
21. Predicting Habitat Change in Poole Harbour Using Aerial Photography

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Predicting habitat change is essential to strategic coastal planning for estuaries to demonstrate compliance with the Habitat Regulations and biodiversity targets and to address its effects on hydrodynamics. Such predictions were made in the Poole Bay and Harbour Strategy Study. Historical trends in habitat change were estimated in Poole Harbour by interpreting georectified aerial photographs and mapping the extents of saltmarsh and reedbed using a GIS. Between 1947 and 1993, 245 ha (38%) of saltmarsh was lost and 47 ha (63%) of reedbed were gained. The rates of change varied across the harbour. Future habitat extents were estimated using continuous compounding rates of change and extrapolation based on the observed trends. The effects of historical and future sea level rise on the extent of saltmarsh were also estimated. The habitat change results are being included in a wider assessment of estuarine processes in the harbour to aid strategic coastal planning.

Introduction

Role of habitat change studies

Studying the extent of existing habitats in estuaries and predicting future habitat change is essential to strategic coastal planning by demonstrating compliance with the Habitat Regulations (the UK Conservation (Natural Habitats Etc.) Regulations 1994) and biodiversity targets. It also enables the potential effects of intertidal habitat change on flooding and navigation to be addressed because, for example, the conversion of saltmarsh to mudflat may affect the hydrodynamics of the estuary. The interlinking of habitat change, sea level rise and estuary form into strategies improves the basis for future flood defence planning and management of habitat resources.

The study described here was undertaken as part of a wider assessment of the estuarine processes considered in the Poole Bay and Harbour Strategy Study. Poole Harbour is a large estuary on the south coast of England, which is fed principally by the Rivers Frome, Piddle, Corfe and Sherford. It is almost an enclosed body of water and has a small tidal range (less than 2 m). Poole Harbour is designated as a Special Protection Area (SPA) and a Ramsar Site for its internationally important flora and fauna supported by its extensive tidal mudflats, saltmarshes, reedbeds, lagoons, freshwater marshes and wet grassland.

Saltmarsh

Saltmarsh vegetation develops in characteristic zones associated with saline or brackish tidal regimes (Burd, 1989; Rodwell, 2000). Poole Harbour contains over 20 different saltmarsh communities and sub-communities, including three Annex 1 habitats (listed in the European Habitats Directive 92/43/EEC) (Edwards, 2002).

Many saltmarshes are now dominated by common Cord Grass, *Spartina anglica*, which has spread naturally and by planting to aid sea defence and land-claim (Davidson, 1991; Raybould, 1997). It first started colonizing Poole Harbour in the 1890s and spread rapidly over a vacant niche on the mudflats (Gray *et al.*, 1991) to cover 800 ha by 1924 (Raybould, 1997). However, since the 1920s there have been substantial losses (Hubbard, 1965, cited by Bird, 1966; Raybould, 2000), which have also been observed in other swards in the south of England (Davidson, 1991). Potential causes of this decline may include:

- die-back of *S. anglica*
- invasion of other species (such as *Phragmites australis*)
- wave erosion
- sea level rise
- deliberate land reclamation
- other anthropogenic causes, such as pollution, dredging, etc. (Gray and Pearson, 1984; Gray *et al.*, 1991; Raybould, 1997).

Hubbard (1965, cited Gray and Pearson, 1984) estimated a loss of 170 ha from the 1920s to 1952, mainly from seaward bays, which may indicate that the harbour was affected by wave erosion. However, die-back was the principal cause of loss of *S. anglica* in Holes Bay (Hubbard, 1965, cited by Raybould, 1997). The changes in *S. anglica* extent has greatly affected the sedimentation process in Poole Harbour, first by accreting and consolidating sediment by rhizome growth during its gain, which deepened navigation channels, then by releasing it during die-back and erosion, which caused a shoaling of the channels (Raybould, 2000).

Reedbeds

Reedbeds are generally characterized by the overwhelming dominance of the common reed *Phragmites australis* (Rodwell, 1995; Cook, 2001), and form on predominantly wet or periodically flooded freshwater or tidal land. Some of the main reedbeds in Poole Harbour are found on either side of seawalls, which indicates that they have both freshwater and marine influences, although others have purely freshwater influences (Cook, 2001). Indeed, in Poole Harbour, *P. australis* has survived salinities of up to about 22 ppt, close to the experimentally determined limit (Rodwell, 1995).

