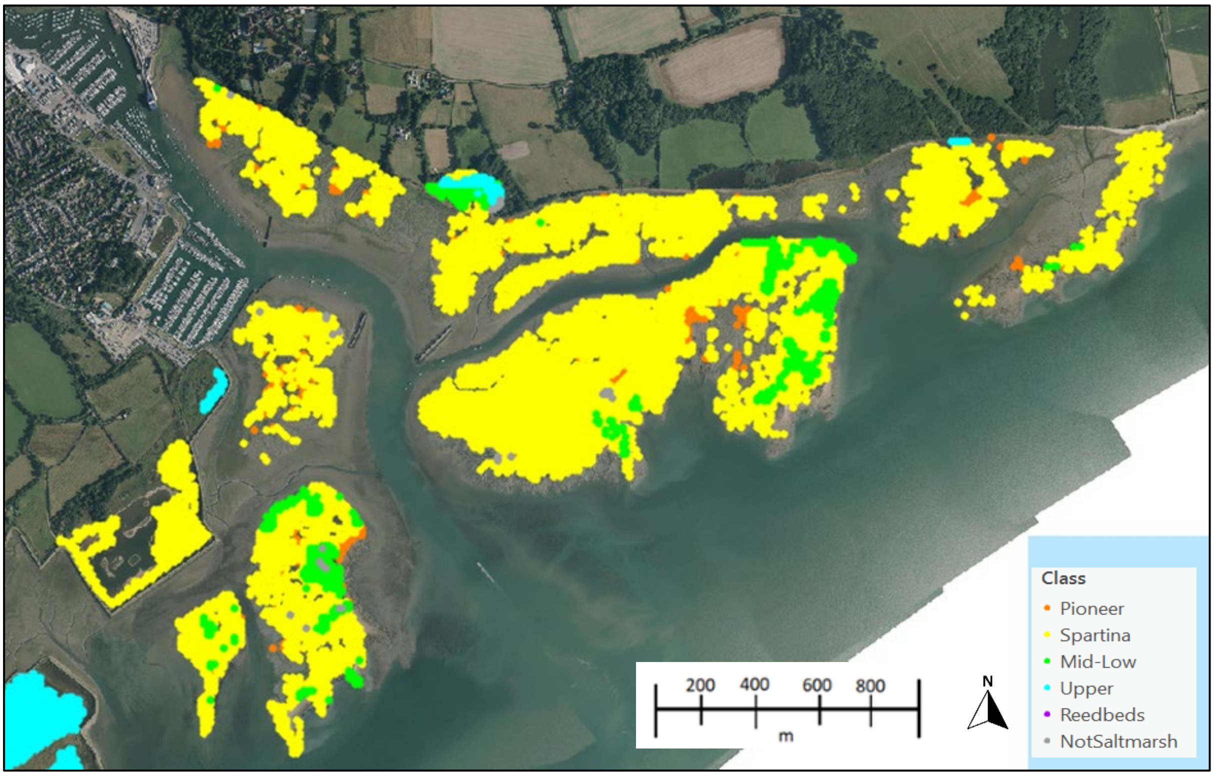



**Figure 53.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Lymington river estuary in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 54a, 54b and 54c), had a net loss of 16.3% of saltmarsh, which equates to 1.5% $yr^{-1}$. This rate is 0.5% per greater than behind Hurst Spit and 0.2% $yr^{-1}$ slower than at Keyhaven. The dominant erosive processes are saltmarsh fragmentation, a result of exposed *Spartina* marsh to easterly wave attack. The number of saltmarsh polygons increased from 299 to 1182, between 2008 and 2019, respectively. As a result, all seaward edges of saltmarsh at Lymington have shown erosion. Marsh directly east of Lymington Harbour suggested a great rate of marsh retreat, this may be due to the funnelling motion of sea water from the barrier in front of the saltmarsh south of the harbour. Internal dissection occurred greatly to the inner reaches of the entire marsh, predominantly removing *Spartina* species. To the east there were localised patches of saltmarsh gain, from the recruitment of pioneer species and *spartina* swards.

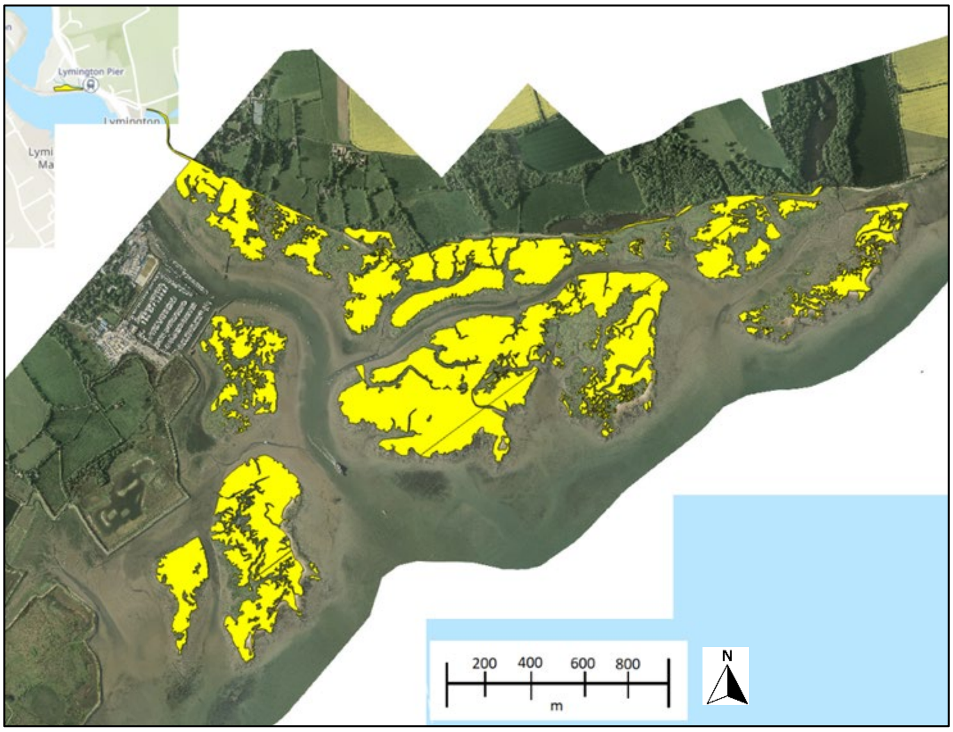



**Figure 54a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Lymington River Estuary in 2008, retrieved from the Environment agency (EA, 2020).


**Figure 54b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Lymington River Estuary in 2016, retrieved from the Environment agency (EA, 2020).

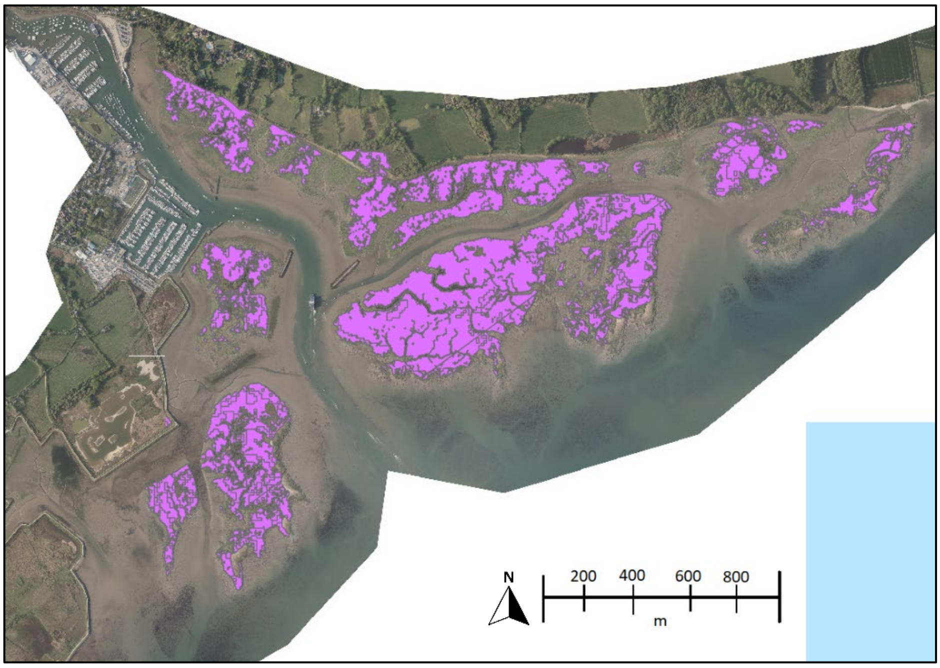



**Figure 54c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Lymington River Estuary in 2019, retrieved from the Environment agency (EA, 2020).

## Keyhaven

Changes between 1971 and 2019 (Figure 55), had a 62% saltmarsh loss (Figure 56), which equates to 1.29% $yr^{-1}$ (Table 21). Changes between 2008 and 2016, revealed the greatest rate of loss, being 2.44% $yr^{-1}$. Changes between 2016 and 2019 had zero saltmarsh loss. Historically massive losses of saltmarsh were seen from the internal dissection along the channel of the marsh.

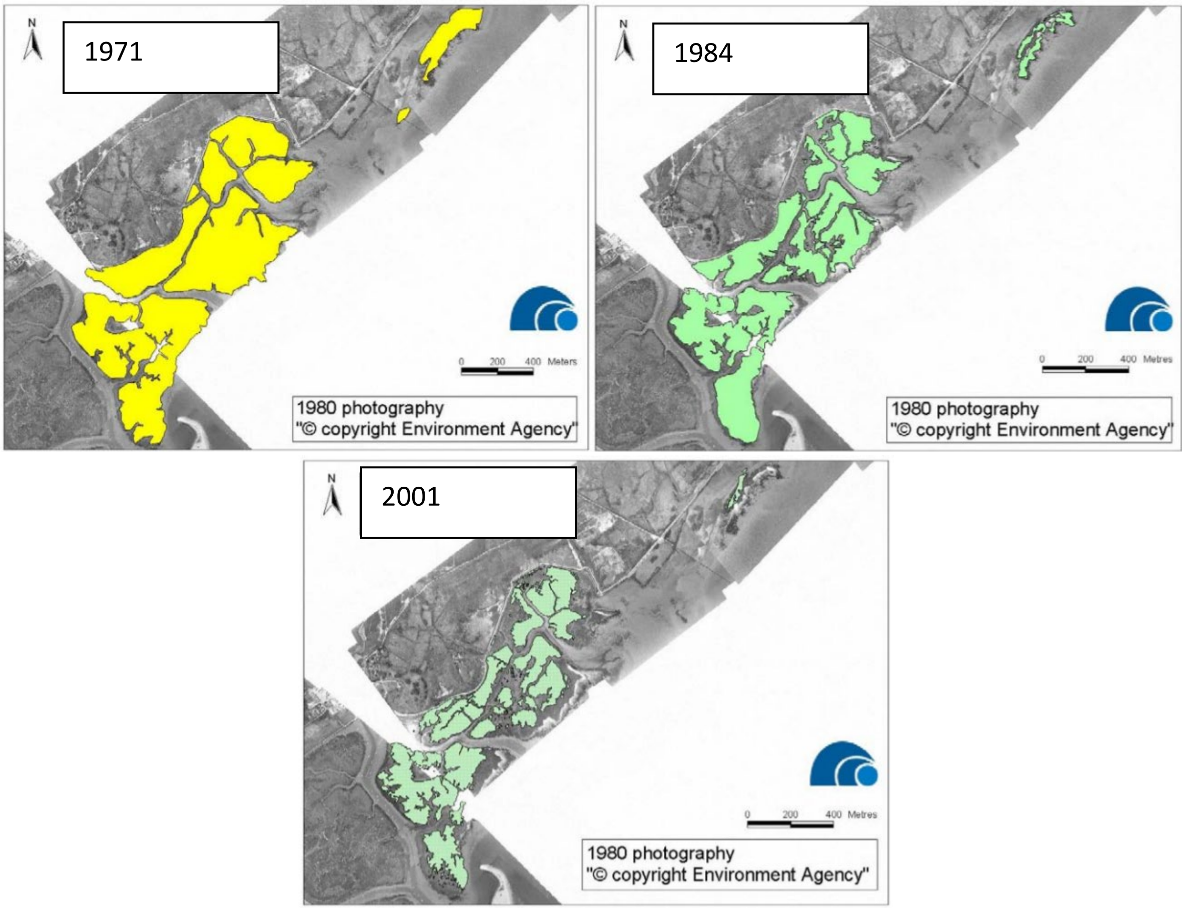



**Figure 55.** Saltmarsh extent at Keyhaven (Cope *et al*., 2008).
(2008 Channel Coastal Observatory, © New Forest District Council, reproduced with permission)

**Table 21.** Saltmarsh extent at Keyhaven.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % loss $yr^{-1}$ |
| 1971 | 85.8 | | | |
| 1984 | 61.3 | 1971-1984 | -5.84 | -0.45 |
| 2001 | 43 | 1984-2001 | -31.38 | -1.85 |
| 2008 | 39.3 | 2001-2008 | -8.60 | -1.23 |
| 2016 | 32.6 | 2008-2016 | -17.05 | -2.44 |
| 2019 | 32.6 | 2016-2019 | 0.00 | 0.00 |
| | | 1971-2019 | -62.00 | -1.29 |

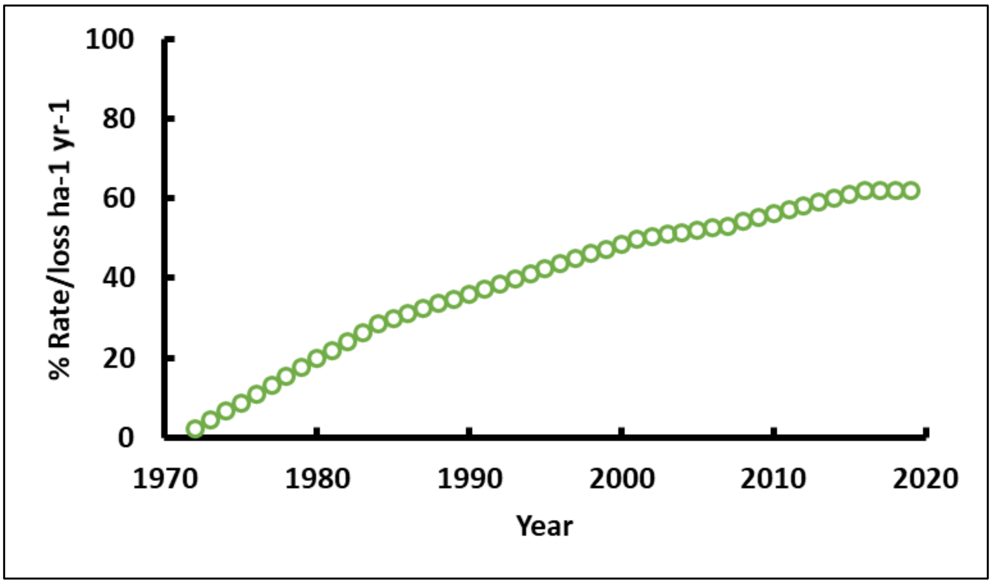



Figure 56. The total percentage rate of saltmarsh loss for Keyhaven from 1971 to 2019.

The worst-case scenario in Keyhaven for loss of the saltmarsh extent is between 1971 and 2019 (Figure 57). Using this data the total rate of decline from 1971 to 2019 (Regression analysis (all years): $F_{1,78}$ = 1100.8, $p \leq 0.001$, $R^2$ = 95.9%), estimates that saltmarsh would reach zero hectares by June 2043 (Table 22). Keyhaven's current rate of loss is consistent and linear and thus a best-case scenario could not be worked out. Work from the SDCP (Cope et al., 2008) estimated that the best-case scenario would predict around zero hectares of saltmarsh by 2042, whereas the worst-case scenario predicted zero saltmarsh by 2024. Therefore, the current estimate of saltmarsh loss is currently following the best-case scenario of the previous estimate.

**Table 22.** Worst-case scenario for expected zero saltmarsh at Keyhaven.

| | **Regression periods** | **Expected Zero Marsh** |
|---|---|---|
| **Worst-case** | **1971 - 2019** | **June - 2043** |

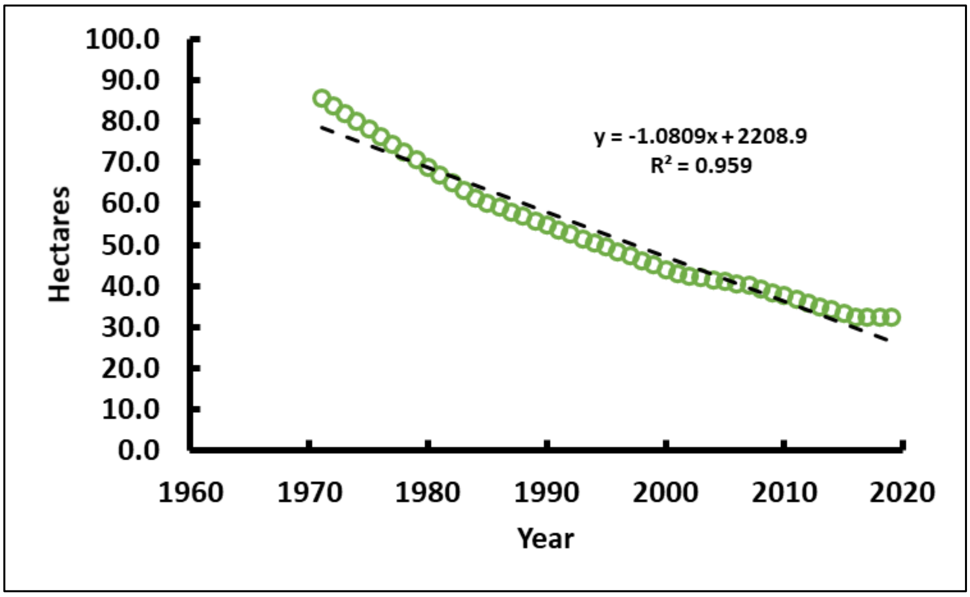



**Figure 57.** Regression analysis for saltmarsh loss in Keyhaven. **A)** the total rate of decline from 1971 to 2019 (Regression analysis (all years): $F_{1,78}$ = 1100.8, $p \leq 0.001$, $R^2$ = 95.9%). Using these data, we estimate saltmarsh will reach zero hectares by June 2043.

### *Saltmarsh species zonation classification of 2016*

Keyhaven has a large area of *Spartina* species in front of the seawall to the centre (Figure 58). A band of upper saltmarsh species colonise an area along the seawall, with spartina species to the front. Hawker's Lake separates two distinct areas of saltmarsh, where Mid-low saltmarsh species dominate the southernly areas of Keyhaven. Large areas of upper saltmarsh species have developed behind the seawall. To the north-east, behind the seawall, Normandy Lagoon is entirely inhabited by *Spartina* species.

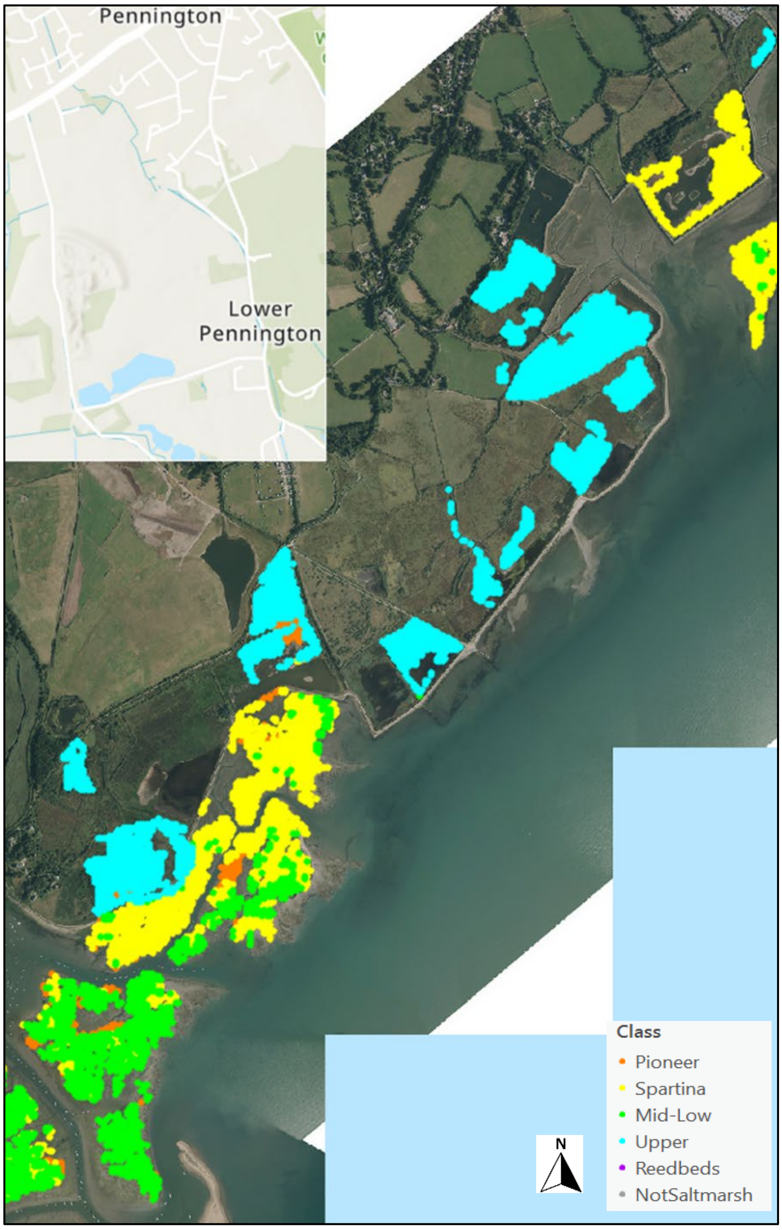



**Figure 58.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Keyhaven marshes in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 59a, 59b, 59c), had a net loss of 20.5% of saltmarsh, which equates to 1.9% $yr^{-1}$. This is the second greatest rate of erosion seen across the whole of the Solent. This rate is 0.7% $yr^{-1}$ greater than behind Hurst Spit. The dominant erosive processes are edge erosion and saltmarsh fragmentation, a result of exposed marsh to easterly wave attack, removing large areas of *Spartina* marsh. Between 2008 and 2019, the number of saltmarsh polygons increased from 164 to 608, respectively. Collectively a large area of marsh has been lost due to internal dissection, particularly to the mid marsh species to the south east. As a result of edge erosion, the *Spartina* island to the east of the main marshes, in front of the seawall, have completely disappeared.

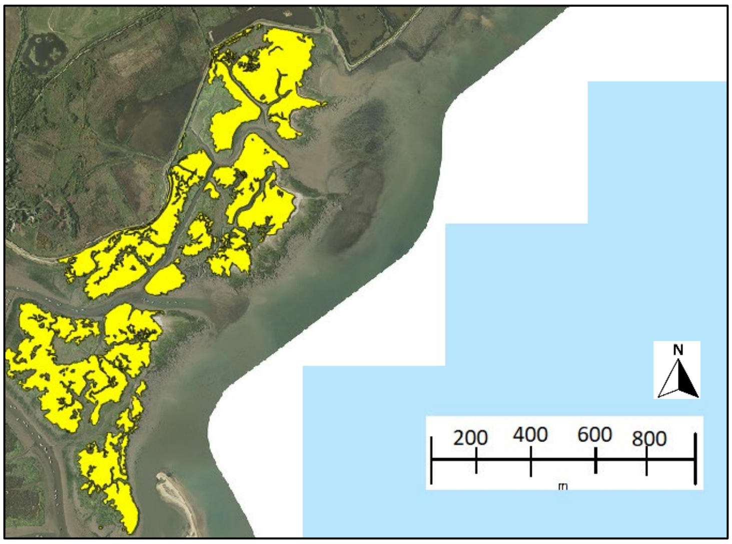



**Figure 59a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Keyhaven Marshes in 2008, retrieved from the Environment agency (EA, 2020).

