Written Representations
for the
Royal Society for the Protection of Birds

29 June 2012

Planning Act 2008

In the matter of:

Planning Application for construction of the Able Marine Energy Park on the South Bank of the River Humber at Immingham, North Lincolnshire

Planning Inspectorate Ref:	**TR030001**
Registration Identification Ref:	**10015550**

1. THE RSPB

1.1. The RSPB was set up in 1889. It is a registered charity incorporated by Royal Charter and is Europe's largest wildlife conservation organisation, with a membership of over 1 million. The principal objective of the RSPB is the conservation of wild birds and their habitats. The RSPB therefore attaches great importance to all international, EU and national law, policy and guidance that assist in the attainment of this objective. The RSPB campaigns throughout the UK and in international fora for the development and effective delivery of such law and policy. In so doing, it also plays an active role in the domestic processes by which development plans and proposals are scrutinised and considered, offering ornithological and other wider environmental expertise.

1.2. The RSPB believes that climate change is the most pressing threat to the UK's wildlife and that wind energy has an important role to play in countering this threat. However, the RSPB will continue to oppose wind farms (or developments for windfarms) in inappropriate locations that risk significant damage to protected species and sites, in just the same way that we do for other developments. At the same time, we will work with developers to find ways to minimise the risk of such damage. Early engagement helps this process, by identifying information requirements and anticipating problems at the earliest stage, so that ways forward can be found and accommodated without unnecessary delay.

2. INTRODUCTION

2.1. This document sets out the core of the RSPB's case. The detail and the evidential basis for the points made in this document are contained in the attached expert evidence of Dr Tony Prater and Mark Dixon.

2.2. It responds to the Applicant's proposals as currently formulated only. It is understood that further detail is to be provided on 29th June 2012. That detail will be responded to at the next stage.

2.3. The RSPB agrees that the Proposals, by building on a substantial area of inter-tidal mudflat and removing that ecological resource from birds, will fail the Integrity Test. It is for the Applicant to demonstrate that the Proposals are IROPI and that there are no alternative solutions - the RSPB has no comment on that save that it is a high hurdle especially given the circumstances here.

2.4. The core issue for the RSPB[1] is whether the Compensation proposed to be provided principally through managed realignment at Cherry Cobb Sands ("the Site") is fit for purpose and will compensate for the environmental resource lost. The RSPB consider that it is plain (on a correct understanding of the Applicant's own evidence and through a proper understanding of the available data) that: (i) the Site will not provide adequate compensatory habitat in the medium and long term - the accretion and erosion issue; and (ii) the Site together with the intended temporary provision at Old Little Humber Farm ("the Farm") is highly unlikely to have the ability to replicate or compensate for the environmental function lost in terms of supporting the displaced population (especially the black-tailed godwit population) – the ecological function issue.

2.5. In terms of the accretion and erosion issue, the design is such that appropriate tidal velocities to avoid excessive accretion within the Site may be achieved in the short term but over time and: (i) as erosion creates channels in the lowest part of the Site and impacts on the breach; and (ii) as accretion occurs in the higher parts of the Site, those velocities will reduce such that accretion rates will increase further reducing the area of inter-tidal mudflat over time below that required and predicted by the Applicant.

2.6. Even if this issue can be overcome, the available evidence does not support the claim that the Site can (either alone or in combination with the temporary further compensation at the Farm) compensate for the ecological function lost. Even on the assumption that the black-tailed godwits ("BTG")[2] can find a suitable alternative roosting site (equivalent to North Killingholme Haven Pits, "NKHP") which is readily available for them if using the Site for feeding during their moulting period (which is not accepted), by reference to experience at Paull Holme Strays ("PHS") there can be no confidence (and there is no scientific base for assuming) that the Site can support anything like the density of BTG as currently supported at NKM.

<u>The proposals including compensation</u>

2.7. The development authorised by the Development Consent Order (TR03001/APP/9) will result in the direct and indirect loss of 38 ha of inter-tidal mudflat in Areas B – D at North Killingholme Marshes ("NKM"). Permanent compensation is proposed at Cherry Cobb Sands ("the Site") with temporary additional provision being made at the Farm.

1 The RSPB has some comments in respect of the mitigation proposals for Curlew as a stand alone issue which are dealt with in the evidence of Dr Prater.

2 Listed in the Humber Estuary SPA designation (Article 4.2) as an overwintering and on passage migratory species (HRA Annex B).

The statutory requirements on compensation

2.8. By virtue of regulation 66 of the Conservation of Habitats and Species Regulations 2010 as amended ("the Habitats Regulations"), in the event of the imperative reasons of overriding public interest and alternative solutions tests being satisfied, the appropriate authority (here the Secretary of State – "the SoS") must:

"secure that any necessary compensatory measures are taken to ensure that the overall coherence of Natura 2000 is protected".

2.9. The essential steps in fulfilling that duty are to ascertain precisely the ecological function and resource which is lost and how that function and resource can be permanently secured elsewhere: see EU Commission Guidance Managing Natura 2000 *para 5.4*[3]*.*

The existing ecological function and resource

2.10. The RSPB will focus on the BTG although other species are also of significance and are addressed in Dr Prater's evidence. A short fact sheet on the BTG is attached as Appendix I to Dr Prater's evidence.

2.11. The importance of NKM and the neighbouring NKHP for BTG especially from late July/August – late October/November (see e.g. ES Chapter 11 para 11.5.50) is clear from the Environmental Statement (ES Chp 11 table 11.8) with a five year mean peak of 2,566 birds[4] or 66% of the peak Humber population being present at NKM. This is remarkable for a small area of estuary.

2.12. During this period of moulting, the birds forage in very high numbers and at exceptionally high densities on NKM (especially at low tides) and use the adjacent NKHP ("where the shallow lagoons

---

[3] Compensation measures needs to be:

- Linked carefully, and scientifically justified by reference, to the impacts on the conservation objectives of the SPA/Ramsar site and their species, as the appropriate assessment must be conducted "*in the light of the best scientific knowledge in the field*" (*Waddenzee* (ECJ Case C-127/02, [2004] ECR 1-7405) para 54).
- Effective in compensating for impacts arising within the SPA.
- Sufficiently precise to allow the competent authority to be "convinced"/certain of them working, therefore full details need to be known at time of considering the application (*Waddenzee* para 56).
- Practical, feasible and workable and where necessary, in place before the relevant impact occurs so as to ensure adverse effects can be compensated for as they occur.
- Legally secured – both in terms of the local planning authority (normally) ensuring that they occur as well as being able to draft conditions/obligations that are fit for purpose and therefore capable of enforcement. Voluntary commitments/agreements DO NOT satisfy the Habitats Regulations. The measures must be secured under planning conditions or planning obligations and therefore directly tied to the planning permission enforceable by the Local Planning Authority.
- Monitoring to ensure workability over appropriate period with a feed back loop mechanism so that should the measures not work more can be provided – often an ecological review group is established to review the monitoring data and advise the developer and the local planning authority on workability and if necessary what else needs to be done.

[4] 5.4% of the international population.

provide ideal habitat" - ES para 11.5.53) predominantly for roosting (before moving elsewhere in winter as the food reserve at NKM is depleted).

2.13. There is no evidence that any other inter-tidal site on the Humber is used (or could be used) by BTG in the autumn to anything like the same extent as at NKM. It is plain that NKM is of the first rank of importance of sites for moulting BTG.

2.14. Further, the package of excellent feeding grounds (on the inter-tidal mudflats - not the salt marshes) at NKM and adjacent roosting site at NKHP (peak count 3,800 on TTTC: ES Chp 11 Table 11.9) provides the ideal combination of food availability and secure roosting (recognised at ES 11.6.19) at this critical and energy intensive time of year such that this is their favoured or optimal site during autumn passage on the estuary (ES para 11.5.76).