Methodology

Measuring historic habitat extents from aerial photographs

Three sets of vertical aerial photographs of Poole Harbour were obtained from 1947, 1972 and 1993 (see Figure 1) covering the area shown in Figure 2. Following georectification from OS mapping, the images from each period were converted into a photo-mosaic and the extents of saltmarsh and reedbed were digitized on-screen using a geographical information system (GIS) software. Areas where there was uncertainty were verified by ground truthing, comparison with independent habitat maps prepared by Dorset Environmental Records Centre and, in the case of the older material, cross-comparison with recent, higher resolution colour photographs.

The total areas of saltmarsh and reedbed were calculated for the whole harbour and the six harbour sections using GIS, from which the past rates of change were derived.

Extrapolating from past change

A range of the future change in saltmarsh and reedbed up to 2053 was then predicted for the whole harbour study area and the six harbour sections based on the past trends. The extent of saltmarsh was estimated using logarithmic continuous compounding, because the magnitude of habitat loss depends on the initial area, gradually tending towards zero. The equations used were:

$$A = Pe^{in}$$

$$i = \log(A/P)/(n \log(e))$$

where P is the principal area, i is the rate of change, A is the area after n years, n is the number of years, e is the base of natural logarithms (2.71828... etc).

The extent of reedbed in 2053 was estimated using an arithmetic extrapolation of the annual rates of observed change. Continuous compounding rates of change were not used because reedbed gain is not necessarily associated with how much is present and compounding cannot predict changes in sections with no reedbed initially.

Although the suite of causal factors contributing towards saltmarsh loss was included in the extrapolations of future loss, it was possible to measure the area lost to deliberate land reclamation using GIS and to distinguish the area directly affected by sea level change.

Effects of sea level rise

The component of saltmarsh loss resulting directly from sea level rise was estimated independently. Maps of the saltmarsh distributions were overlaid on topographical data obtained from a 1998 LiDAR survey in GIS using a digital terrain model (DTM) of Poole Harbour. This enabled an estimate of the saltmarsh elevation and thus the