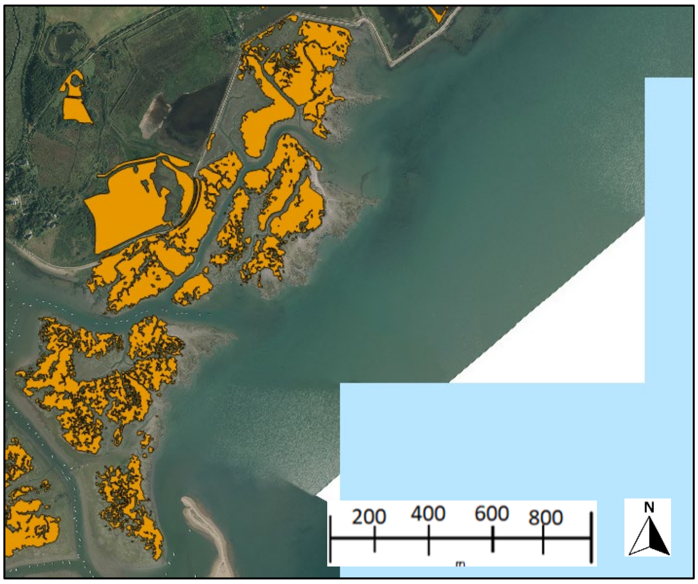



**Figure 59b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Keyhaven Marshes in 2016, retrieved from the Environment agency (EA, 2020).


**Figure 59c.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Keyhaven Marshes in 2019, retrieved from the Environment agency (EA, 2020).

*Broad Site Saltmarsh Extent Data Review*

The saltmarsh extent between 2008 and 2019 (Figure 60a, 60b and 60c) had a net loss of 9.1% of saltmarsh, which equates to 0.82% $yr^{-1}$. Saltmarsh extent differs here to the previous historical comparisons as saltmarsh species are present behind the seawall, which were previously not included. There is no change in saltmarsh between the datasets of 2008-2019 for the saltmarsh behind the seawall. Changes to the saltmarsh were documented previously in the report within the Keyhaven site.


Figure 60a. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Keyhaven Marshes in 2008, retrieved from the Environment agency (EA, 2020).

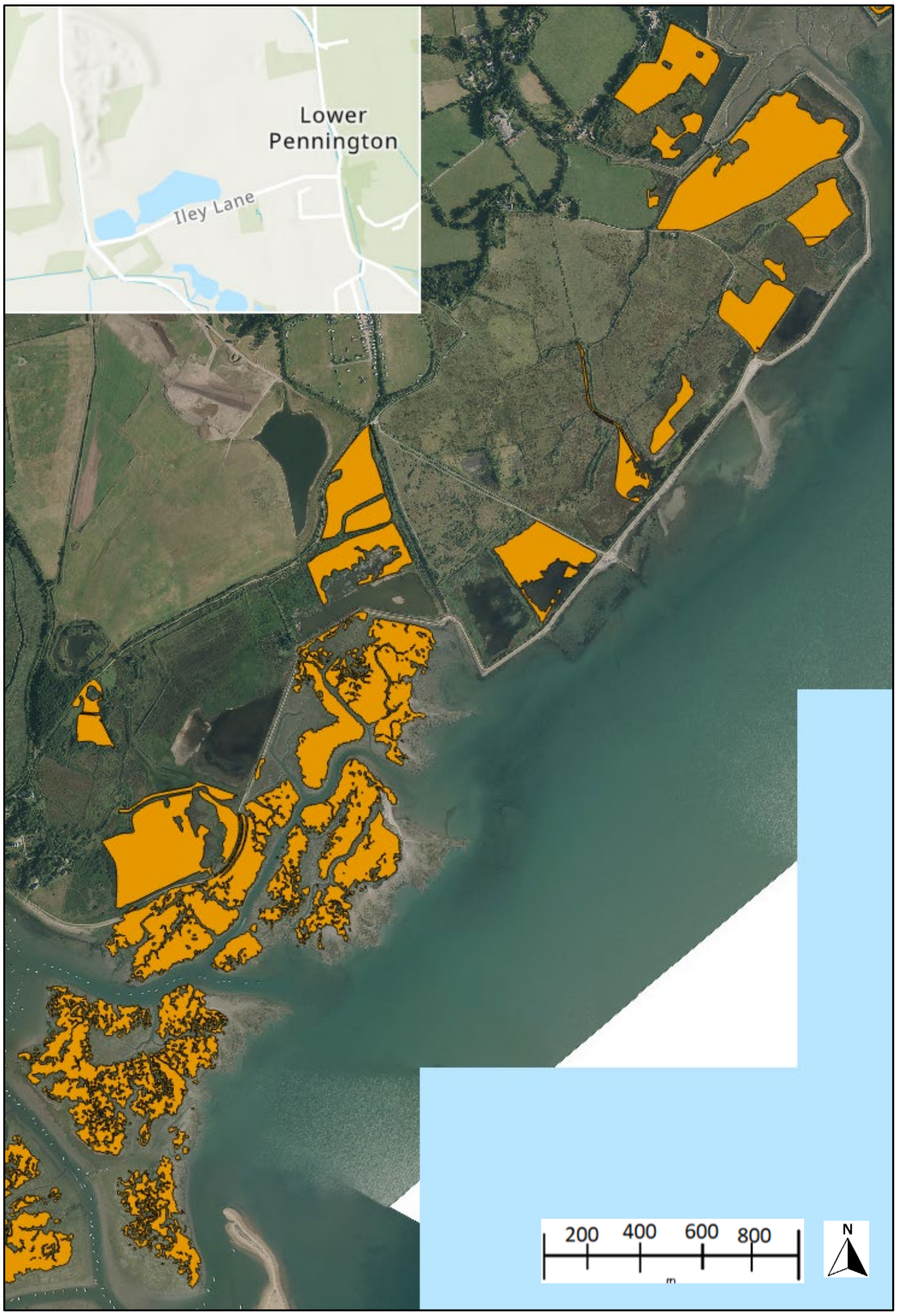



**Figure 60b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Keyhaven Marshes in 2016, retrieved from the Environment agency (EA, 2020).

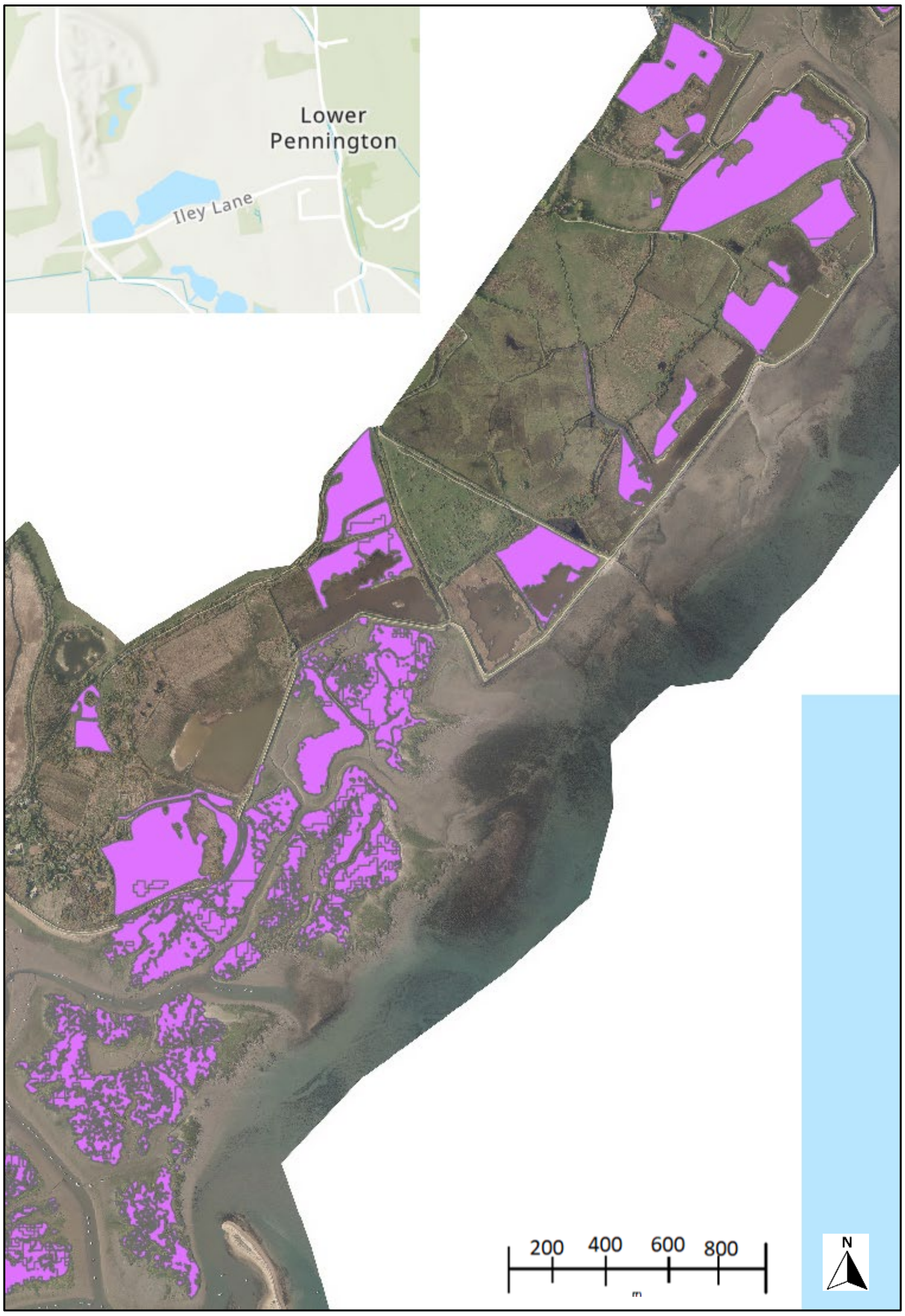



**Figure 60c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Keyhaven Marshes in 2019, retrieved from the Environment agency (EA, 2020).

## Hurst Spit

Changes between 1954 and 2019 (Figure 61), had a 42.58% saltmarsh loss (Figure 62), which equates to 0.85% $yr^{-1}$ (Table 23). Changes between 1984 and 2001 revealed the greatest rate of loss, being 1.85% $yr^{-1}$. Changes between 2001 and 2008, had a 3.63% rate of gain, being 0.52% $yr^{-1}$. Changes between 2016 and 2019 had zero saltmarsh loss. Changes between 2016 and 2019 revealed the smallest rate of loss, being 0.02% $yr^{-1}$.

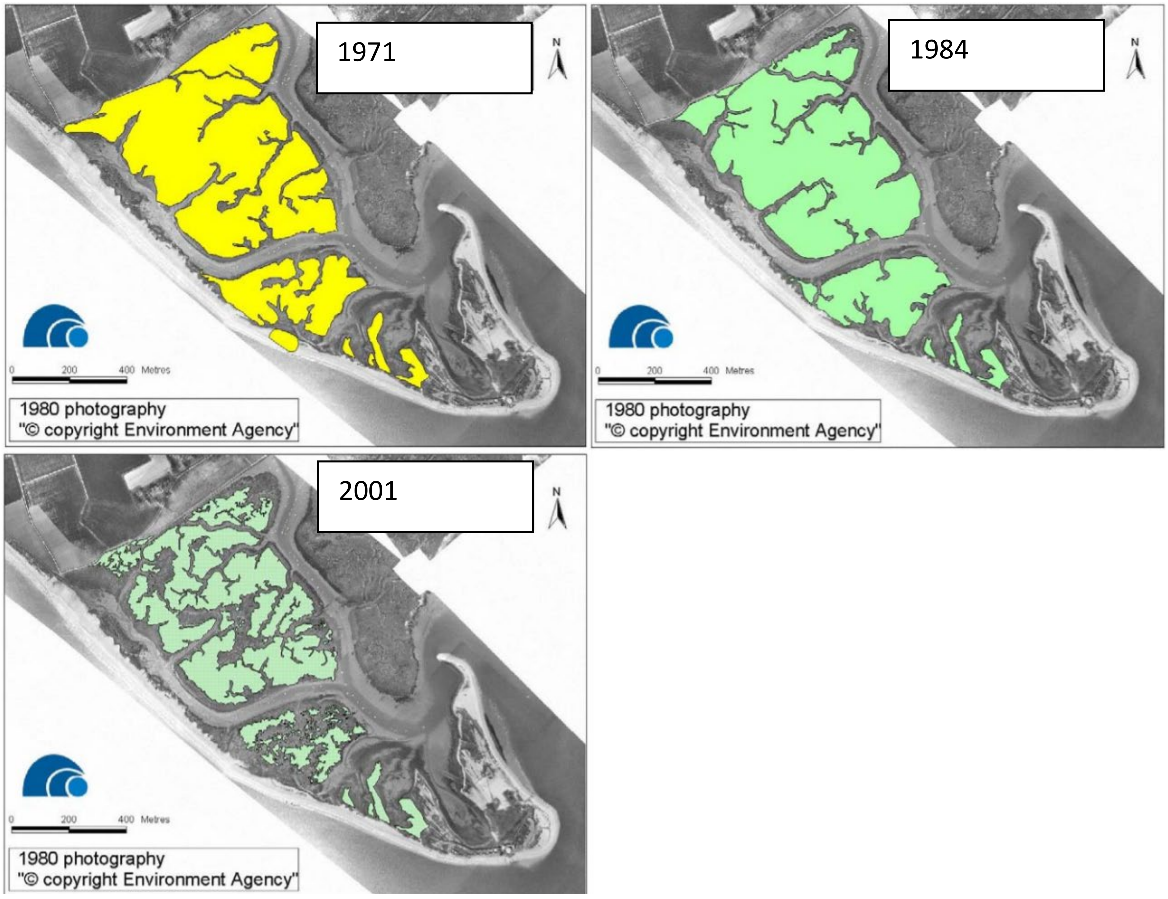



**Figure 61.** Saltmarsh extent at Hurst Spit (Cope *et al*., 2008).

(2008 Channel Coastal Observatory, © New Forest District Council, reproduced with permission)

**Table 23.** Saltmarsh extent at Hurst Spit Estuary.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % loss $yr^{-1}$ |
| 1971 | 61.6 | | | |
| 1984 | 58 | 1971-1984 | -5.84 | -0.45 |
| 2001 | 39.8 | 1984-2001 | -31.38 | -1.85 |
| 2008 | 41.3 | 2001-2008 | +3.63 | +0.52 |
| 2016 | 36.6 | 2008-2016 | -11.38 | -1.63 |
| 2019 | 36.6 | 2016-2019 | 0.00 | 0.00 |
| | | 1971-2019 | -40.58 | -0.85 |

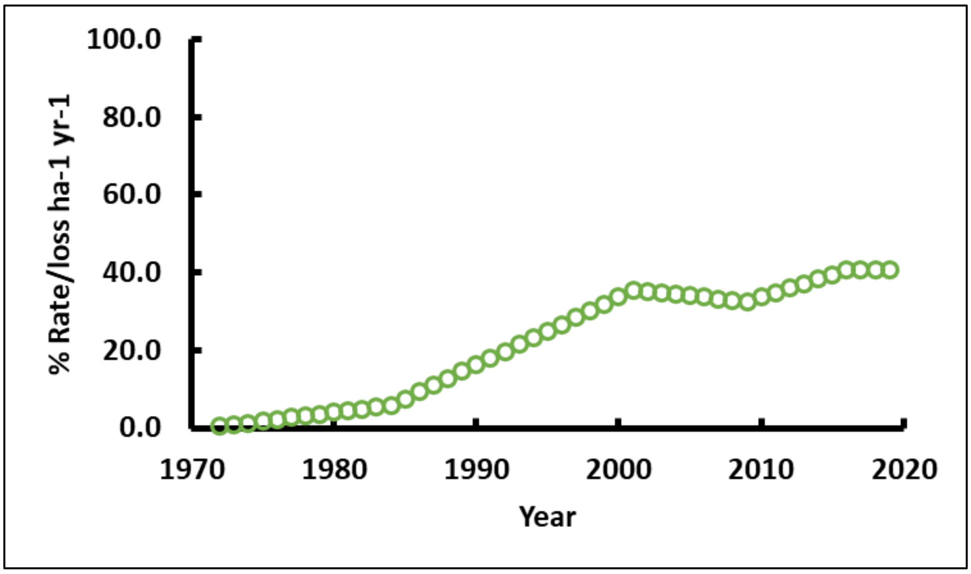



**Figure 62.** The total percentage rate of saltmarsh loss for Hurst Spit from 1971 to 2019.

The worst-case scenario in Hurst Spit Marsh for loss of the saltmarsh extent is between 1971 and 2019 (Figure 63A). Using this data the total rate of decline from 1971to 2019 (Regression analysis (all years): $F_{1,78}$ = 801.9, $p \leq 0.001$, $R^2$ = 94.5%), estimates that saltmarsh would reach zero hectares by February 2074 (Table 24). The best-case scenario in Hurst Spit Marsh is between 2001 and 2019 (Figure 63B). Using this data the rate of decline from 2001 to 2019 (Regression analysis (from 1984): $F_{1,34}$ = 30.5, $p \leq 0.001$, $R^2$ = 64.2%), estimates that saltmarsh would reach zero hectares by 2168 (Table 24). Work from the SDCP (Cope et al., 2008) estimated that the best-case scenario would predict around 12 hectares of saltmarsh by 2100, whereas the worst-case scenario predicted zero saltmarsh by 2038. Therefore, both previous estimates of saltmarsh loss of the SDCP have been extended, with worst-case scenario being extended by 36 years (Cope *et al.,* 2008).

**Table 24.** Best and worst-case scenarios for expected zero saltmarsh at Hurst Spit.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| **Worst-case** | **1971 - 2019** | **February 2074** |
| **Best-case** | **2001 - 2019** | **2168** |

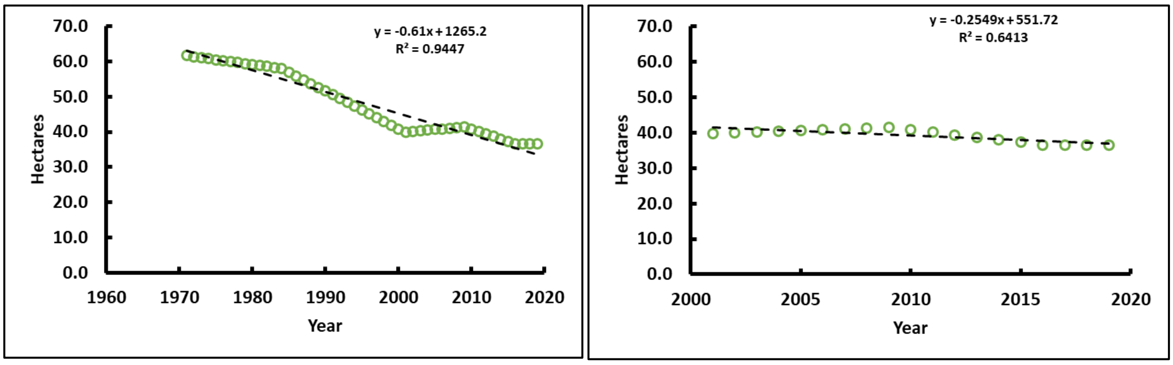



**Figure 63.** Regression analysis for saltmarsh loss in Hurst Spit. **A)** the total rate of decline from 1971 to 2019 (Regression analysis (all years): $F_{1,78}$ = 801.9, $p \leq 0.001$, $R^2$ = 94.5%). Using these data, we estimate saltmarsh will reach zero hectares by March 2074. **B)** the rate of decline from 2001 to 2019 (Regression analysis (from 1984): $F_{1,34}$ = 30.5, $p \leq 0.001$, $R^2$ = 64.2%). Using these data, we estimate saltmarsh will reach zero hectares by the 2168.

*Saltmarsh species zonation classification of 2016*

Hurst spit has a large mix of all saltmarsh species (Figure 64). Behind the Spit recurve is the largest collection of pioneer species across the Solent. Behind the old recurve is a strong patch of upper saltmarsh species, surrounded by pioneer species, largely due to the difference in elevation. The northern area of Hurst Spit is dominated by a mix of *Spartina* species and mid-low saltmarsh species. *Spartina* species dominate the saltmarsh closest to Saltgrass Lane. To the west a large cluster of Reedbeds and upper saltmarsh species occupy the area above Sturt Pond.

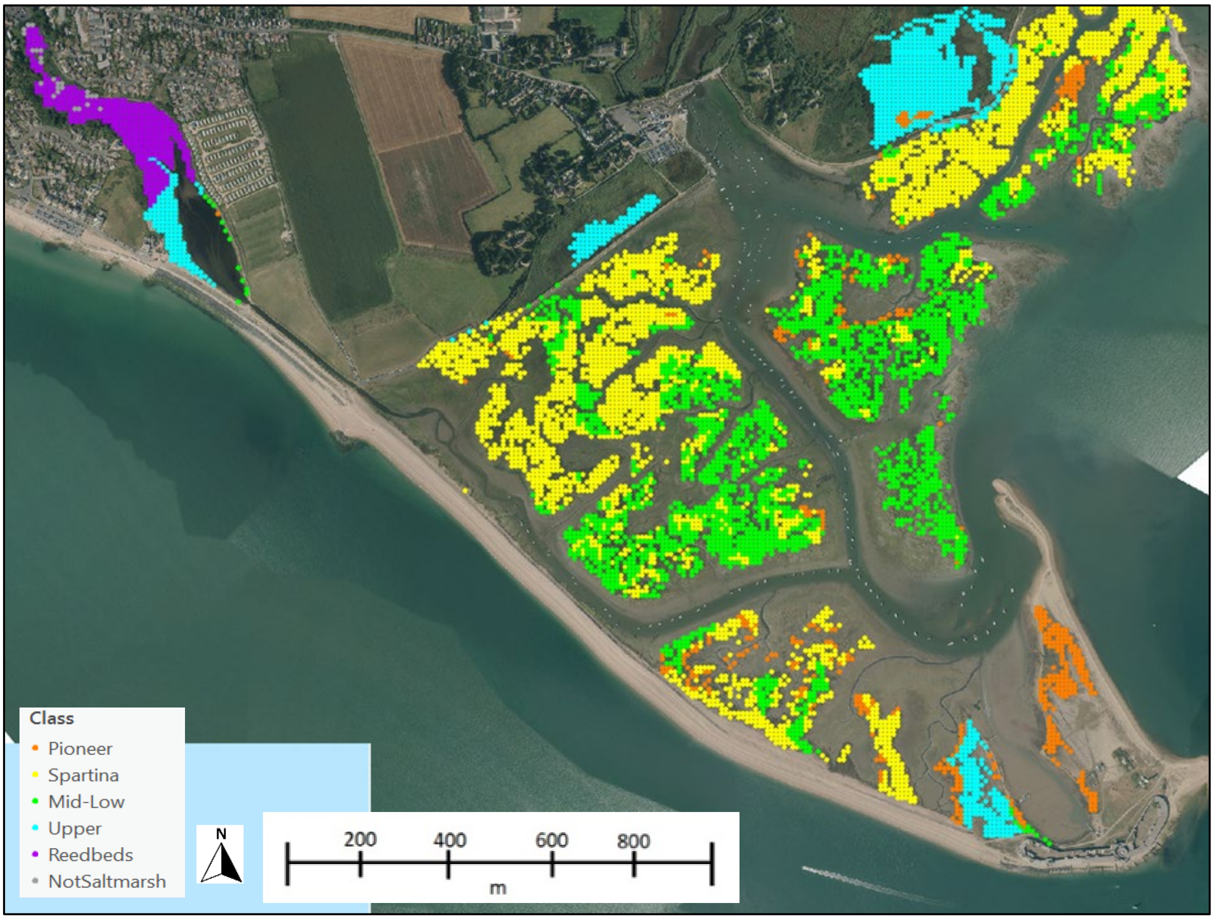



**Figure 64.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Hurst Spit area in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 65a, 65b and 65c), had a net loss of 12.8% of saltmarsh, which equates to 1.2% $yr^{-1}$. The dominant erosive processes are internal dissection, a historically prevalent issue at Hurst Spit (Cope *et al*., 2008). This is supported by the increase in saltmarsh polygons between 2008 and 2019, from 165 to 549, respectively. A large area of pioneer saltmarsh has been lost behind the last recurve of the spit. Some reclamation off saltmarsh occurred behind the old Spit recurve, where new pioneer species have established.

