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SUMMARY

Background

Paull Holme Strays (PHS) is the site of the first major managed realignment scheme on the Humber. Created by the Environment Agency as part of a flood risk management scheme, the site provides approximately 80ha of new intertidal habitat (hereafter referred to as ‘the inside’) and is fronted by the extensive Paull Holme Sands mudflat (hereafter referred to as ‘the outside’). It was initially anticipated that the PHS site would ultimately create approximately 45ha of mudflat and 35ha of saltmarsh. The site is adjacent to the Humber Estuary Special Protection Area (SPA)/Ramsar site and possible Special Area of Conservation (pSAC). These designations form part of the Natura 2000 network of ‘European Sites’ and illustrate the international importance of the estuary for, amongst other things, intertidal habitats and the wildfowl and waders they support. Nationally, the Humber Estuary is also designated as a Site of Special Scientific Interest (SSSI) for its mudflats, sandflats and saltmarsh habitats.

The main objectives of the PHS managed realignment project were to:

- provide cost effective flood risk management for the area;
- create intertidal habitat to compensate for that lost through implementation of this and other flood defence schemes in the middle estuary;
- address additional habitat losses arising from coastal squeeze and identified in the Coastal Habitat Management Plan (CHaMP). These losses occur, when tidal defences prevent intertidal habitats migrating inland, in response to rising sea levels.

The Draft Humber Estuary Flood Risk Management Strategy (Environment Agency, 2005) was approved by the Environment Agency’s Board in 2006 and is currently under review by Defra. It proposes a suite of managed realignment schemes with complementary objectives, including conservation of the Natura 2000 site’s integrity. PHS was the first of the planned schemes to become operational and another at Alkborough Flats has recently been constructed and was breached in September 2006. Alkborough will provide approximately 170ha of new intertidal habitat and is already reported to be attracting substantial numbers of estuary birds. These outcomes of these schemes will help to inform the design of further managed realignment projects.

A 5-year monitoring programme began in late 2003 to monitor the accretion and erosion at the site and to assess the development of intertidal habitat and associated assemblages especially benthic invertebrates, birds and vegetation (Figure A). The scope of this PHS environmental monitoring project includes:

- environmental monitoring (e.g. accretion/erosion, benthic invertebrates, saltmarsh vegetation and bird use) over the site (both inside and outside where appropriate) as agreed in the Environmental Action Plan (EAP) and planning consent; and
- an annual environmental monitoring report, incorporating the results of the above studies with those generated through monitoring undertaken by voluntary groups.

The monitoring results may be usefully considered in the light of this basic time line for the development of the site and its land use:

- Pre September 2001 – Site largely in arable use, the land being bare between plantings typically of oilseed and cereals. There was also some rough grassland, hedgerows and some well-vegetated brackish water pools (old borrow pits) present.
- September 2001 to September 2003 – Site under various stages of construction with large areas of disturbed or bare ground, ephemeral pools (especially during winter flooding) with ex-arable areas reverting to rank vegetation.
- Post September 2003 – Breaches created on 5th September 2003 and site subject to tidal inundation creating large areas of new open water (where new borrow pits were flooded) and encouraging development of mudflat and saltmarsh areas.

The results of the third year of monitoring are summarised in this report.

Accretion, erosion and vegetation

During 2005 – 2006, the realignment site continued to accrete sediments, and to do so at a much higher rate than the less sheltered areas outside the site. Over twenty-eight months of monitoring since May 2004, the lower elevation areas of the site have accumulated on average 23 cm of material (which approximates to an average of 30 cm of sediment in 3 years when back-calculated to the time of the breach in September 2003), compared to 1.7 to 9.6 cm at similar elevations outside the site. Vegetation is now beginning to colonise the new mudflat areas inside the site. Higher elevations in the southern part of the site provide suitable areas for saltmarsh to develop, and this zone has accumulated an average of approximately 4 cm of sediment since the breach. Vegetation development has continued during 2005-2006. There are now twenty plant species typical of saltmarsh present in this part of the realignment. These include common cord-grass (*Spartina anglica*), common glasswort (*Salicornia europaea*), saltmarsh-grass (2 *Puccinellia* species) and sea aster (*Aster tripolium*). Very little of the pre-breach vegetation remains except at the highest elevations. Saltmarsh development appears to have been successful to date, with 23 of 36 monitoring sites in the new saltmarsh now supporting vegetation. The sites in the southern sector of the realignment are particularly well developed, and show 59% vegetation cover on average. The volunteers' botanical monitoring also reported most of the twenty saltmarsh species identified by the Centre of Ecology and Hydrology.

The continued high level of accretion on the low mudflat areas of the site is of particular interest as it is not only much higher than accretion at equivalent sites outside the realignment,

but also appears to be building material up to elevations that might eventually be suitable for saltmarsh. This is evident in the colonisation of the edges of the new mudflat by saltmarsh plants. The higher than anticipated accretion inside the site appears to be due to the 'settling-tank' effect promoted by the sheltered conditions. Elevation is a key factor in the development of saltmarsh, as shown by the greater development of saltmarsh vegetation at higher elevations in the PHS site (Plate B).

Invertebrates

Benthic invertebrate communities on the established mudflats outside the site have remained relatively stable over time, but have undergone substantial changes inside the site. This fluctuation inside the realignment is to be expected as it is still in an early stage of ecological succession. In 2004 the oligochaete *Paranais litoralis* dominated the benthic fauna, whilst in 2006 there was an increased dominance of *Hediste diversicolor*, Collembola and *Hydrobia ulvae*. The latter is an important food organism for a number of waterbirds. Collembola are not estuarine *per se*, but are likely to be present inside the realignment due to the site's history and to its proximity to terrestrial environments. In addition, there has been a general shift from many, small, invertebrates to an increasing number of larger invertebrates, with the overall invertebrate biomass inside the site now being greater than that of sampling locations outside the site. This pattern is also typical of recolonisation of an area by aquatic invertebrates. However, general diversity of invertebrates is still greater outside the realignment than inside it.

Freshwater invertebrate diversity was also monitored in four sites behind the new realignment. These sites consist of three soke dykes and a pond, all of which were created behind the realigned Humber Bank as part of the realignment scheme, and which compensated for the loss of a borrow pit that had supported a rich invertebrate fauna. These sites have been monitored each year since the breach. As in previous years, freshwater invertebrate diversity continues to be greatest in one of the soke dykes monitored, which has a well-developed vegetation/open water complex. However, there is an increase in brackish water indicator species, indicating changes in salinity over time.

Birds

The development of the above benthic invertebrate community provides a valuable food source for waterbirds, and the waterfowl assemblage present within the site is now considered broadly typical of a mid-estuary community. However, although bird numbers have increased at the site over time, they appear to use it primarily for roosting and loafing rather than for feeding. The target initially set for the site, to have at least 3,000 individual birds using the site has been consistently exceeded in all three years, most notably due to the 12,600 Golden Plover (*Pluvialis apricaria*) and 2,100 Black-tailed Godwit (*Limosa limosa*) that are now recorded using the site.

The target for 30 species of feeding wintering waterbirds has not yet been met. The 2005-2006 total was 29 species, with not all of these feeding. Over time, however, there has been a shift towards foraging on the site by target species including Dunlin (*Calidris alpina*, now 26% dominance of the foraging community) and Black-tailed Godwit (*Limosa limosa*, 33% dominance of the foraging community). Of the 29 species recorded, 19 were waders, including the target species of Redshank (*Tringa totanus*), Dunlin, Shelduck (*Tadorna tadorna*) and Curlew (*Numenius arquata*). The volunteers' bird data also included Golden Plover, Black-tailed Godwit, and Dunlin as important species. Avocet (*Recurvirostra avosetta*) were once again recorded breeding in the site; 29 pairs bred in 2006 and there was a noteworthy peak of 103 birds in June 2006. The site is therefore progressing well towards the targets set for birds in the EAP, but has not yet fully achieved those targets.

The possible long-term development of the new mudflat into saltmarsh is likely to reduce the available foraging mudflat habitat for birds. However, additional saltmarsh could provide high tide refuges for birds, as well as roosting and nesting sites. The outcome of saltmarsh and mudflat development at Paull Holme Strays, and the resulting composition of the bird community, will provide an important basis for the design and monitoring of further realignment schemes along the Humber.



Plate A: Aerial view of Paul Holme Strays site following the embankment breaches (October 2003, Environment Agency)



Plate B: The site in the third year post-breach (January 2006, Environment Agency)

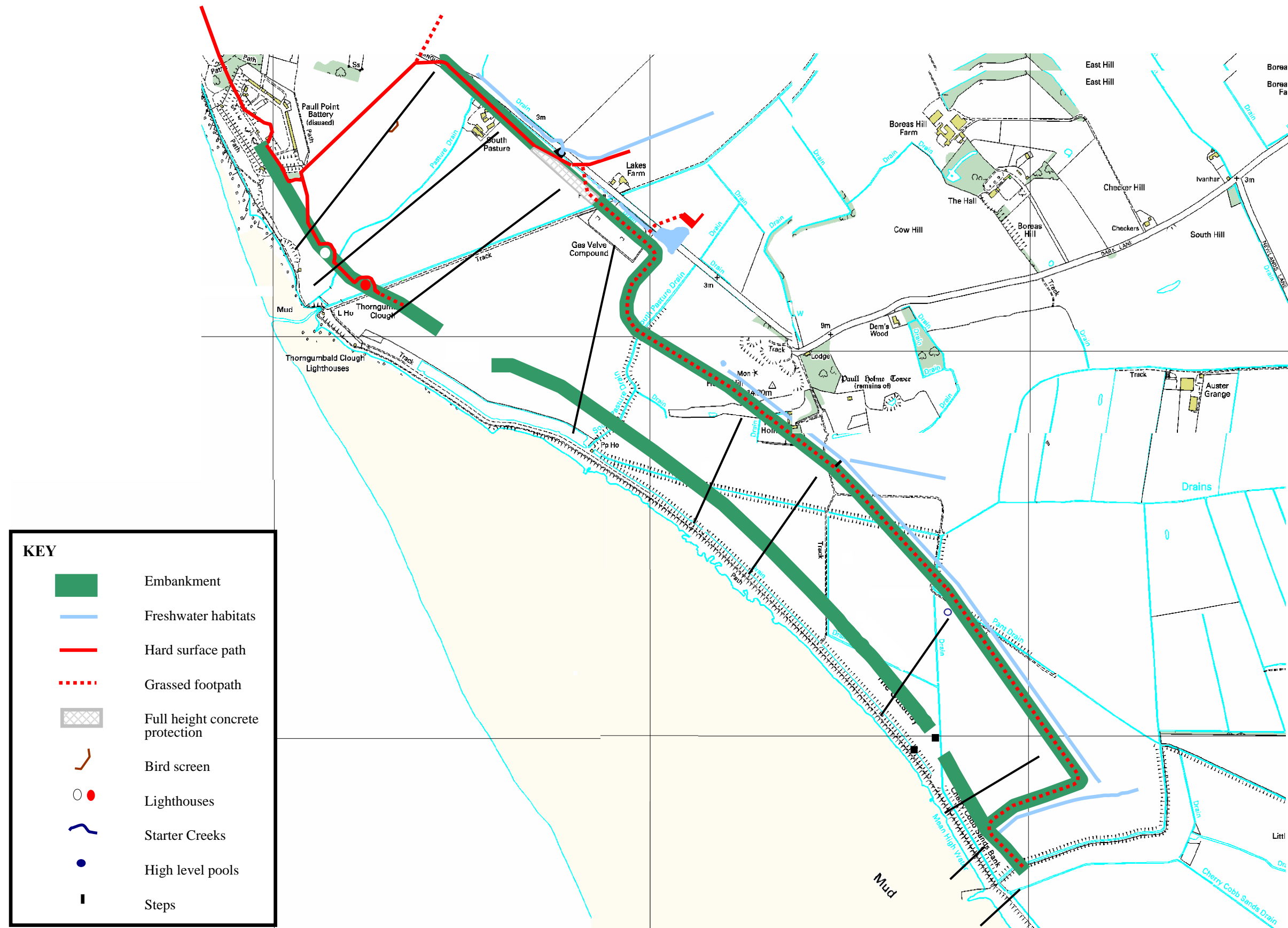


Figure A: Map showing study area with transects (black lines) for benthic invertebrates, vegetation and accretion monitoring within the realignment site.