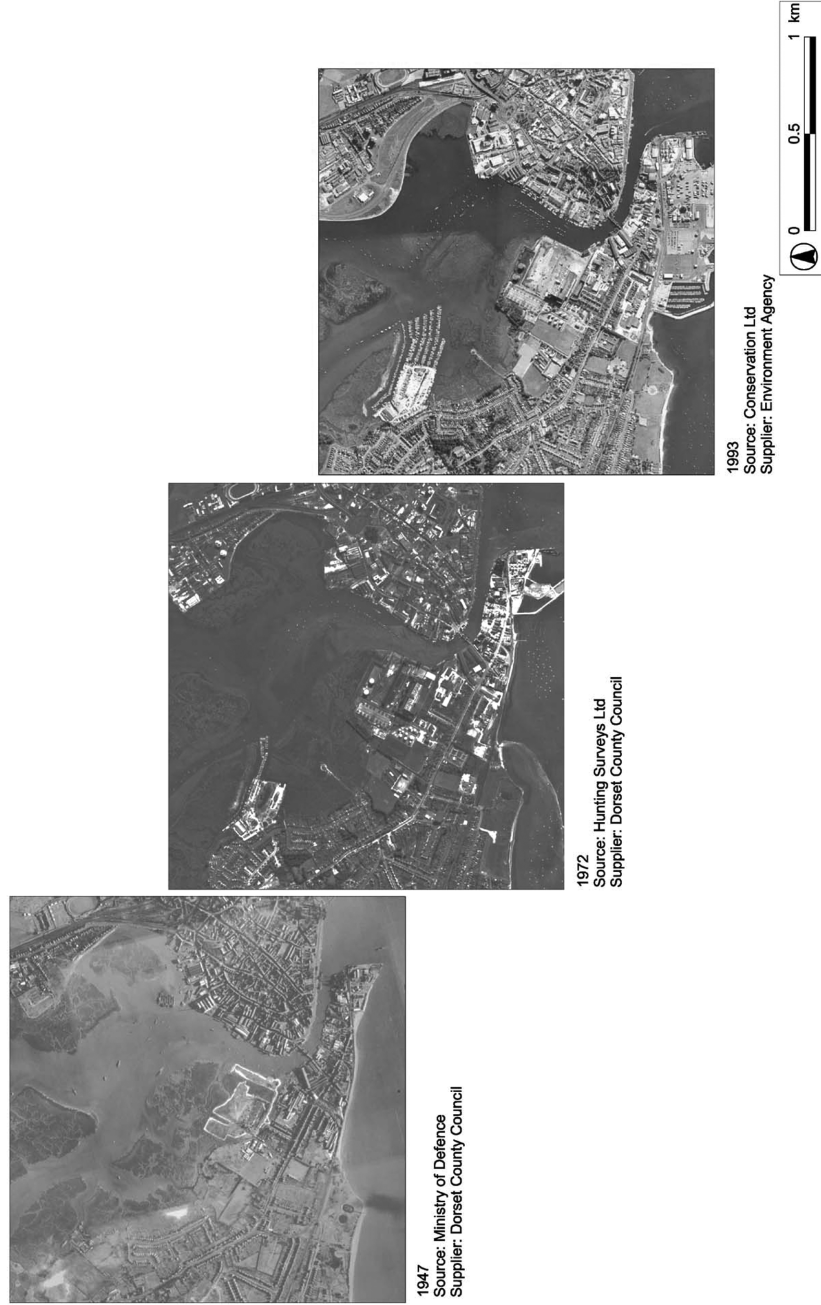


Figure 1 Aerial photography used for habitat mapping.