2.15. There is no evidence of any equivalent package of remotely similar value being available anywhere else on the Humber or that a site with only one part of the package would perform the ecological function performed by NKM and NKHP.

2.16. The ecological resource and function which the compensation provision has to meet is:

2.16.1. inter-tidal mudflat able to support the feeding requirements of a substantial majority of the Humber population of BTG in the autumn moulting period (at least a peak of 2,566 and possibly considerably higher); and

2.16.2. adjacent or readily accessible high quality roosting sites.

The precautionary approach

2.17. A precautionary approach is required to the compensation requirements. The approach in *Waddenzee* paragraphs 55-56 applies. The Applicant has to demonstrate that there is no reasonable scientific doubt that its proposals will secure the requisite extent and quality of compensatory habitat.

The compensation site

2.18. It is accepted that, in principle, the creation of new inter-tidal habitat could be relied on as compensation as long as the provision is adequate to replicate the ecological function and resource of the area lost for the long term.

2.19. The RSPB has fundamental concerns about:

2.19.1. whether the compensation proposals will secure an adequate quantum of inter-tidal mudflat in medium and long term to compensate for that lost; and

2.19.2. whether the inter-tidal mudflat can sustain the populations displaced by the development proposal.

The managed realignment - erosion and accretion

2.20. The key issue is not the area of potential inter-tidal mudflat created at the outset, but the impact of accretion and erosion on it in the medium and longer term. Accretion to saltmarsh is the primary concern (as demonstrated at the existing managed realignment sites in the Humber): see ES Chapter 28 para 28.2.26 and Annex 32.5. The RSPB considers that principally because of the very high sediment loadings in the Humber any conventional managed realignment design (as proposed here) is unlikely to result in large areas of sustainable mudflat in the medium term and that here the extent of the managed realignment will very significantly diminish over the years.

The Applicant's case

2.21. Based on experience at Paul Holmes Strays ("PHS") (ES Annex 32.5 Table 4 p7), the Applicant predicts rapid accretion at the Compensation Site (ES Annex 32.5 Chp 5, Fig 3 and para 5.2.1). Accretion will lead, on the Applicant's own analysis, to saltmarsh colonisation of around "60 per cent coverage after 5 years" (ES Annex 32.5 para 5.2.1). No predictions appear to be provided for the longer term. On any view, the process will not stop at five years. The Applicant's own evidence demonstrates that the essential design feature of the Site (the V shaped breach with 2m ODN invert) which minimise accretion in the short term will be lost over time such that the loss of inter-tidal mudflat will continue.

2.22. Further, the Applicant correctly accept that the "predicted change in ground levels probably have an accuracy of +/-50%" (para 5.1.4 ES 32.4). In accordance with the precautionary principle, the requirements to "secure" adequate compensation and the *Waddenzee* approach, this uncertainty has to be reflected in the extent of compensation planned for and provided. In other words the Applicant must be able to secure the delivery of more than their central estimate of required compensation so as to take account of this inevitable uncertainty.

2.23. The Applicant contends that the detail of the contours within the Site can be reviewed with Natural England ("NE") prior to implementation in order to seek to maximise the amount of inter-tidal mudflat secured in the Site. It appears that this scope for further work is relied on in support of the compensation case. The RSPB considers that that approach is not permissible. The Applicant has to *now* demonstrate that adequate compensation (taking into account uncertainties) will be provided to sustain the ecological function in the long term. They cannot proceed on the basis that the overall parameters (the size and location of the managed realignment site and the design of the breach) are set *now* through the DCO and they will *then* do the best they can within those parameters. They have to demonstrate *now* that within those parameters long term adequate compensation will be provided.

<u>Velocities, breach and erosion</u>

2.24. In order to limit accretion and thus retain inter-tidal mudflat, the breach is designed to ensure that tidal velocities within the site "are high enough to prevent or severely limit deposition" (ES para 28.2.27). The maintenance of those velocities is critical to the avoidance of excessive accretion and thus loss of inter-tidal mudflat within the compensation site.

2.25. In what follows it is important to recognise that the issue is not so much velocities at and around the breach (where velocities will be such as to lead to erosion and not accretion) but velocities at the higher parts of the site away from the breach where lower velocities will result in higher accretion.

2.26. The use of a flat "V" shape breach with an invert (base) at about 2m ODN (i.e. above the surrounding recontoured ground levels in the Site) is the means of maintaining those velocities because the smaller the cross section of the breach, the greater the velocity with which the tide will have to flow through the breach to empty and fill the Site and consequently the greater the velocities across the Site.

2.27. In the short term, the breach design (with a limited cross-section) will ensure sufficient speeds to wash away settled sediments and hence maintain mudflats.

2.28. However, the breach itself is not protected from erosion (ES para 32.6.22) and the high velocities initially achieved will in turn cut channels close to the breach and erode the breach over time (ES Chapter 28.2.25; 32.6.8, 32.6.18, 32.6.22 and see ES Annex 32.4 section 3.3) creating a larger cross-section. This will result in decreasing speeds of the flood and ebb tides across the higher parts of the Site. The changes by virtue of erosion are "subject to considerable uncertainty" (ES Chp 32.6.20) but the Applicant predicts that they will occur within 5 years allowing the whole site to drain at low tide[5] - in other words within 5 years the design feature to maintain high velocities will have been lost.

Volume of water

2.29. Further, as the substantial level of accretion predicted by the Applicant occurs, the volume of water required to fill the Site will decrease (the volume of the void will be less) and the velocity of flow will thus further decrease resulting in a further increase in accretion rates.

2.30. Taking the immediate post-breach water volume at high tide of 1.26 million cubic metres and allowing for an average minimum accretion of just 400mm (far less than in fact predicted by the Applicant), the volume of water across the whole site will decrease by 40% with a consequential decrease in velocities and increase in accretion.

The result

2.31. It is therefore plain, on the Applicant's own evidence, that over time:

2.31.1. the velocities (initially secured by design in order to avoid excessive accretion) will decrease;

2.31.2. accretion will increase in the parts of the Site away from the breach itself; and

[5] In other words the invert will by then have lowered from 2m to 1 – 1.5m ODN (the lowest level on the re-contoured site closest to the breach).

2.31.3. the cycle will repeat (erosion at breach, accretion away from breach) leading to accretion over much of the Site creating substantial saltmarsh but not the necessary compensatory inter-tidal mud flats.

2.32. There is therefore no evidential or scientific basis for concluding that the requisite amount of inter-tidal mudflat will maintained long term.

Further impacts

2.33. The 2m ODN invert will mean that initially all water cannot escape at low tide. There will initially be a pool within the site (covering all areas of ground at less than 2m ODN. These areas will not be inter-tidal mudflat at the outset - they will be submerged. Further, the pool effect will increase accretion rates as silt has more time to settle in it. It is accepted that this effect will be temporary (because within five years the breach - and invert - will be eroded to the point where the whole Site drains).

2.34. It appears that the design of the breach will accelerate the impacts outside the Site. By seeking to increase velocities in the Site, the inevitable consequence of the design is that velocities will, initially, be higher just beyond the breach outside the Site than they would otherwise be.

2.35. The above issues are covering in detail in Mark Dixon's evidence attached as Annex C (his summary evidence is attached below as Annex C1).

The ecological function

The existing ecological function to be compensated for

2.36. As summarised above, the ecological function here comprises the foraging opportunities on NKM and the functional links with NKHP which together provide an excellent environment for BTG in the moulting period as reflected in the remarkable numbers and densities using this area.

2.37. Dr Prater highlights issues with the data available. Accurate data is of course fundamental in determining "precisely" the ecological function of the area to be lost. However, on the limited data available (from one year's TTTC counts only) NKM accommodates a peak of 2,566 birds and NKHP (which has a very strong functional link with NKM) has five yearly average maximum of 3,338 and WEBS and TTTCs data for autumn 2010 at 3,555 and 3,800 respectively.