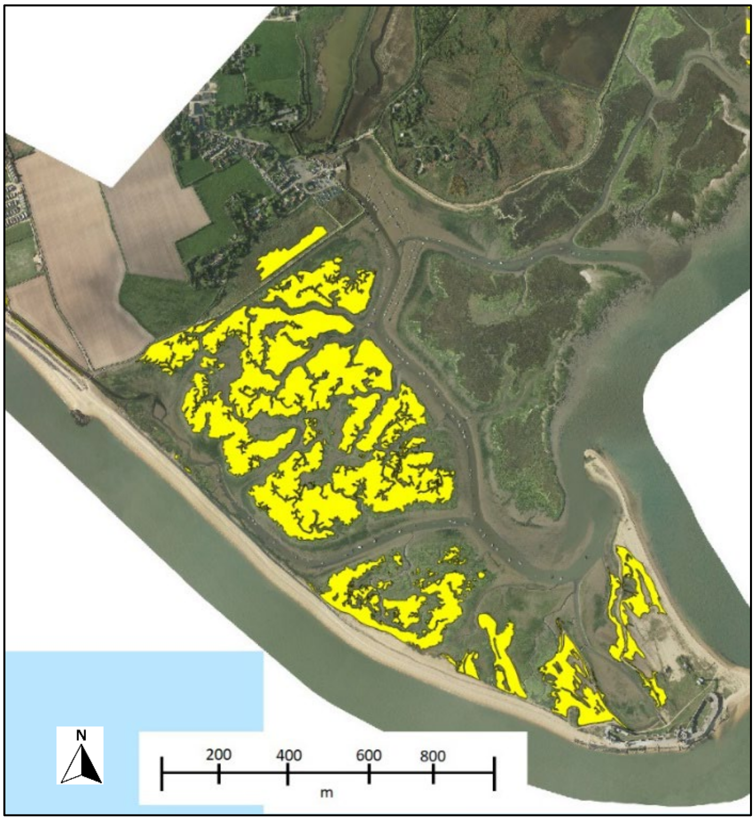



**Figure 65A**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Hurst Spit in 2008, retrieved from the Environment agency (EA, 2020).

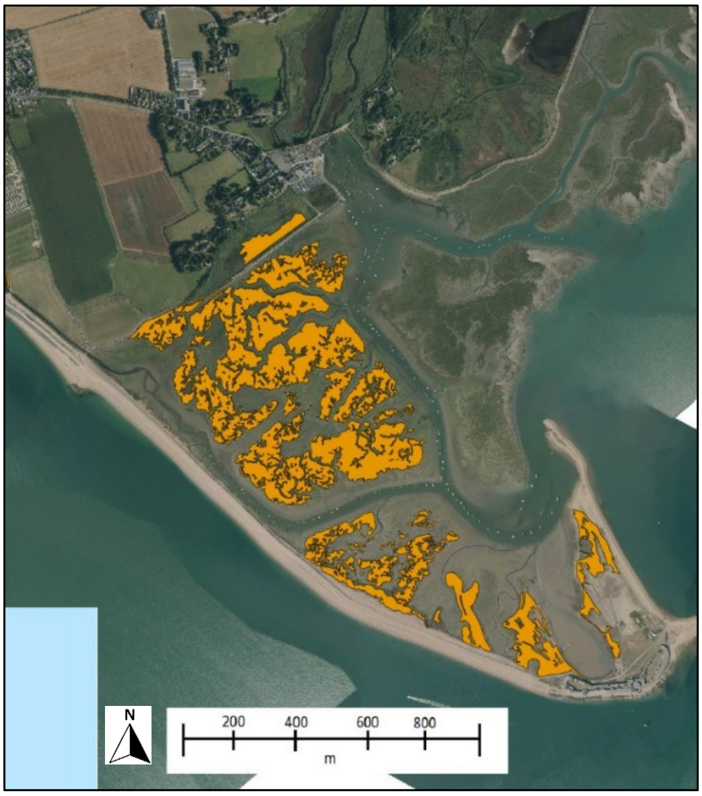



**Figure 65b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Hurst Spit in 2016, retrieved from the Environment agency (EA, 2020).


**Figure 65c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Hurst Spit in 2019, retrieved from the Environment agency (EA, 2020).

*Broad Site Saltmarsh Extent Data Review*

The saltmarsh extent between 2008 and 2019 (Figure 66a, 66b and 66c) had a net loss of 9.4% of saltmarsh, which equates to 0.85% $yr^{-1}$. Saltmarsh extent differs here to the previous historical comparisons as saltmarsh as saltmarsh species are present behind the seawall at the north of hurst spit and above Sturt Pond. There is little change between the datasets, except that saltmarsh extent grew from the edges at Sturt Pond.

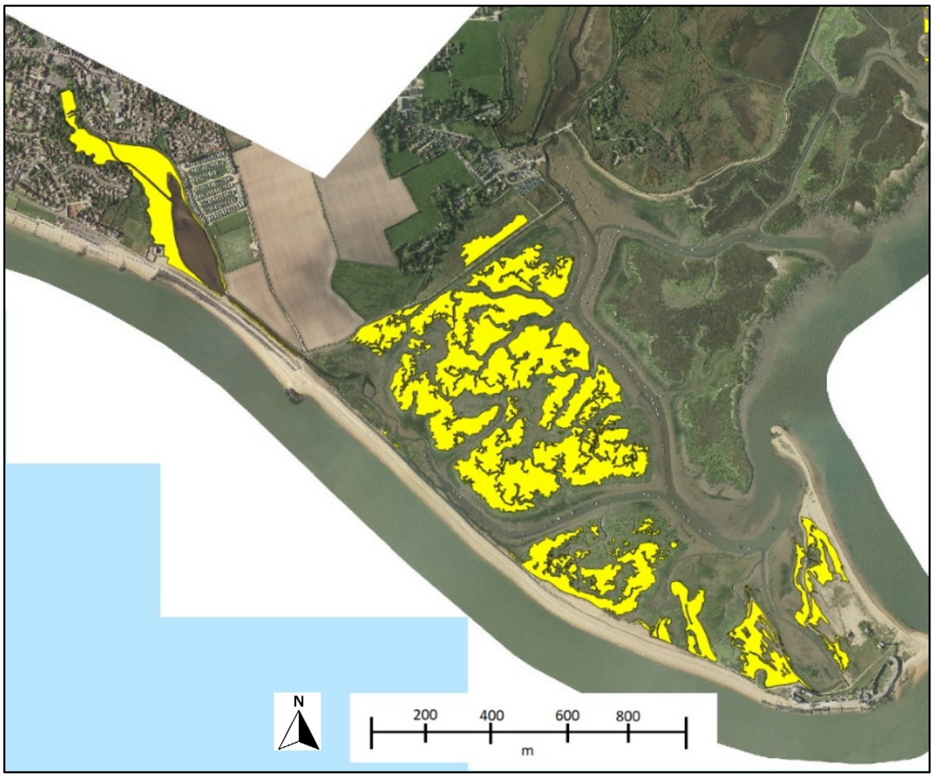



**Figure 66a.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Hurst Spit in 2008, retrieved from the Environment agency (EA, 2020).


**Figure 66b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Hurst Spit in 2016, retrieved from the Environment agency (EA, 2020).

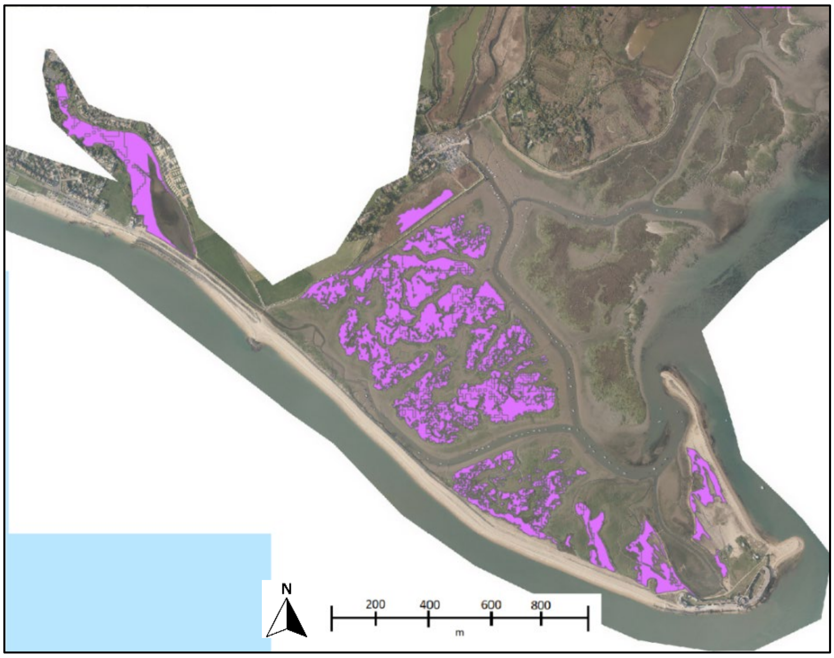



**Figure 66c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Hurst Spit in 2019, retrieved from the Environment agency (EA, 2020).

## Yar Estuary

Changes between 2008 and 2019 (Figure 67a, 67b and 67c), had a 4.07% saltmarsh loss (Figure 68), which equates to 0.37% $yr^{-1}$ (Table 25). Changes between 2008 and 2016, revealed the greatest rate of loss, being 0.58% $yr^{-1}$. Saltmarsh extent between 2016 and 2019 had no saltmarsh change. Saltmarsh extent between 2016 and 2019 had no saltmarsh change.

**Table 25.** Saltmarsh extent at Yar Estuary.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 2008 | 45.7 | | | |
| 2016 | 43.84 | 2008-2016 | -4.07 | -0.58 |
| 2019 | 43.84 | 2016-2019 | 0.00 | 0.00 |
| | | 2008-2019 | -4.07 | -0.37 |

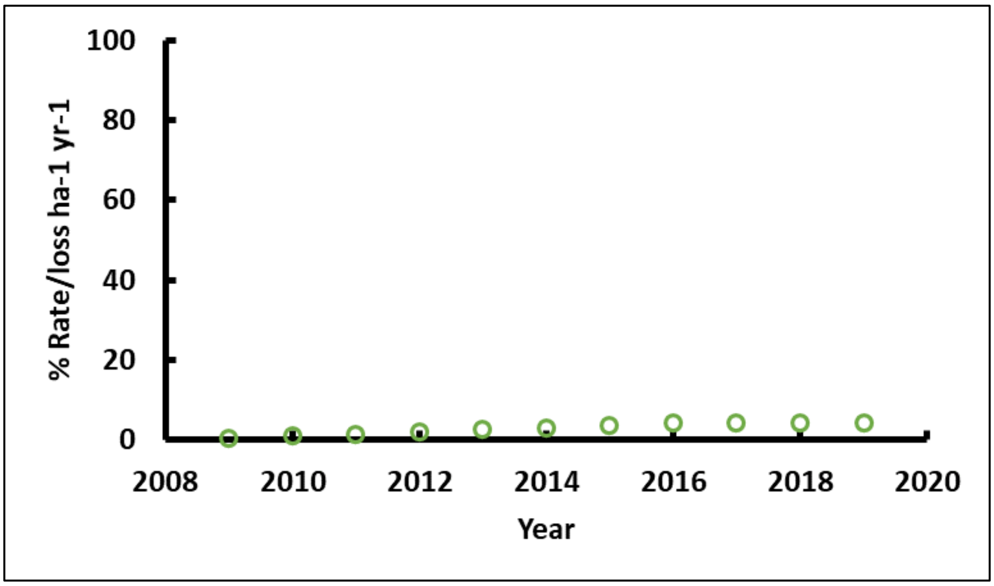



**Figure 68.** The total percentage rate of saltmarsh loss for Yar Estuary from 2008 to 2019.

Only one scenario could be worked out at the Yar Estuary as the saltmarsh extent had one rate of loss between the recorded data (Table 26). The total rate of decline from 2008 to 2019 (Regression analysis (all years): $F_{1,78} = 192.5$, $p \leq 0.001$, $R^2 = 95.1\%$), from the regression line it was estimated that saltmarsh would reach zero hectares by 2256 (Figure 69).

**Table 26.** Best worst scenario for expected zero saltmarsh Brading Marshes to St. Helen's Ledges.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| Worst-case | 2008 - 2019 | 2256 |

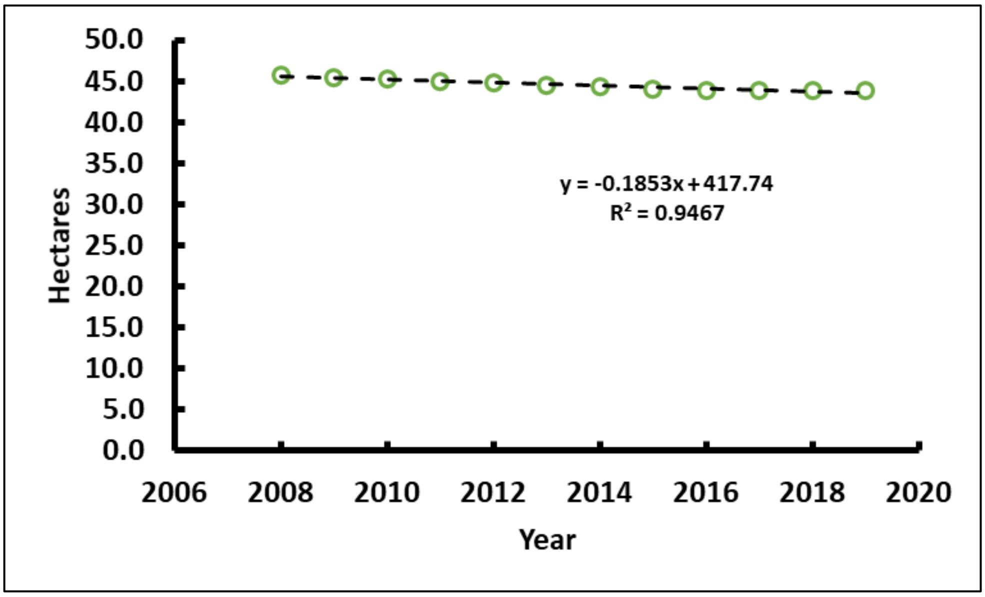



**Figure 69.** Regression analysis for saltmarsh loss in Yarr Estuary. **A)** the total rate of decline from 2008 to 2019 (Regression analysis (all years): $F_{1,78}$ = 192.5, $p \leq 0.001$, $R^2$ = 95.1%). Using these data, we estimate saltmarsh will reach zero hectares by 2256.

*Saltmarsh species zonation classification of 2016*

The Yar estuary saltmarsh is well-developed and protected from wave attack (Figure 70). Dense bands of reedbeds dominate the upper reaches of the estuary, there are also swards of *Spartina* species on the west shore. From the mid estuary to the upper reaches, Reedbeds dominate the shores of the Yarr Estuary. From the shore mid-low saltmarsh species dominate the area up to the main channel. The Lower reaches of the estuary are a mixture of mid-low and *Spartina* species. Pioneer species are only found scattered in the lower reaches of the estuary.

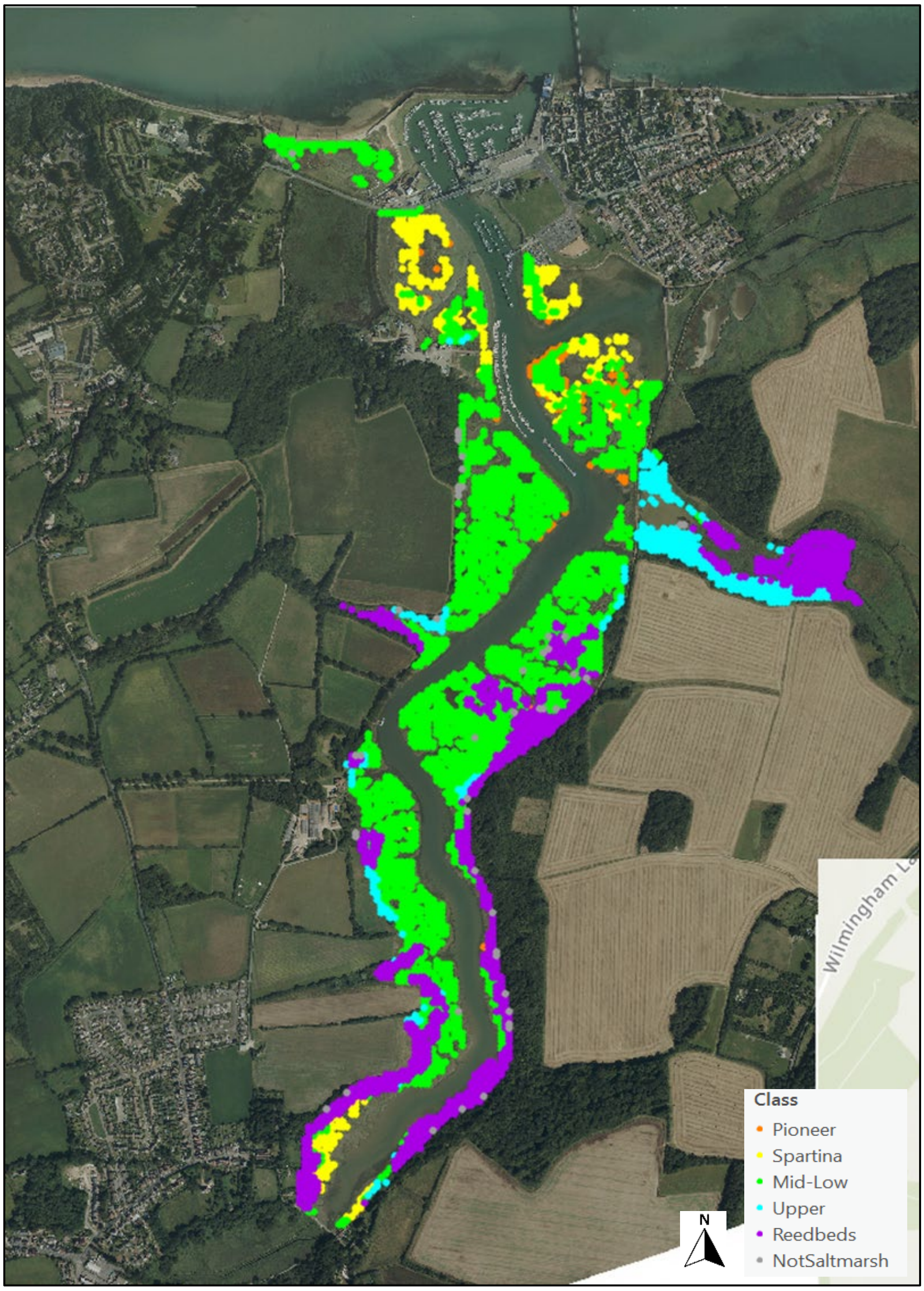



**Figure 70.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of the River Yarr in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 67a, 67b and 67c), revealed a net loss of 4.07% of saltmarsh, which equates to 0.37% $yr^{-1}$. The dominant erosive processes occurring in the River Yarr Estuary is internal dissection, particularly to the mid-low saltmarsh species. Between 2008 and 2019, the number of saltmarsh polygons increased from 55 to 328, respectively. Saltmarsh at the lower reaches of the Yarr Estuary suggested the greatest amount of erosion, particularly south of Thorley Brook of the mid-low saltmarsh species. The mid-section of Western Yarr suggested a net growth of mid-low saltmarsh species. The upper reaches of the Yarr suggested the lowest rate of saltmarsh loss, with the reedbeds holding their position.

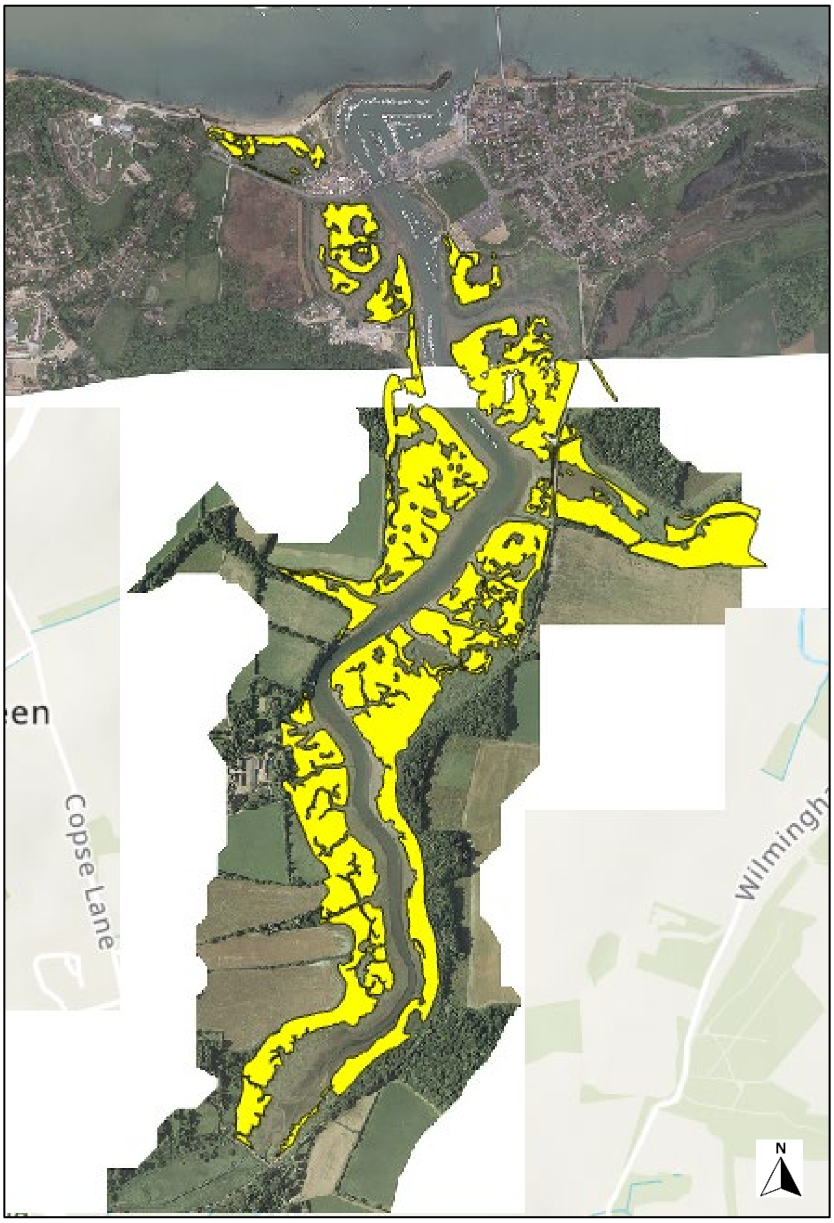



**Figure 67a.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the River Yarr in 2008, retrieved from the Environment agency (EA, 2020).


**Figure 67b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the River Yarr in 2016, retrieved from the Environment agency (EA, 2020).