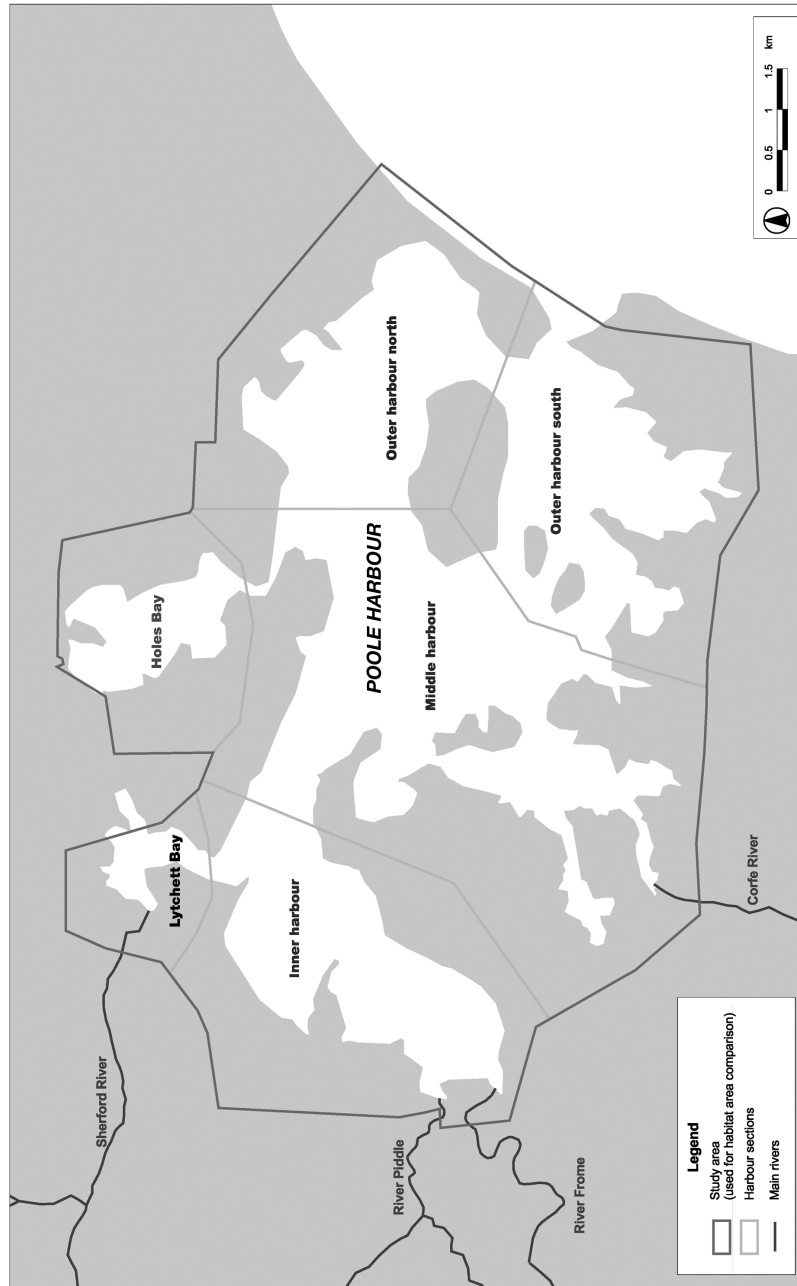


Figure 2 Study area.

percentage liable to be inundated for any given estimate of future sea level rise. Historic sea level rise was taken as a rate of 1.3 mm year⁻¹ and future sea level rise was taken as a rate of 5 mm year⁻¹ from 2003 (MAFF, 1999; website reference 1).

In estimating the effects of sea level rise, the lowest and highest extent of saltmarsh were taken to be the fifth and ninety-fifth percentile elevation values, to discount saltmarsh growing in marginal habitat and to remove the effects of any errors from the mapping or elevation data.

A range of saltmarsh areas affected by sea level change was calculated to allow for the differences in saltmarsh ability to migrate to higher elevations and the presence of a constraint to migration, such as a sea defence structure (Table 1). In other words, net loss is a balance between saltmarsh being submerged and lost from the lowest elevations and the extent of 'coastal squeeze' to the saltmarsh at the highest elevations.

Results

Observed habitat change

The extents of the saltmarsh and reedbed in the whole study area in 1947, 1972 and 1993 are shown on Figures 3 and 4. Between 1947 and 1993, the area of saltmarsh in the whole

Table 1 Methodology used to calculate areas of historic and future saltmarsh loss due to sea level change

Possible saltmarsh response to sea level change	Estimated historic saltmarsh loss due to sea level change (1947–93)	Estimated future saltmarsh loss due to sea level change (1993–2053)
No saltmarsh migration at a constrained or unconstrained site (erosion)	The lowest 0.060 m of saltmarsh, i.e. area between the lowest elevation (fifth percentile) and an elevation 0.060 m higher	The lowest 0.263 m of saltmarsh, i.e. area between the lowest elevation (fifth percentile) and an elevation 0.263 m higher
Saltmarsh migration at a constrained site (coastal squeeze)	The highest 0.060 m of saltmarsh, i.e. area between the highest elevation (ninety-fifth percentile) and an elevation 0.060 m lower	The highest 0.263 m of saltmarsh, i.e. area between the highest elevation (ninety-fifth percentile) and an elevation 0.263 m lower
Saltmarsh migration at an unconstrained site	Area of net saltmarsh loss would be nil	Area of net saltmarsh loss would be nil