1

INTRODUCTION

1.1 **Overview and Geographical Setting**

1.1.1 Throughout the early 1990s considerable work was conducted on behalf of the National Rivers Authority (predecessor to the Environment Agency) to assess tidal defence needs in the Humber Estuary. Whilst a long term flood risk management strategy was being developed as the Humber Estuary Shoreline Management Plan (HESMP), the investigations also showed that urgent flood defence improvements were required at a number of locations, including the Thorngumbald Clough to Little Humber section on the north bank of the estuary to the east of Hull. Subsequent investigations, consultations and design development led to the submission of a planning application in August 2000 for a scheme comprising managed realignment of the defence and including creation of a new retired embankment and breach of the existing bank. This was expected to result in the creation of approximately 80ha of new intertidal habitat.

1.1.2 A number of mitigation, monitoring, management and enhancement measures were identified within the Environmental Statement (ES), which was published in August 2000 to accompany the planning application for the Thorngumbald (Paull Holme Strays) Scheme. An Environmental Action Plan (EAP) was compiled to provide details of how these requirements (including a number of planning conditions) would be addressed and implemented during the detailed design, construction and post construction phases of the project. An Environmental Steering Group (ESG) was set up to ensure the continued involvement of key consultees throughout the design, construction and operational phases of the scheme.

1.1.3 The scheme is now completed and the existing bank was breached and the site first flooded in early September 2003.

1.1.4 The Draft Humber Estuary Flood Risk Management Strategy was approved by the Environment Agency's Board in 2006 and is currently under review by Defra. It proposes a suite of managed realignment schemes with complementary objectives. PHS is the first of the planned schemes and another at Alkborough has recently been constructed and was breached in September 2006, providing a further 170ha of new intertidal habitat. In combination these schemes will ensure that the integrity of the European Sites is maintained in the long term. The design and monitoring of further managed realignment schemes is being informed by the lessons learned and successes at PHS

1.2

Purpose of This Report

1.2.1

Since the PHS site was breached on the 5th September 2003, it has been rapidly changing as a result of twice daily tidal inundations and changes in sediment distribution. To monitor such change, a five year programme of environmental monitoring at the Paull Holme Strays ‘realignment site’ was established (inside and outside the realignment area where appropriate) to meet the requirements of the planning conditions, EAP and, where possible, the wider aspirations of the ESG. This programme comprises the following:

- Development of a basis for monitoring over the site (inside and outside of realignment area where appropriate);
- Incorporation of additional monitoring by volunteer groups and others when available;
- Collation of additional information not covered by specific monitoring contracts (e.g. tide and surge, meteorological information etc);
- Collation of all monitoring results on an annual basis and production of an annual summary report to be circulated widely.

This Report is the third annual summary report of environmental monitoring carried out at the site up until September 2006.

1.3

Use of Paull Holme Strays as ‘Compensatory Habitat’

1.3.1

The Paull Holme Strays (Thorngumbald) scheme (Figure 1.1) is within and/or adjacent to the Humber Estuary Special Protection Area (SPA)/Ramsar site and possible Special Area of Conservation (pSAC). The proposed works were deemed to have the potential for ‘likely significant effect on the European Sites’ and consequently an ‘appropriate assessment’ was carried out under the Conservation (Natural Habitats & c) Regulations 1994 (SI No. 2716) (the Habitats Regulations). The ‘competent authority’ (East Riding of Yorkshire Council) decided that the works had potential for an ‘adverse effect on the integrity of the European Site’, but it was demonstrated that the scheme should go ahead for reasons of ‘overriding public interest’ and that there were no less damaging alternatives available. In fact, in the longer term, the scheme is likely to provide nature conservation benefits through the creation of new intertidal habitat. Through this habitat creation the scheme also provided ‘compensation’ for habitat losses at urgent tidal defence works being carried out elsewhere in the estuary.

1.3.2

The requirement for formal ‘compensation’ under the Habitats Regulations for adverse effects on the European Site, at UW1 (Thorngumbald) (the

Paull Holme Strays scheme) and UW15-17 (SCM Jetty to East of Oldfleet drain, on the south bank of the estuary), was formally agreed with Defra and a number of consultees. It was also agreed that the habitat created at UW1 would be used to address the direct losses associated with another Environment Agency scheme at Barton Haven. Although there is no requirement for formal ‘compensation’ at this location, the Environment Agency is providing ‘replacement’ habitat as part of its wider ‘no net habitat loss’ approach to the delivery of tidal defences in the Estuary. The details of this estuary wide approach are currently being agreed through consultation on the Draft Humber Estuary Flood Risk Management Strategy.

1.4

Paull Holme Strays Environmental Action Plan

1.4.1

A formal Environmental Action Plan (EAP) was developed for the PHS project and was agreed with the Planning Authority and other key consultees as part of the planning permission for the scheme. The EAP described the habitat creation and other mitigation measures identified in the Environmental Statement, outlined the monitoring programme and identified targets for habitat creation and species usage.

1.4.2

Details of the environmental targets for the site are provided in Appendix A. In summary the quantitative targets set were:

- Habitat creation to compensate for direct scheme losses at PHS and at Immingham (a scheme known as Urgent Works 15 to 17) = 2.43ha (of which 1.53 ha should be mudflat and 0.9ha saltmarsh)
- Habitat creation to compensate for coastal squeeze losses at PHS and Immingham = 10.58ha (of which 5.58ha should be mudflat and 5ha saltmarsh)
- Habitat creation to compensate for direct scheme losses at Barton Haven = 0.03ha mudflat.

1.4.3

The qualitative targets set were:

(a) Mudflat

The mudflat created must support an invertebrate assemblage of similar species, population abundance and biomass to reference sites in the middle estuary (see table in Appendix A).

(b) Saltmarsh

The developing saltmarsh habitat should support a range of species which are representative of the middle and lower saltmarsh communities in the

area (see tables in Appendix A). Upper saltmarsh should be retained on the remnant floodbank.

(c) Birds

- At least 30 species of feeding wintering waterbirds: Redshank (*Tringa totanus*), Dunlin (*Calidris alpina*), Shelduck (*Tadorna tadorna*) and Curlew (*Numenius arquata*) must be present; and
- At least 12 species of roosting wintering waterbirds: Golden Plover (*Pluvialis apricaria*) must be present.

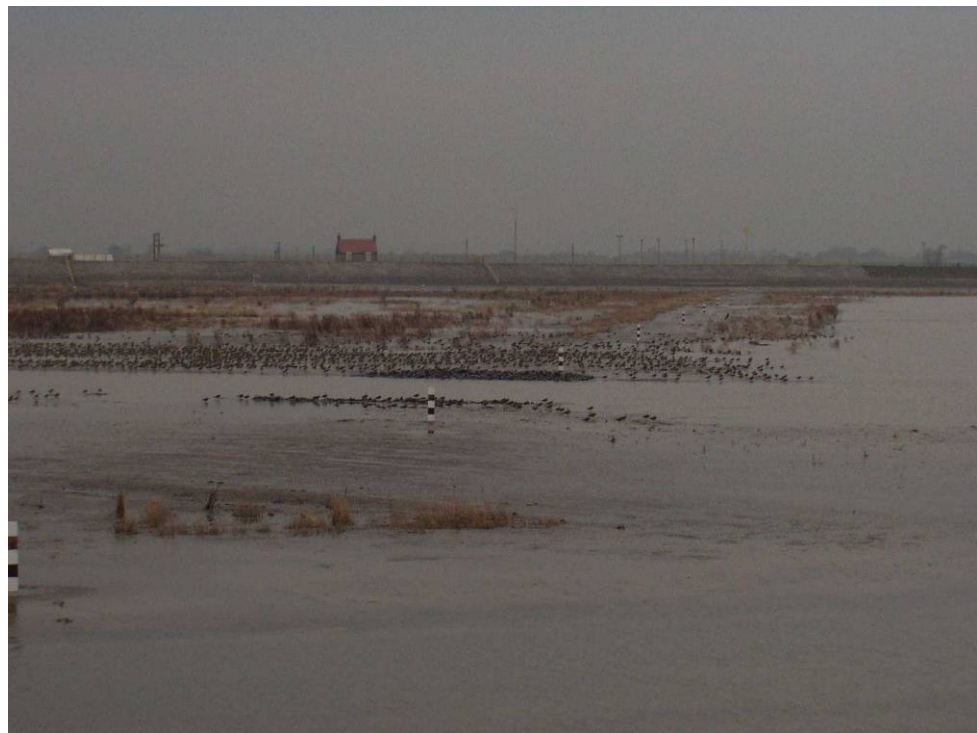


Plate 1 - Bird Roost (Helen Richardson, Environment Agency)

1.4.4

These targets were based on the bird populations on the Humber remaining stable over the review period. As such, it might be necessary to calibrate bird counts in relation to the overall bird populations on the estuary for different species.

1.5

The Monitoring Programme

1.5.1

The following is a brief outline of the specific monitoring studies which are being undertaken as part of the project. Where appropriate, statistical data analysis is undertaken.

Accretion & Erosion Monitoring

- 1.5.2 The accretion and erosion monitoring is being carried out by the Centre for Ecology and Hydrology (CEH) and an outline methodology can be found in Appendix B (Brown & Brown, 2006; the full methodology can be found in the first annual report, Brown & Garbutt, 2004). Accretion/erosion surveys were conducted in the spring and autumn of 2005 and are presented in the second annual report (Brown, Garbutt & Brown, 2005). This report focuses in particular on the outcomes of the third round of monitoring in 2006. The approach comprises a number of transects across the site to cover existing intertidal habitats seaward of the old embankment and 'new' intertidal habitats inside the site (see plan in Appendix B). Each transect has several sampling sites at which sedimentation was measured twice annually. Sedimentation was measured at stations along each transect using a combination of buried expanded metal accretion plates and pairs of canes set up to support a level bar (Appendix B). Results are included in the third annual report (Appendix B, Brown & Brown, 2006) and summarised in Section 2.2.
- 1.5.3 As a result of changes in site topography noticed soon after breaching, the Institute for Estuarine and Coastal Studies (IECS) undertook an interim study to assess the extent (magnitude) of these changes between December 2003 and March 2004 (when CEH took over). To ensure continuity, the methodology used was approved by all concerned and the results of this initial survey, which was described in full in the first Environmental Monitoring Report (Environment Agency, 2005a), are part of the overall long term accretion/erosion monitoring programme.
- 1.5.4 In brief, the aims of this programme are:
- To monitor sedimentation (accretion and/or erosion) at established sites twice annually (Spring and Autumn).
 - To monitor the height of the 34 posts above the gas pipelines annually to ensure that they are not threatened by erosion and exposure.
 - To monitor sedimentation at three sites in the Humber (Kilnsea, Skeffling and Welwick) annually. This monitoring is undertaken in order to provide an overall context with regard to natural fluctuations in the Humber. Results of these investigations are included in a separate report.