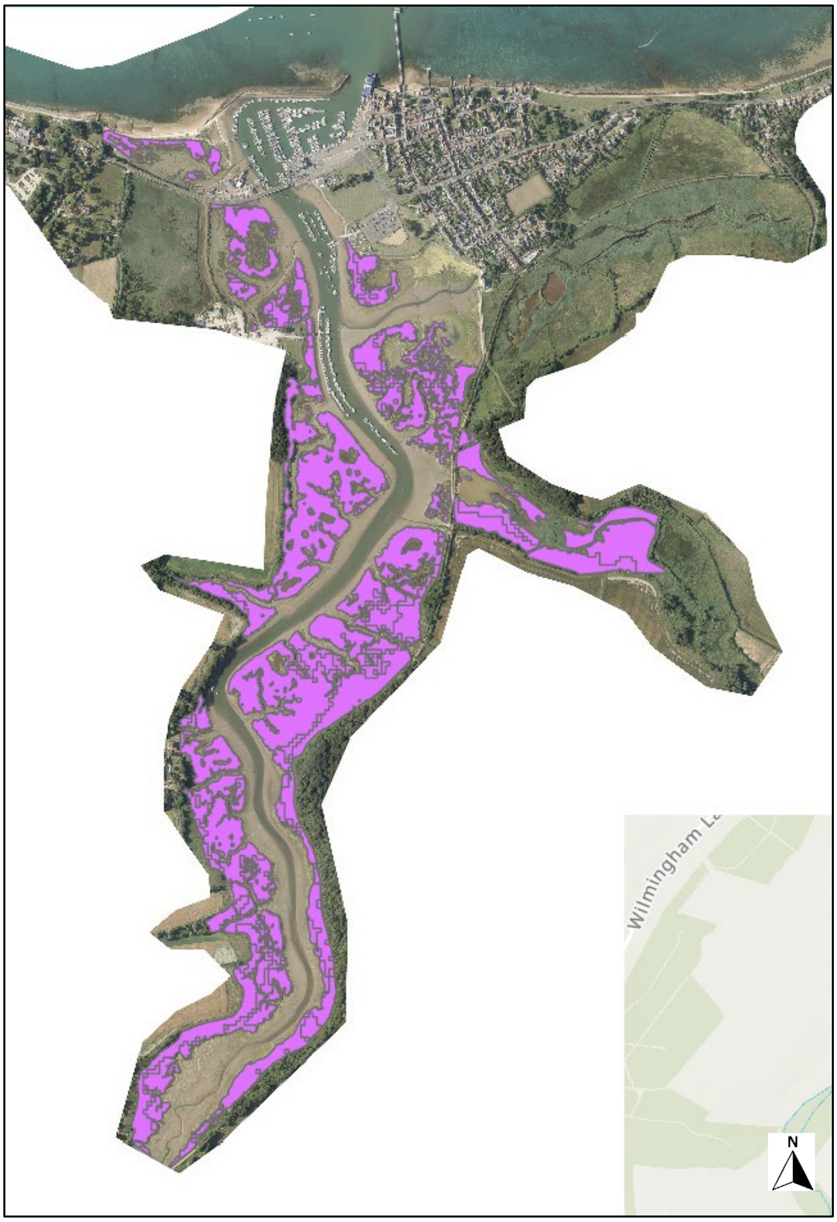



**Figure 67c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the Yarr Estuary in 2019, retrieved from the Environment agency (EA, 2020).

## Newtown Harbour

Changes between 2008 and 2019 (Figure 71a, 71b and 71c), revealed a 12.84% saltmarsh loss (Figure 72), which equates to 1.61% $yr^{-1}$ (Table 27). Changes between 2008 and 2016, had the greatest rate of loss. Changes between 2016 and 2019 indicated zero saltmarsh loss

**Table 27.** Saltmarsh extent at Newtown Harbour.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 2008 | 80.29 | | | |
| 2016 | 69.98 | 2008-2016 | -12.84 | -1.61 |
| 2019 | 69.98 | 2016-2019 | 0.00 | 0.00 |
| | | 2008-2019 | -12.84 | -1.17 |

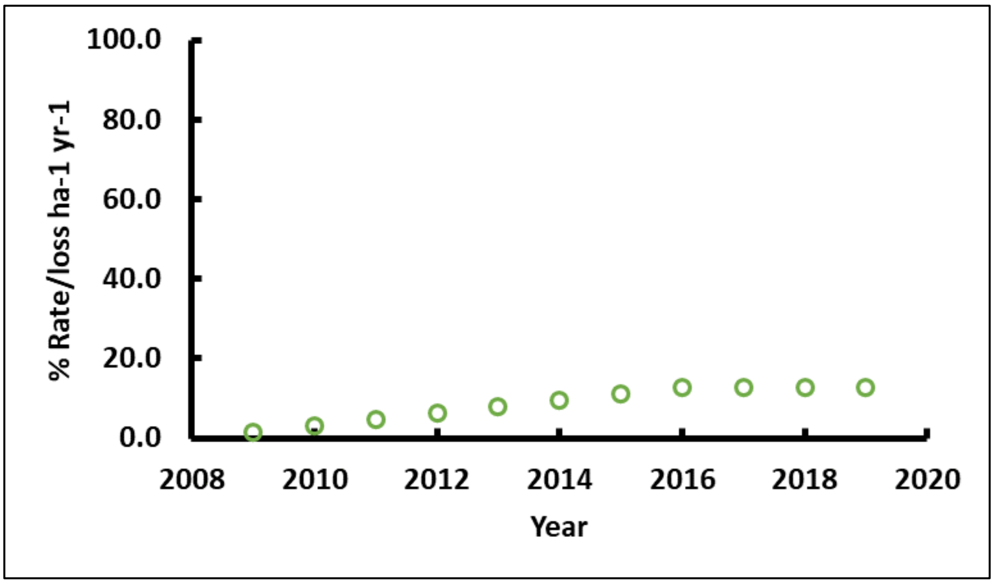



**Figure 72.** The total percentage rate of saltmarsh loss for Newtown Harbour from 2008 to 2019.

The worst-case scenario in Newtown for the saltmarsh extent is between 2008 and 2019 (Figure 73). The total rate of decline from 1954 to 2019 (Regression analysis (all years): $F_{1,78}$ = 176.6, $p \leq 0.001$, $R^2$ = 94.6%), we estimated that saltmarsh would reach zero hectares by June 2085 (Table 28). No best-case scenario as data showed no change in rate.

**Table 28.** Worst-case scenario for expected zero saltmarsh at Newtown Harbour.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| **Worst-case** | **2008 - 2019** | **2085.5** |

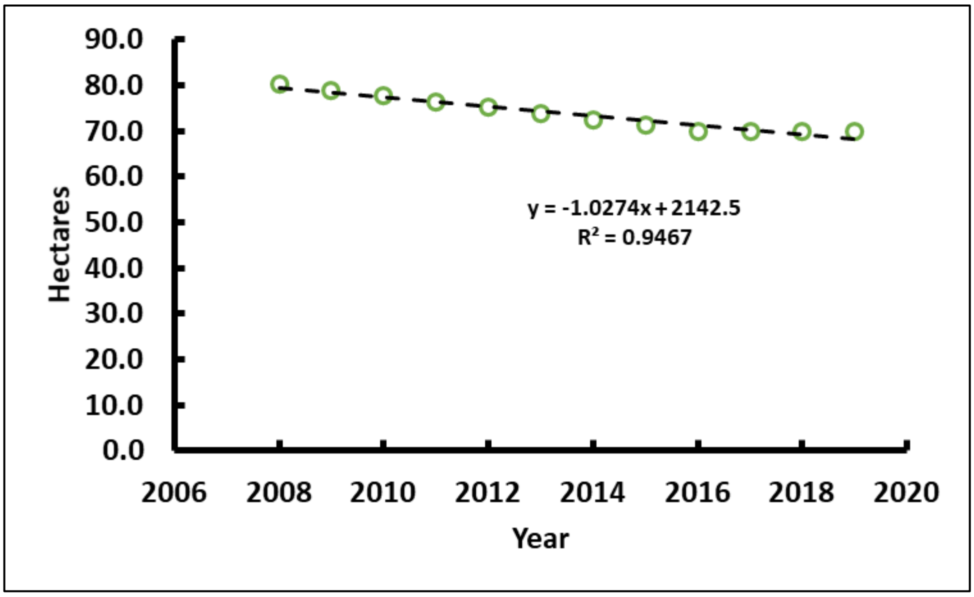



**Figure 73.** Regression analysis for saltmarsh loss in Newtown Harbour. The total rate of decline from 1954 to 2019 (Regression analysis (all years): $F_{1,78}$ = 176.6, $p \leq 0.001$, $R^2$ = 94.6%). Using these data, we estimate saltmarsh will reach zero hectares by June 2085.

*Saltmarsh species zonation classification of 2016*

Newtown Harbour is dominated by mid-low saltmarsh species that span the whole of the Harbour (Figure 74). The centre of the harbour, south of East Spit, is a well-developed marsh with *Spartina* and pioneer species encompassing a large area of mid-low saltmarsh species. A band of upper saltmarsh species dominates most of the shoreline along the south and east harbour. Behind the Hampstead Spit is a well-developed marsh with a transition of upper saltmarsh species to pioneer species. The south-west of Newtown Harbour is dominated by mid-low saltmarsh species and some pioneer species.

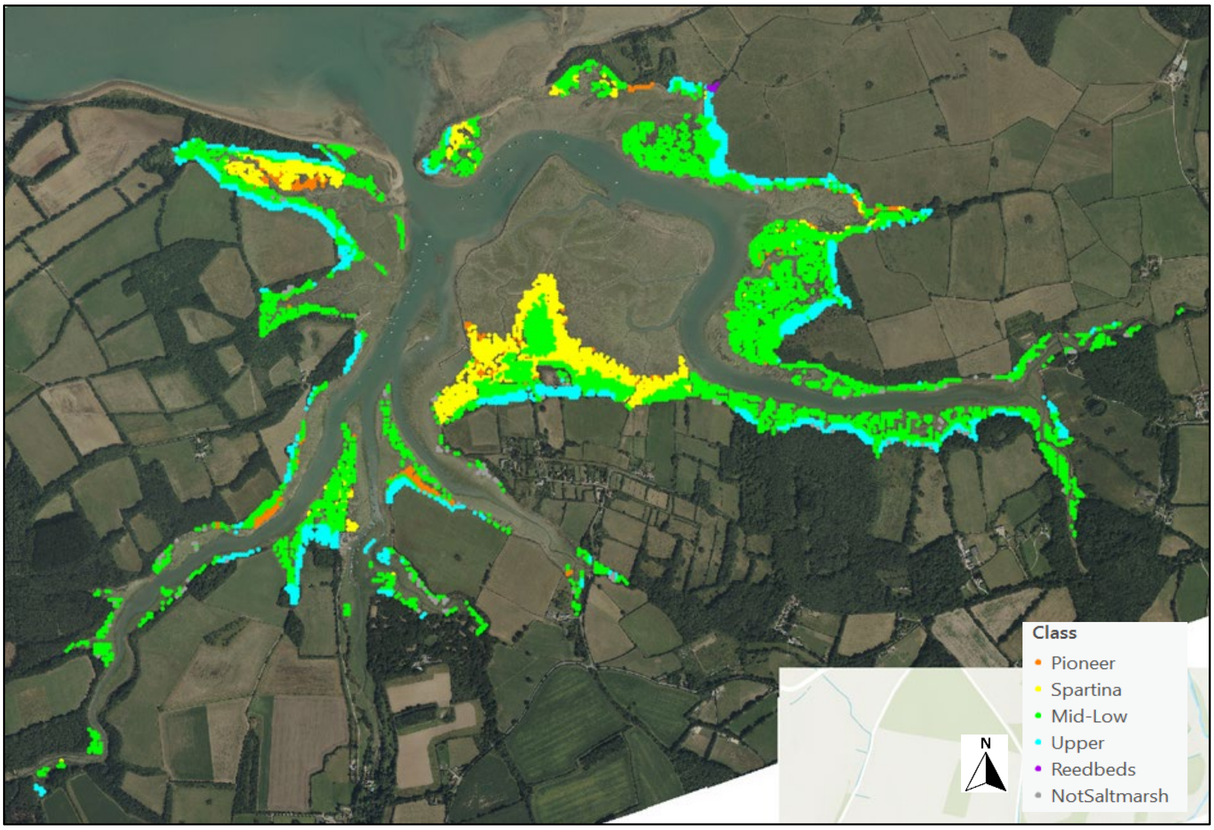



**Figure 74.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Newtown Harbour in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 71a, 71b and 71c), had a net loss of 12.84% of saltmarsh, which equates to 1.17% $yr^{-1}$. The dominant erosive processes occurring in Newtown Harbour is edge erosion, with large areas of the upper harbours mid-low saltmarsh species displaying internal dissection. The centre of the Newtown harbour is exposed to wave attack and as such the *Spartina* saltmarshes directly behind the entrance to the harbour has seen the greatest edge erosion. Within Newtown Harbour the number of saltmarsh polygons increased from 213 to 903, between 2008 and 2019, respectively, suggesting many saltmarsh fragmentations. West of Newtown Creek No.4 Buoy has lost a large area of mid-low saltmarsh species through edge erosion and internal dissection. In the east along Clamerkin Brook, opposite the National Trust East Bird Hide, the mid-low saltmarsh species have been completely removed and reduced to mudflats. Growth of all saltmarsh species present occurred along the inner most reaches of the marshes behind East Spit and Hamstead Spit.

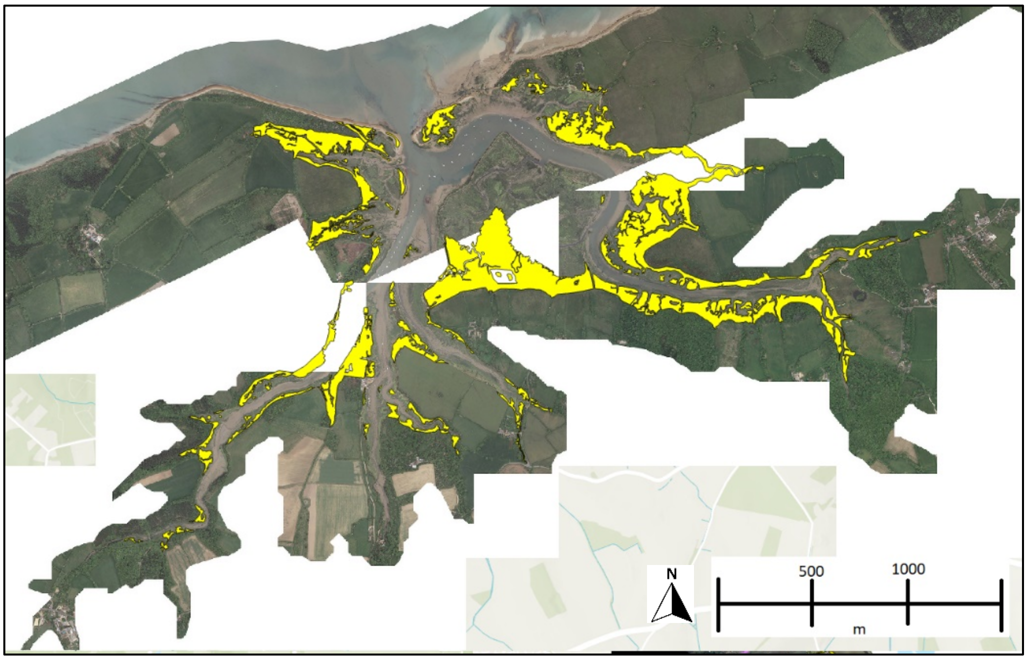



**Figure 71a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Newtown Harbour in 2008, retrieved from the Environment agency (EA, 2020).

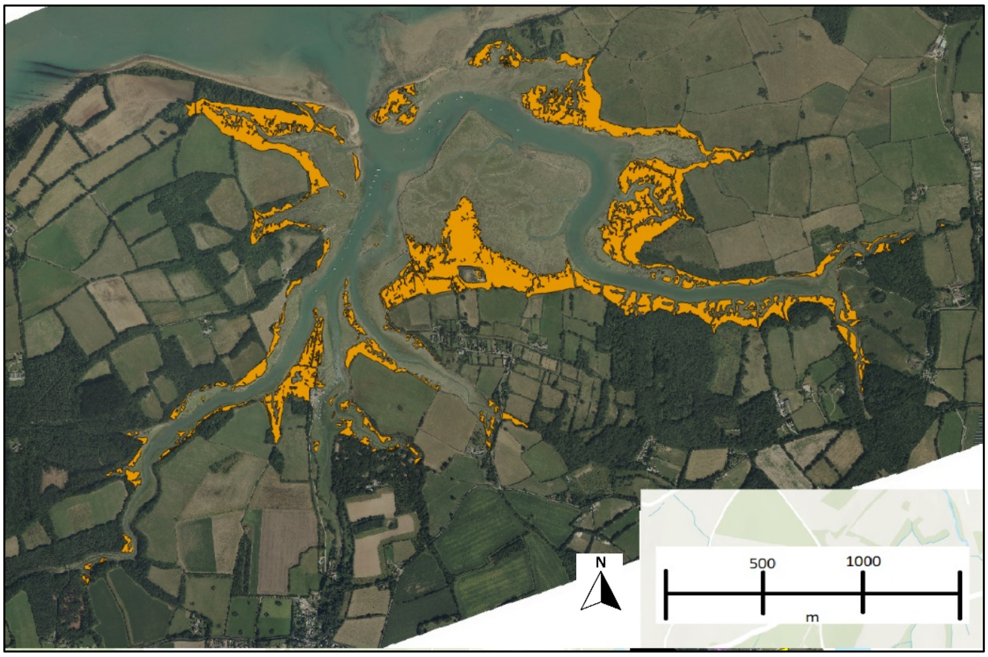



**Figure 71b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Newtown Harbour in 2016, retrieved from the Environment agency (EA, 2020).

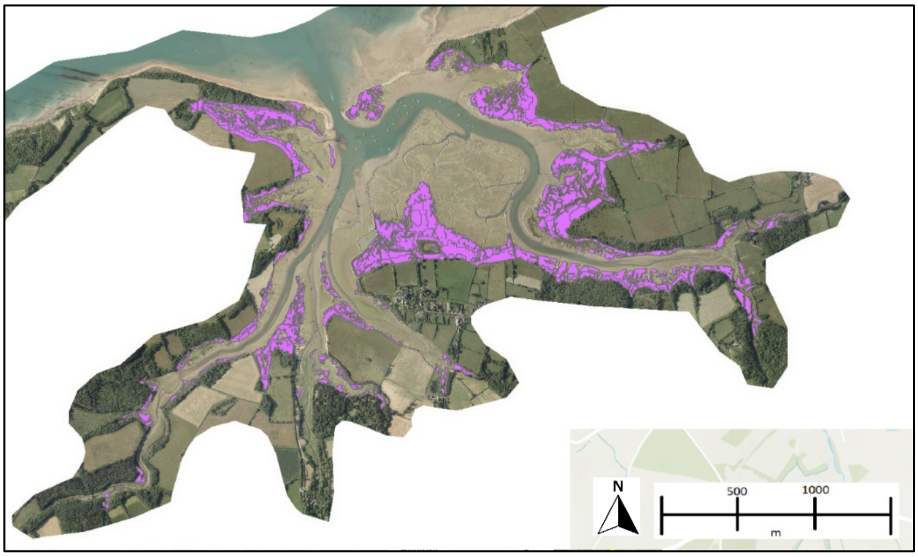



**Figure 71c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Newtown Harbour in 2019, retrieved from the Environment agency (EA, 2020).

## Thorness Bay

Changes between 2008 and 2019 (Figure 75a, 75b and 75c), had a 19.90% saltmarsh gain (Figure 76), which equates to 1.81% $yr^{-1}$ (Table 29). Changes between 2008 and 2016, revealed the greatest rate of gain, being 1.77% $yr^{-1}$. Saltmarsh extent between 2016 and 2019 had no saltmarsh change.

**Table 29.** Saltmarsh extent at Thorness Bay.

| Year | Area (Ha) | Period | Total saltmarsh change | |
|---|---|---|---|---|
| | | | % change | % change $yr^{-1}$ |
| 2008 | 1.53 | | | |
| 2016 | 1.91 | 2008-2016 | +19.90 | +1.81 |
| 2019 | 1.91 | 2016-2019 | 0.00 | 0.00 |
| | | 2008-2019 | +19.90 | +0.81 |

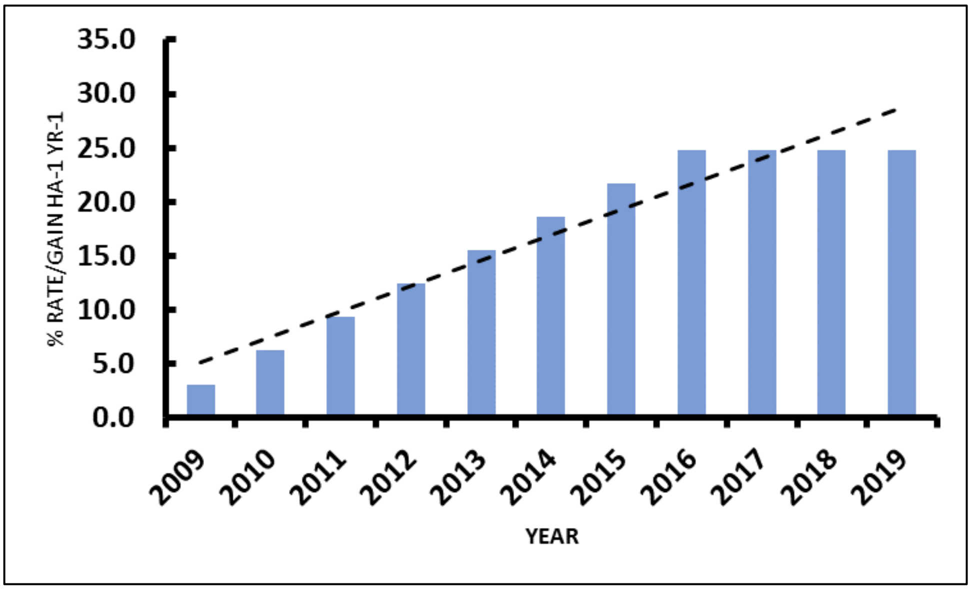



**Figure 76.** The total percentage rate of saltmarsh gain for Thorness Bay from 2008 to 2019.

There is no worst-case scenario at Thorness Bay as saltmarsh extent grew between the recorded data (Figure 77). The total rate of increase from 2008 to 2019 (Regression analysis (all years): $F_{1,78}$ = 89.63, $p \leq 0.001$, $R^2$ = 90.0%),the best-case scenario of the saltmarsh extent is between 2008 and 2019 estimated that by 2030 Thorness Bay will reach 2.5 hectares (Table 30). Saltmarsh between A 2016-2019 illustrated no change in saltmarsh extent.

**Table 30.** Best-case scenario for expected zero saltmarsh at Medina Estuary.

| | **Regression periods** | **Expected Marsh by 2030** |
|---|---|---|
| **Best-case** | **2008 - 2019** | **2.5** |

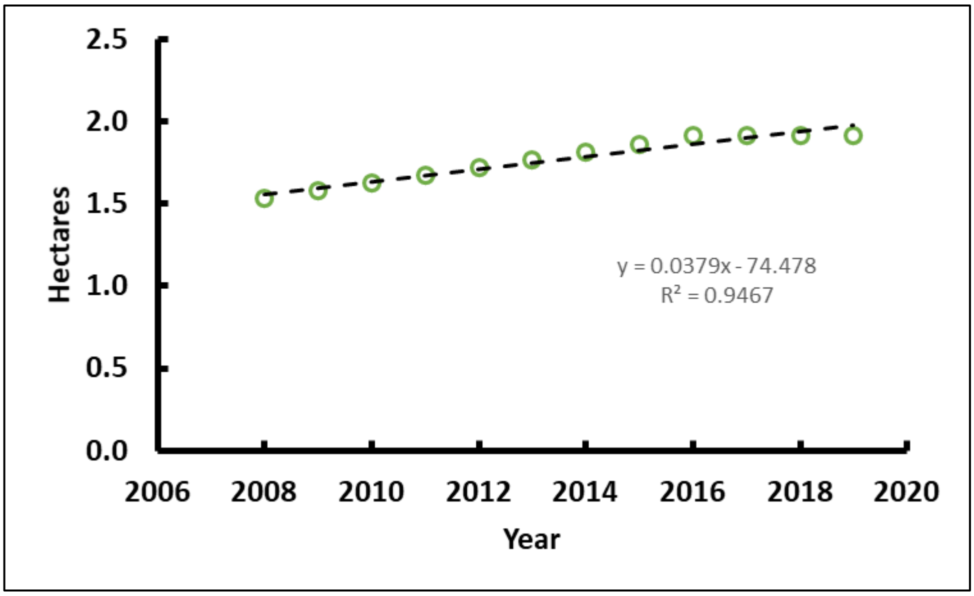



**Figure 77**. Regression analysis for saltmarsh loss in Thorness Bay. A) the total rate of increase from 2008 to 2019 (Regression analysis (all years): $F_{1,78}$ = 89.63, $p \leq 0.001$, $R^2$ = 90.0%). Using these data, we estimate saltmarsh will reach 2.5 hectares by 2030.