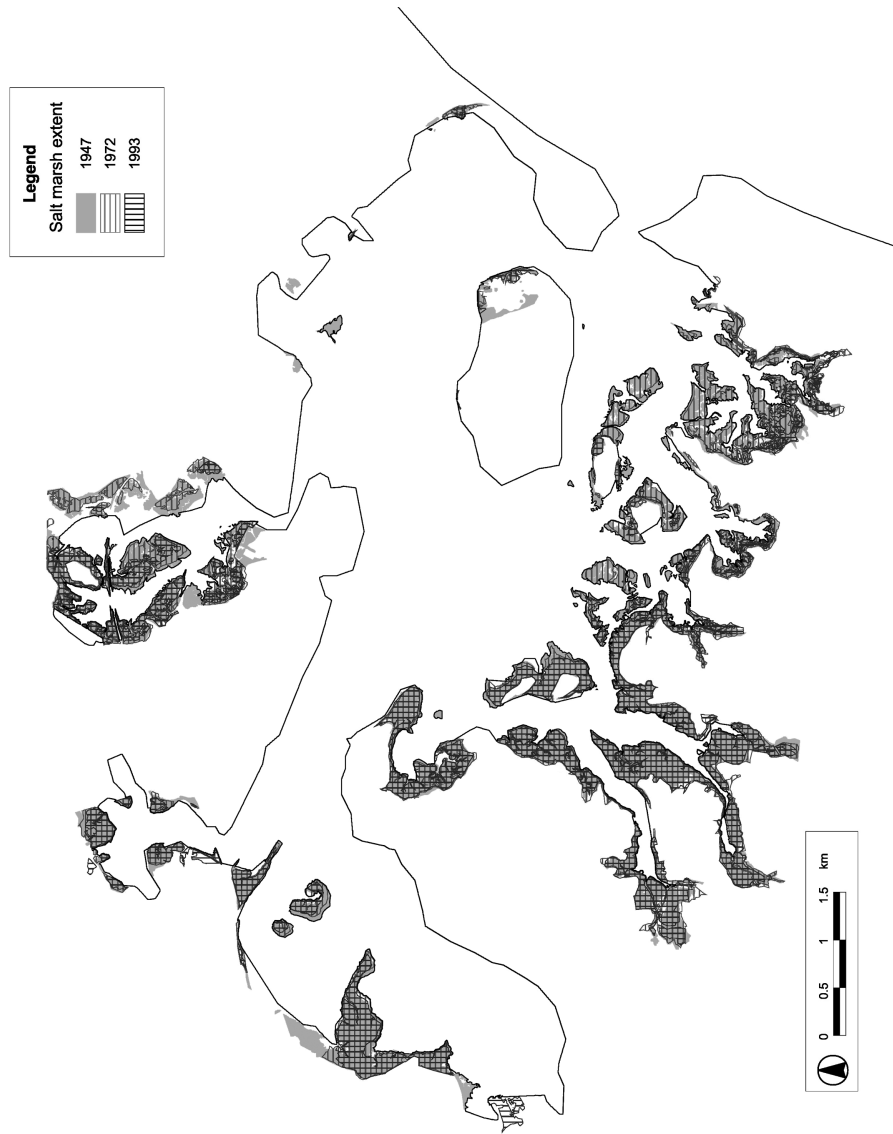


Figure 3 Change in saltmarsh extent 1947-93.

harbour study area decreased by 245 ha (38% of 1947 extent), whilst the area of reedbed increased by 47 ha (63% of 1947 extent) (Table 2). The rates of change varied over the years with saltmarsh loss accelerating and reedbed gain decelerating to virtually no change since 1972 (Figure 5).

Between 1947 and 1993, all six sections of the harbour experienced a loss in saltmarsh, although at different rates (Figure 6). The greatest rate of loss was in the Outer Harbour South (1972–1993) and the least was observed in Lytchett Bay (1947–1993). Likewise, the changes in reedbed also differed around the harbour over the years (Figure 6). Between 1947 and 1993, Inner Harbour, Middle Harbour and Outer Harbour North experienced a gain in reedbed and Lytchett Bay experienced a slight loss. However, between 1972 and 1993, only two sections experienced a gain in reedbed and two experienced a loss.

Extrapolation from past change

The results of extrapolating the 1947–93 and 1972–93 trends of habitat change to 2053 are shown in Table 4. Losses of saltmarsh are expected to be between 183 ha and 244 ha (47–63% of 1993 extent), whilst reedbed gains would be between 0 and 61 ha (0–50% of 1993 extent).

Effects of sea level rise

Between 1947 and 1993, up to 9 ha of saltmarsh were lost directly from sea level rise if migration did not occur, or up to 0.6 ha as a result of coastal squeeze (up to 3.5% and 0.2%, respectively of the observed saltmarsh loss). By 2053, the amount of saltmarsh estimated to be lost due to future sea level change would be up to 76 ha if migration does not occur, or up to 150 ha as a result of coastal squeeze. The study of saltmarsh elevations also found that between 1947 and 1993 most saltmarsh had been lost at the lowest range of elevations (Figure 7).