2.38. The Compensation package as a whole (taken together with any demonstrated continuing use by BTG of NKHP) must be able to provide for at least these maximum foraging numbers and for the numbers using the "package" of foraging and roosting sites.

Experience of managed realignment sites

2.39. The experience of managed realignment sites in the Humber does not demonstrate that they are used by BTG for foraging in significant numbers.

2.40. Data from Chowderness provides no evidential or scientific basis for managed realignment sites accommodating remotely comparable numbers or densities of BTG. At Welwick, there has been occasional use by comparatively small numbers in 2008 and by higher numbers on the borrow pits, in 2009/10. There is no evidence of this site being used by large numbers of birds at very high densities for foraging or for it providing an attractive "package" of foraging and roosting opportunities for large numbers of BTG .

2.41. PHS was designed to provide 35ha of inter-tidal mudflat and is relied on extensively in the HRA and ES as a comparative example of what may be achieved at the Site. On a proper analysis of the full data, it is plain that PHS is not used extensively by BTG for foraging (even after 6 years) with a mean autumn count of 10 foraging birds in 2006, 153 in 2007 and 12 in 2008. Further, confidence that the food resource at PHS is sufficient to make it an attractive foraging location is not supported by most recent data.

2.42. In fact the data from PHS properly understood:

2.42.1. does not demonstrate increasing usage by foraging birds over time;

2.42.2. does not demonstrate the capacity of managed realignment sites to accommodate large numbers of BTG;

2.42.3. does not demonstrate that the food resource is adequate to support large populations.

2.43. Far from giving confidence that managed realignment can be of equivalent value to that lost, PHS clearly demonstrates that the foraging value is limited. This is further demonstrated by a correct analysis of the density data including that in Annex 35.6 Table 1 p21. Apparently those data look at average densities across the year even though NKM is overwhelmingly used between August and November with very limited use outside this period. Even looking across the whole year, Annex 35.6, page 21 identifies that the density on NKM is 6.3 times the claimed density on PHS (183 per sq km compared to 29 per sq km) – implying a need for a compensation site to be many times larger than the area lost.

2.44. Looking at the correct data (for autumn only) from HRA Table C2.9, the mean count on the application site area (33.9ha) is 882 the *average* density at NKM is 2602 per sq km. If one looks at the peak count (2566) the density is 7569 per sq km.

2.45. There can be no doubt that NKM supports a density of BTG of a different order of magnitude from that at PHS. It is not known whether this is due to the food resource, the nature of the environment, less attractive roosting areas, any other factor (such as site fidelity) or a combination of some or all of these. What matters is that it is plain that the ecological function is not remotely replicated hectare by hectare.

2.46. The RSPB considers that these basic and fundamental points make it impossible to have confidence that experience elsewhere demonstrates that the ecological function at NKM can be successfully replicated on even 78 ha of long term inter-tidal mudflat at the Site.

The Farm

2.47. The Farm is designed to provide additional potential temporary roosting and feeding areas. On the basis of the current plans available to it, the RSPB does not consider that the proposals have any potential to achieve the objective set. The site is 1.5km away from the inter-tidal area and the Site. The maintenance of the water environment is entirely dependent on rainwater - this will be very challenging to secure through all the seasons and especially in summer leading into autumn. The design is such that there will be no substantial islands and no substantial bodies of water. The food resource is likely to be very limited, it is unlikely that it can be increased rapidly and given the clay soil, may be difficult for birds to access.

Continued use of NKHP

2.48. It may therefore be that BTG feeding at the Site are forced to roost (and undertake supplementary foraging) elsewhere including NKHP. But NKHP is a substantial distance from the Site (5.3km) and no assessment has been made as to the extent to which a functional link can or would become established (and at what ecological cost to the birds) between the Site and NKHP.

2.49. The above issues are covered in detail in Dr Prater's evidence attached as Annex B (his summary evidence is attached below as Annex B1).

2.50. Additional legal matters are covered in Appendix 1 below.

2.51. The RSPB's response to the Examining Authority's Written Question (as set out in the Examining Authority's letter to Interested Parties, dated 5 March 2012, Annex C) relevant to the RSPB is set out in Annex A attached to these representations.

APPENDIX 1

1. LEGAL MATTERS

The Habitats Regulations

1.1. The RSPB has focused its attention on the Conservation of Species and Habitats Regulations 2010 (as amended)(the Habitats Regulations) but please note that a number of these requirements are also set out in the Infrastructure (Environmental Impact Assessment) Regulations 2009 (as amended). However it was not felt necessary to include references to those regulations as well.

1.2. The Habitats Regulations set out the sequence of steps to be taken by the competent authority (here the Secretary of State) when considering authorisation for a project that may have an impact on an European site before deciding to authorise that project. These are as follows:

1.2.1. Step 1 Under reg 61(1)(b), consider whether the project is directly connected with or necessary to the management of the SPA. If not –

1.2.2. Step 2 Under reg 61(1)(a) consider, on a precautionary basis, whether the project is likely to have a significant effect on the SPA, either alone or in combination with other plans or projects (the Significance Test).

1.2.3. Step 3 Under reg 61(1), make an appropriate assessment of the implications for the SPA in view of its conservation objectives. Reg 61(2) empowers the competent authority to require an applicant to provide information for the purposes of the appropriate assessment. There is no requirement or ability at this stage to consider extraneous (non-conservation e.g. economics, renewable targets etc) matters in the appropriate assessment.

1.2.4. Step 4 Pursuant to reg 61(5) and (6), consider whether it can be ascertained that the project will not, alone or in combination with other plans or projects, adversely affect the integrity of the SPA, having regard to the manner in which it is proposed to be carried out, and any conditions or restrictions subject to which that authorisation might be given (the Integrity Test).

1.2.5. Step 5 In light of the conclusions of the assessment and in accordance with reg 61(5) and (6), the competent authority shall agree to the project only after having ascertained that it will not adversely affect the integrity of the SPA, alone or in combination with other plans or projects.

1.3. As set out in the recently published National Planning Policy Framework Ramsar sites are given the same protection as European sites and therefore should be included in the consideration and assessment process set out above[1].

1.4. It is the RSPB's view that for this Application, subject to ongoing discussions concerning the necessary mitigation and compensation measures, alone, would adversely effect the SPA, SAC and Ramsar site.

[1] The National Planning Policy Framework, pg 28, para 118, http://www.communities.gov.uk/publications/planningandbuilding/nppf.

Annex A

Examining Authority's
First Written Questions
Response by the
Royal Society for the Protection of Birds

29 June 2011

Planning Act 2008

In the matter of:

Planning Application for construction of the Able Marine Energy Park on the South Bank of the River Humber at Immingham, North Lincolnshire

Planning Inspectorate Ref:	**TR030001**
Registration Identification Ref:	**10015550**

Examining authority's first written questions
Annex D 1 - Page 12-24 of Rule 8 Letter 31st May 2012

Questions primarily for Natural England and the Royal Society for the Protection of Birds
96. Key species identified as likely to be affected by the proposed development are the black-tailed godwit, redshank and curlew. Have any natural changes in the populations or distributions of these species been observed since the designation of the European sites? If so, what if any reasons can be ascribed to these changes?