*Saltmarsh species zonation classification of 2016*

Thorness bay has a small area of saltmarsh, comprised solely of mid-low saltmarsh species behind the sandy shoreline (Figure 78). Raised farmland to the east prevents landward saltmarsh migration.


**Figure 78.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Thorness Bay in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 75a, 75b and 75c), had a net gain of 19.90% of saltmarsh, which equates to 1.81% $yr^{-1}$. Saltmarsh grew from the north, south and west edges of the marsh. However, erosion occurred to the saltmarsh inwards from the farmland to the east. The number of saltmarsh polygons increased from 1 to 2 between 2008 and 2019, respectively, due to the growth of saltmarsh to the north of the marsh.

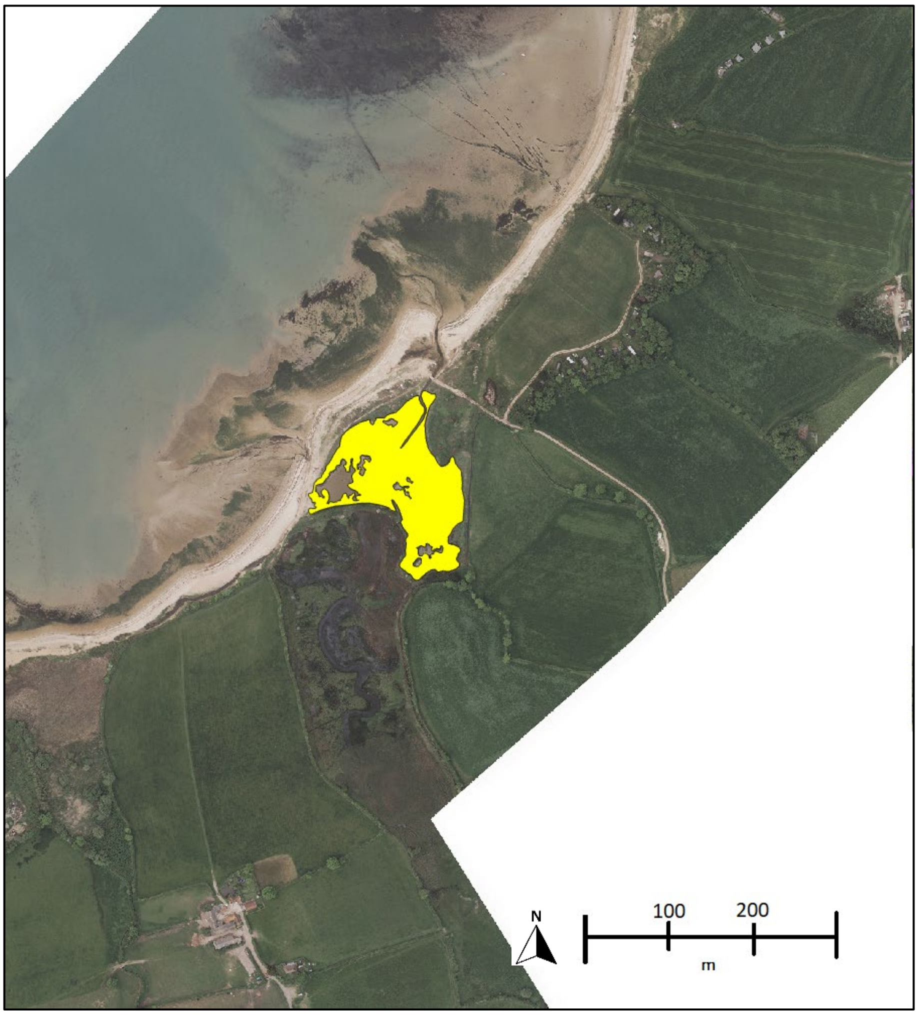



**Figure 75a.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Thorness Bay in 2008, retrieved from the Environment agency (EA, 2020).

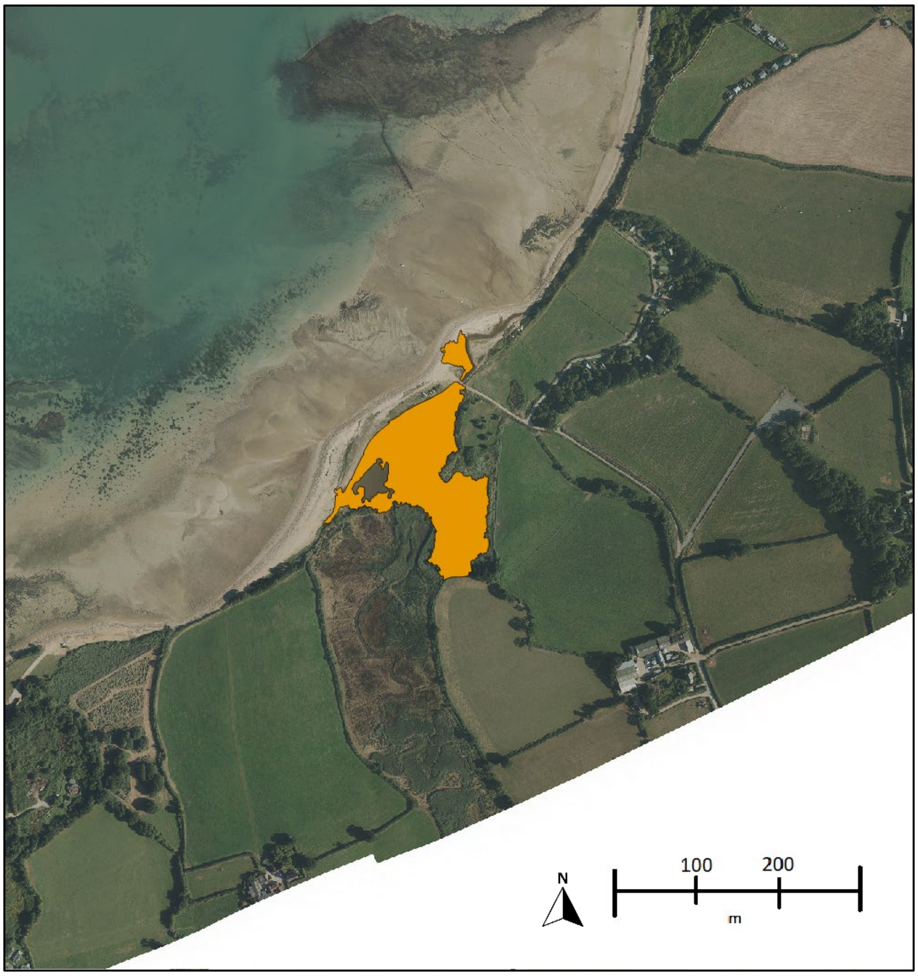



**Figure 75b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Thorness Bay in 2016, retrieved from the Environment agency (EA, 2020).


**Figure 75c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Thorness Bay in 2019, retrieved from the Environment agency (EA, 2020).

### Medina Estuary

Changes between 2008 and 2019 (Figure 79a, 79b and 79c), had a 11.61% saltmarsh loss (Figure 80), which equates to 1.06% $yr^{-1}$ (Table 31). Changes between 2008 and 2016, revealed the greatest rate of loss, being 1.65% $yr^{-1}$. Saltmarsh extent between 2016 and 2019 had no saltmarsh change. Saltmarsh extent between 2016 and 2019 had no saltmarsh change.

**Table 31.** Saltmarsh extent at Medina Estuary.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % change | % change $yr^{-1}$ |
| 2008 | 12.57 | | | |
| 2016 | 11.11 | 2008-2016 | -11.61 | -1.17 |
| 2019 | 11.11 | 2016-2019 | 0.00 | 0.00 |
| | | 2008-2019 | -11.61 | -1.06 |

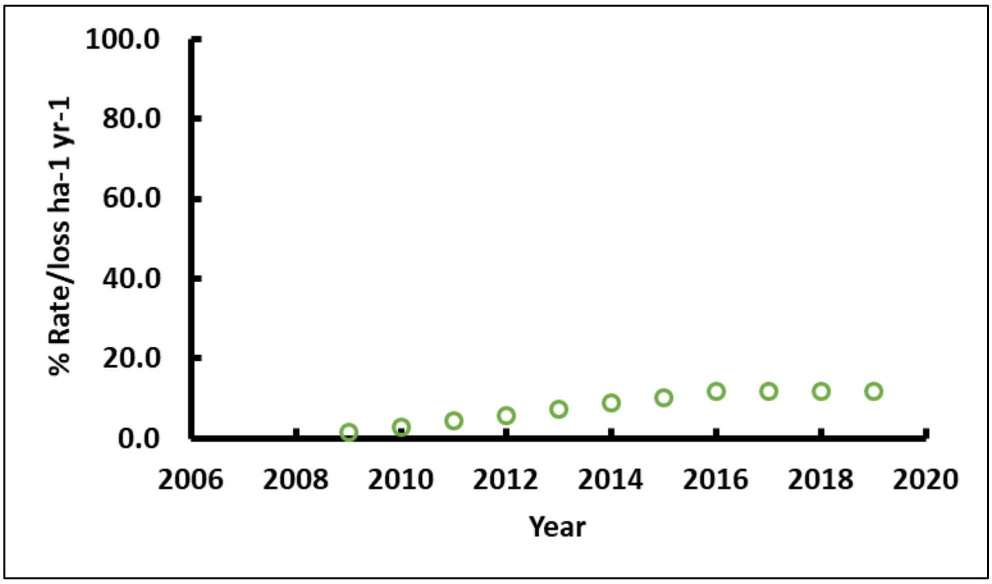



**Figure 80.** The total percentage rate of saltmarsh loss for Medina River Estuary from 2008 to 2019.

The worst-case scenario in Newtown Harbour for the saltmarsh extent is between 2008 and 2019 (Figure 81). The total rate of decline from 2008 to 2019 (Regression analysis (all years): $F_{1,78}$ = 181.7, $p \leq 0.001$, $R^2$ = 94.8%), we estimated that saltmarsh would reach zero hectares by 2094 (Table 32).

**Table 32.** Worst-case scenario for expected zero saltmarsh at Medina Estuary.

| | Regression periods | Expected Zero Marsh |
|---|---|---|
| Worst-case | 2008 - 2019 | 2094 |

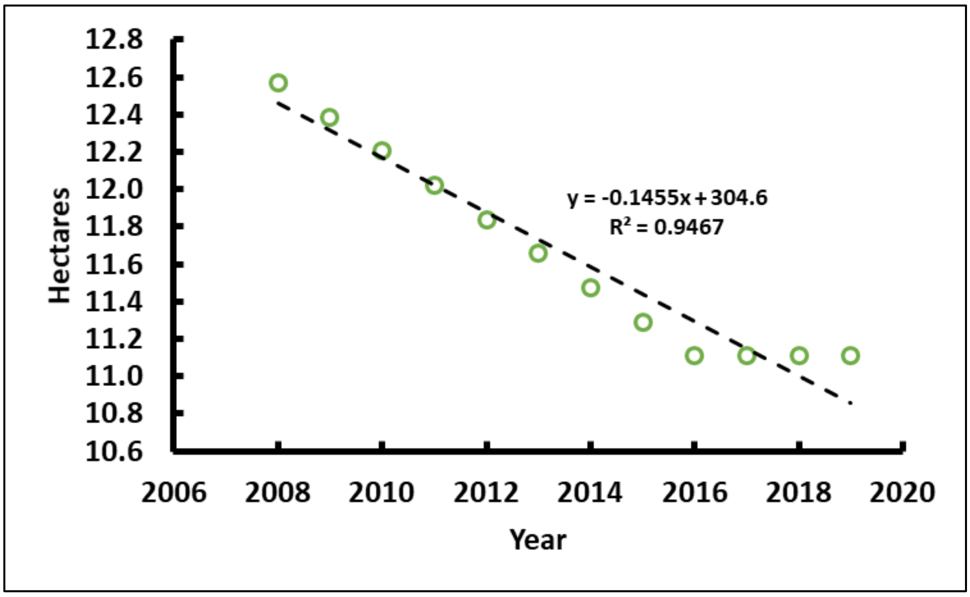



**Figure 81.** Regression analysis for saltmarsh loss in Medina Estuary. **A)** the total rate of decline from 2008 to 2019 (Regression analysis (all years): $F_{1,78}$ = 181.7, $p \leq 0.001$, $R^2$ = 94.8%). Using these data, we estimate saltmarsh will reach zero hectares by 2094.

*Saltmarsh species zonation classification of 2016*

There are no marshes in the developed coastal region of the lower Medina Estuary (Figure 82). Patches of mid-low and upper saltmarsh species dominate the midsection of the estuary. In the upper reaches of the Medina Estuary, reedbeds are present within the Dodnor nature reserve and north of the trading estate.


**Figure 82.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of The Medina Estuary in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 79a, 79b and 79c), had a net loss of 11.61 % of saltmarsh, which equates to 1.17% $yr^{-1}$. The dominant erosive processes occurring in the Medina Estuary is edge erosion. Erosion only occurred within the main channel to the mid-low and upper saltmarsh species. Between 2008 and 2019, the number of saltmarsh polygons increased from 39 to 140, respectively, suggesting that the edge erosion is causing some larger saltmarsh areas to fragment.

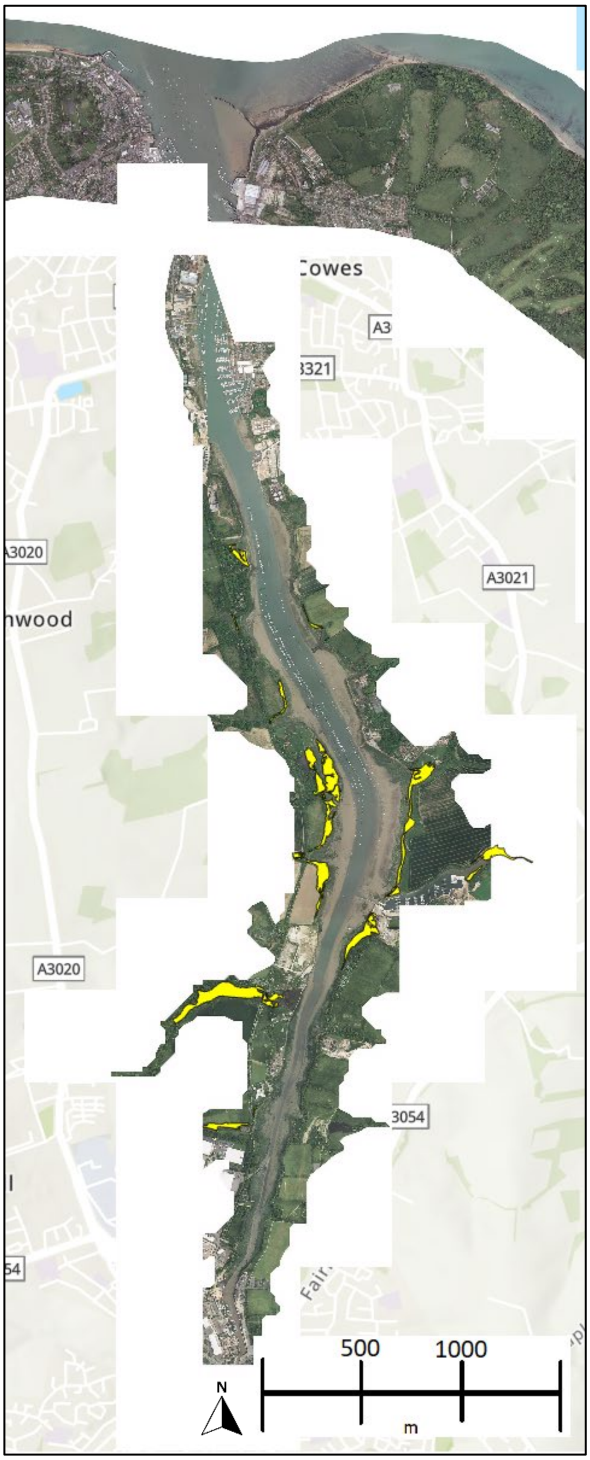



**Figure 79a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the Medina Estuary in 2008, retrieved from the Environment agency (EA, 2020).


**Figure 79b**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the Medina Estuary in 2016, retrieved from the Environment agency (EA, 2020).


**Figure 79c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the Medina Estuary in 2019, retrieved from the Environment agency (EA, 2020).

## King's Quay Shore

Changes between 2008 and 2019 (Figure 83a, 83b and 83c), had a 33.84% saltmarsh gain (Figure 84), which equates to 3.07% $yr^{-1}$ (Table 33). Changes between 2008 and 2016, revealed the greatest rate of saltmarsh gain, being 4.83% $yr^{-1}$. Saltmarsh extent between 2016 and 2019, had no change in saltmarsh.

**Table 33.** Saltmarsh extent at King's Quay Shore.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 2008 | 2.17 | | | |
| 2016 | 3.28 | 2008-2016 | +33.84 | +4.83 |
| 2019 | 3.28 | 2016-2019 | 0.00 | 0.00 |
| | | 2008-2019 | +33.84 | +3.07 |

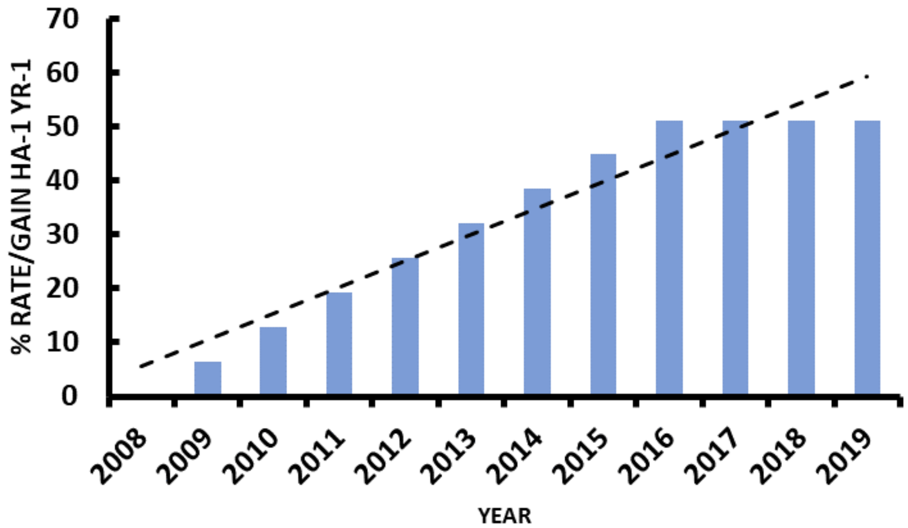



**Figure 84.** The total percentage rate of saltmarsh gain for King's Quay Shore from 2008 to 2019.

There is no worst-case scenario at King's Quay shore as saltmarsh extent grew between the recorded data (Figure 85). The total rate of increase from 2008 to 2019 (Regression analysis (all years): $F_{1,78}$ = 192.8, $p \leq 0.001$, $R^2$ = 95.1%), a regression line for best-case scenario of the saltmarsh extent between 2008 and 2019 estimates that by 2030 will reach 4.6 hectares (Table 34). Saltmarsh change between 2016-2019 indicated no change in saltmarsh extent.

**Table 34.** Best-case scenario for saltmarsh at King's Quay Shore.

| | Regression periods | Expected Marsh by 2030 |
|---|---|---|
| Best-case | 2008 - 2019 | 4.6 |

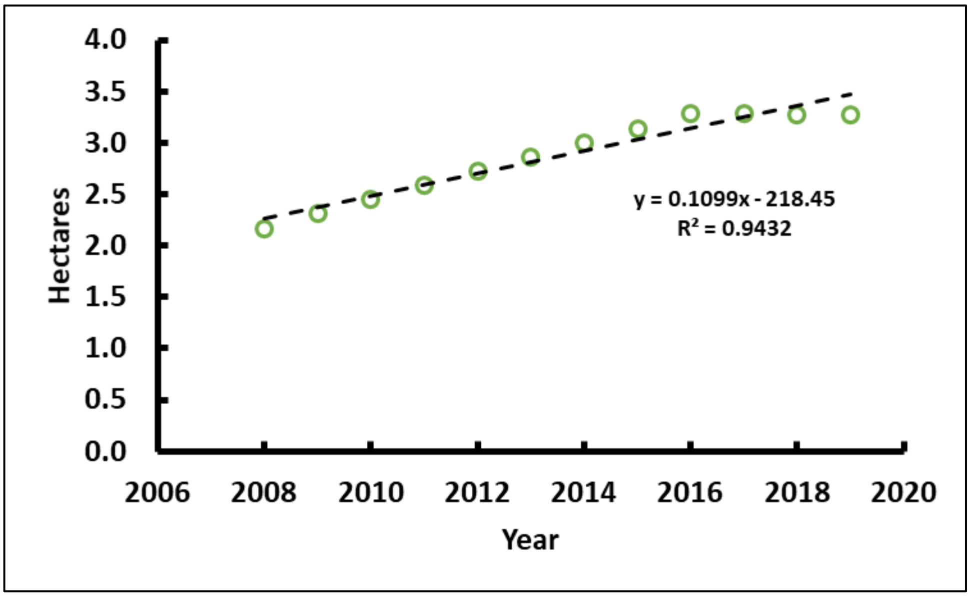



**Figure 85.** Regression analysis for saltmarsh gain in King's Quay Shore**.** The total rate of increase from 2008 to 2019 (Regression analysis (all years): $F_{1,78}$ = 192.8, $p \leq 0.001$, $R^2$ = 95.1%). Using these data, we estimate saltmarsh will reach 4.6 hectares by 2030.

*Saltmarsh species zonation classification of 2016*

To the upper reach King's Quay Shore is a dense patch of reedbeds species (Figure 86). At the mouth of the estuary is a mixed patch of mid-low and upper saltmarsh species, with clusters of *Spartina* species swards. Ryde sands and Wooton creek is most likely ecologically extinct due to the few and sparse patches of upper and mid-low species saltmarsh present.