Summary of causes of habitat change

Several causes of habitat change were confirmed during the study (Table 4).

Table 2 Areas of saltmarsh and reedbed from historical aerial photographs in the whole harbour study area

Habitat	Observed area (ha)		
	1947	1972	1993
Saltmarsh	634	549	389
Reedbed	75	122	122
Total	709	671	511



Figure 4 Change in reedbed extent 1947 -93.

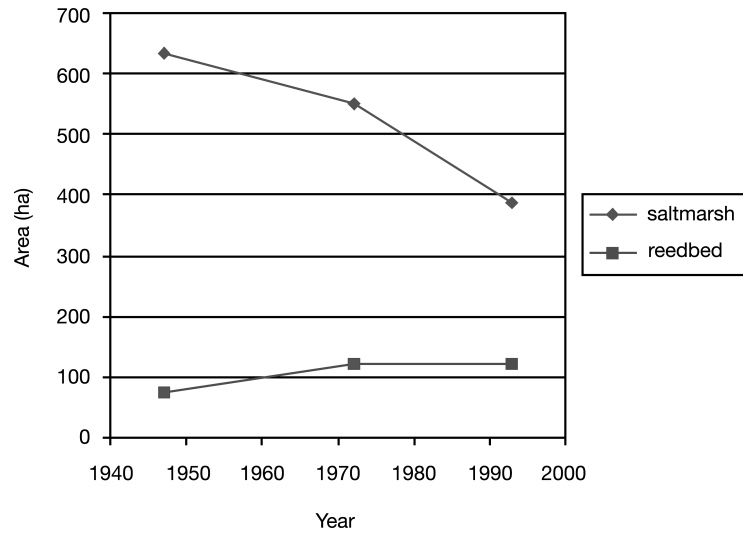


Figure 5 Observed habitat areas in the whole harbour study area.

Table 3 Predicted changes in saltmarsh and reedbed in the whole harbour study area

Habitat	Extrapolation from observed trend	Projected area in 2053 (ha)	Projected change in area since 1993 (ha)	Projected percentage change in area (%)
Saltmarsh	1972–93	145	-244	-63
	1947–93	205	-183	-47
Reedbed	1972–93	122	0.5	0.4
	1947–93	183	61	50