Black-tailed Godwit ***Limosa limosa islandica***

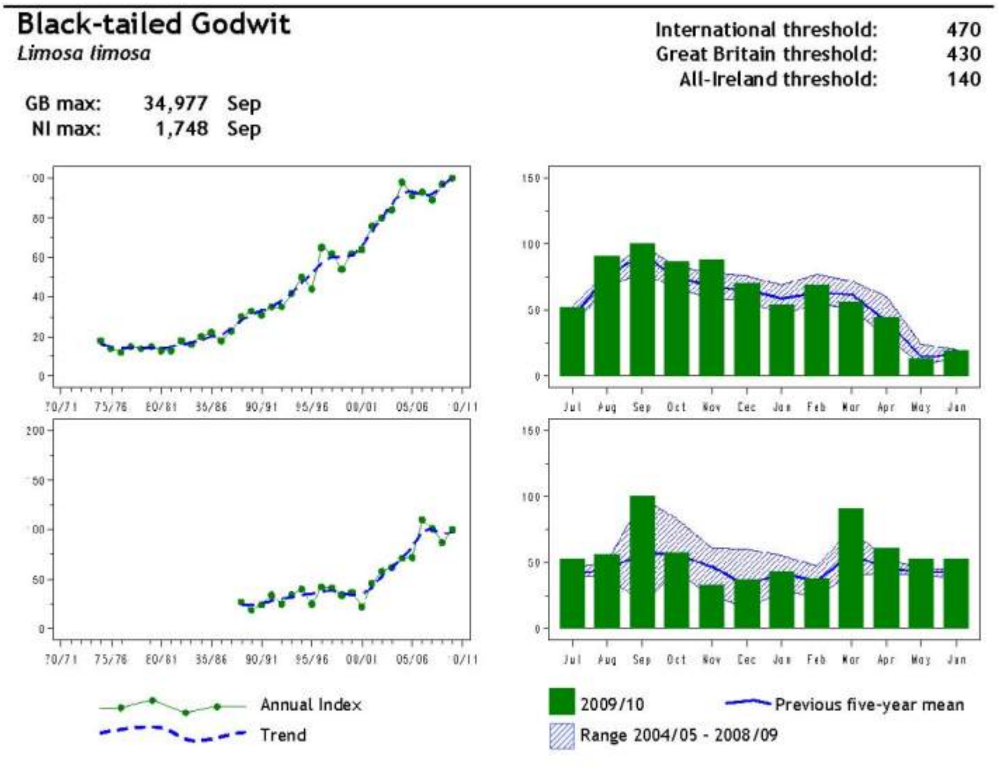


Figure 52.a, Annual indices & trend for Black-tailed Godwit for GB (above) & NI (below).

Figure 52.b, Monthly indices for Black-tailed Godwit for GB (above) & NI (below).

The population occurring on the Humber, and virtually all in the UK, are of the race *L.l.islandica* which breed almost entirely in Iceland. They occur on passage and in winter down to Iberia, with a few in North West Africa. They are essentially estuary feeding birds.

The Humber Estuary SPA and Ramsar sites were re-designated in 2007 and used count data from 1996-2001. So on designation, the WeBS report for 2000/01 (Pollitt, M. *et al* 2002 The Wetland Bird Survey 2000/01; BTO) can be compared with the latest, 2009/2010 report (Holt *et al* 2011) in the diagram above. The numbers then of *L.l.islandica* were at an index of c55% of the current population. In other words, numbers have nearly doubled: the maximum number counted in the UK was 21,183 in 2000/01 compared with 34,977 in 2009/10.

The main reason for the increase in numbers has been the rise in the breeding population in Iceland; Gill *et al* (2007) (see Dr Prater's evidence - Annex B2, Appendix VI Tab 7 (p47-48)) identifies the main driver for this as warmer temperatures and agricultural expansion in Iceland creating an increase in breeding opportunities. This appears to be as a result of global warming.

Redshank *Tringa totanus*

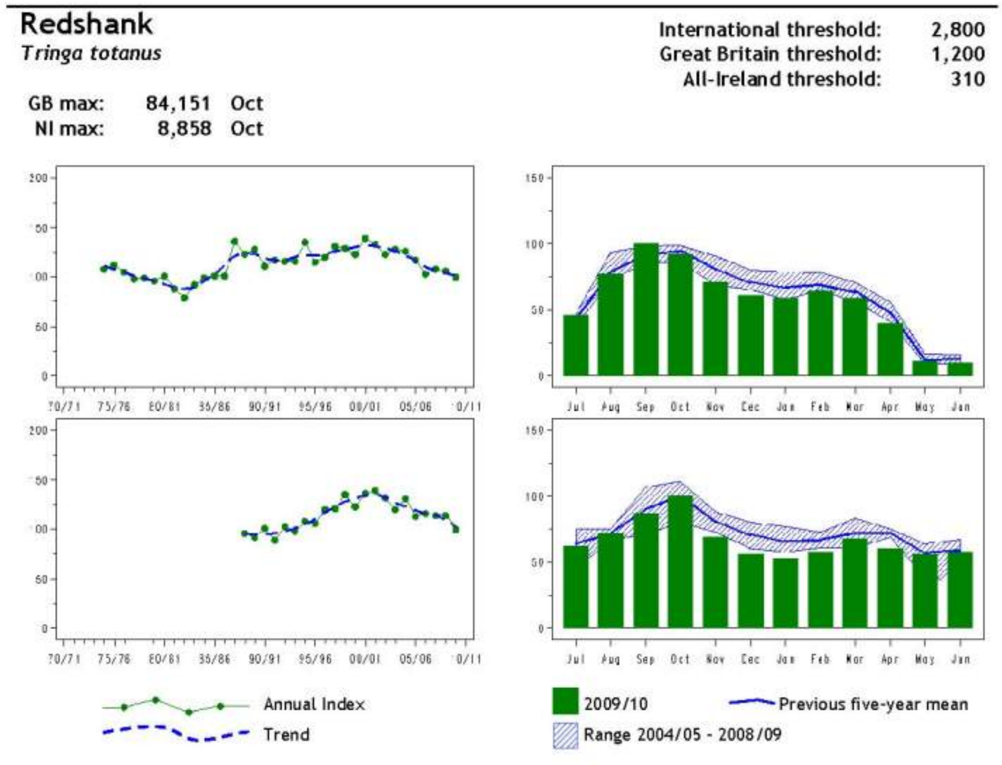


Figure 56.a, Annual indices & trend for Redshank for GB (above) & NI (below).

Figure 56.b, Monthly indices for Redshank for GB (above) & NI (below).

The Redshank which occur in the UK are primarily from two races, *T.t.brittanica* and *T.t.robusta*. The former breeds in the UK and is a short distant migrant while the latter breeds in Iceland and winters almost solely in Britain and Ireland. The two races occur together on passage and winter on estuaries and counts are of the races combined; it is possible to separate them on biometrics and full breeding plumage when in the hand.

The Humber Estuary SPA and Ramsar sites were re-designated in 2007 and used count data from 1996-2001. So on designation, the WeBS report for 2000/01 (Pollitt, M. *et al* 2002 The Wetland Bird Survey 2000/01; BTO) can be compared with the latest, 2009/2010 report (Holt *et al* 2011) in the diagram above. Since 2001 the numbers have shown about a 10% decrease; this is reflected by a decrease in the numbers counted for the WeBS counts from a maximum of 94,213 in 2000/01 to 84,151 in 2009/10. Monitoring across Europe shows that both *T.t.brittanica* and *T.t totanus* breeding populations have shown long term declines (EU 2009 Management Plan for Redshank *Tringa totanus*). In the UK, Redshank breeding numbers decreased by 35% between 1995 and 2009 (BTO Breeding Birds Survey 2010). It is thought that while some past decrease in *T.t.robusta* occurred numbers are probably fairly stable. The cause of the decreases are undoubtedly many and include drainage of breeding areas, loss of saltmarshes to sea level rise and development, agricultural intensification and inappropriate management; decreases are seen across the European range both in coastal and landlocked countries. Within the UK there has been a slight movement of distribution towards the east coast (Rehfisch *et al* 2004 Ibis 146: Suppl 1: 70-81).