Saltmarsh Vegetation

- 1.5.5 The intertidal vegetation monitoring is being carried out by the Centre for Ecology and Hydrology (CEH) and an outline methodology can be found in Appendix B. Briefly, the approach uses the same transects and sampling sites as for the accretion and erosion monitoring described above and comprises permanent quadrats of different sizes to survey the vegetation, ensuring they are representative of each area but also allow the identification of fine scale changes. All quadrats were photographed. The vegetation survey was conducted in July 2006.
- 1.5.6 A considerable amount of vandalism to many of the measurement sites occurred in the second year of monitoring (2005). However, damaged quadrats were replaced with new ones and details of the necessary changes in methodology are given in Appendix B.
- 1.5.7 Vegetation cover and composition were monitored at sampling stations along the same transects as accretion and erosion rates. There were eight transects within the managed realignment area and two transects within an area of saltmarsh adjacent to the realignment site. Samples were collected at several scales:
- Large quadrats of 5m x 5m associated with each accretion monitoring transect, to give an overview of vegetation inside and outside the realignment site.
 - Five 1m x 1m quadrats, one over each sedimentation plate/level bar and nested within the 5 x 5m quadrats, to provide % cover of vascular plants, algae, litter and bare ground along each transect.
 - One of the above 1 x 1m quadrats at each station inside the realignment site was divided into 100 10cm² cells for detailed analysis on colonisation, establishment and spread of saltmarsh species at different elevations in the realignment site.
- 1.5.8 A transitional zone was also monitored. Five 2 x 2m quadrats were set up in 2004, but the markers for these quadrats had been removed by vandals by 2005. Instead, five new 5 x 5m quadrats were set up and assessed using the same methodology as the other quadrats within the site.

Benthic Invertebrate Monitoring

- 1.5.9 The benthic invertebrate monitoring is being undertaken by the Institute of Estuarine and Coastal Studies (IECS) of the University of Hull and the full methodology is in Appendix C. The approach comprises annual sampling at 25 (of the 28) locations on previously described transects to represent

existing and 'new' intertidal habitats; a number of replicate core samples are tested for invertebrate analysis and one for organic carbon and particle size analysis (if needed) at each location; samples are then analysed for species composition and abundance, wet weight biomass, mean lengths of large invertebrates, and organic content. Results are included in the third annual report (Appendix C and summarised in Section 2.4).

Ornithological Monitoring

1.5.10 Ornithological monitoring is being undertaken by the Institute of Estuarine and Coastal Studies (IECS) of the University of Hull (full methodology is reproduced in Appendix D). Pre-breach monitoring using a single count point methodology allowed good views of the fronting mudflats and the majority of the retreat area, whilst minimising the potential for counter disturbance. An important prerequisite of the pre-breach programme was to assess the level of impact to the avifauna from the construction programme. Following the breach, a two point count approach was used and care taken to minimise disturbance to the avifauna of the area. Counts were conducted over a half tide cycle, either high to low or low to high water.

1.5.11 Observations of usage and behaviour (and behaviour change, e.g. disturbance) were also recorded. Quarterly summary reports and an annual report of all results in an overall project context have been produced (Appendix D) and are summarised in Section 2.5.

Volunteer and Other Surveys

1.5.12 A programme of additional monitoring was organised by the Environment Agency to gain information about the wider biodiversity of the site. This was mainly carried out by volunteers and comprised monitoring of marginal vegetation and invertebrates in the new soke dyke and new pond, Odonata and Lepidoptera, mammals and additional bird monitoring of the whole site (complementing IECS studies). This monitoring was undertaken in specific sectors at the PHS site as indicated in Appendices E and F. With the exception of the results from Freshwater Invertebrates and Other Data Collection (see below) results from this additional monitoring are described in Appendix E. Botanical and water vole monitoring have also been conducted, although the latter was not undertaken in the third year.

(a) Bird Surveys

Bird surveys were carried out by Hull Valley Wildlife Group (HVWG).

(b) General Surveys: HVWG and others

A number of general walkover surveys were undertaken throughout the year. The information collected on these surveys was segregated into sectors and species and location within sector noted on recording sheets. All species seen, of interest to the surveyor, were noted.

(c) Freshwater Invertebrates

Realignment of the Humber bank between Paull and Thorngumbald resulted in the loss of a large borrow pit behind the original embankment which supported a variety of aquatic macro-invertebrates including rare coastal invertebrates. New aquatic habitats were provided in the form of extensive dykes and a pond behind the new embankments with vegetation and invertebrates transferred from the borrow pit to the new water bodies in an attempt to establish communities. A survey of aquatic macro-invertebrates was undertaken by Martin Hammond, to evaluate both effectiveness of translocation and the overall fauna. The results are included in Appendix F.



Plate 2 – Pond (Martin Hammond, 2005)

(d) Other Data Collection

Other data and monitoring included photo monitoring (aerial photos and volunteers' photos), tide and surge data (EA) and rainfall data (EA). These data have been included in the Annual Report as Appendix G (rainfall and tide data) and Appendix H (photo monitoring).

SUMMARY OF MONITORING RESULTS

2.1

Introduction

2.1.1

A consistent approach to the monitoring is essential to maximise understanding of habitat creation schemes, including their potential functional gain. Standard monitoring methods were therefore employed to measure the rates of accretion/erosion at the realignment site, vegetation coverage, bird use of the site and benthic diversity (Appendices B, C and D). The different surveys used to monitor habitat development at Paull Holme Strays were intended to be complementary so that results could be readily inter-related, to provide a holistic view of the development of saltmarsh and mudflat habitats following the breach. This approach is also useful in the design of other managed realignment sites.

2.1.2

The results of the monitoring may be usefully considered in the light of this basic time line for the development of the site and its land use:

- Pre September 2001 – Site largely in arable use, the land being bare between plantings typically of oilseed and cereals. There was also some rough grassland, hedgerows and some well-vegetated brackish water pools (old borrow pits) present.
- September 2001 to September 2003 – Site under various stages of construction with large areas of disturbed or bare ground, ephemeral pools (especially during winter flooding) with ex-arable areas reverting to rank vegetation.
- Post September 2003 – Breaches created and site subject to tidal inundation creating large areas of new open water (where new borrow pits were flooded) and encouraging development of mudflat and saltmarsh areas.
- March 2005 – 1st Annual Monitoring Report covering the period October 2003 to November 2004.
- March 2006 – 2nd Annual Monitoring Report covering April 2004 to October 2005

2.1.3

Results from the third year of monitoring are presented in the following sections.

2.2

Accretion and Erosion

2.2.1

The goal of sampling was to establish the patterns of accretion and erosion starting from a baseline set of measurements obtained in May 2004, eight

months after the breach. This section summarises the results of monitoring in the third year of monitoring (2006), with reference to the changes since the first and second years of monitoring (2004 and 2005). Full details of previous years' monitoring are presented in the Second Annual Report (Environment Agency 2006).

2.2.2

Twenty eight months of monitoring (May 2004 to September 2006) on sixty sites inside and outside the realignment show that, based on actual data, there has been a mean total accretion of the order of 23 cm (range 9 – 60 cm) in the northern sector of the site. This mean is 30 cm based on back-calculations to the time of the breach. In the higher elevation southern sector of the site, a mean total accretion of 3.8 cm (range 0.5 – 12 cm) up to September 2006 was recorded, very slightly below the mean total of 4.1 cm (range 0.4 to 13 cm) that had been recorded up to September 2005. There has also been a steady accretion in the mudflat outside the site since the breach, but at a much slower rate of 1-5 cm on saltmarsh areas and 1.7 - 9.6 cm on mudflat areas. Vegetation is beginning to colonise the edges of the northern sector although most of this area is still bare mudflat. The southern sector is at elevations suitable for saltmarsh establishment. Figure 2.1 shows mean total accretion each year using the actual data collected since May 2004 (without back-calculation).

2.2.3

The accretion of sediments showed a steady increase in the realignment site in 2006, as in previous years, but the rate of this increase had levelled off relative to rates in 2004 and 2005. In general, accretion rates on mudflat areas inside the realignment were much greater than that of accretion on mudflat outside the realignment, again exhibiting the 'settling-tank effect' seen in previous years due to the more sheltered nature of the mudflats inside the realignment. When comparing saltmarsh areas inside and outside the realignment site:

- There was greater accretion on saltmarsh inside the site at lower elevations, but;
- Similar accretion rates inside and outside the site when higher elevation sites were compared.

2.2.4 Accretion rates once again showed a typical inverse relationship with elevation inside the realignment site (see full details in Appendix B), and this occurred on both higher elevation saltmarsh sites and lower elevation mudflat sites. Accretion was greatest in the lower north-western part of the site, and least in the higher south-eastern part of the site (elevation ranged from 1.95 m to 3.49 m above ODN).

2.2.5 This same relationship also occurred outside the realignment site on saltmarsh areas, but was not seen on mudflat areas. Given the patterns of accretion in the mudflat areas of the realignment site, it is considered possible that larger areas of realignment site than originally anticipated could develop as saltmarsh in the longer term.

2.2.6 Measurements over the gas pipeline once again showed sediment accretion at most stations with some scouring immediately around the base of some of the posts, but with no overall cause for concern.

2.3 Saltmarsh Vegetation

2.3.1 This section summarises the development of saltmarsh vegetation inside the Paull Holme Strays managed realignment site during the third year since the breach of the original sea defences in 2003. Reference is also made to changes in vegetation since the first and second years of monitoring in 2004 and 2005.

2.3.2 In general, vegetation cover increased across the whole site between 2004 and 2006, and the frequency and abundance of typical saltmarsh species increased at the expense of species intolerant of saline conditions. A total of 20 saltmarsh and salt tolerant species was recorded within the realignment site. Twenty-three sites inside the realignment had some vegetation on them, and of these, 6 sites had 75% cover or more, 13 sites had 50% vegetation cover or more, and 17 sites had 25% cover or more (Figure 2.1). This indicates an increase in general vegetation cover since 2004, with coverages now ranging from <1% to 95% at the highest site (this latter site contains some remnant pre-breach vegetation). Mean cover in the low-lying northern sector was 7.7%, with the higher southern sector showing mean cover of 59%.

2.3.3 The twenty typical saltmarsh species are presented in Table 2.1.

Table 2.1 Typical saltmarsh species identified at the site in 2006

Latin name	Common name
<i>Agrostis stolonifera</i>	Creeping Bent
<i>Aster tripolium</i>	Sea Aster
<i>Atriplex littoralis</i>	Grass-leaved Orache
<i>Atriplex portulacoides</i>	Sea-purslane
<i>Atriplex prostrata</i>	Spear-leaved Orache
<i>Cochleria anglica</i>	English Scurvy-grass
<i>Elytrigia atherica</i>	Sea Couch
<i>Festuca rubra</i>	Red Fescue
<i>Glaux maritima</i>	Sea-milkwort
<i>Parapholis strigosa</i>	Hard-grass
<i>Phragmites australis</i>	Common Reed
<i>Plantago maritima</i>	Sea Plantain
<i>Puccinellia distans</i>	Reflexed Saltmarsh-grass
<i>Puccinellia maritima</i>	Common Saltmarsh-grass
<i>Salicornia europaea</i>	Common Glasswort
<i>Scirpus maritimus</i>	Sea Club-rush (new in 2006)
<i>Spartina anglica</i>	Common Cord-grass
<i>Spergularia marina</i>	Lesser Sea-spurrey
<i>Spergularia media</i>	Greater Sea-spurrey
<i>Suaeda maritima</i>	Annual Sea-blite

- 2.3.4 In addition, *Elytrigia repens* (Common Couch) remained as a remnant from pre-breach vegetation, but only at the upper tidal limit.
- 2.3.5 The low-lying mudflat areas in the north of the realignment site have now accreted to suitable elevations for pioneer plants such as *Spartina anglica* (Common cord-grass) to colonise around the edges. Elevation is a key factor for colonisation and species composition. There was no vegetation cover inside the realignment on mudflats below 2.3 m ODN, but at 2.3 – 2.6 m ODN the mean cover was up to 1.3%, rising to 44% at 2.6 to 3.0 m ODN and finally was up to 74% at elevations of 3.0 to 3.5 m ODN.
- 2.3.6 At lower elevations in the range 2.3 – 2.6 m ODN, four sites inside the realignment contained pioneer zone vegetation, with species number increasing from 1 in 2004, to 3 in 2005 and 4 in 2006. Species included *Spartina*, *Salicornia europaea*, *Aster tripolium* and *Puccinellia maritima*. This elevation range is equivalent to the pioneer saltmarsh outside the realignment site. Between 2.6 and 3.0 m ODN, *P. maritima* was the dominant species inside the realignment, followed by *Salicornia* and *A. prostrata*, with *E. repens* having disappeared since 2004 due to the

flooding regime at this elevation. Species number at this elevation in 2006 was 14, up from 11 species in 2004 and 2005. All the saltmarsh species in this elevation range have increased in cover in the past year and are typical of saltmarsh communities at the same elevations outside the realignment site.