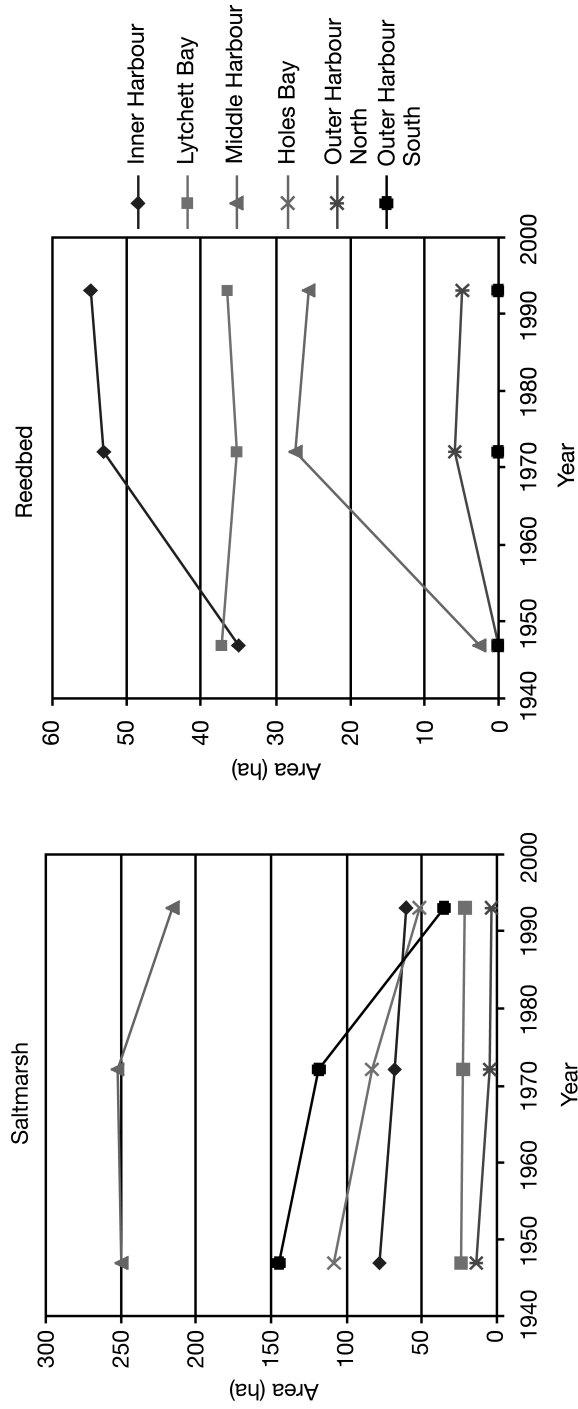


Figure 6 Area of observed saltmarsh and reedbed around Poole Harbour.

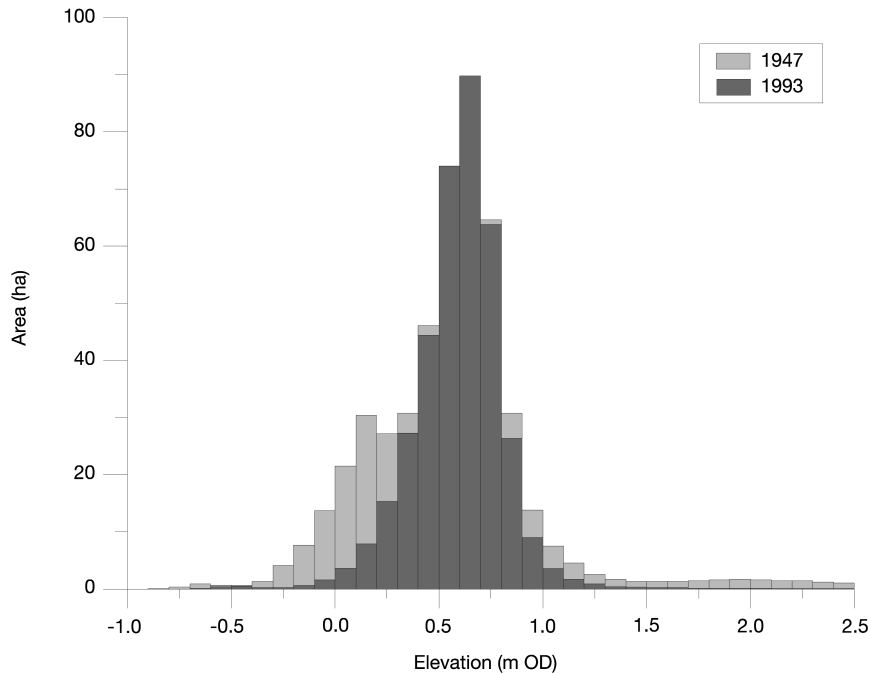


Figure 7 Distribution of saltmarsh with respect to elevation in 1947 and 1993.

Sensitivity analysis

Georectification of the aerial photographs and habitat mapping were estimated to have potentially introduced minimal error. However, sensitivity to scientist interpretation was considered to be the greatest potential cause of error, but the various verification methods described above reduced this.

Discussion

Review of methodology

The use of aerial photographs proved to be invaluable in measuring habitat change, as had been shown by Gray and Pearson (1984). However, several assumptions were made and there may have been opportunities for the introduction of error. The main assumption was that the observed rates of change from the past would continue unaltered in the future, but extrapolation of past change is not necessarily an accurate guide to the future. Also, extrapolation depends on which observed trend is used, and estimating the effects of sea level change depends on the response of the saltmarsh. Therefore, a range of results has been presented as a guide.