Curlew *Numenius arquata*

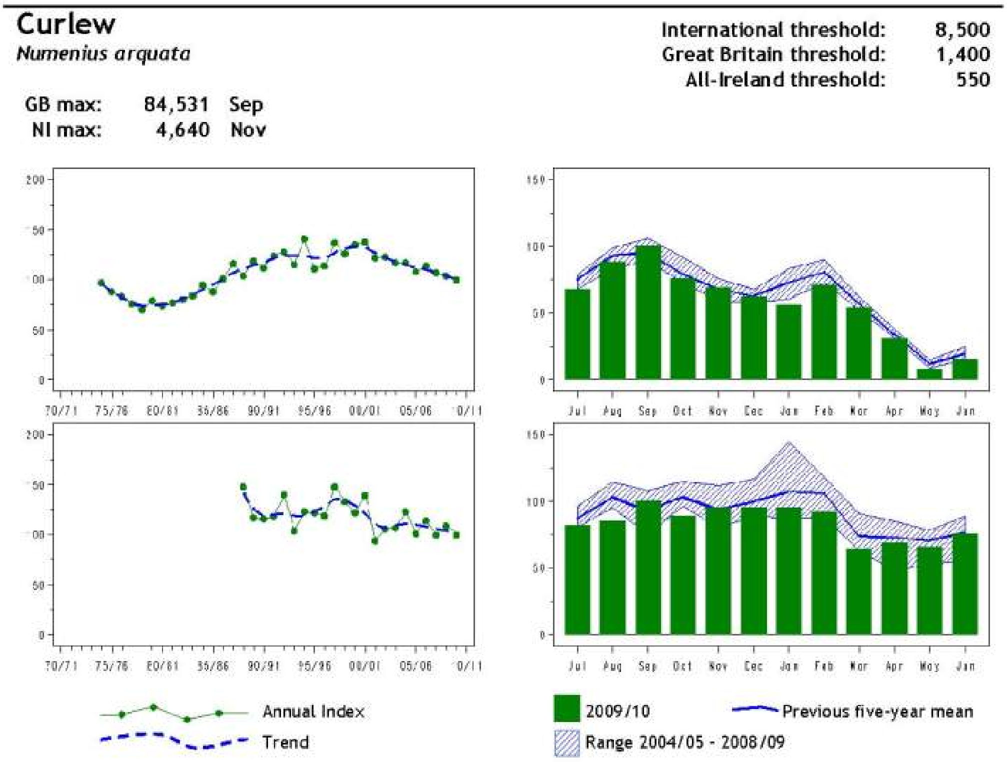


Figure 54.a, Annual indices & trend for Curlew for GB (above) & NI (below).

Figure 54.b, Monthly indices for Curlew for GB (above) & NI (below).

The Curlew which occur on UK estuaries come from a wide breeding range including the UK, Scandinavia and western Europe but are considered to be all of a single nominate race.

The Humber Estuary SPA and Ramsar sites were re-designated in 2007 and used count data from 1996-2001. So on designation, the WeBS report for 2000/01 (Pollitt, M. *et al* 2002 The Wetland Bird Survey 2000/01; BTO) can be compared with the latest, 2009/2010 report (Holt *et al* 2011) in the diagram above. The index of numbers counted in the UK has shown an approximate decline of 10% since designation of the Humber. The actual number counted in 2000/01 was 87,521 and in 2009/10 was 84,531.

Monitoring across Europe has shown a steady decline in breeding numbers in nearly all populations to the early 2000s (EU 2007 Management Plan for Curlew *Numenius arquata*). In the UK, Curlew breeding numbers decreased by 41% between 1995 and 2009 (BTO Breeding Birds Survey). Changes in land use, agricultural practices and nest predation are considered to be the main drivers for population declines across the EU.

Annex B1

Summary Proof of Evidence
of Dr Tony Prater
for the
Royal Society for the Protection of Birds

29 June 2011

Planning Act 2008

In the matter of:

Planning Application for construction of the Able Marine Energy Park on the South Bank of the River Humber at Immingham, North Lincolnshire

Planning Inspectorate Ref:	**TR030001**
Registration Identification Ref:	**10015550**

RSPB

1. QUALIFICATIONS AND EXPERIENCE

1.1. I am Dr Tony Prater. My qualifications and experience are set out in P1-6 of my proof.

2. THE SCOPE OF MY EVIDENCE

2.1. My evidence covers information presented in the Application documents. I examine the proposed compensation and mitigation measures for maintaining the functional coherence of the designated sites and their specific interest. It considers:

2.1.1. Numbers and ecological relationships of the important bird species within and adjacent to the Application site.

2.1.2. The Impacts on the key species and habitats.

2.1.3. Ecological and practical issues associated with the mitigation proposals and the Cherry Cobb and Old Little Humber Farm Compensation sites.

3. THE SITE, ITS HABITATS AND FUNCTION FOR BIRDS

3.1. The inter-tidal mudflats of the Application site, in the Humber SPA/Ramsar site, are of importance for 8 species plus the Assemblage of estuarine birds. They are of international importance for the Icelandic Black-tailed Godwit holding in 2010 up to 2566 (5.4% of the global population) and on the adjacent roost up to 3,800 (8%) individuals, from August to October. The adjacent permanent grassland is functionally linked to the inter-tidal area for feeding Curlew.

3.2. The ecological function of the Application site for Black-tailed Godwits is as a critical autumn feeding area with a secure roost site very close to the mudflats which is used by moulting birds at a time of high energy requirements. Although not documented by the ES, the foods taken are likely to be *Macoma balthica* and *Hediste diversicolor*, the former is present in good numbers especially in the mid-shore while the latter is restricted to the upper shore.

3.3. Black-tailed Godwits feed for a short time (2-3 hours) on each tidal cycle and so feeding birds spend a substantial part of the tidal cycle loafing on the mudflats.

3.4. Throughout its range the Icelandic Black-tailed Godwit is essentially an estuarine feeder using adjacent wet grassland a little in autumn, more in winter and substantially in spring. It also chooses to roost in areas where there is limited disturbance from predators and people, especially where there are fresh or brackish water lagoons with islands.

<u>The assessment of the site for its bird populations</u>

3.5. In Section 6.3 of the Applicant's Habitat Regulations Assessment (the HRA) the impact on the eight species plus the Assemblage is assessed. I agree with most of the comments here and that these adverse effects cannot be mitigated. However, Curlew and redshank appear to be omitted from summary paragraph 6.6.3 (first bullet point).

3.6. In addition the Assemblage has been considered wrongly.

<u>The functionally linked terrestrial habitat loss</u>

3.7. I agree with HRA 5.4.21 that there will be permanent loss of functionally linked land due to the terrestrial part of the Application, principally for Curlew, which forage on both the mudflats when exposed and the fields at high water. There are proposals to mitigate for that loss.

4. <u>ECOLOGICAL IMPLICATIONS OF THE MITIGATION PROPOSALS FOR AREA A</u>

4.1. There is a need to provide mitigation for the loss of the supplementary feeding for Curlew. The Mitigation Area A (File 4, Drawings 23(a), AME 02007) will become, principally, wet permanent pasture.

4.2. I agree that Mitigation Area A is important to cater as supplementary feeding for Curlew. The proposals to increase the area of wet permanent pasture, 150m buffers and 16.7ha core area are welcomed. However there are a number of issues which remain to be agreed or maybe problematic:

4.2.1. The restricted 50m buffer zone to the north.

4.2.2. The main objective to produce wet permanent pasture with pools/scrapes; a hydrological regime should be included.

4.2.3. The development of wet pasture and the concomitant invertebrate populations is likely to take 2-4 years; detailed proposals are not included in the Application documents.