2.3.7

At elevations above 3.0 m ODN inside the realignment, species number was 14. There were also 14 species at these elevations in 2005 and 8 species in 2004. A total of 23 species have been observed over all three years in these sites. Six terrestrial ruderal species present in 2004 had disappeared by 2005. 'Weedy' species are being lost from the site. Dominant species in 2006 still included *E. repens* and *A. prostrata*, although these are beginning to decline. *Spergularia marina* has increased its cover from 0.1% in 2004 to 20% in 2006. Slender Hare's-ear (*Bupleurum tenuissimum*), a nationally scarce species that occurs on thinly vegetated ground or disturbed coastal sites, was not recorded in 2006, as was suggested might happen in 2005.

2.3.8

The transition zone between inside and outside the realignment contained a mean species number of 15, with a total species number of 19 in 2006. In general, the realignment site is developing saltmarsh as expected for each given elevation. One important aspect of the realignment site's development as a whole is the pattern of accretion in the mudflat sector. This is still occurring much more quickly than mudflat sites of equivalent elevation outside the realignment, and the beginnings of vegetation colonisation on higher elevation mudflat sites within the realignment suggests that, over time, the mudflat will develop into saltmarsh. This has important long-term implications for mudflat invertebrates and birds, as discussed below.



Plate 3 - Southern sector of the realignment, looking towards the southern breach (Sue Brown, CEH, summer 2006)



Plate 4 - Northern sector of the realignment (Sue Brown, CEH, summer 2006)

2.4 Benthic Invertebrates

2.4.1

This section summarises the results and data analysis from the first three years of monitoring of benthic invertebrates inside and outside the managed realignment area. Monitoring in 2004 aimed to establish benthic community structure and sediment properties of the newly accreting mudflats within PHS relative to an established mudflat community adjacent to the managed site. The 2004 data also served as a baseline for future surveys.

2.4.2

In 2004, 20 species of benthic invertebrates were encountered in the survey area, with Oligochaeta (particularly Enchytraeidae) and Nematoda dominating the communities inside and outside the site. Also in 2004, biomass, abundance, species number and species diversity were significantly higher in the established mudflat outside than inside.

2.4.3

In 2005, 25 species were recorded across the survey area, with communities again dominated in abundance by Enchytraeid oligochaetes and nematodes. Most other species of oligochaetes were not as dominant in 2005 as they were in 2004. Species abundances across the survey area were comparable with those of 2004, showing no significant between-year differences. Data analysis in 2005 showed distinct communities inside and outside the site (see Second Annual Report, Environment Agency, 2006, for details).

2.4.4

In 2006, the following patterns were observed in the benthic invertebrate community data:

2.4.5

The benthic communities on the established mudflats outside the realignment site have remained relatively stable over time in their composition, whilst those inside the site have changed substantially. Inside the realignment, species richness, abundance and Shannon-Wiener diversity have increased significantly since 2004 (Figure 2.3). Both communities are typical for this region of the Humber.

2.4.6

In 2006, 24 species were recorded from the entire survey area, with 17 of these being encountered inside the realignment. The community as a whole has changed considerably inside the realignment area since 2004, being now much less dominated by the oligochaete *Paranais litoralis* than in previous years. This species accounted for 53% of the total abundance inside the realignment in 2004, but now accounts for only 2%. The community inside the realignment site in 2006 was dominated by *Hediste diversicolor* and Collembola, with an increased dominance of *Hydrobia ulvae* (an important prey item for some species of waterbird).

- 2.4.7 In 2006, invertebrate communities inside the realignment site were significantly different in their composition from those outside the site. There were on average more species (6.9) at sampling stations outside the site than inside it (3.7), and abundance was also significantly higher outside the site than within it (16,211 individuals m^{-2} outside the site compared to 3679 individuals m^{-2} inside the site). Shannon-Wiener diversity was also significantly higher outside the realignment site than within it (Figure 2.3). However, biomass was slightly (but not significantly) higher within the realignment site than outside it. This indicates that the community composition in the realignment site has shifted to become composed of fewer, larger individuals than previous years. A decrease in abundance in 2005, followed by the increase in 2006 in abundance of larger organisms, is a fluctuation that is typical of benthic communities in early stages of their development.
- 2.4.8 Outside the realignment site there were statistically significant differences in invertebrate community composition between the mid/upper shore and the lower shore, as was also the case in the previous two years. This reflects the difference in sediment types in the two areas with the sediments becoming increasingly sandy towards the lower shore. Overall, however, communities outside the realignment have not changed significantly over time, which is in contrast to the changes seen in community composition inside the realignment site (Figure 2.4).
- 2.4.9 Colonisation is considered to be occurring to the greatest extent close to the breach locations, where communities inside the realignment are the most similar to those on the upper shore outside the site (Figure 2.4).
- 2.4.10 Community development is thought to be related to tidal inundation and, to a lesser extent, to accretion, with colonisation being greatest at moderate accretion levels. However, analysis of invertebrate community composition in relation to a comprehensive set of current (2006) accretion data has not been conducted, and it is recommended that this is carried out in future (see recommendations in Section 3.2).
- 2.4.11 Whilst species richness, abundance and diversity have increased inside the site since 2004, these metrics are still significantly lower than outside the realignment site. As such, the community inside the realignment site is not yet considered stable or fully developed. This is typical of invertebrate communities in early stages of development, and has been seen in other restoration studies (see Discussion, Section 3.1).

2.5

Ornithology

2.5.1

The Paull Holme Sands mudflat, which fronts the managed realignment site, is part of the larger Humber Estuary SPA/Ramsar site and pSAC. As such, it was important to monitor the status of bird communities and use of the site by birds. This monitoring contributed to assessing the success of the scheme with respect to mitigation and compensation for habitats lost to other flood defence schemes in the Humber.

2.5.2

Key targets to indicate success included the established use of the new site by birds including:

- At least 30 species of feeding wintering waterbirds: Redshank (*Tringa totanus*), Dunlin (*Calidris alpina*), Shelduck (*Tadorna tadorna*) and Curlew (*Numenius arquata*) must be present;
- At least 12 species of roosting wintering waterbirds: Golden Plover (*Pluvialis apricaria*) must be present, and
- At least 3,000 individual birds should be recorded using the site

2.5.3

Monitoring of bird usage of the area was commenced before construction and breaching of the realignment site in order to both provide baseline information but also to record the effects of construction disturbance etc. This report focuses on the period between September 2005 and August 2006. Comparisons have also been made with bird abundance, behaviour and communities for the previous 2 years' monitoring.

2.5.4

Twenty-nine species were recorded in the realignment area in 2005/2006; of which 19 species were waders, seven species were wildfowl and three were 'other' waterbirds (e.g., divers, grebes, cormorants). This compares to thirty species observed in 2004/2005, including 16 species of waders, 8 species of wildfowl and 6 'other' species. Similarly to the previous year, Golden Plover and Lapwing (*Vanellus vanellus*) were the most abundant birds in 2005/2006, with up to 12,600 and 2,100 individuals respectively. Black-tailed Godwit (*Limosa limosa*) was third most abundant species in 2005/2006, with 2,000 individuals using the managed realignment area.

2.5.5

The abundance of intertidal wader species that use the newly created mudflats at Paull Holme Strays has increased in the past year, including species such as Dunlin, Curlew, Redshank and Shelduck. The numbers of roosting/loafing Golden Plover continue to be high enough to make the site of international and national importance for this species. Black-tailed Godwit were also recorded at nationally important levels. Waders in general were the most numerous group within the realignment area at high tide, with lower numbers (except Golden Plover and Lapwing) at low tide.

Relationships between tidal state and wildfowl abundance, however, are still not yet clear.

- 2.5.6 The majority of birds on the realignment site continue to be roosting/loafing rather than feeding/foraging. Overall use of the site by foraging waterbirds was greater than in the previous reporting periods, but not significantly so, as large numbers of roosting Lapwing and Golden Plover were also using the site both immediately before and after the breach and this skewed the results when Lapwing and Golden Plover were included.
- 2.5.7 There were significant inter-year differences in site usage for some of the individual species, with Black-tailed Godwit, Bar-tailed Godwit, Dunlin, Curlew, Redshank and Grey Plover all recorded as foraging in greater numbers in 2005/2006. These species are all specialist intertidal feeders and were not seen foraging on the mudflats at low water during the first winter post-breach (2003/2004). Amongst wildfowl species, there were no significant inter-annual changes in the numbers of foraging birds.
- 2.5.8 Amongst the foraging birds using the site, Golden Plover dominated the community in 2003/2004 (87% dominance), and in 2004/2005 estuarine waders began to appear in the realignment site. Black-tailed Godwit were the dominant foraging species in 2004/2005 (33% dominance), and Dunlin dominated the foraging community in 2005/2006 (26% dominance).
- 2.5.9 Overall, the diversity of the intertidal bird community has increased in the last year, with a much greater range of wader species present than in 2003/2004, when Golden Plover were overwhelmingly the dominant foraging species.
- 2.5.10 The species composition of the foraging community of waterbirds within the realignment site differed significantly between years, and also differed significantly from the non-foraging community in 2004/2005 (Figure 2.6, generated from multi-dimensional scaling analysis). These differences were attributed to a change in species dominance and overall shifts in species composition.
- 2.5.11 For non-foraging birds, Golden Plover, Lapwing and Teal remained the most numerically dominant species (in that order) across all three years post-breach. In 2005/2006 (Year 3), the percentage dominance of the non-foraging community for these three species was 92%, 5% and 1.4%, respectively. Figures for these species in previous years are reported in the Year 1 and Year 2 Monitoring Reports.

- 2.5.12 Breeding Avocet were still continuing to use the site during the current reporting period, with 29 pairs observed breeding in 2006 and 103 individuals using the realignment site. This is the fourth consecutive year that Avocet have successfully bred on the breach site, and their use of the site is not apparently linked to tidal fluctuations.
- 2.5.13 There is no evidence of a change in bird community composition on the mudflats outside the realignment site, but there were statistically significant differences between the community composition inside and outside the realignment site in 2003/2004 and 2004/2005 (Figure 2.7). In 2005/2006, there was no such difference, indicating that after three years of operation the bird community inside the realignment site has reached equilibrium with that outside the site. Across all three years, Dunlin, Redshank, Knot, Black-tailed Godwit, Curlew and Shelduck dominated the bird community on the mudflats outside the realignment site.
- 2.5.14 Whilst foraging waders appear to have increased in abundance at the site, they had not yet attained the target of 30 species of feeding wintering waterbirds during the current reporting period. Dunlin, Redshank and Curlew were, however, amongst the target of 30 species. In addition, it is possible that the birds using Paull Holme Strays are not 'new' birds to the region *per se*, but rather they have moved onto the site from nearby areas such as the mudflats fronting Saltend.
- 2.5.15 As such, it is considered that whilst the waterfowl assemblage and site function is in general moving towards that of a typical mid-estuary intertidal area, and for some species provides ideal conditions, it has not yet developed an invertebrate prey assemblage capable of supporting a waterfowl population characteristic of the middle estuary at a density comparable to that of adjacent areas.
- 2.5.16 As discussed earlier it is possible that the mudflats within the realignment site will accrete to elevations that allow the establishment of saltmarsh vegetation in the longer term, and this may result in less open mudflat habitat available upon which the birds at Paull Holme Strays can feed. However, the value of saltmarsh habitats in providing high tide refuges, breeding sites for waders, and foraging habitat for wintering passerine birds, should also be recognised when setting targets for coastal realignment.