Table 4 Summary of the causes of habitat change

Potential cause of change in saltmarsh extent	Observed saltmarsh loss (1947–93) (ha)	Future saltmarsh loss (1993–2053) (ha)	Comment
Combination of causes (except land reclamation):			
• <i>Spartina</i> die-back	245	183–244	This assumes that all of these processes will continue unchanged in the future
• invasion by other species			Range of future loss given depends on which observed trends are used in the extrapolation
• wave erosion			
• sea level rise			
• other anthropogenic causes			
<i>Spartina</i> die-back	Note ¹	Note ²	Evidence of this as most observed saltmarsh loss was experienced at the lowest elevations, where <i>Spartina</i> lies; maybe less important in future as most now lost
Invasion of saltmarsh by other species, e.g. <i>Phragmites</i>	Note ¹	Note ²	Evidence of this as 22 ha of saltmarsh has converted to reedbed between 1947 and 1993
Wave erosion	Note ¹	Note ²	Evidence of this as most decline observed in seaward parts of the harbour
Other anthropogenic causes, such as pollution, dredging, etc.	Note ¹	Note ²	Direct evidence cannot be established using this methodology
Sea level rise	Up to 9 (erosion) or 0.6 (coastal squeeze)	Up to 76 (erosion) or 150 (coastal squeeze)	Evidence that 1947 saltmarsh was submerged by the 1993 sea levels. 1993 saltmarsh will be submerged by predicted 2053 sea levels. Range as it depends on the opportunity for saltmarsh migration. Likely to be dominating causal factor in the future and may result in more loss than predicted above
Land reclamation	30	Expected to be small	Removed from analysis of future change. Evidence of this in the past from aerial photographs and may occur in the future, but to a smaller extent due to current environmental regulations

¹The amount of the saltmarsh loss directly caused by this individual factor is unknown.

²The amount of the future saltmarsh loss that will be directly caused by this individual factor is unknown.

Observed habitat change

This study has confirmed that several causal factors may have occurred in Poole Harbour in the last 50 years (see Table 4). The aerial photographs showed that 30 ha of saltmarsh were lost to deliberate land reclamation. However, an important reason for habitat changes in Poole Harbour is likely to be the decline of *Spartina anglica*, which has been observed by many other authors (see Bird, 1966; Gray and Pearson, 1984; Raybould, 2000). The histograms of saltmarsh elevations (Figure 7) show that most saltmarsh was lost at the lower elevations, which is the zone where *S. anglica* is mainly found (Burd, 1989). This may suggest that *Spartina* die-back and/or wave erosion occurred. Saltmarsh was invaded by other species, as 22 ha had converted to reedbed between 1947 and 1993.

A substantial reduction of saltmarsh occurred at seaward locations, which was also observed by Gray and Pearson (1984), which suggests that wave erosion has been a key cause of saltmarsh loss. Another likely cause is the direct effects of sea level change, causing up to 9 ha (4%) of the observed saltmarsh loss.

Predicted habitat change

In the future, the direct effects of sea level change are expected to be much greater than previously observed, as the rate of sea level rise is expected to be greater (MAFF, 1999). Saltmarsh loss directly from sea level rise is expected to be up to 150 ha by 2053, and it is likely to become the dominating causal factor for saltmarsh loss in the future and may mean that the total saltmarsh loss may be greater than that made by the extrapolations. The impact of sea level rise depends on the saltmarsh ability to migrate to higher elevations as fast as sea level rise. In the future, the impact of 'coastal squeeze', where constraints would stop saltmarsh from retreating, will be greater than that of submergence at the lower elevations as most saltmarsh communities now lie at the higher elevations.

Habitat resource planning

The observed and predicted changes to these internationally important habitats have implications for habitat resource planning. To comply with the Habitats Regulations and Biodiversity Action Plan targets, provision should be made for recreating saltmarsh to replace that which is lost. This study could be used to identify areas where further monitoring of habitat change, replanting measures or managed realignment of coastal defences might be appropriate.

Conclusions

This is believed to be the most reliable and up to date study of saltmarsh loss and reedbed gain in Poole Harbour, although the results should be considered as a guide to possible future change. It has also confirmed the several causes of past habitat change and that sea level rise is likely to become a dominating cause of saltmarsh loss in the future.

The study has implications for sustainable estuary management since the replacement of the lost habitat will be required to comply with nature conservation obligations, such as through the managed realignment of coastal defences.

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www.pol.ac.uk/psml/datainfo/rlr.trends permanent service for mean sea level, hosted by Proudman Oceanographic Laboratory, based on 2001 data.