5. ECOLOGICAL IMPLICATIONS OF THE COMPENSATION REQUIREMENTS

5.1. I agree with that some of the adverse effects of the Application cannot be mitigated and therefore compensation is required. Before discussing the compensation proposed there are two issues which need to be considered.

The function that needs to be replaced

5.2. As the Black-tailed Godwit is present in internationally important numbers, I will consider this first. For this species it is quite clear from the through the tide counts (TTTCs) and the WeBS counts for 2010/11 (Appendix 3), that August to October (HRA Table 6.6), is the critical time. So, any compensation has to replicate that autumn function in order to properly compensate for the loss of their feeding grounds plus the long-term presence of a secure roost nearby. averaging data over the whole year would be inappropriate.

5.3. There are also seven other species and the wider Assemblage which will also be adversely affected (HRA section 3 and Table 5.7). It is important that their requirements are not overlooked. I accept that the compensation proposed should broadly cover their requirements.

Defining the number of birds to be accommodated

5.4. Appendix 2 of my proof identifies that the serious problems with the data identified by the Applicant especially the very low counts of Black-tailed Godwits in September and November. Unfortunately, the HRA and Annex 35.6 Table 1 does not present numbers in the context of defining the critical autumn function. This is a fundamental problem. The only data which can be used is that in the HRA and supporting documents and this is used without prejudice to any clarification or corrections needed.

5.5. On this basis, Annex 35.6 (p21) shows that the density on the Application site is 6.3 x Paull Holme Strays (PHS). If the autumn data were assessed, the density difference would be much greater. The autumn peak count on the Application site should be the target for replicating the full autumn function.

<u>Ecological implications of the Cherry Cobb realignment</u>

<u>The ability of those mudflats to replace the functions lost</u>

5.6. The target numbers have to be defined first to identify if the lost function can be replaced with the compensation proposals. In relation to Black-tailed Godwit, the numbers feeding on the Application site are at least 2,566 and roosting at the nearby NKHP, 3,800. Although there are problems with the data, these would have to be the minima for targets.

5.7. The second issue is the long-term ability of the site to cater for birds in appropriate numbers. As Mr Dixon describes (Annex C2), the RSPB has serious doubts that the accretion rates there will lead to a sufficient area of inter-tidal mud in the medium or long term. The lack of an assessment of this critical aspect makes it very difficult to make an ecological judgement as to its capacity to deliver this autumn function. However, the detailed bird counts from nearby PHS, Chowder Ness and Welwick realignments provide some important guidance.

5.8. Chowder Ness and Welwick have small numbers of godwits on an irregular occurrence, and so provide no confidence that those realignments can deliver.

5.9. PHS shows, on a longer set of data, that far from the site being a very good site for godwits, the initial encouraging start has now tailed off :

5.9.1. The number of foraging godwits, in the last three autumns reported, have been means of 10, 153, and 12.

5.9.2. The total foraging and non-foraging birds over the last three autumns reported have been 32, 199, 270 which are all lower than the first three years.

5.9.3. The invertebrate populations have changed over the years but despite three foods of godwits forming the bulk of the biomass, godwits are only present in moderate numbers.

5.9.4. The biomass (wet weight) increased in the early years but by 2010 fell away to 21.3 g/m2 from 49.8 g/m2 in 2008, much lower than the figure of 40g/m2 used in Annex 35.6 for theoretical holding capacity.

5.10. Thus the detail provided in Annex 35.6 (p25-26) which underpins the concept that the Cherry Cobb realignment will work has no foundation in practice and has to remain a set of theoretical calculations, some of which are based on flawed assumptions. PHS provides no scientific confidence that a similar realignment would deliver the critical autumn function for Black-tailed Godwits.

<u>Ecological implications of the Old Little Humber Farm compensation</u>

5.11. The RSPB, with its extensive knowledge of developing wet grassland for birds, has very severe doubts that this particular site has any potential to achieve the objective set which is to provide a site for Black-tailed Godwits until the realignment matures. In particular:

5.11.1. The site's location, about 1.5km away from the inter-tidal and the Cherry Cobb realignment, is very poor; a site close to the inter-tidal is required.

5.11.2. The site's entire water budget will be dependant on rainwater for its autumn function; this is likely to prove severely limiting.

5.11.3. The site will have no substantial excavations on it to achieve substantial bodies of permanent water with islands for security.

5.11.4. The invertebrate population of arable fields is severely depleted and cannot be increased rapidly to achieve the target now identified in Annex 35.6 (p25) as 40g/m^2 wet weight.

5.11.5. Even if measures were taken to improve fertility of the site, it is extremely unlikely that the target biomass would be able to be reached within two to four years.

5.11.6. The very dry soil in autumn over a large part of the site would mean that earthworm accessibility would be very difficult – the silty clay tends to dry very hard indeed.

5.12. The calculations referred to in HRA 9.2.13 based on Annex 35.6 p25-27 are just theoretical concepts with no basis for the practical assumptions being made for the site. They do not provide any confidence that the autumn functionality of Black-tailed Godwit feeding on wet grassland can be achieved at this site.

Annex B2

Proof of Evidence
of Dr Tony Prater
for the
Royal Society for the Protection of Birds

29 June 2011

Planning Act 2008

In the matter of:

Planning Application for construction of the Able Marine Energy Park on the South Bank of the River Humber at Immingham, North Lincolnshire

Planning Inspectorate Ref:	**TR030001**
Registration Identification Ref:	**10015550**

RSPB

CONTENTS

1. QUALIFICATIONS AND EXPERIENCE

1.1. I am Dr Tony Prater. I hold the degree of Bachelor of Science with Honours in Zoology from the University of Exeter and the degree of Doctor of Philosophy in wetland avian ecology from the University of East Anglia. I am a Member of the Institute of Ecology and Environmental Management.

1.2. I am presently employed by the RSPB as Ecological Advisor, with special reference to estuaries and wetlands, to the Casework Department at Sandy, Bedfordshire. I have held this post since 2006. I have, however, spent my entire career working principally in avian biology and conservation. Having completed my studies, I worked on an RSPB contract on the Morecambe Bay Barrage Feasibility Study (1968-70). I then became Estuaries Officer and Senior Populations Officer for the British Trust of Ornithology and held that position from 1970 to 1979. Here I set up and developed the Birds of Estuaries Enquiry which later was renamed Wetland Birds Enquiry (WeBS). It was during this period that I became familiar with the Humber Estuary. I joined the RSPB's South East regional office as Regional Officer in 1979 and held that post until 1986, moving to East Anglia as Regional Officer 1986 to 1994. Following that, I was Conservation Manager for Wales until 2006.

1.3. In these positions I have had responsibility for both scientific and management input into many wetlands, including estuaries, and wetland bird species throughout the UK. Abroad I have advised on the management of habitats and scientific work in areas as diverse as the Dutch Wadden Sea coasts, the coastal marshes at Mai Po, Hong Kong and the Tejo estuary in Portugal. I have written four books (including *Estuary Birds of Britain and Ireland* in 1981 and *Shorebirds* in 1986), contributed to another nine books and written over 40 scientific publications, principally on wetlands and the ecology of their birds. I have held the post of co-ordinator of counts for the International Waterfowl Research Bureau (1972-1978) where I was part of the team developing the criteria to underpin the Ramsar Convention[a] for the importance of wetlands and was the Editor of the Wader Study Group Bulletin (1970-78).