2.6 Volunteer and other Survey Results

Freshwater Invertebrates

- 2.6.1 Sampling of freshwater invertebrates was again conducted at four sampling points in 2006. These sampling points consist of a pond and three soke dykes behind the realigned Humber Bank, and were established as part of the scheme in compensation for loss of a borrow pit that supported a diverse invertebrate fauna. They have been monitored in 2004 and 2005. The 2006 surveys showed that the realignment site now supports a total of 61 invertebrate taxa, including 44 'core' taxa (Appendix E). Seven species are defined as Nationally Scarce (although these designations are expected to change in the near future).
- 2.6.2 Ten of these taxa are brackish indicator species, including five beetles (Coleoptera), the brackish water corixid *Sigara stagnalis* and the amphipod *Gammarus zaddachi*. This amphipod is now ubiquitous. In previous years there had been up to five brackish water indicator species (Table 2.2).
- 2.6.3 Thirty three species of Coleoptera (beetles) were recorded from the four sampling points in May 2006, which is 66% of all 50 species recorded since monitoring began in 2004. Eleven water bug species (Hemiptera-Heteroptera) were recorded, of a total of 21 species recorded since 2004. The brackish water corixid *Sigara stagnalis* is now well established. Nymphs of one mayfly (Ephemeroptera), *Cloeon dipterum*, were recorded in the new dyke at Sampling Point SP3. The only caddis (Trichoptera) recorded in 2006 were larvae of the species pair *Limnephilus affinis/incisus*. The ecologically wide-ranging *L. marmoratus* was no longer present.
- 2.6.4 The richest of the four Sampling Points was again the new dyke at SP3, with 44 core taxa including 4 scarce beetle species and a Nationally Scarce soldier fly. The vegetation structure at this site needs careful management to maintain the appropriate complex of open water and vegetation cover that is required to support a diverse aquatic invertebrate fauna.
- 2.6.5 Species newly recorded from the water bodies in May 2006 included the water beetles *Haliphus fluviatilis*, *Liopterus haemorrhoidalis*, *Enochrus halophilus*, *Ochthebius marinus* and *Phytobius leucogaster*, the Emperor Dragonfly (*Anax imperator*), the amphipod *Corophium volutator* and the prawn *Palaeomonetes varians*.
- 2.6.6 Sampling in May 2006 confirmed that the pond at Sampling Point SP1 has become highly saline (at least 27 mS cm⁻¹) and no longer supports any

Coleoptera, Hemiptera, Trichoptera, Odonata or Mollusca. Only the amphipod *G. zaddachi* was recorded. SP2, the dyke nearest the car park, also shows elevated salinity.

Table 2.2 Brackish water indicator species in water bodies at Paul Holme Strays, 2004-2006

Species	2004	2005	2006
<i>Corophium volutator</i>			•
<i>Gammarus zaddachi</i>	•	•	•
<i>Palaeomonetes varians</i>			•
<i>Limnephilus affinis / incisus</i>	•		•
<i>Sigara stagnalis</i>		•	•
<i>Haliplus apicalis</i>	•	•	•
<i>Agabus conspersus</i>	•	•	•
<i>Enochrus bicolor</i>	•		•
<i>Enochrus halophilus</i>			•
<i>Ochthebius marinus</i>			•

Birds and Other Fauna

2.6.7 The voluntary monitoring made use of sectors as opposed to transects (as used to monitor accretion/erosion and vegetation) since there was a need to split the site into a small number of large sampling size blocks (sectors) rather than survey lines. A Sector Map showing the number and size of the sectors used and all voluntary monitoring results are included in Appendix F.

2.6.8 Volunteer bird surveys (Figure 2.8) over the past three years have shown up to 20,800 birds using the site in winter (monthly maxima). Dominant species in 2003-2004 and 2004-2005 included Golden Plover, Black-tailed Godwit, and Dunlin. There were also several hundred passerines such as Linnet, Meadow Pipit and Fieldfare in these years. In 2005-2006, bird numbers appeared reduced and the peak monthly maximum was just over 8,000 birds, occurring in January 2006, but this may be due to changes in survey coverage. The data from IECS indicate that birds in general are increasing their use of the site. The dominant species recorded by volunteers were Golden Plover and Black-tailed Godwit, as in previous years.



Plate 5 - Black-tailed Godwit (Roy Lyon, Hull Valley Wildlife Group, August 2006)



Plate 6 - Bird Hide at Paull Holme Strays (Roy Lyon, Hull Valley Wildlife Group, October 2006)

2.6.9 Other fauna observed in 2005-2006 included five species of Odonata (dragonflies and damselflies). The majority of these were blue-tailed damselflies (*Ischnura elegans*), seen in July 2006; and a male emperor dragonfly (*Anax imperator*) was also observed. Butterflies seen primarily consisted of Meadow Brown butterflies; there was also one roe deer seen in April 2006.

Botanical Survey

2.6.10 The volunteer botanical survey indicated presence of typical saltmarsh species including most of those listed in section 2.3, and also covered surrounding habitats which included common rye-grasses (*Lolium* spp.) and meadow-grasses (*Poa* spp.).

Rainfall and Tide and Surge Data

2.6.11 As with previous years there were several substantial rainfall events at Great Culvert during spring and summer 2006, occurring roughly once a month from May 2006 to August 2006. There were three peaks of rainfall in July 2006 for Winstead. Tides were again not unusual for the area. The raw data for tidal and rainfall monitoring are presented in Appendix G. In future years, the tidal data in particular will be more directly used in the analysis of floral and faunal changes at PHS, wherever possible.

3.1 General Discussion

- 3.1.1 The Humber Estuary CHaMP estimates that in the absence of action nearly 600ha of intertidal habitat (saltmarsh and mudflat) will be lost between 2000 and 2050, due to forecasted sea level rise and the effects of ‘coastal squeeze’. Coastal squeeze is the term given to the ‘drowning out’ of intertidal habitats that are unable to migrate inland as sea levels rise due to the presence of hard coastal defences. The Draft Humber Estuary Flood Risk Management Strategy (2005) identifies a suite of managed realignment and intertidal habitat creation schemes to address this, and the adverse effects of improving existing defence structures.
- 3.1.2 The project at Paull Holme Strays is the first of the ‘strategic’ managed realignments to be delivered by the Environment Agency in the Humber Estuary and contributes 80ha (45ha of mudflat and 35ha of saltmarsh) of habitat creation to the strategic requirement. Monitoring development of the habitats and communities supported by the managed realignment site is crucial to measuring the success of the PHS site itself in meeting the biodiversity targets set in the Environmental Action Plan (EAP) and is also important for developing a wider understanding of such habitat creation projects.
- 3.1.3 The development of mudflat and saltmarsh as illustrated by the accretion/erosion monitoring and vegetation surveying should be taken into consideration when predicting the future development of the invertebrate and bird communities at Paull Holme Strays. If the newly created mudflat eventually develops into saltmarsh, as is likely based on the patterns of accretion and vegetation colonisation of mudflats inside the realignment, then the habitat available to benthic invertebrates, and hence to foraging birds that rely on intertidal benthos, may be reduced in the longer term. However, saltmarsh habitats are also a valuable BAP Priority habitat, and are in decline along other parts of the British coastline.
- 3.1.4 Benthic invertebrates and birds are continuing to show increased use of the Paull Holme Strays site, and the overall waterbird community composition in particular appears typical of middle estuary communities. The benthos is typical for this area of the Humber. Bird numbers and species richness appeared to have reached their targets as set out in the EAP, with the exception of foraging waders, which had not yet attained the target of 30 species of feeding wintering waterbirds during the current reporting period.

- 3.1.5 With regard to invertebrates, the shift from dominance of *Paranais litoralis* to that of *Hediste diversicolor*, Collembola and *Hydrobia ulvae* provides for a typical middle estuary invertebrate food resource for some species of waterbirds and *Hydrobia ulvae* is a particularly important resource for Shelduck (*Tadorna tadorna*). It should be noted that Collembola is generally a terrestrial taxon and although their increase is noteworthy, their presence is more indicative of the realignment's proximity to terrestrial habitats than it is indicative of community development.
- 3.1.6 The presence of 17 of the 24 species surveyed in 2006 within the realignment, and the typical progression from smaller, more abundant individuals to fewer but increasing numbers of larger ones, is also an encouraging sign. Invertebrate community diversity inside the realignment is still less than that of the community outside, indicating a relatively slow community development. This is not entirely unexpected since the site is still only in its third year of development following the breach. Other studies of artificially created saltmarshes and mudflats also show evidence of slow community development (e.g., Levin et al. 1996 found that invertebrate communities in artificially created saltmarsh could retain early successional characteristics for four years; see Appendix C for full discussion). Tidal patterns may also contribute to the patterns of community development seen at Paull Holme Strays. Some sites flood and drain regularly, others do not flood very often and some areas do not drain. Therefore, suitable habitat is restricted. Accretion has been so high in some parts of the north western side of the site that these areas experience very infrequent tidal inundation.
- 3.1.7 The site is being used by Dunlin, Golden Plover, Shelduck, Teal, Redshank and Bar-tailed Godwit for foraging, in sufficient numbers to address some of the targets set out in the EAP. However, the site is not yet being used by the target of 30 species of wintering waterbirds for feeding purposes, and appears to still have a primary function as a loafing or roosting site rather than for feeding. One potential reason for this is that birds may be using other parts of the estuary, such as Saltend, for foraging and using Paull Holme Strays for roosting activity.
- 3.1.8 In essence, it is not currently thought that the mudflats at Paull Holme Strays are supporting 'new' birds to the region, but that individuals have moved into the area from adjacent sites to take advantage of certain niche conditions. This is not necessarily a cause for concern, however, as it may simply mean that the site, and the estuary as a whole, is not at carrying capacity for waterbirds. The site at Paull Holme Strays is continuing to develop an invertebrate community that can support feeding waterbirds,

especially intertidal waders, and progress is likely to continue over the next two years of monitoring. Current densities of feeding usage within the site are not yet at the level recorded from adjacent areas in the middle Humber.

- 3.1.9 It is likely that in the short- to medium-term the bird and invertebrate communities will continue to develop towards their EAP targets, but in the longer term, accretion and vegetation development patterns may well mean that some of the newly created mudflat habitat will develop into saltmarsh. This habitat would be less attractive to most species of foraging waterfowl, and as such, ultimately the overall abundance of the foraging waterfowl community may decrease.
- 3.1.10 Saltmarsh is, however, valuable as high tide roosting refuge for many species of waterfowl as well as being used as a breeding area by waders and a feeding resource by passerine birds.
- 3.1.11 The continued high rates of accretion on mudflats inside the realignment site are due to its sheltered nature (relative to existing mudflats outside the realignment), and this pattern of accretion has important implications for the design of future realignment schemes. Creating less sheltered areas may be necessary to maintain newly created mudflats in future realignment schemes and prevent them from developing into saltmarsh, if mudflat habitat is the desired endpoint of management.
- 3.1.12 Additionally, historical use of a site can play an important role in community development, with sites that are remnants of historical wetlands showing the most rapid development. The site at Paull Holme Strays has been cut off from tidal inundation for over a century, and has been heavily manipulated in the interim. This phenomenon has occurred in other aquatic habitat restorations also, such as wetland restorations, which can exhibit different degrees of success depending on the nature of historical drainage and land use (Puchniak, 2002). When applying the lessons from Paull Holme Strays to other realignment schemes, historical land use and its influence on the likely success of a scheme should be considered in setting targets and indicators for successful habitat recreation. It is possible that the targets set out in the EAP for Paull Holme Strays should be revisited, given that saltmarsh habitats are valuable in themselves, even though they appear to be replacing created mudflats (see recommendations).

3.2

Conclusions & Recommendations

3.2.1

The Paull Holme Strays project represents the first managed realignment site to be completed in the Humber Estuary. The results of the first three years of the 5 year monitoring investigation indicate rapid physical development of intertidal habitats. Although bird and invertebrate communities are still in early successional stages, the site is already supporting many of the interest features of the European Site. Further realignment sites that are identified in the Draft Humber Estuary Flood Risk Management Strategy (2005) will benefit from the knowledge being amassed at PHS, which thus far indicates that replication of such schemes will provide sufficient habitat to ensure the integrity of the European Site is maintained over the next 100 years.