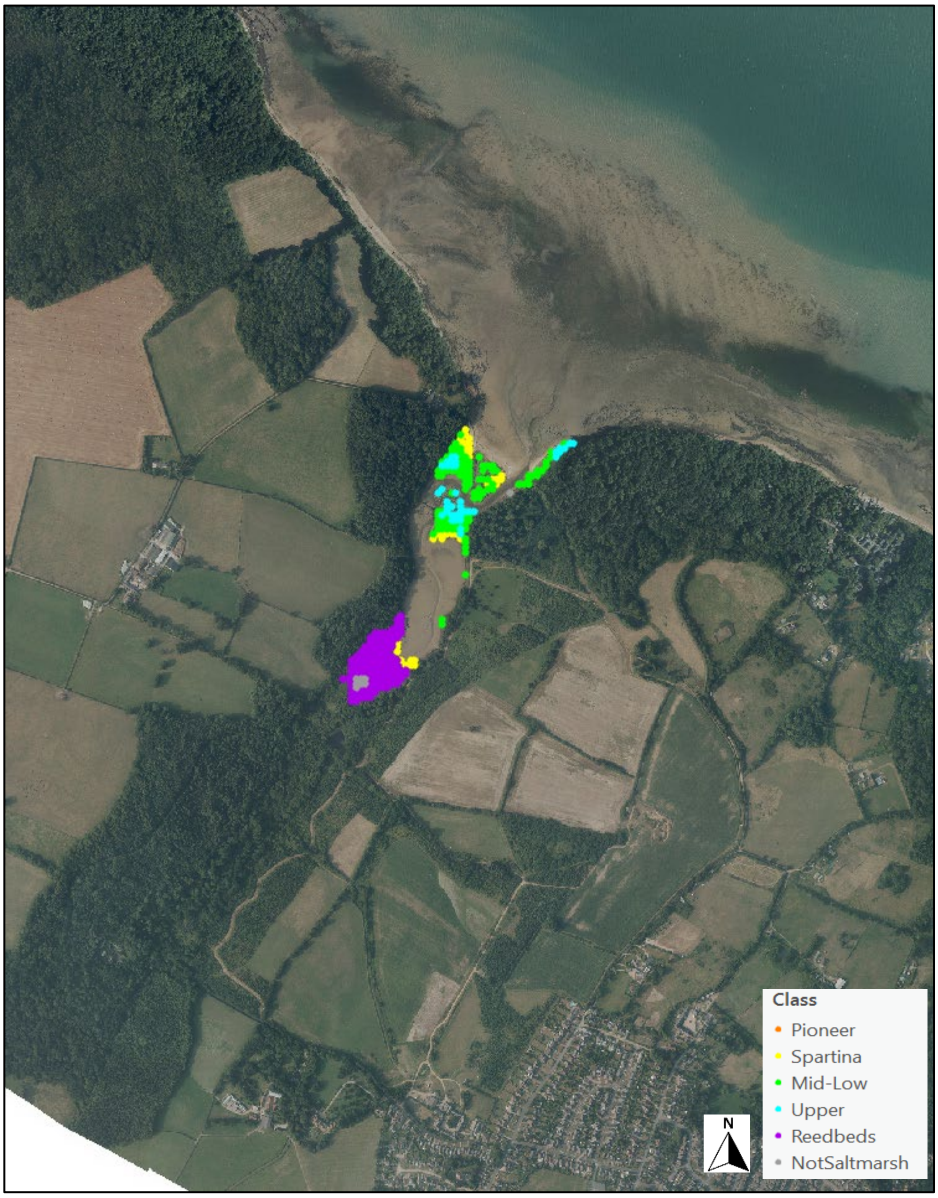



**Figure 86.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of King's Quay Shore in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 83a, 83b and 83c), had a net gain of 33.84% of saltmarsh, which equates to 3.07% $yr^{-1}$. The reedbeds grew in the South west of King's Quay Shore, which, from aerial photography shows strong development of marsh species. Although this should be interpreted with caution as this could be due to differences in the seasons in which photos were taken. Between 2008 and 2019 the number of saltmarsh polygons increased from 37 to 64. Therefore, suggesting that fragmentation is occurring within the lower reaches of the marsh, as in later years the upper marsh increased in size. Some edge erosion occurred to the lower shore and mid-low saltmarsh species too.

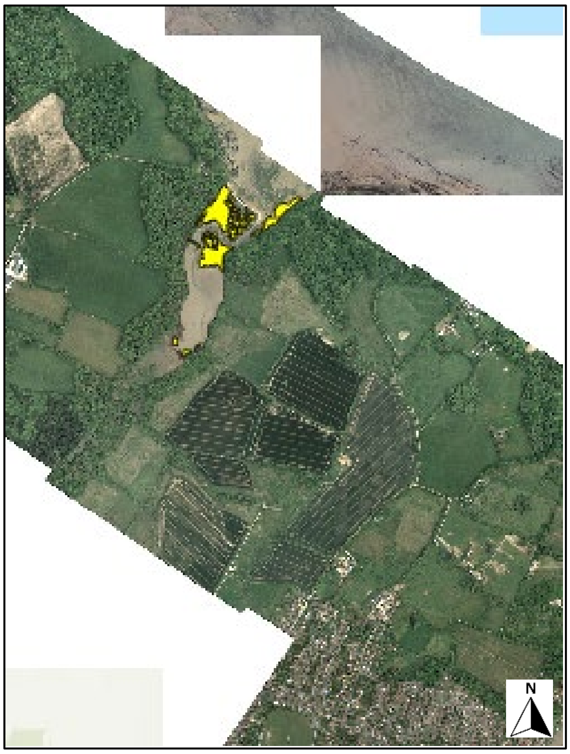



**Figure 83a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of King's Quay Shore in 2008, retrieved from the Environment agency (EA, 2020).

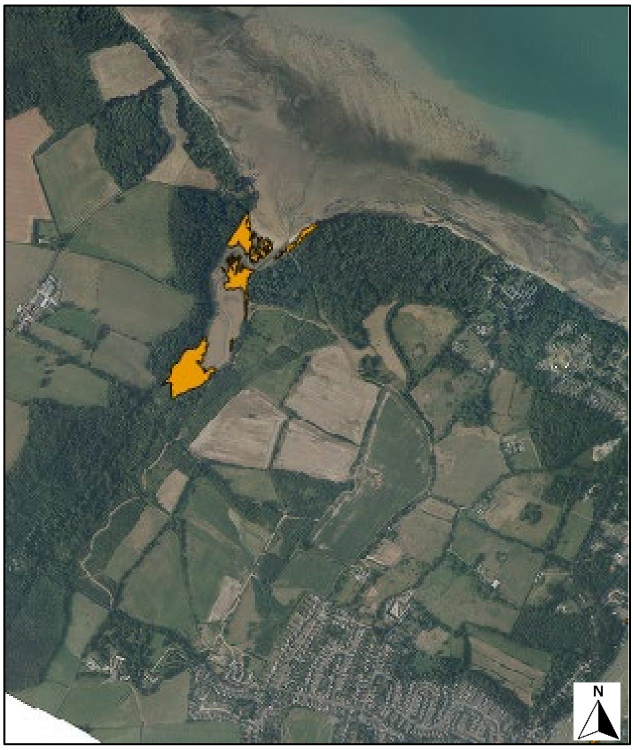



**Figure 83b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of King's Quay in 2016, retrieved from the Environment agency (EA, 2020).

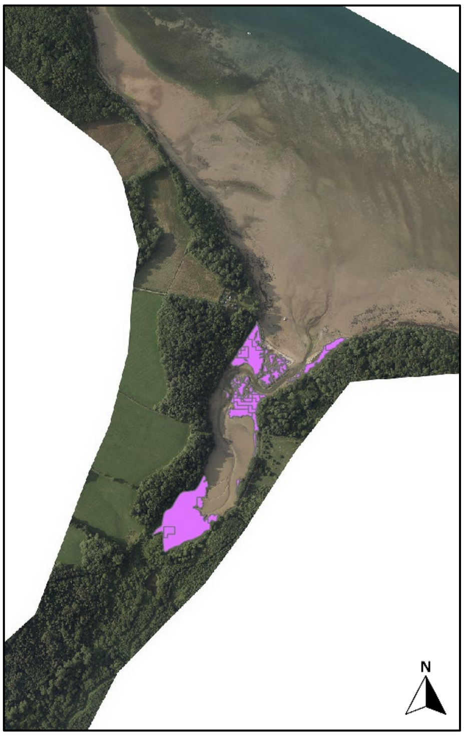



**Figure 83c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of King's Quay Shore in 2019, retrieved from the Environment agency (EA, 2020).

### Ryde Sands and Wooton Creek

Changes between 2008 and 2019 (Figure 87a, 87b and 87c), had a 2.94% saltmarsh loss (Figure 88), which equates to 0.27% $yr^{-1}$ (Table 35). Changes between 2008 and 2016, revealed the greatest rate of loss, being 0.42% $yr^{-1}$. Saltmarsh extent between 2016 and 2019 had no saltmarsh change. Saltmarsh extent between 2016 and 2019 revealed no saltmarsh change.

**Table 35.** Saltmarsh extent at Ryde Sands and Wootton Creek.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % change | % change $yr^{-1}$ |
| 2008 | 0.34 | | | |
| 2016 | 0.33 | 2008-2016 | -2.94 | -0.42 |
| 2019 | 0.33 | 2016-2019 | 0.00 | 0.00 |
| | | 2008-2019 | -2.94 | -0.27 |

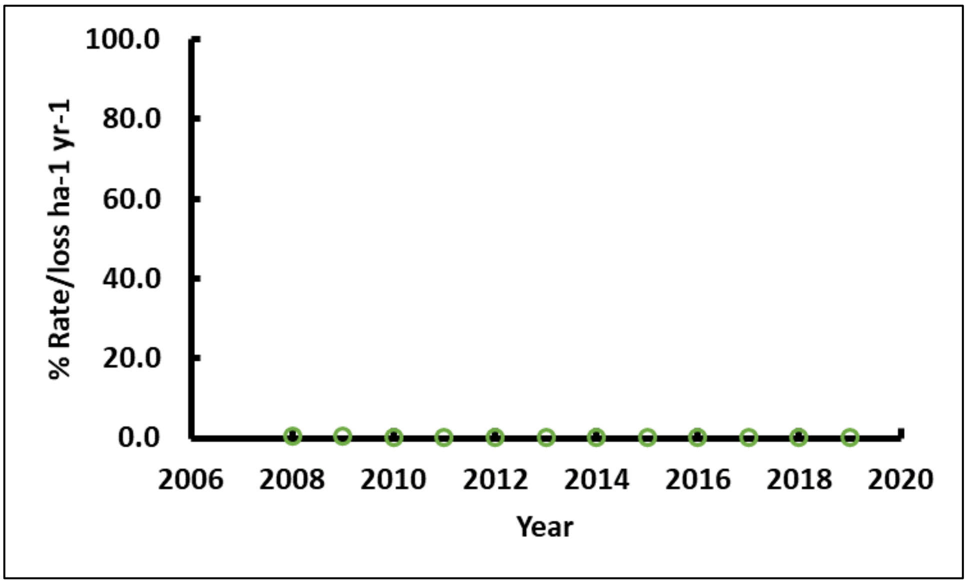



**Figure 88.** The total percentage rate of saltmarsh loss for Ryde Sands and Wootton creek from 1946 to 2019.

There is no worst-case scenario at Ryde Sands and Wootton Creek as saltmarsh extent is too small and is functionally extinct. Saltmarsh extent between 2016 and 2019 indicated 0.01 hectares of marsh lost across 13 years.

*Saltmarsh species zonation classification of 2016*

Ryde sands and Wootton creek SSSI's saltmarsh are ecologically extinct with small patches of upper and mid-low species of saltmarsh (Figure 89). Upper saltmarsh species are found on the shoreline on the east of the Wootton Creek, surrounded by mid-low saltmarsh species. A singular patch of mid-low saltmarsh species remains at behind the island near the entrance of the creek.


**Figure 89.** An aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh zonation classification of Wootton Creek in 2016, retrieved from the Environment agency (EA, 2020). There are 6 classes.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 87a, 87b and 87c), had a net loss of 2.94% of saltmarsh, which equates to 0.27% $yr^{-1}$. The dominant erosive process occurring to the remaining marsh is edge erosion of the lower shore. Fragmentation of saltmarsh occurred as the number of saltmarsh polygons increased from 6 to 7, between 2008 and 2019, respectively.


**Figure 87a**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Wootton Creek in 2008, retrieved from the Environment agency (EA, 2020).

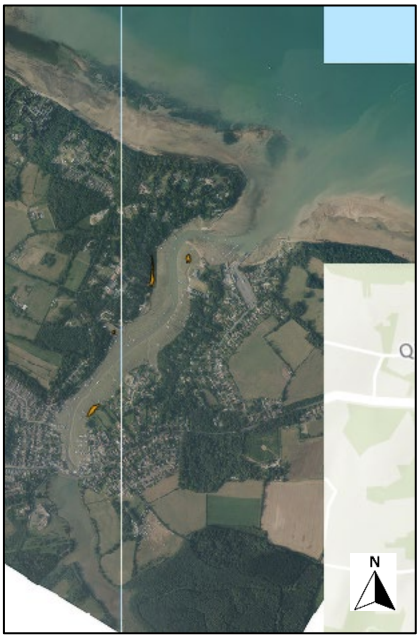



**Figure 87b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Wootton Creek in 2016, retrieved from the Environment agency (EA, 2020).


**Figure 87c**. Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of the Wootton Creek in 2019, retrieved from the Environment agency (EA, 2020).

## Brading Marshes to St. Helen's Ledges

Changes between 2008 and 2019 (Figure 90a, 90b and 90c), had a 37.36% saltmarsh gain (Figure 91), which equates to 3.40% $yr^{-1}$ (Table 36). Changes between 2008 and 2016, revealed the greatest rate of saltmarsh gain, being 5.34% $yr^{-1}$ (Figure 91). Saltmarsh extent between 2016 and 2019, indicated no change in saltmarsh.

**Table 36.** Saltmarsh extent at Brading Marshes to St. Helen's Ledges.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 2008 | 4.41 | | | |
| 2016 | 7.04 | 2008-2016 | +37.36 | +5.34 |
| 2019 | 7.04 | 2016-2019 | 0.00 | 0.00 |
| | | 2008-2019 | +37.36 | +3.40 |

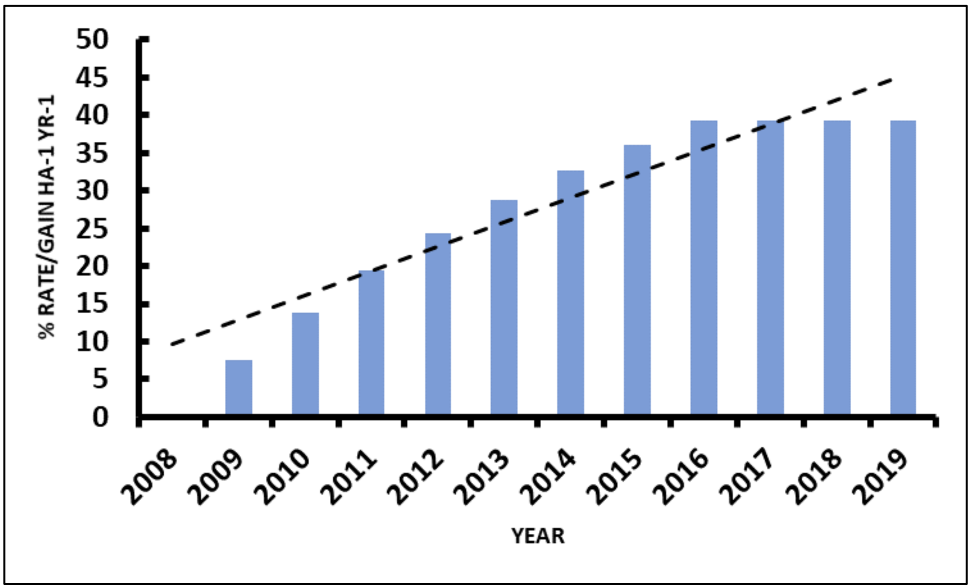



**Figure 91.** The total percentage rate of saltmarsh gain for Brading Marshes to St. Helen's Ledges from 2009 to 2019.

There is no worst-case scenario at Brading Marshes to St. Helen's Ledges as saltmarsh extent grew between the recorded data (Figure 92). The total rate of increase from 2008 to 2019 (Regression analysis (all years): $F_{1,78}$ = 158.7, $p \leq 0.001$, $R^2$ = 94.1%), the best-case scenario of the saltmarsh extent is between 2008 and 2019 estimates that by 2030 will reach 10 hectares (Table 37).

**Table 37.** Best-case scenario for expected zero saltmarsh Brading Marshes to St. Helen's Ledges.

| | Regression periods | Expected Marsh by 2030 |
|---|---|---|
| Best-case | 2008 - 2019 | 10 |

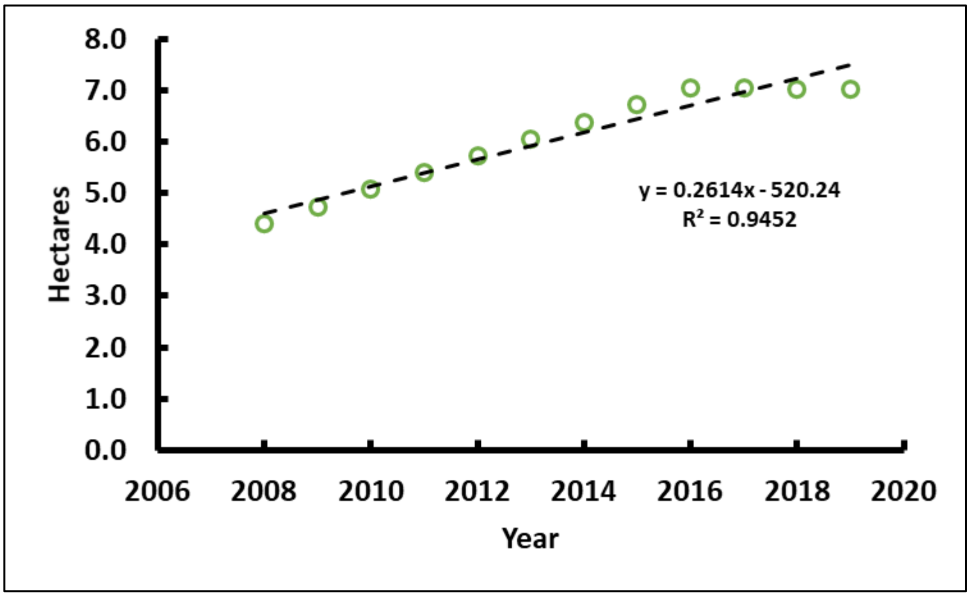



**Figure 92**. Regression analysis for saltmarsh gain from Brading Marshes to St. Helen's Ledges. The total rate of increase from 2008 to 2019 (Regression analysis (all years): $F_{1,78}$ = 158.7, $p \leq 0.001$, $R^2$ = 94.1%). Using these data, we estimate saltmarsh will reach 10 hectares by 2030.

*2008-2019 Aerial Photography and Saltmarsh Extent Review between 2008 and 2019*

Changes between 2008 and 2019 (Figure 90a, 90b and 90c), had a net gain of 37.36 % of saltmarsh, which equates to 3.40% $yr^{-1}$. The greatest gains in saltmarsh were seen behind Bembridge causeway, although the lack of satellite coverage of the marshes in 2008 makes it hard to confirm whether this is new marshland or due to inaccuracies in the methods used to measure saltmarsh extent. Between 2008 and 2019 the number of saltmarsh polygons increased from 21 to 35, respectively. Although, this may be due to an inaccurate data collected between 2008 and greater accuracy within the 2016 and 2019 studies.


**Figure 90a.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Brading Marshes to St. Helen's Ledges in 2008, retrieved from the Environment agency (EA, 2020).


**Figure 90b.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Brading Marshes to St. Helen's Ledges in 2016, retrieved from the Environment agency (EA, 2020).


**Figure 90c.** Aerial imagery (Channel Coastal Observatory, 2020) map showing saltmarsh extent of Brading Marshes to St. Helen's Marshes in 2019, retrieved from the Environment agency (EA, 2020).

## Historical saltmarsh change summary

**Table 38**. A summary of all areas containing saltmarsh within the Solent, between the years 2008 and 2019. Colours were assigned to the characteristics of the saltmarsh: red an indicator of 'poor' (p), amber of 'moderate' (m), green of 'good' (G) and black where no data exists (see page 16 for full explanation).

| Site Name | Total saltmarsh remaining in 2020 (ha) | Total Saltmarsh change (ha) | % change | %change/ yr-1 | % of saltmarsh polygon change | Best-case scenario for expected zero saltmarsh (year) | Worst-case scenario for expected zero saltmarsh (year) | Summary of Saltmarsh condition | Dominant species/marsh change | Restoration opportunity |
|---|---|---|---|---|---|---|---|---|---|---|
| Chichester Harbour | 315.8 | -26 (p) | -7.6 (p) | -0.69 (p) | -11.08 (m) | 2323 (G) | 2054 (m) | Unfavourable (p) | Large areas of *Spartina* islands were completely eradicated, displaying coastal squeeze conditions, | |
| Langstone Harbour | 62.8 | -10.6 (p) | -14.4 (p) | -1.31 (p) | -49.72 (m) | Mar-77 (m) | 2015 (p) | Unfavourable (p) | Large areas of *Spartina* islands were completely eradicated, displaying coastal squeeze conditions | |
| Portsmouth Harbour | 48 | 5.4 (G) | 11.25 (G) | 1.02 (G) | 158.9 (p) | 2255 (G) | 2017 (p) | Unfavourable (p) | Large areas of upper saltmarsh areas grew along the coastline, whereas saltmarsh in the centre of the harbour increased in fragmentation, displaying coastal squeeze conditions | |
| River Hamble | 38.5 | -5.2 (p) | -12.3 (p) | -1.12 (p) | 213.4 (p) | | 2130 (G) | Unfavourable (p) | Large losses of mid-low saltmarsh species around the lower Hamble with some small gains in upper saltmarsh species and reedbeds, displaying coastal squeeze conditions | |
| Lower Test Valley | 47.5 | -11.3 (p) | -19.2 (p) | -1.75 (p) | 261.5 (p) | | 2059 (m) | Unfavourable (p) | Large losses of upper saltmarsh species due to fragmentation of the marsh, some fragmentation within reedbeds | |
| Southampton Water | 153..9 | -6.8 (p) | -4.3 (p) | -0.39 (p) | 137.3 (p) | 2176 (G) | Jun-50 (p) | Unfavourable (p) | Losses mainly to outer edges of saltmarsh, some internal dissection and fragmentation from outer most edges, displaying coastal squeeze conditions | Managed realignment of some areas, into farmland |
| Calshot | 7.4 | 0.1 (G) | 3.2 (G) | 0.29 (G) | -42.6 (m) | Apr-83 (m) | Jun-2027 (p) | Unfavourable (p) | Increase in saltmarsh due to the landward migration of upper saltmarsh area, although outermost edges of the *Spartina* marsh have fragmented and eroded, displaying coastal squeeze conditions | Managed realignment, into farmland |
| Beaulieu River Estuary | 63.9 | -3.1 (p) | -5.8 (p) | -0.52 (p) | 333.4 (p) | 2178 (G) | 2051 (p) | Unfavourable (p) | Increase in saltmarsh due to the landward migration of saltmarsh area, although outermost edges of the marsh have fragmented and eroded, displaying coastal squeeze conditions | Managed realignment, into farmland |
| Pitts Deep and Sowley | 2.8 | -1.1 (p) | -28.2 (p) | -2.56 (p) | -6.6 (p) | 2045 (p) | 2019 (p) | Unfavourable (p) | Losses to outer most edges of the *Spartina* marshes and the complete erosion of Sowley marsh, displaying coastal squeeze conditions | Managed realignment, into farmland |
| Lymington River Estuary | 91.6 | -14 (p) | -14.0 (p) | -1.27 (p) | 395.3 (p) | | Apr-2045 (p) | Unfavourable (p) | Large amounts of internal fragmentation, outmost reaches of saltmarsh eroding fastest, large losses of *Spartina* species and some pioneer species, displaying coastal squeeze conditions | Realignment of east Lymington, into farmland |
| Keyhaven | 32.6 | -6.7 (p) | -17.05 (p) | -1.55 (p) | 370.7 (p) | | Jun-2043 (p) | Unfavourable (p) | Large amount of internal fragmentation, losses to both mid-low saltmarsh species and *Spartina* species, displaying coastal squeeze conditions | |
| Hurst Spit | 36.6 | -3.7 (p) | -11.38 (p) | -1.03 (p) | 332.7 (p) | 2168 (G) | Feb-2074 (m) | Unfavourable (p) | Continued loss of saltmarsh via internal fragmentation, losses to both *Spartina* and mid-low saltmarsh species, displaying coastal squeeze conditions | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| River Yarr | 43.8 | -1.86 (p) | -4.07 (p) | -0.37 (p) | 596.4 (p) | | 2256 (G) | Unfavourable (p) | Losses seen due to increase in fragmentation via increased channel widths and depth, particularly within the mid-low saltmarsh species and *Spartina* species, displaying coastal squeeze conditions | Managed realignment, into farmland |
| Newtown Harbour | 79.98 | -10.31 (p) | -12.84 (p) | -1.17 (p) | 423.9 (p) | | Jun-2025 (p) | Unfavourable (p) | Edge erosion dominates due to the strong waves entering from the harbour entrance, particularly to the *Spartina* species, internal dissection occurring to a wide area of mid-low and pioneer saltmarsh species, displaying coastal squeeze conditions | Managed realignment, into farmland |
| Thorness Bay | 1.9 | 0.38 (G) | 19.9 (G) | 0.81 (G) | 100 (G) | 2.5ha by 2030 (G) | | Fair (m) | Expansion of original mid-low marsh, with wider cover of marsh than previously recorded. May display coastal squeeze conditions in future | |
| Medina River Estaury | 11.1 | 1.46 (p) | -11.6 (p) | -1.06 (p) | 359 (p) | | 2094 (m) | Unfavourable (p) | Displaying strong coastal squeeze conditions of remaining saltmarsh, internal dissection to the mid-low and upper saltmarsh species at the outer edge of the marsh | |
| King's Quay Shore | 3.3 | 1.11 (G) | 33.8 (G) | 3.07 (G) | 173 (p) | 4.6ha by 2030 (G) | | Fair (m) | Saltmarsh change should be interpreted with caution due to the differences in seasons in which the data points were taken | |
| Ryde Sands and Wootton Creek | 0.3 | -0.01 (p) | -2.94 (p) | -0.27 (p) | 116.7 (p) | extinct | Extinct | Extinct | Saltmarsh can be said to be functionally extinct due to the small size of the marsh, displaying coastal squeeze conditions | |
| Brading Marshes to St. Helen's Ledges | 7.0 | 2.63 (G) | 37.36 (G) | 3.4 (G) | 166.7 (p) | 10ha by 2030 (G) | | Unfavourable (p) | Large growth in saltmarsh behind the Bembridge causeway, although lack of aerial photography makes interpretation of this data difficult, saltmarsh still displaying internal dissection and coastal display conditions | |

### Changes in extent of saltmarsh for each SSSI unit from 2008-2019

Between 2008 and 2016, 13 of the 17 SSSI sites containing saltmarsh, across the Solent showed loss in saltmarsh extent (Table 39). The four SSSI units which appear to show an increase in extent of saltmarsh are Thorness Bay, King's Quay Shore and Brading Marshes to St. Helens Ledges on the Isle of Wight and Portsmouth Harbour .