1.4. In addition to my positions of employment I have also served terms on a number of committees and organisations relating both to avian biology and conservation and wider

[a] Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar, Iran, 1971).

environmental issues. These include the Scientific Committee of the Wildfowl and Wetlands Trust (1975-77); the Council of the Estuarine and Brackish Water Sciences Association (1980-83); the Chichester Harbour Conservancy Advisory Committee (1983-86); the Severn Tidal Power Group's Environmental Committee (1988-89); the Regional Rivers Advisory Committee of Southern Water and the National Rivers Authority (1982-1986); the Regional Rivers Advisory Committee of Anglian National Rivers Authority (1986-94); the Fisheries, Ecology and Recreation Advisory Committee of the Environment Agency, Wales (1995-2006); the Regional Flood Defence Committee of the Environment Agency, Wales (1995-2000); the Broads Plan Committee of the Broads Authority (1990-93); the Wales Biodiversity Group of the National Assembly for Wales (1996-present); the Scientific Committees of several Wildlife Trusts (1979-1999); and the Gwent Levels Wetland Reserve Steering Group (1996-2006).

1.5. During my career with the RSPB I have provided advice and support to staff on a wide range of estuary issues including, the Severn barrage, compensation in relation to port developments at Dibden Bay (Southampton Water), Port of Bristol, and the ports of Felixstowe and Bathside Bay. I was the RSPB lead on developing the nature reserve of Newport Wetlands as part of the compensation package for the loss of Cardiff Bay; this developed wet permanent coastal grassland, reprofiled and restored ditches, developed saline lagoons and freshwater lagoons with reedbeds in addition to managing the adjacent mudflats and saltmarshes and developing public access.

1.6. I am also a member of the International Wader Study Group, British Trust for Ornithology (BTO), Wildfowl and Wetlands Trust and British Ornithologists Union plus many County Societies.

1.7. I am very familiar with the nature conservation interests in and around the Humber and north Lincolnshire coast. I first visited the area in 1970. I have provided professional advice to local RSPB staff on the Humber in relation to the development of refuges for Special Protection Area (SPA) birds in the South Humber Gateway area and in the initial as well as the final Application proposals. I have visited the area regularly since leaving the BTO both as a birdwatcher and an RSPB estuary specialist.

2. THE SCOPE OF MY EVIDENCE

2.1. My evidence will cover information presented in the documents accompanying the Application (the Application documents). I will concentrate on the main matters of contention and will not be covering the very many erroneous comments in the documents because to do so would make this a very long document. In particular I will examine the relevance of and practical capacity for the delivery of the proposed mitigation and compensation measures for maintaining the functional coherence of the designated site and its specific interest. I will consider the:

2.1.1. Important bird species within and adjacent to the Application site, the numbers involved and their ecological relationship with the habitats of the area in particular the North Killingholme Marshes (NKM), North Killingholme Haven Pits (NKHP) and North Killingholme Fields (NKF) (see Appendix I Maps 1-3).

2.1.2. Direct and indirect impacts on the key species and habitats of the development site.

2.1.3. Ecological issues associated with the mitigation proposals.

2.1.4. Ecological implications of the managed realignment compensation at Cherry Cobb with particular reference to other realignment sites

2.1.5. Ecological and practical issues associated with the wet grassland compensation at Old Little Humber Farm.

3. THE SITE, ITS HABITATS AND FUNCTION FOR BIRDS

3.1. The inter-tidal part of the Application site (NKM) is part of the SPA, Special Area of Conservation (SAC) and Ramsar site of the Humber Estuary (see Appendix I Maps 1-3), NKHP are part of the SPA/Ramsar site. These areas hold important numbers of several species of estuary birds which contribute to the classification of the Humber SPA. Remarkably for a small area of the estuary, there are internationally important numbers of Icelandic Black-tailed Godwits *Limosa limosa islandica.* Up to 2,566 foraging on NKM (HRA, p5-9, Table 5.1); thus the Application site holds 5.4% of the international (global) population. The roost at NKHP with

3,800 (HRA, p5-23 Table 5.2) holds over 8% (international levels are shown in the answer to the Examining Authority's Question 96, from Calbrade *et al* 2010). A short fact sheet on this species is provided as Appendix II (attached). Apart from NKHP, some of the terrestrial part of the site includes areas, especially permanent grassland, functionally linked to the SPA/Ramsar site, and particularly important for Curlew *Numenius arquata*. The data sets used and numbers recorded in them are presented in the HRA (especially Section 5.3, p5-7, Section 6.3, p6-2 and Annex C, plus ES Chapter 11 and Annex 11.9). I do not query the use of the techniques as described – particularly the Through The Tide Counts (TTTCs) for describing the use of the NKM and the NKHP, the WeBS data for also counting the roost on NKHP and placing the site, the Humber and its birds into a wider context of importance and the field surveys identifying the numbers and location of birds on the terrestrial land. There are issues, however, relating to the bird numbers and the lack of clarity for the calculations made in the HRA and the supporting ES, some of these are considered in Appendix III (attached).

<u>The ecological function of the Application site for Black-tailed Godwits</u>

3.2. The HRA (6.3.30–39, p6-11 to 15) describes the numbers and use of the NKM and NKHP for this species. Some of the comments I agree with but others are questionable. I agree that NKM is an important autumn area where they feed and moult in close proximity – feeding and loafing on NKM and loafing and roosting on NKHP. The autumn period extends from late July through to the end of October in relation to the passage and moulting functions of most estuary birds including the Black-tailed Godwit. However, I do not see the relevance of the reference to (6.3.30, p6-12) the WeBS mean peak count being 50. This does not accord with Table 6.6, (p6-12) which gives 145 but far more importantly, the WeBS counts do not count the birds feeding on the inter-tidal area, they count birds at high tide when a few might remain to roost on the top of the shore. I do not accept that WeBS core count data on the intertidal mud flats are of any assistance in assessing the value of the ecological resource there. The vast majority of birds which have fed on the inter-tidal are, at high tide, on the NKHP and the WeBS total counted for that area 2004/05-2008/09 show a mean peak of 3,338 (HRA Table 5.2, p5-23); the counts for 2010/11 are in Appendix IV Table 1 (attached).

3.3. In HRA paragraph 6.3.32 (p6-13), it is suggested that the move away from NKM may be due to food depletion. This would be my view too. I think a critical feature, which is underplayed in the HRA, overlooked is the important linkage between birds moulting and feeding on both

NKM and NKHP. In my view it is a critical functional link in this area. Throughout the UK and throughout the European range of the Icelandic Black-tailed Godwit it is essentially an estuarine feeder which uses wet grassland to supplement its diet to a small extent in autumn, a greater extent in winter and is substantially found on wet grassland sites in spring (Gill *et al* 2007 – see Appendix VI Tab 7). The aspect which is critical for this is permanency of the wet grassland to supplement the feeding, not a temporary feature. In addition, the need for a secure and reasonably undisturbed roosting area nearby where moulting birds can go to at any stage of the tidal cycle is the other essential pillar of the ideal place. At NKM this combination is provided with NKHP. It will have to also be provided at any alternative site.

3.4. One reason why NKHP is so suitable is the permanent water and islands with some shallow water as well so that the birds can roost undisturbed by humans or potential predators such as foxes.