3.2.2

Key points and conclusions raised through the PHS monitoring programme are:

- Elevation appears to be the main influence on patterns of accretion and saltmarsh vegetation, with implications for benthic invertebrate diversity and hence bird usage of the site.
- Accretion at lower elevations in the realignment site continues to be much higher than at the same elevations outside the realignment. The ‘settling-tank’ effect of accretion is still occurring due to the more sheltered nature of the mudflat inside the realignment.
- Colonisation by typical saltmarsh vegetation was initially sparse (2004), possibly due to limited seed and propagule dispersion within the site. However, results in 2005 and 2006 show that the site is rapidly developing the desired saltmarsh and mudflat communities, and that saltmarsh is developing at elevations that typically allow such species to establish. Colonisation of the edges of mudflat areas indicates that these too will eventually become saltmarsh in the long term.
- Benthic invertebrate communities within the managed realignment continue to show lower diversity, abundance and biomass than outside the site. This is still likely to be a function of the site’s age, but in later years the accretion patterns observed in the mudflat may become a more important driver of invertebrate community composition. Age of site, and potentially accretion effects, mean that the benthic community is arguably not yet rich enough to support significant numbers of feeding birds, making the site less important for bird foraging than other adjacent sites on the Humber. The possible succession of new mudflats into saltmarsh also casts some doubt on the long term ability of the site to support large flocks of foraging waterfowl.

- Waders appear to currently use the site more for roosting than foraging (large flocks especially of Lapwing and Golden Plover were recorded at above-target levels). However, feeding waders are using the site more than in previous years and in the short- to medium-term the site's development is encouraging.
- Target species such as Avocet, Black-tailed Godwit and Golden Plover continue to occur in numbers that make the site nationally important, and wildfowl numbers have increased substantially since the first year post-breach.
- The monitoring programme being implemented appears to be providing a sound basis for observing the development of the site over time and its fulfilment of the targets identified in the EAP.
- A more comprehensive picture of the project's success will only be possible when additional data is gathered in the course of future monitoring, but the 2006 season has added substantially to the existing picture of the scheme's success.

3.2.3

The main recommendations arising this year are:

- Patterns of vegetation, benthic diversity, accretion and bird use appear most importantly to be correlated to elevation and to site age. Comprehensive baseline topographic surveys should be an essential component of all future monitoring programmes for realignment sites.
- Accretion and tidal data should be incorporated into the analysis of benthic invertebrate community development in future years, to allow more direct links between accretion patterns, elevation and invertebrate community development.
- The Environmental Steering Group for Paull Holme Strays should give consideration to the long-term objectives for the site (and possible revision of the EAP targets) in light of the potential succession of mudflat into saltmarsh and the impact this would have on invertebrate communities and foraging birds.
- Analysis of future monitoring data and changes over time may aid development of predictive models for areas undergoing managed realignment.
- It is recommended that present results be integrated and assessed with other Humber based (and UK based) projects.
- Comparisons with the outcomes of other managed realignments in similar habitats, including those assessed for longer periods of time (i.e. more than 5 years), should be made wherever possible, to

provide a wider context for the patterns of saltmarsh and mudflat development, accretion, benthic invertebrate community development and bird use of the site at Paull Holme Strays.

- Other examples of habitat creation and restoration can also be used to assess how the habitat creation scheme at PHS has succeeded or failed, with particular regard to the role of previous land uses at restoration sites in determining success or failure of restoration/creation.

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Figures

Figure 1.1 General Plan of the Paull Holme Strays Site

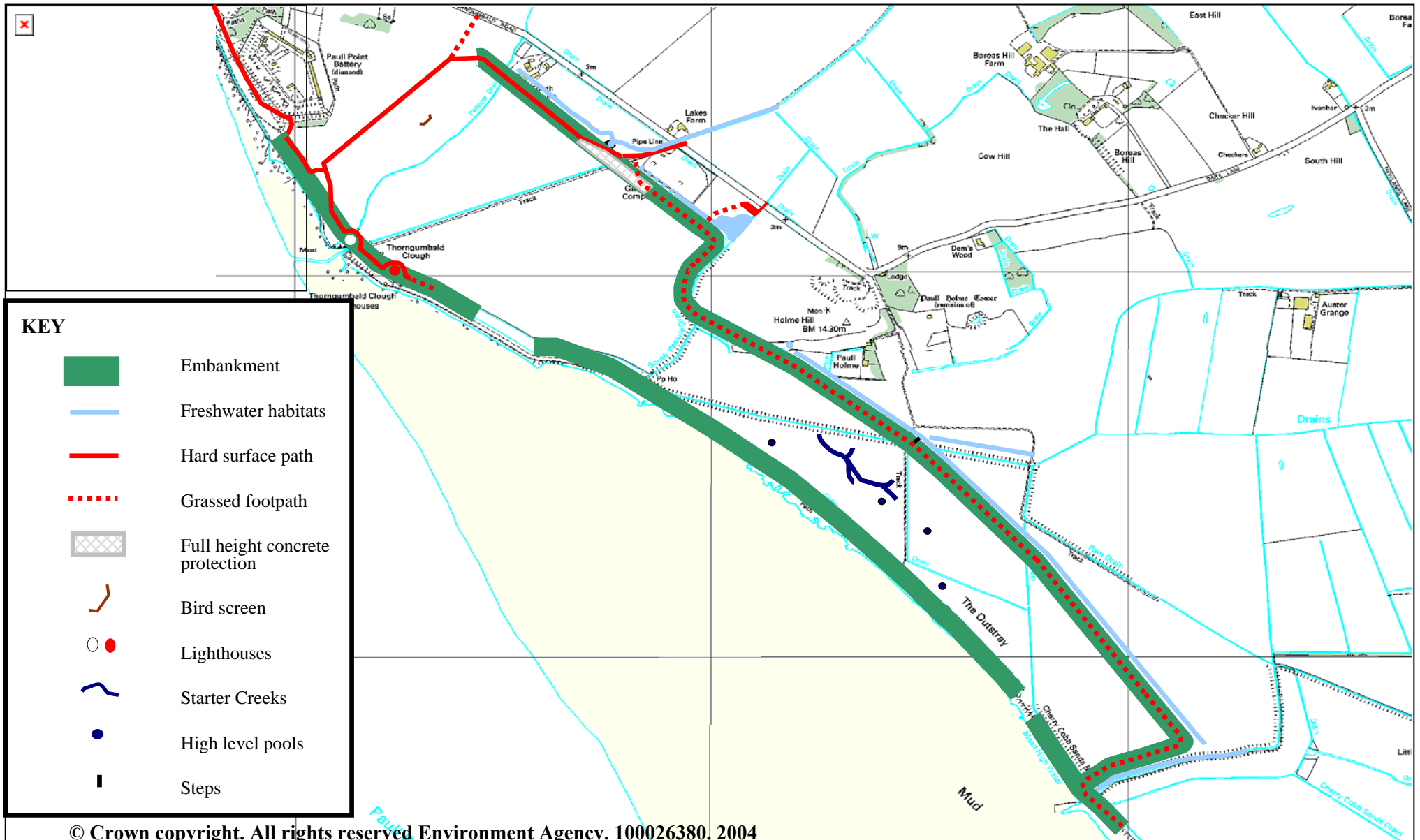


Figure 2.1 Mean cumulative accretion inside the realignment as measured since May 2004. Mean of 30 cm (300 mm) given in text is based on back-calculation to September 2003, the time of the breach. Accretion values ranged substantially in each year; see text and Appendix B for full explanation.

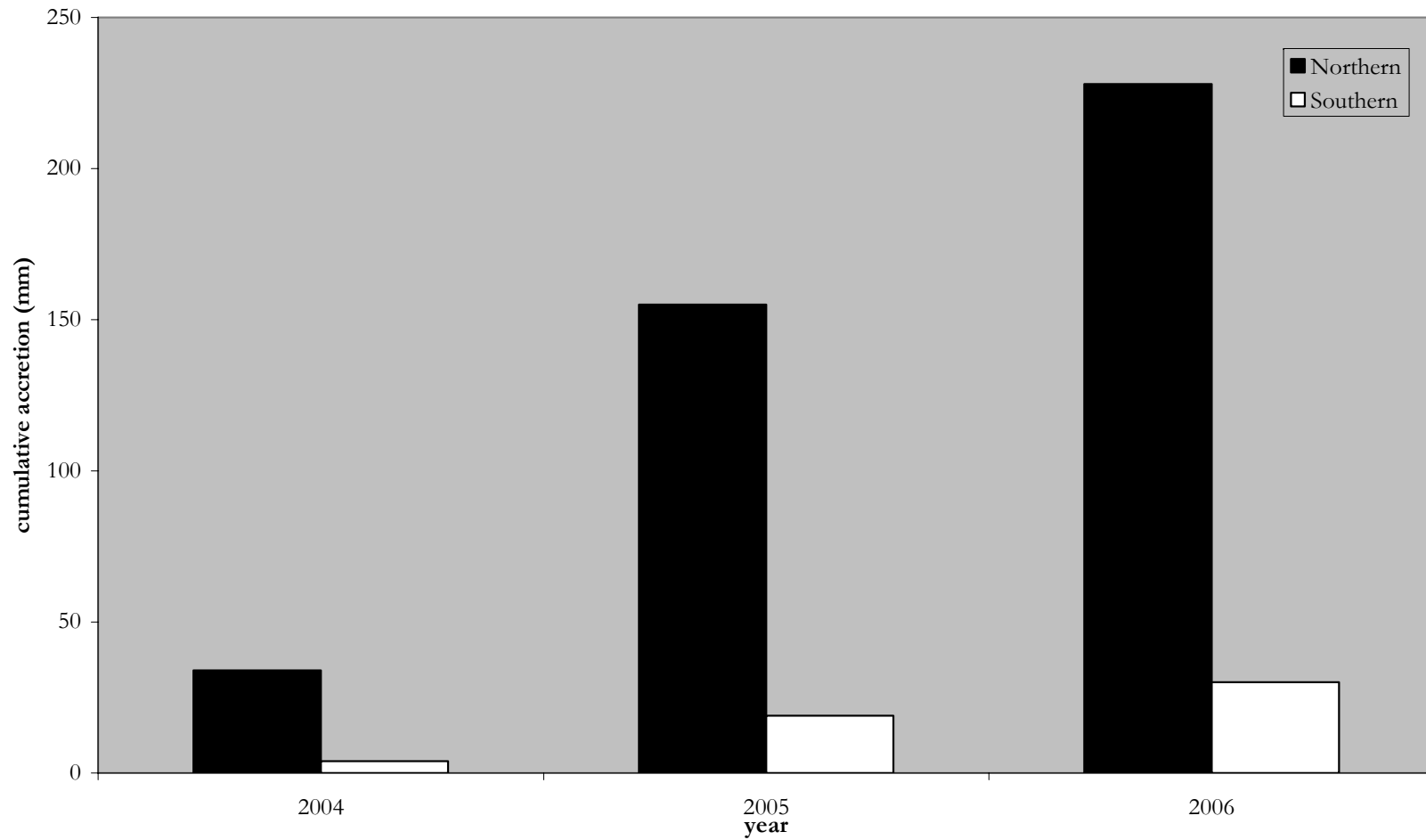


Figure 2.2: Total Percentage Vegetation Cover in the 25m² quadrats inside the realignment (calculated from sum of individual species cover). + = cover at <0.2% Note: Site 7.1 (2006) is a replacement site as the original has been eroded by a channel this year.