Between 2016 and 2019 the saltmarsh extent data suggested no changes in saltmarsh extent within 13 SSSI sites. Two sites, including the North Solent SSSI and Hurst Castle and Lymington River Estuary SSSI, were the only areas to suggest saltmarsh loss. However, three sites suggested an increase of saltmarsh extent between 2016 and 2019. These sites being Portsmouth Harbour SSSI, Lee on the Solent to Itchen Estuary SSSI and Lower Test Valley SSSI.

**Table 39** The total saltmarsh extent (hectares) for each SSSI in the Solent and north Isle of Wight, containing saltmarsh areas. A green box represents a positive change (+) in saltmarsh extent to the previous data set, a red box represents a negative change (-) in saltmarsh extent to the previous data set and a grey box represents no suggestive change (nc) in saltmarsh extent with the previous dataset.

| SSSI Designation | Area of Saltmarsh (Ha) | | |
|---|---|---|---|
| | 2008 | 2016 | 2019 |
| Chichester Harbour SSSI | 341.8 | 315.8 (-) | 315.8 (nc) |
| Langstone Harbour SSSI | 73.4 | 62.8 (-) | 62.8 (nc) |
| Portsmouth Harbour SSSI | 42.6 | 45.9 (+) | 48.0 (+) |
| Lee on the Solent to Itchen Estuary SSSI | 27.8 | 26.4 (-) | 27.8 (+) |
| Lincegrove & Hacketts Marshes SSSI | 13.5 | 12.2 (-) | 12.2 (nc) |
| Upper Hamble Estuary and Woods SSSI | 13.2 | 11.7 (-) | 11.7 (nc) |
| Lower Test Valley SSSI | 58.8 | 47.0 (-) | 47.5 (+) |
| Eling and Bury Marshes SSSI | 17.9 | 16.4 (-) | 16.4 (nc) |
| Hythe to Calshot SSSI | 146.6 | 145.3 (-) | 145.3 (nc) |
| North Solent SSSI | 66.8 | 64.0 (-) | 63.9 (-) |
| Hurst Castle & Lymington River Estuary SSSI | 226.7 | 201.4 (-) | 200 (-).6 |
| Yar Estuary SSSI | 45.7 | 43.8 (-) | 43.8 (nc) |
| Newtown Harbour SSSI | 80.3 | 70.0 (-) | 70.0 (nc) |
| Thornes Bay SSSI | 1.5 | 1.9 (+) | 1.9 (nc) |
| Medina Estuary SSSI | 12.6 | 11.1 (-) | 11.1 (nc) |
| King's Quay Shore SSSI | 2.2 | 3.3 (+) | 3.3 (nc) |
| Ryde Sands and Wootton Creek SSSI | 0.3 | 0.3 (nc) | 0.3 (nc) |
| Brading Marshes to St Helen's Ledges SSSI | 4.4 | 7.0 (+) | 7.0 (nc) |

In 2019 there was a total of 1033.3 hectares of saltmarsh present within the Solent. This value resulted from the addition of all the areas of saltmarsh from the 19 sites documented within the 17 SSSIs in the Solent. Changes between 2008 and 2019, show an 8.29% saltmarsh loss, which equates to 0.75% $yr^{-1}$ (Table 40). Changes between 2008 and 2016 revealed the greatest rate of saltmarsh loss, being 1% $yr^{-1}$. The rate of saltmarsh loss between 2016 and 2019 was much lower than between 2008 and 2016, being 0.14% $yr^{-1}$.

**Table 40**. Saltmarsh extent across the Solent.

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| 2008 | 1126.7 | | % Change | % Change $yr^{-1}$ |
| 2016 | 1037.6 | 2008-2016 | 7.91 | 1.00 |
| 2019 | 1033.3 | 2016-2019 | 0.42 | 0.14 |
| | | 2008-2019 | 8.29 | 0.75 |

## Total Saltmarsh by geographical sectioning

In order to distinguish where the greatest rates of saltmarsh change is occurring within the Solent, the study area was split into four sections. The grouping of saltmarsh extent within each section allows the comparison of saltmarsh extent within the same area and could be used to highlight where restoration or intervention is most necessary. Sections were grouped by saltmarsh in the North (Calshot to River Hamble), West (Hurst Spit to Beaulieu River Estuary) and East (Portsmouth Harbour to Chichester Harbour) Solent and on the Isle of Wight. The saltmarsh change by area are as shown:

### West Solent

In the West Solent the greatest percentage loss of saltmarsh area occurred at Pitts Deep and Sowley, where 91.52% of saltmarsh has been lost since 1954 (Figure 93). Furthermore, the mean average percentage saltmarsh loss was the greatest at Pitts Deep and Sowley of 1.41 $hr^{-1}$ $yr^{-1}$. Although, Pitts Deep and Sowley is the smallest area of saltmarsh in the West, this area has now almost completely disappeared. The greatest overall loss of saltmarsh occurred at Lymington River Estuary, where 180.3 hectares of saltmarsh has been lost since the first record in 1946, being 67.71% of the overall marsh (Figure 93).

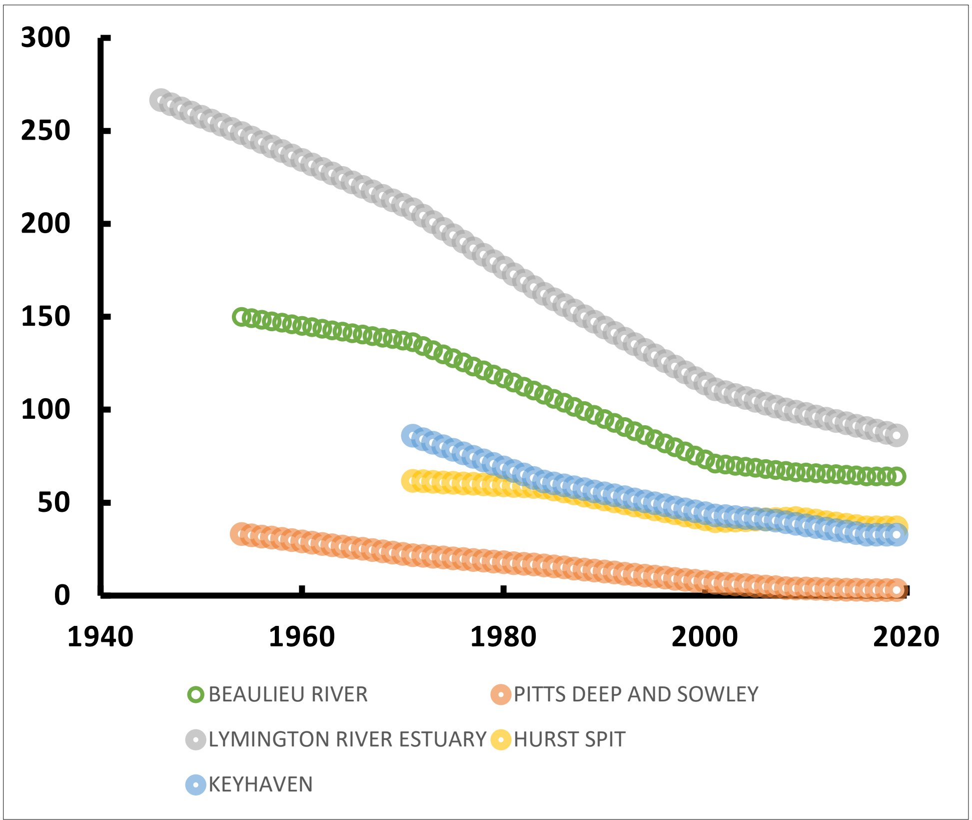



**Figure 93**. Historical change in saltmarsh extent between 1946 and 2019, west Solent.

### East Solent

In the East Solent the greatest percentage loss of saltmarsh area occurred at Langstone Harbour, where 85.66% of saltmarsh has been lost since 1946 (Figure 94). Furthermore, the mean average percentage saltmarsh loss was the greatest at Langstone Harbour of 1.17 $hr^{-1}$ $yr^{-1}$, which is 0.24 $hr^{-1}$ $yr^{-1}$ slower than saltmarsh to the west. The greatest overall loss of saltmarsh within the Solent occurred at Chichester Harbour, the largest of all sites, where 401.5 hectares of saltmarsh has been lost since the first record in 1946, being 55.97% of the overall marsh (Figure 94). Although, saltmarsh at both Langstone Harbour and Chichester Harbour show signs of slowing, continual losses of saltmarsh remain.

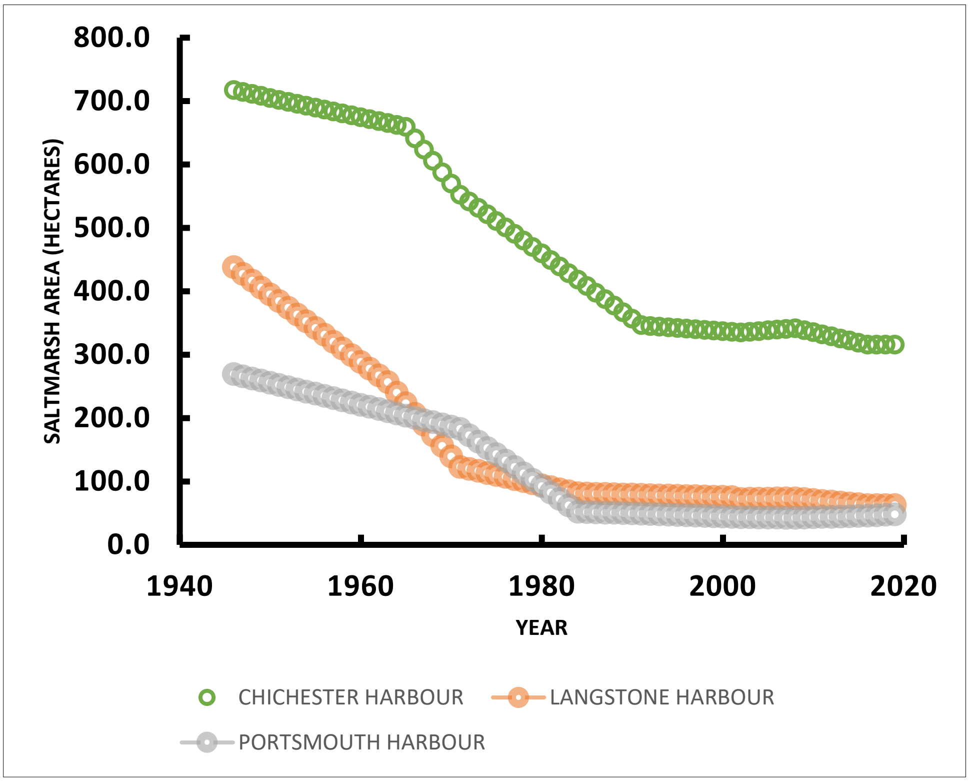



**Figure 94.** Historical change in saltmarsh extent between 1946 and 2019, east Solent.

## North Solent

In the North Solent the greatest percentage loss of saltmarsh area occurred at Calshot Marsh, where 78.74% of saltmarsh has been lost since 1940. The mean average percentage saltmarsh loss was the greatest at the Lower Test marshes at 1.75 $hr^{-1}$ $yr^{-1}$, which is the greatest rate of saltmarsh loss across the Solent, being 0.34 hr-1 yr-1 greater than the recorded yearly rate of loss at Pitts Deep and Sowley in the West. The greatest overall loss of saltmarsh in the North Solent occurred in Southampton Water, the largest site in the north, where 286.7 hectares of saltmarsh has been lost since the first record in 1946, being 65.07% of the overall marsh (Figure 95). Saltmarsh rate of loss is continual for all sites across the north Solent.

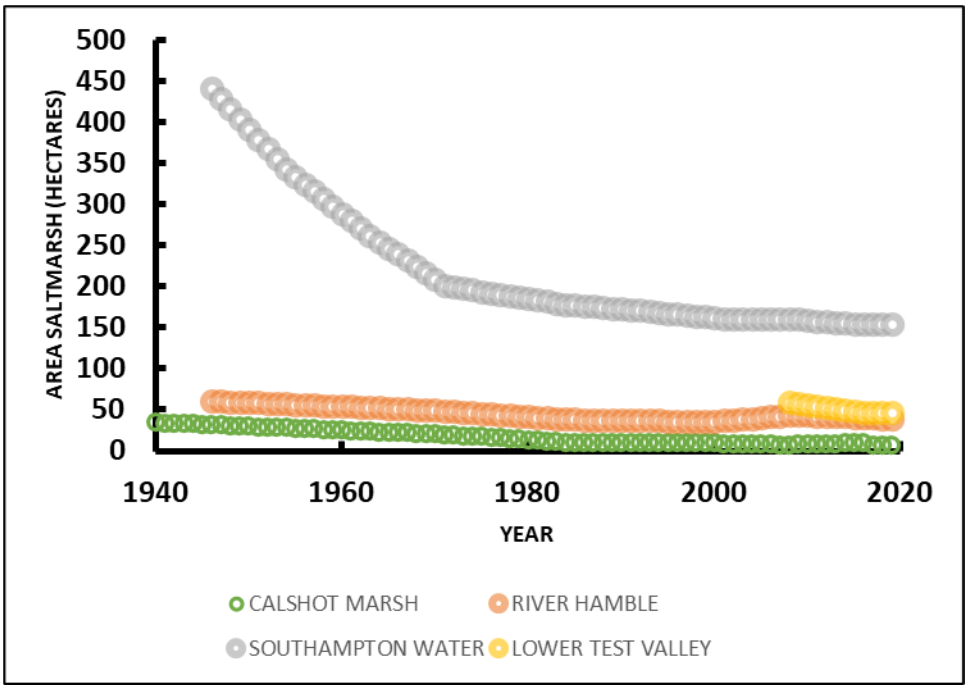



**Figure 95**. Historical change in saltmarsh extent between 1940 and 2019, north Solent.

## Isle of Wight

On the Isle of Wight the greatest percentage loss of saltmarsh area, between 2008 and 2019, occurred at Newtown Harbour, with a total loss of 10.3 ha, equating to 12.84% of saltmarsh. Although, data before 2008 are missing, this is the lowest rate of loss across the Solent. The mean average percentage saltmarsh loss on the Isle of Wight was the greatest at Newtown Harbour at a rate of 1.17 $hr^{-1}$ $yr^{-1}$, which is greater than the average rate of saltmarsh loss across the Solent at 0.95 hr-1 yr-1. (Figure 96).

However, the Isle of Wight was the only geographical section to show overall positive increases in saltmarsh area since their first records in 2008. Although, these areas are also the smallest across the entire Solent and their ability to contribute to ecological functions may be limited when compared with other larger areas.

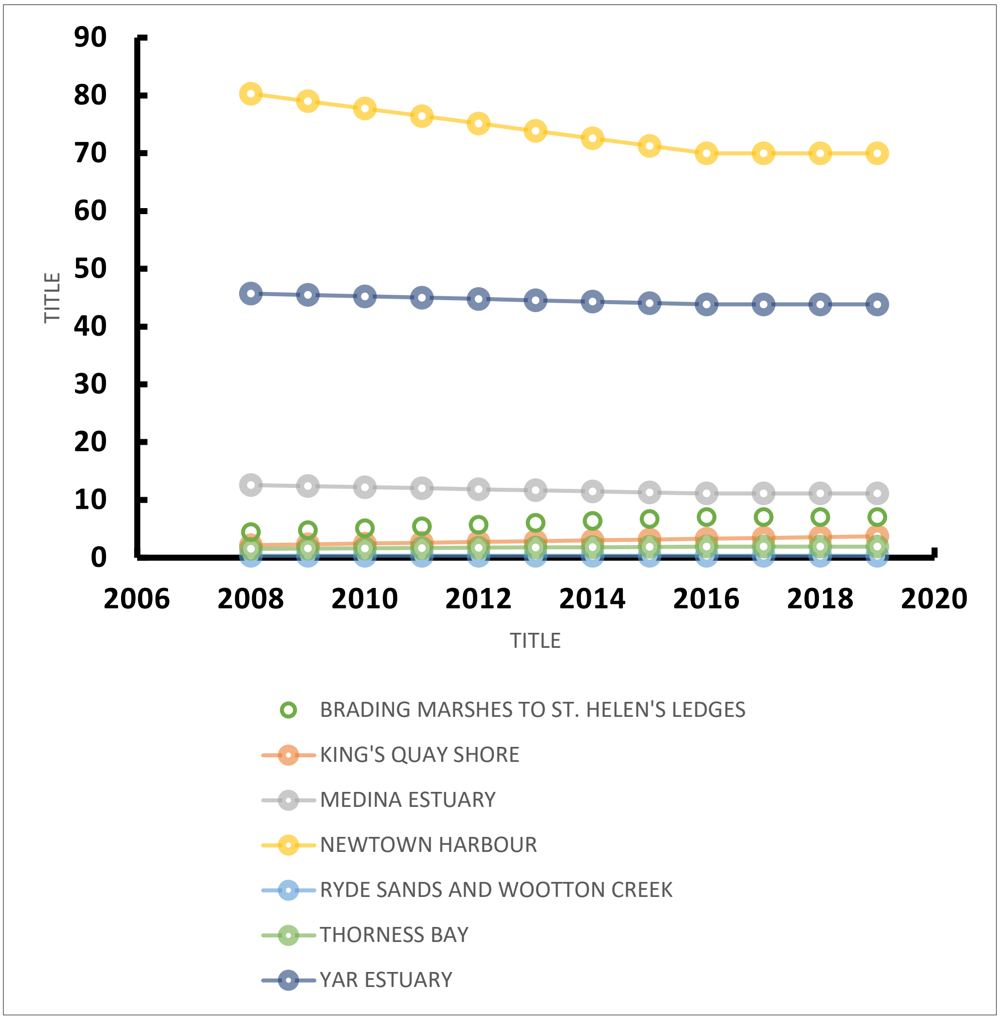



**Figure 96.** Historical change in saltmarsh extent between 2008 to 2019, north Isle of Wight.

## SAC assessment and review

### Solent Maritime

The data shows that between 2008 and 2016 there has been a 13.15% or 159.6 hectares loss of saltmarsh within Solent Maritime SAC (Table 41). Between 2016 and 2019 a smaller decrease of 6.46 hectares is indicated. Therefore, between 2008 and 2019 the Solent Maritime SAC has lost 166.06 hectares, equating to a loss of 15.09 hectares $yr^{-1}$. There were sites that saw a slight increase in saltmarsh between 2008 and 2016, which included King's Quay Shore SSSI and Thorness Bay SSSI, of 1.1 and 0.4 hectares, respectively. Between 2016 and 2019 the only site within the Solent Maritime (SAC) to show a positive increase in saltmarsh growth was in Lower Test Valley SSSI of 0.5 hectares.

**Table 41.** The saltmarsh extent within the Solent Maritime (SAC).

| Year | Area (Ha) | Period | Total Saltmarsh Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 2008 | 1213.9 | | | |
| 2016 | 1054.3 | 2008-2016 | -13.15 | -1.64 |
| 2019 | 1047.87 | 2016-2019 | -0.61 | -0.20 |
| | | 2008-2019 | -13.68 | -1.24 |

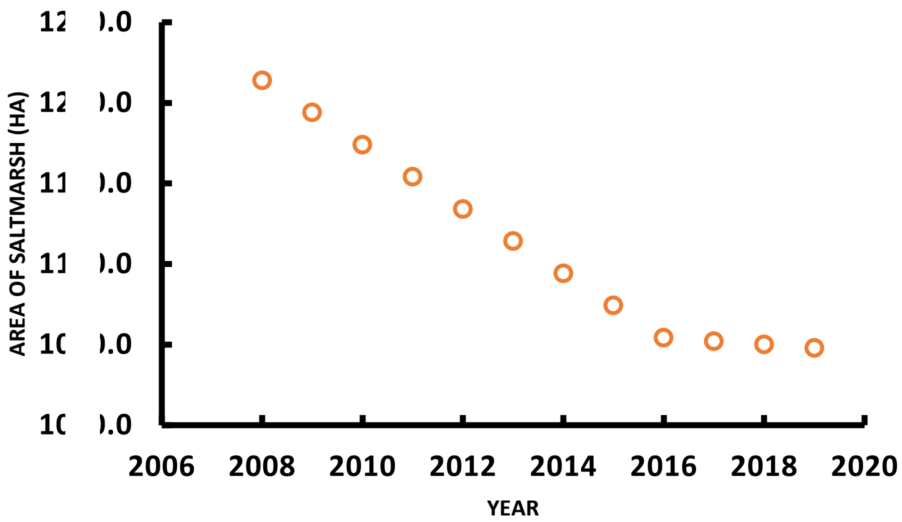



**Figure 97.** Historical change in saltmarsh extent between 2008 to 2019, Solent Maritime SAC.

### Solent and Isle of Wight Lagoons

Between 2008 and 2006 the Solent and Isle of Wight Lagoons SAC showed losses of 14.25 hectares saltmarsh (Table 42). Between 2016 and 2019 the saltmarsh extent within the Solent and Isle of White Lagoons SAC suggested further losses of 2.81%. Therefore, between 2008 and 2019 the Solent and Isle of Wight Lagoons SAC suggested losses of 17.13 hectares, equating to a loss of 1.56 hectares $yr^{-1}$.