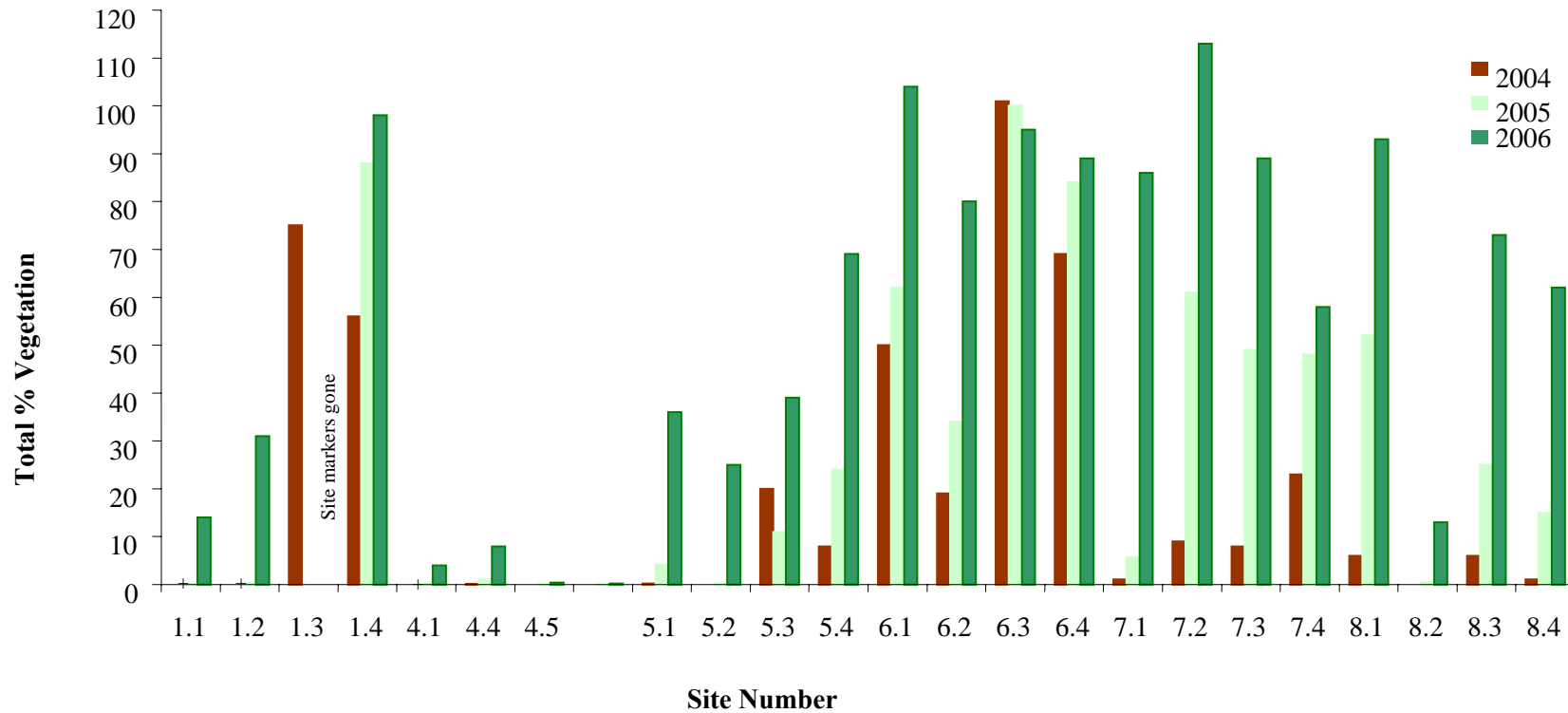


Figure 2.3: Summary of diversity statistics for benthic invertebrates at Paull Holme Strays inside and outside the managed realignment (adapted from Appendix C). A: species number, B: abundance, C: biomass and D: Shannon-Wiener diversity. Bars indicate standard deviations.

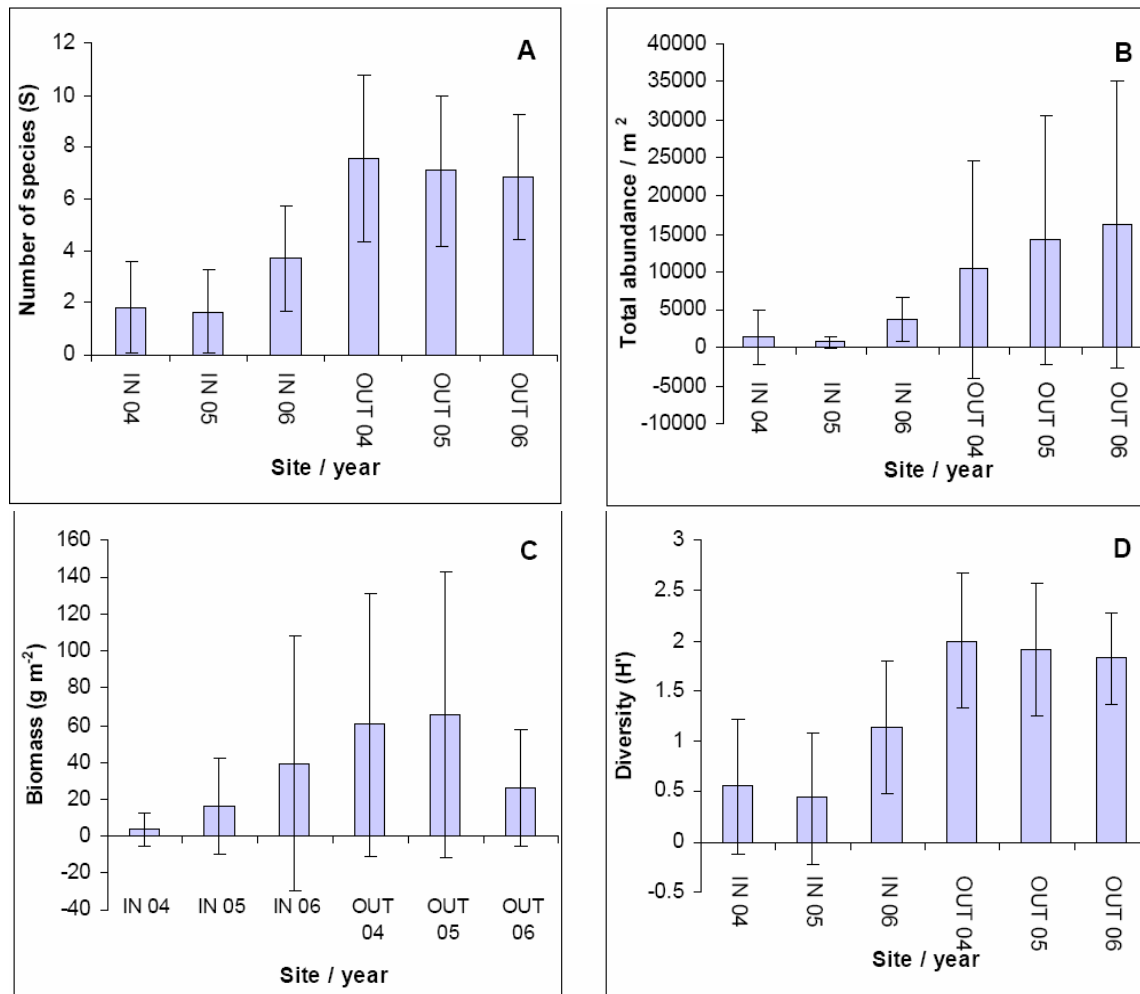


Figure 2.4: Community composition inside and outside the site over the three year monitoring period since the breach (adapted from Appendix C). Labelled sites are within the alignment but close to the western breach and becoming similar to upper shore communities outside the breach.

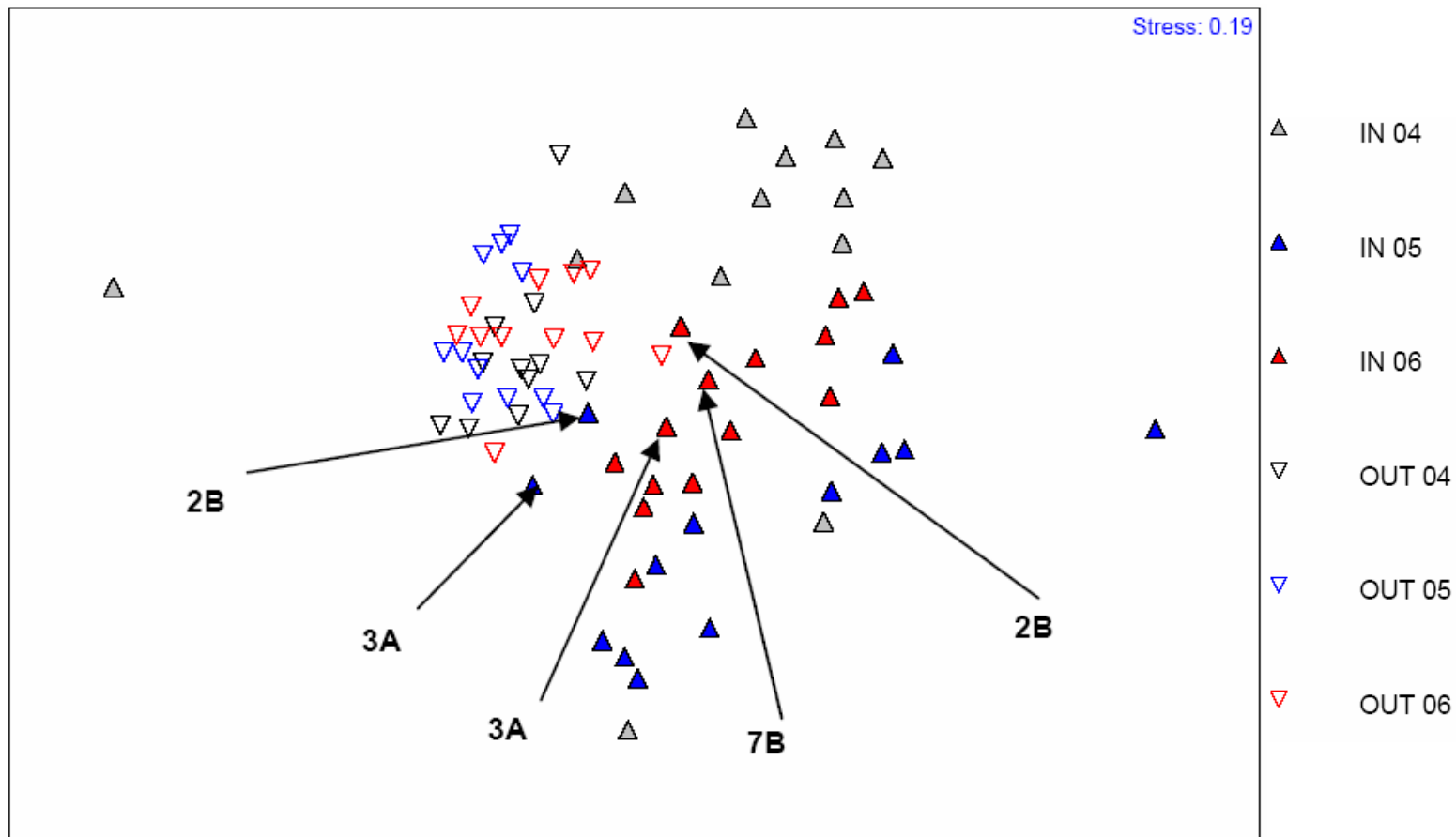


Figure 2.5 Trends in abundance at low water (▲) and high water (■) for waders and wildfowl at Paul Holme Strays for the September 2005 to August 2006 period (adapted from Appendix D)

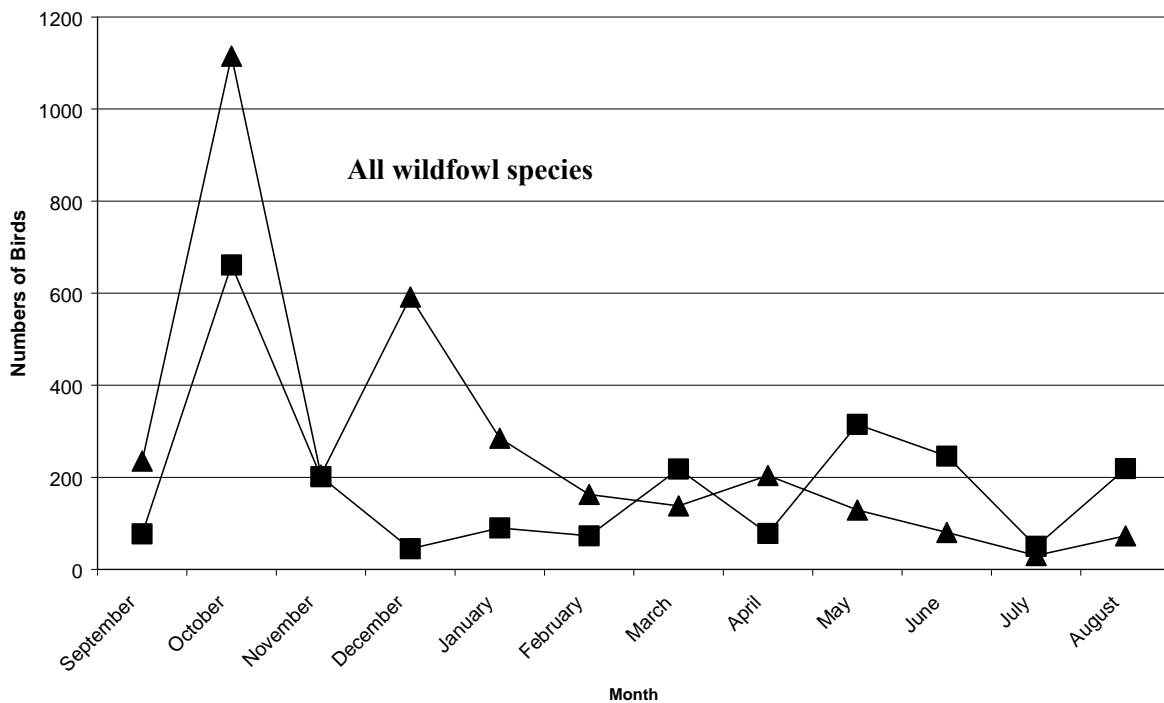
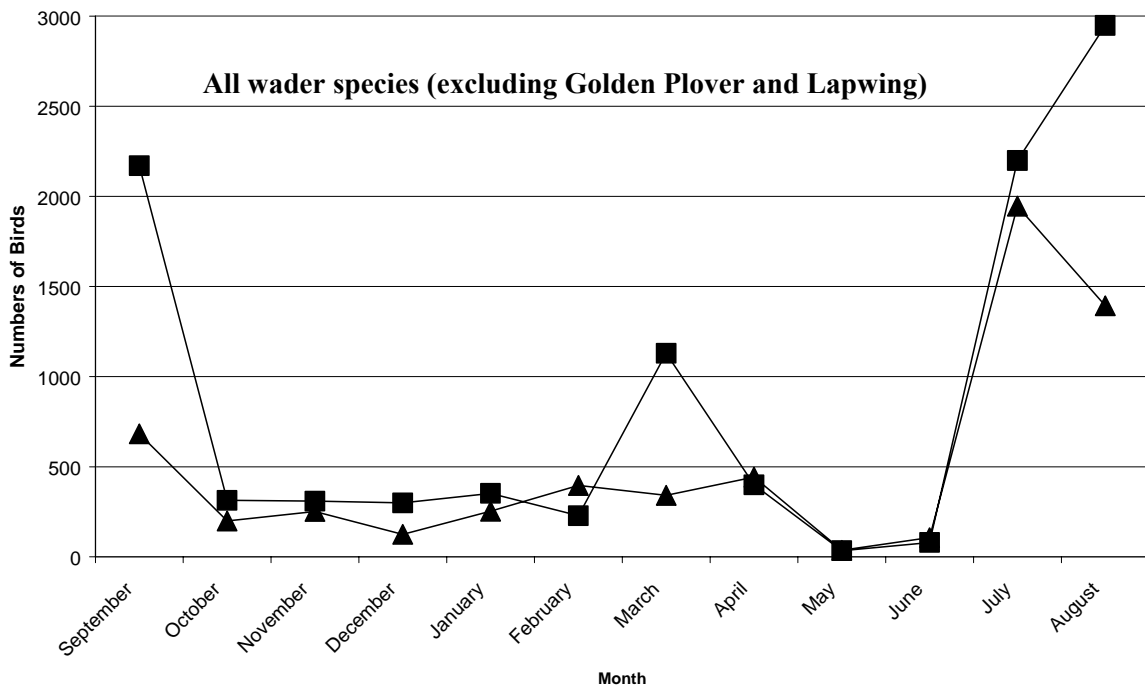


Figure 2.6 Changes in community composition for foraging and non-foraging birds inside the realignment site across all three survey years (adapted from Appendix D)

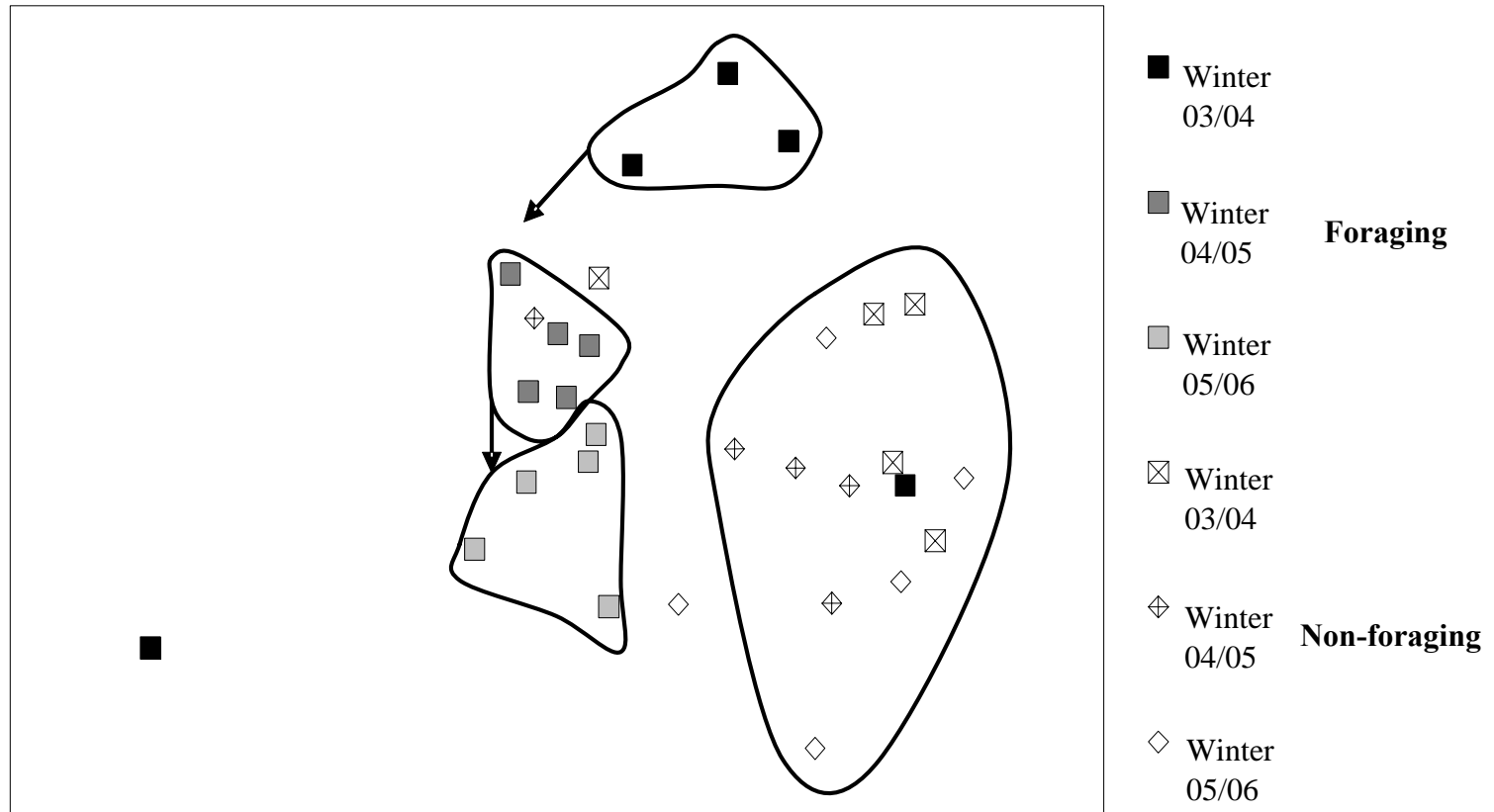


Figure 2.7 Changes in community composition for birds inside and outside the realignment site across all three survey years (adapted from Appendix D)

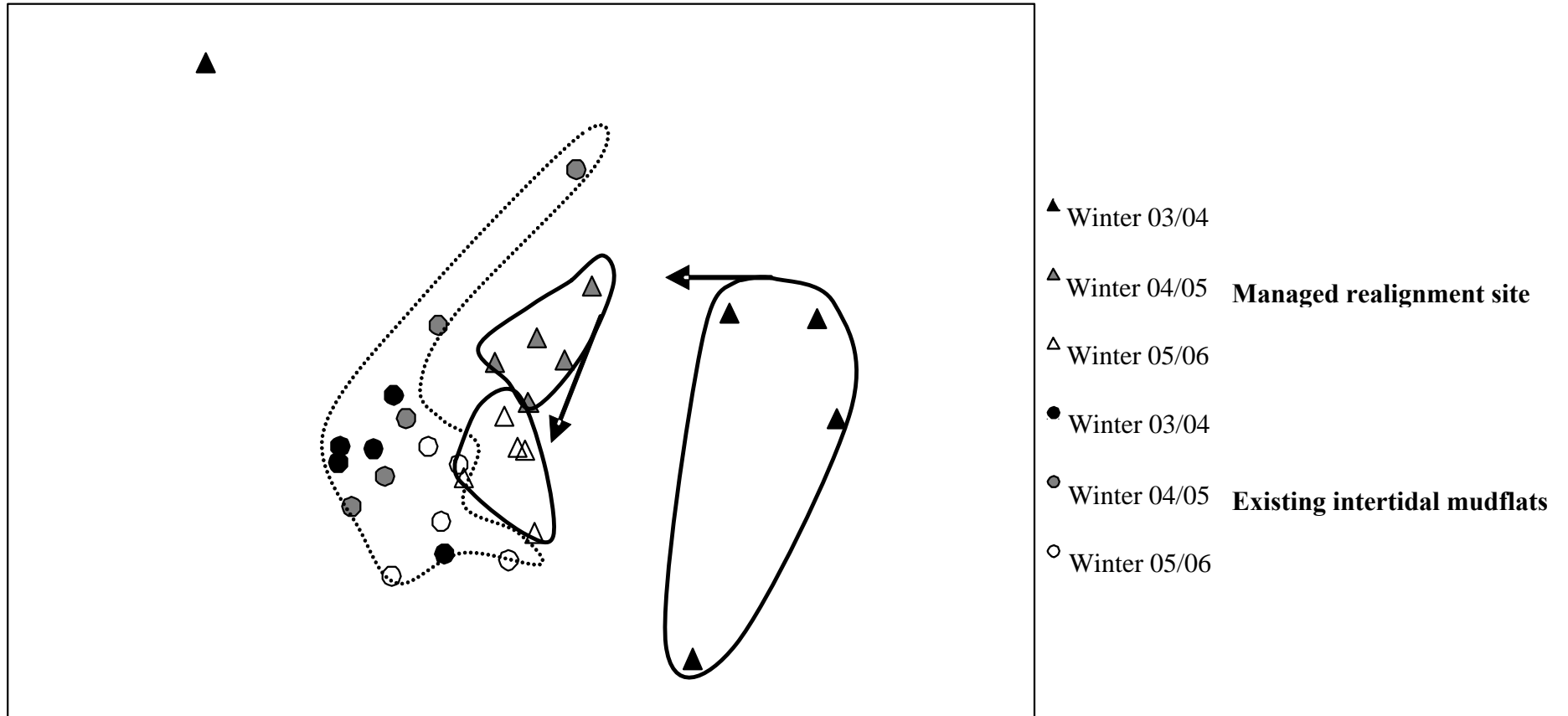


Figure 2.8 Monthly maxima for bird data collected by volunteers at Paull Holme Strays since 2003.