**Table 42.** The saltmarsh extent within the Solent and Isle of Wight Lagoons (SAC).

| Year | Area (Ha) | Period | Total Change | |
|---|---|---|---|---|
| | | | % Change | % Change $yr^{-1}$ |
| 2008 | 116.68 | | | |
| 2016 | 102.43 | 2008-2016 | -12.21 | -1.53 |
| 2019 | 99.55 | 2016-2019 | -2.81 | -0.94 |
| | | 2008-2019 | -14.68 | -1.33 |

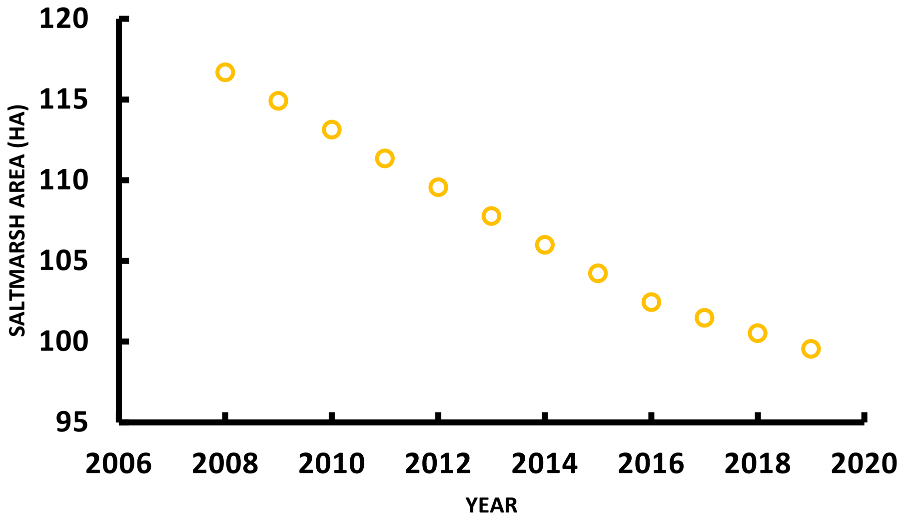



**Figure 98.** Historical change in saltmarsh extent between 2008 to 2019 Solent and Isle of Wight Lagoons SAC.

## Storm Surge Frequency

Storm surges are the abnormal rise in seawater, above the normal predicted astronomical tides, during a storm. The Solent coastline is particularly exposed to storm surges due to strong storm winds from over the Atlantic Ocean. This makes the Solent particularly vulnerable to flooding and erosion (Wadey *et al.*, 2020). Increased wind wave and storm surges generated during storms can alter the horizontal and vertical dynamics of saltmarsh areas, by altering the normal sediment import and export; often also removing sediment from the saltmarsh system completely (Leonardi *et al.,* 2017). This study included an analysis of storm surge frequency since the 1960's as a potential explanation for the rate of saltmarsh loss for sites across the Solent.

Through interpretation of historical storm surge records within the Solent, it was found that the 2000's had the greatest number of storm surge events occurring, with an average of 2.7 events (± 1.8 storm surge events) per year (Figure 99). This was significantly greater than the number of storm surges occurring in the 60's, 70's and 80's. Storm surges occurred as little as 1 in 2 years (± 0.8 storm surge events) in the 60's, 70's and 80's, however storm surge events neared one in 1.5 years by the 80's (± 1.6 storm surge events). No significant differences were found between the 60's 70's and 80's ($p \geq 0.05$). However, in the 90's it was found that 2 storm surges occurred per year (± 2.1 storm surge events), which was significantly greater than in the 60's and 70's. The 10's had the greatest standard error of ± 3.2 storm surge events due to the relatively low frequency of storm surges, however the year of 2013-2014 had the greatest record in storm surges of all years.

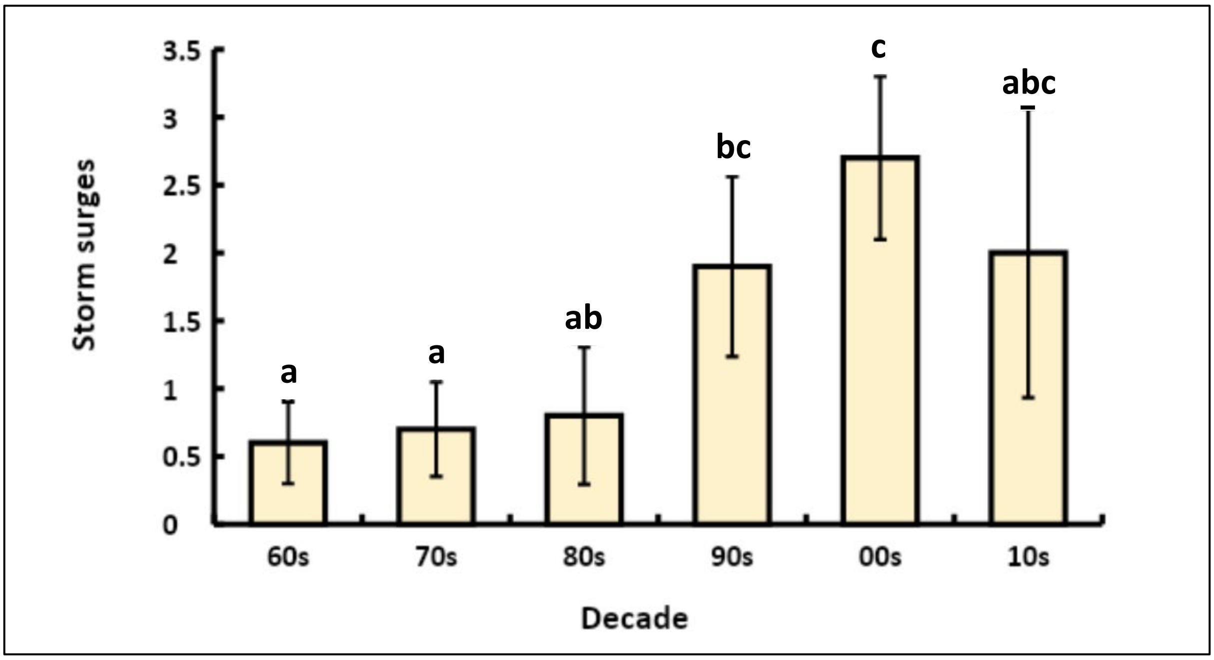



**Figure 99.** Storm surges recorded within the Solent by decade, using data obtained and adapted from SCOPAC (Wadey *et al.*, 2020). Storms have significantly increased since the 1960s to the 2000s (One-Way ANOVA, decade vs. storm surges: $F_{5,52} = 3.3$, $p \leq 0.05$, mean ± SE). Letters above the bars = Tukey's Pairwise comparisons.

# Discussion

## Condition of saltmarsh

The extent of saltmarsh in the Solent has decreased by a total of 1784.3 ha or on average by 51.19% since the 1940's, with the highest percentage loss of saltmarsh reaching 91.52%, within the Pitts Deep and Sowley area. Saltmarsh found in areas where wave hydrodynamics are altered naturally by spits and bars or anthropogenically by sea locks, sea walls and other wave-energy dissipating techniques, show reduced rates of erosion, often much lower than the average saltmarsh loss found across the Solent. These areas can be found naturally at the Beaulieu Estuary (saltmarsh behind the sandbar) and Newtown Harbour (where two spits either side of the harbour entrance restrict the entry of high energy waves). Furthermore, the saltmarsh found in the river Yarr is relatively protected (showing a loss of only 4.22% or 1.86 ha between 2008 and 2019), as the entrance to the river has been altered to protect moored boats within the marina. Only four areas showed an increase in saltmarsh extent, three on the Isle of Wight and the other at Portsmouth Harbour. The Isle of Wight sites are all small, of less than 10 hectares saltmarsh and with limited historical knowledge, only dating back as far as 2008. These sites include Brading Marshes to St Helen's Ledges, King's Quay Shore and Thorness Bay.

Through interpretation of the aerial photography and saltmarsh extent data, it should be highlighted that the greatest losses of saltmarsh were as a result of internal dissection of saltmarsh. Here the width of creeks widened and the length in which creeks extended into the saltmarsh also increased. This was particularly highlighted in sites within the West and East Solent sites. The rise in sea level may be a contributing factor to the erosion occurring within creeks, displaying common characteristics of coastal squeeze where natural vertical succession is limited. Furthermore, sites located in the West Solent sites displayed large losses of edge erosion, where the greatest losses of saltmarsh were lost on the edges of saltmarsh, furthest away from the shore. This was particularly evident at the Pitts Deep and Sowley and Keyhaven sites.

Using Natural England and Environment Agency ground-truthed data from the 2016 Environment Agency Geomatics surveys meant a simplistic overview of generic species and saltmarsh boundaries of species found within the saltmarsh could be made. The data enabled the identification of the dominant species types found at a specified location within saltmarsh areas. In some areas a clear succession of species was seen showing a full range of species from pioneers to developed reedbeds, such as in the Beaulieu Estuary, Yar Estuary and Newtown Harbour. Although no historical mapping of Solent saltmarsh species was available , by using the 2016 saltmarsh zonation data and comparing these images to the overall saltmarsh extent provided by the SDCP (Cope *et al.,* 2008) and the Environment Agency, an estimation of the area of saltmarsh that has been lost can be deduced. Burd (1989) described *Spartina* species dominating the south coast. After examining the saltmarsh within the Solent from the 2016 Natural England saltmarsh extent data, *Spartina* species still dominate many areas, particularly in the east and west. However, it could be deduced from historical saltmarsh extent records that many sites have seen large losses of the *Spartina* dominated marshes.

## Carbon storage potential of saltmarsh

It is estimated that carbon storage within saltmarsh is around 65 – 74 t C $ha^{-1}$ (BES, 2020; Burden, Garbutt and Evans, 2019). From the total Solent saltmarsh extent data, it can be estimated that the saltmarsh in the Solent currently stores around 69,030 – 78,588 tonnes of carbon. This is considerably less than the amount of carbon that would have historically been stored due to the reduction in total extent. Using this estimation of carbon storage, it can be estimated that in 1946, from 5 sites alone (Chichester Harbour, Southampton Water, Langstone Harbour, Portsmouth Harbour and Lymington Estuary), the Solent saltmarsh held twice the carbon that it holds now, with an estimated figure of 157,738 tonnes of carbon. Long established saltmarshes are one of the greatest coastal habitats for sequestering carbon, with rates in the UK of around 1.20 – 1.50 t C $ha^{-1}$ $yr^{-1}$ (BES, 2020, Burden *et al* 2019; Beaumont *et al*, 2014). It can be estimated that the remaining saltmarsh from the Solent, sequesters around 1,274.4 – 1,593.0 t C yr$^{-1}$. In 2009 saltmarsh sequestration rates were valued to provide anywhere between 34.56 – 118.26 £ ha$^{-1}$ yr$^{-1}$ (Keating *et al.*, 2015). From the remaining saltmarsh we estimate that the saltmarsh within the Solent provides between £35,710 – £122,198 of carbon sequestration per year. If the Solent's saltmarshes are maintained at their current extent, their sequestration capacity over the period 2020-2100 is valued to be in the region of £10 million UK sterling.

## Costs of restoration

Craft et al (2003) estimates that it takes around 65 years for a saltmarsh to be fully restored and therefore fully functioning. However, current restored sites are at most 26 years old, which is insufficient to determine how long a saltmarsh takes to be fully equivalent to other natural systems (Burden *et al.*, 2019). The Environment Agency's general guideline figure for saltmarsh restoration is £8,250 per hectare (price from 2006), while low to high mudflats range from £5,500 – £45,000. However, if significant engineering is required for a site then prices may exceed figures of £67,000 ha$^{-1}$ (reported from projects occurring worldwide) (Bayraktarov *et al.*, 2016). Following restoration of saltmarshes, carbon accumulation rates are between 0.65 - 1.04t C ha$^{-1}$ yr$^{-1}$ (Burden *et al.*, 2019).

## Coastal protection benefits of saltmarsh

Saltmarsh naturally provides coastal protection through the dissipation of wave energy and has been shown to reduce wave attenuation by 60-80% (Moller *et al*, 2014). This reduction in wave height is due to the increased friction caused by the seabed. Without this protective barrier many areas along the Solent have become increasingly vulnerable to wave erosion. The protection offered by saltmarshes are an important natural resource and tool for shoreline management plans in alleviating erosive processes and reducing flood risks (Boorman, 2003). Managed realignment processes, involving the creation of new saltmarsh, can protect areas of the coast under risk from rising sea levels (Bray and Cottle, 2004).

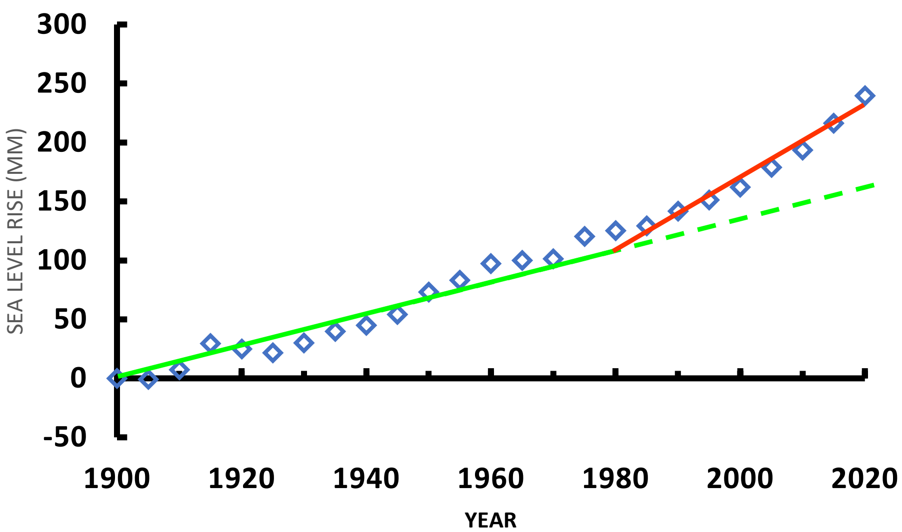



**Figure 100.** Global average sea level change. Green line shows Linear regression for 1900-1980 (y = 8.1917x - 17.706; $R^2$ = 0.9666), while the green dotted line is a continuation of this regression. Red line shows linear regression for 1980-2020 (y = 14.165x + 100.04; $R^2$ = 0.9635). (NOAA, 2022).
(Altimetry data are provided by the NOAA Laboratory for Satellite Altimetry under the terms of their data use policy).

Rising sea levels is a continuing pressure that must be acknowledged within the future of coastline protection. Evidence adopted from the Environment Protection Agency (2021) shows that the rate of sea level rise is increasing at a faster rate in the last 40 years (Figure 100). Between 1900 and 1980, the average global sea level was increasing at 1.56mm $yr^{-1}$ . However, between 1980 and 2020, the average rise in sea level increased to 2.86mm $yr^{-1}$ . This is alarming for many of the saltmarsh areas already under threat and displaying characteristics of saltmarsh lost. There is strong evidence to support that rising sea levels is a confounding factor, alongside coastal squeeze from coastal developments, for saltmarsh loss (Fagherazzi *et al,* 2019). Sea level rise increases the tidal volume within a saltmarsh and thus increases the volume of water that flows through channels and creeks. Subsequently the increase in tidal volume has the energy to increase the movement of sediments into and out of a saltmarsh (Rundershausen *et al.,* 2017; Farherazzi *et al.,* 2019).

Building a sea defence behind existing saltmarsh has been shown to decrease the construction and maintenance costs of the sea defence (Adnitt *et al*., 2007). Sea defences are used to protect landbound assets by deflecting wave energy, often back onto the existing saltmarsh. However, this alteration in hydrodynamics increases the removal of sediment from the saltmarsh and prevents the natural landward migration of the saltmarsh (Adnitt *et al*., 2007).

Furthermore, high wave energy during storms increases erosion of the saltmarsh by increasing the fragmentation of larger saltmarsh islands. By visually analysing aerial photography from 1940 to 2019, it can be seen that much of the saltmarsh displayed fragmentation of the remaining marshes, this could be due to the erosion caused by rising sea levels and the subsequent elevated tidal flows (Rudershausen *et al.,* 2017). As a result of this erosion, creeks have widened in many locations across the Solent, which has caused a great increase in the number of saltmarsh polygons identified using ArcGIS. Within the Yar estuary and Newtown Harbour saltmarsh polygons increased by 596.4% and 423.9%, respectively. This condition change is of concern as these two locations display some of the healthiest, structured saltmarsh within the Solent. Please note, this deduction is based on visual interpretation of historical aerial photography and analysis of saltmarsh zonation data only. Although, the saltmarsh extent has been interpreted from images of a reliable resolution (down to 20x20cm), this report would benefit from ground truthing to confirm the extent of saltmarsh in some areas. Areas within the West Solent suggested the highest increase in saltmarsh fragmentation, these sites included: Beaulieu River, Lymington marshes, Keyhaven and Hurst Spit, displaying an increase of 333%, 395%, 371% and 333%, respectively. The process of fragmentation is particularly destructive to saltmarsh as the deepened gullies can remove large areas of saltmarsh sediment and leave the remaining marsh less stable, thus allowing elevated tidal flows to further break up the marsh (Rudershausen *et al.,* 2017).

## Additional ecosystem services of saltmarsh

Saltmarsh represent the meeting of two important habitats, the marine environment and the terrestrial environment, providing a wide range of resources for birds, nekton and other wildlife all year round (Natural England, 2019; Natural England and Environment Agency, 2016; Fagherazzi et al., 2019; Lockwood and Drakefors, 2020). The wide range in elevation provides high tide refuges for many birds that feed on the lower adjacent mudflats (Natural England, 2018). Subsequently, allowing birds to wade and graze for food close to safe nearby roosting areas, away from tidal inundations. This is of particular importance to the 25 wildfowl species that can be found in the Solent, some of which are rated amber and red under the Birds of Conservation Concern 4: the red list for birds (Natural England, 2018). A very large abundance of birds relies on the vegetation for grazing during the winter months (Natural England, 2021), these include the Black-tailed godwit, Dark-bellied brent goose and the teal. During the summer months, particularly between April and September, Common tern, Little Tern, Mediterranean gull, Roseate tern, and the Sandwich tern all utilise the saltmarsh for breeding. The seeds of annual saltmarsh plants, such as *Salicornia sp.*, act as a rich source of food for many of the Solent's passerine birds (Boorman, 2003).

By offering warm, shallow, and structurally heterogenetic habitats, saltmarshes are an incredibly important habitat in providing nursery grounds to juvenile fishes that are abundant in food and inaccessible to larger predators. Non-predatory juveniles (such as mullets and herrings) can convert high energy, good quality saltmarsh foods into vagile biomass, which succinctly feed predatory fish and birds within the trophic relay (Stevens *et al.,* 2006). Furthermore, to escape desiccation and thermal stress, larger nekton moves to substantial creeks and seagrass beds, directly linking saltmarsh biomass to local seagrasses and the wider coastal environment. Several habitats are often relied upon during their life stages (Stevens et al., 2006; Deegan and Rountree, 2002). Therefore, it is challenging to understand the direct contribution saltmarshes have to fisheries. However, A study by Stevens, Montague and Sulak (2006) investigated 'the trophic relay' in which a conceptual model estimated the predator-prey interactions. It was estimated that the annual production of saltmarsh fin fishes was around 31.0g m-2 saltmarsh, with relative yields of 12 to 20% to piscivorous fishes, 8 to 13% to piscivorous birds, and 18 to 29% to export within an estuary (Jinks *et al*., 2020). Applying this study to within the Solent it could be estimated that the Solent contributes to the production of 320 tonnes of fin fish per year. Using the MMO's key landings from the UK Sea Fisheries Statistics (2018), the Solent's saltmarshes production of fin fish could be contributing £50.3 Million worth of fin fish to the fishing industry. This estimation of fin fish production from saltmarsh would be considerably lower than the historical estimate back in 1946 due to the reduction in saltmarsh extent across the Solent.

While there have been many fish population surveys through recent years, particularly in Langstone Harbour (MacCallum, 2012; MacCallum, 2013; MacCallum, 2014; MacCallum, 2015; MacCallum, 2016; MacCallum, 2017; Pickett *et al*., 2002), few studies have addressed the gap in data of juveniles aged 0 to 2 years (0- to 2-group), particularly within the bass population. The Solent encompasses the most important nursery areas for sea bass on the south coast of England (Pickett *et al*., 2002). Yet, from the studies available, there is a consistently low representation of the sea bass 0- to 2-group in the Solent, especially displayed in the Langstone Harbour surveys. Surveys within the British channel shown an inconsistency and an underrepresentation in sea bass 0- to 2-groups, therefore suggesting that recruitment of juvenile seabass could occur deeper within shallow creeks and margins (e.g. in <5 m water) (Pickett *et al*., 2002). Sea bass are believed to spawn in shallow waters because of the increase in temperature (Pawson, 1992; Ellis *et al*., 2012; MacCallum, 2012). There are gaps in the studies of the population dynamics representing juvenile fish. This highlights the question of where does bass recruitment take place, particularly if the Solent is renowned for being the main sea bass nursery ground along the south Coast?

## Concluding remarks

The re-establishment of the Solent's saltmarsh would significantly improve the structural complexity and diversity of the coastal ecosystems. By improving saltmarsh extent, there would be an increase in the amount of carbon sequestered into the Solent. This would benefit the UK by reducing the net footprint by offering increases blue carbon sink storage. The photosynthetic plants absorbing the carbon would therefore provide an abundance of organic carbon that could support and sustain a much greater biodiversity of species. In doing so, the resilience of the ecosystem would be strengthened, providing reliable sources and numerous alternatives if species become threatened by specific threats, including infections and changes to climate.

Not only would re-establishment of the saltmarsh benefit the ecosystem but there would be significant benefits to the economy surrounding the habitat. The restoration of saltmarshes would provide indirect benefits to the local tourist industry. The increased ability to support rare and endangered species would provide a great attraction for many bird watchers, dog walkers and tourists, who are often willing to travel to enjoy the natural wildlife provided by strong ecosystems. Furthermore, this would also benefit the local economy by improving local businesses, including coffee shops, sandwich bars and restaurants. The increase in saltmarsh area would allow the sustainability of larger and more prosperous fisheries. Increased nursery habitat areas for juvenile fish would sustain larger piscivorous bird species but would also feed back into the larger trophic relay. The abundance of fish moving from saltmarshes to larger estuaries and the greater Solent would increase the abundance of local fish. Subsequently, decreasing the fishing effort required of fishing fleets and offering greater prosperity to recreational fishers. Furthermore, restoration of the Solent's saltmarshes would provide greater protection from the effects of climate change. Storm surge frequency increased in the Solent, the number of storm surges occurring in the 60's 70's and 80's is significantly lower than the number of events that occurred in the 2000's. Therefore, to help mitigate against climate change and to restore the saltmarsh that has been lost over the past 80 years, restoration would provide an extremely beneficial natural climate change buffer to coastal developments and assets along the Solent shore.

## Data Limitations and Recommendations

Due to the resolution of the satellite images, a full assessment of the condition of the saltmarsh was not possible. The resolution of the aerial photography contained high resolutions to distinguish between larger and smaller foliage and some saltmarsh species. However, the resolution was not high enough to distinguish greater details. This meant that negative indicators and disturbances to the saltmarsh, either natural or anthropogenic, were impossible to identify and distinguish. These include the likes of trampling by wading public walkers or vehicles and macroalgal blooms. Therefore, we suggest ground truthing is needed to provide data for some of the key attributes associated with saltmarsh and would also benefit in the identification of other negative indicators. These surveys will enable a greater depth and range of descriptive data than can be interpreted by aerial photography. In addition, ground truthing in all 19 sites would verify and validate this report, as extensive literature searches resulted in no other evidence being found to support erosion pressures changing since the SDCP report (Cope *et al,* 2008).

Although the data from Natural England on species zonation was used, they were generic and broad. Furthermore, historical zonation records do not exist before 2016 and the resolution of species zonation, presented by the online data sets, was inadequate to appropriately comment upon and develop a satisfactory evaluation on the condition of the saltmarsh. Furthermore, due to restrictions associated with the Covid-19 pandemic, which occurred during the time of writing this report, additional survey effort to collect data on the vegetation structure, zonation and sward structure was not possible. Therefore, it should be highlighted that future ground truthing is needed to facilitate the detailed identification of species presence. Walk-over surveys would enable accurate assessments of species composition and sward heights, while also providing further informative details on small creeks and saltpans that are not visible on aerial photos. The benefit of walk-over surveys is that area characteristics can also be commented upon, i.e. algal-mat zones can be identified to accurately map saltmarsh extent when compared with aerial photography interpretation, to understand management measures, provide evidence for adverse activities including vehicle damage trampling etc and finally, walk-over surveys can enable the identification of invasive, non-invasive and rare species.

To gain greater accuracy in the amount of fish that are supported by saltmarsh, fish abundance and biomass could be measured using SMURF devices. Relationship between saltmarsh and fisheries is less frequently reviewed. Recommendations of long term adaptative-management studies are needed to demonstrate any link between saltmarsh loss and reduced fisheries, or alternatively, small-scale case studies on calorific requirements or isotopic studies to portray food webs (Harrison Day *et al.*, 2020).

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