3.5. The food taken has not been specifically identified by the ES or the HRA and the benthic invertebrate surveys for NKM (Annex 10.1) help only a little to assess the invertebrates of importance. The surveys took place on 14 May 2010, so the autumn populations are not known. However, from other studies of Black-tailed Godwit diets (Gill *et al* 2001 – see Appendix VI Tab 6, Moreira 1994 – see Appendix VI Tab 13), the main species taken were the bivalves *Macoma balthica*, *Scrobicularia plana* and *Mya arenaria* and the polychaete worms *Hediste diversicolor* and *Arenicola marina*. Only the medium or larger (although some are much too large to be eaten by godwits) individuals are taken. The benthic samples in May found only *Macoma* and *Hediste* of these present in more than a trace. In the transects (2-7) (Annex 10.1, p10, Figure 2 and data in Table 4, p15) these are the only ones that seem to be in the main godwit feeding area. All *Hediste* were in the upper shore sample and most of the *Macoma* were in the middle and lower samples. My calculations (see Appendix IV Table 2) show that the numbers/m^2 of *Macoma* are 67 on the upper shore, 367 on the mid shore and 117 on the lower shore while the *Hediste* on the upper shore were at 517/m^2. I believe it is important to try to understand the species taken and their location in relation to being able to design and manage the required compensation. Here, HRA Figure 6.1 (p6-14) clearly shows that feeding takes place across the tidal cycle and that very substantial numbers of birds are feeding towards low water; given the distribution of the two likely key prey species, it is almost certain that *Macoma* is the main food and *Hediste* will be taken on the upper shore towards high water. Gill *et al* (2001) (see Appendix VI Tab 6) showed that a site was vacated when the bivalve (*Macoma*) numbers dropped to 150/m^2 or fewer. Hence food depletion is highly likely at NKM hence the departure of the BTG in November

3.6. It is important to recognise, as implied by HRA 6.3.33 (p6-13), that Black-tailed Godwits only need to feed for a few hours (often only two or three) per tidal cycle in the autumn and because they are in moult (an energetically demanding process), they can rest for the rest of the time. This has two implications, firstly when looking at count data, it is inappropriate to consider loafing/resting birds as not feeding ones because they are likely to feed before or after the observation; secondly, that loafing opportunities without excessive energy expenditure are vital and when they are loafing, disturbance should be kept to a minimum to enable their energy reserves to be maintained especially given their reduced ability to fly when in moult.

<u>The assessment of the site for its bird populations</u>

3.7. In Section 6.3 (p6-2) of the Shadow AA in the HRA the impact is assessed of the Application on NKM of eight species plus the Assemblage which are of importance within the Humber Estuary SPA/Ramsar site. I agree with most of the comments here and that the adverse effects of the Application on these species and the Assemblage cannot be mitigated. However, there appears to be two omissions from the summary paragraph 6.6.3 (p6-33) (first bullet point) in that both Curlew and Redshank are left out. This is despite an adverse effect being noted for 3% of the SPA population in Curlew (para 6.3.52, p6-19) and 9% of Redshank (para 6.3.58 p6-21). The differences regarding Black-tailed Godwit are covered above (paras 3.2-3.6). The mitigation proposals for Curlew will be considered below.

3.8. The only other point which needs to be commented upon is the inappropriate way that the Assemblage has been calculated. The figure for the Humber is given as 140,197 (HRA 6.3.60, p6-21, and based on the winter only data in Table C1.1, pC-1 in Annex C Supporting Ornithological Information for 2004/05-2008/09). Not only does this not follow the standard procedure of including all months when assessing the overall use of a site by waterfowl, but it is at odds with the published information in the WeBS report 2008/09 (Calbrade, N. *et al* 2010 – see Appendix VI Tab 2) where the Assemblage for that period is given as 157,785. That becomes even more surprising when Table C1.2 (pC-2) is considered where the mean peak count for the Assemblage is given as 112,619. The misunderstanding of the term Assemblage is perhaps best seen on page E 38 of Annex E Screening Assessment of Humber Estuary Birds. '**Assemblage** – Assemblage population counts show the peak number of birds present on the Humber on any one day.' That is not the Assemblage.

3.9. The correct use of the Assemblage figure originated from Atkinson-Willes, Scott and Prater (1982) (see Appendix VI Tab 1) which was accepted by the parties to the Ramsar Convention. This is to take the maximum figure for each species for the year which are totalled and averaged over 5 years. Thus one can see from the Ramsar and SPA citations (HRA Annex B) that for the period 1996/97-2000/01 the figure was 153,934. This official definition is the same as is found in Pollitt *et al* (2003) (p146) (see Appendix VI Tab 14) and used in subsequent Wetland Bird Survey Reports including Calbrade *et al* (2010) (p160) (see Appendix VI Tab 2) which is where 157,785 is given.

3.10. If the correct usage of Assemblage was followed, the Assemblage of the key species alone on the NKM (from Tables 6.2-6.9 in the HRA section 6.3), would be the sum of the maxima counted on TTTCs; this would be a minimum of 5,026, not c3,550 as given.

<u>The functionally linked terrestrial habitat loss</u>

3.11. I agree with HRA 5.4.21 (p5-41) that there will be permanent loss of functionally linked land due to the terrestrial part of the Application, principally for Curlew, which forage on both the estuarine mudflats when exposed and the fields at high water. For the location of fields of importance see HRA Figures 5.13, 5.14 and 5.15 (p5-25 to 27). The mitigation proposals for this will be considered below.

4. ECOLOGICAL IMPLICATIONS OF THE MITIGATION PROPOSALS FOR AREA A

4.1. The Application identifies the possibility of providing some mitigation for Curlew which feed in functionally linked land which will be developed. I agree that there is the need to provide this mitigation as it provides supplementary feeding, mainly at high water, for Curlew which feed also on the adjacent inter-tidal flats of the SPA/Ramsar site. The RSPB has discussed with the Applicant and others, the design principles for mitigation land on the South Humber Bank for several years. The proposal is to set aside 47.8ha within the Applicant's ownership for mitigation. The site (Annex 4.5, Landscape Masterplan) is currently a mixture of arable and permanent pasture and will become, principally, wet permanent pasture – the inland habitat used for feeding by Curlew in this area. The management is broadly defined in the text box in AME - 02007 and HRA 6.3.50 (p6-18).

4.2. I agree that Mitigation Area A/permanent pasture adjacent and permanent pasture to the south outwith the Applicant's ownership is important to be maintained to cater as supplementary feeding for Curlew remaining on Sector E of the inter-tidal flats. The proposals to increase the area of wet permanent pasture, is welcomed. It is also welcomed that the buffer zone for boundaries not within the Applicant's ownership will be 150m and that the core area of the site will be 16.7ha (HRA 6.3.50, p6-18). There are a number of issues which remain to be agreed or which may be problematic; they are:

4.2.1. There is only a 50m buffer zone to the north, in relation to operational land. While the intention is to limit disturbance here, specific proposals are not given.

4.2.2. The main objective is to produce wet permanent pasture with pools/scrapes but changes to the hydrological regime and field drainage to achieve this are not included.

4.2.3. The development of wet pasture from arable fields and the concomitant invertebrate populations is likely to take several, probably two to four years, so the objective of all the site being in suitable condition by the time the existing pasture fields are lost, will not be met. It is possible that with the remaining areas under suitable pasture that this medium term problem will not be a major issue. Proposals for reverting to wet grassland are not included in the Application.

4.3. However, the mitigation proposals, with a degree more clarity on how they will be achieved, are likely to be in the right order of magnitude.

5. ECOLOGICAL IMPLICATIONS OF THE COMPENSATION REQUIREMENTS

5.1. I agree with the conclusions that the adverse effects of the Application cannot be mitigated and therefore compensation is required. The compensation proposals in the Application (ES Chapter 28) are twofold, the development of 100ha realignment at Cherry Cobb and an intended short-term 38.5ha of wet grassland at Old Little Humber Farm to support Black-tailed Godwits until the realignment is shown to be delivering for that species. I will consider these separately. However, before I do that, there are a number of issues which need to be considered, notably:

5.1.1. Defining the function that is being lost and needs to be replaced.

5.1.2. Defining the number of birds which are being displaced in order to identify the scale of compensation needed.

<u>The function that needs to be replaced</u>

5.2. Different species use the Application site in different ways at different times. In broad terms most species use the site primarily as a wintering ground. Black-tailed Godwits and Ringed Plovers use the area to be developed primarily in the autumn. Curlews use both the inter-tidal and the permanent grasslands for feeding and roosting for much of the non-breeding season. A small number of other species use it as a pre-migration area in the spring.

5.3. As the Black-tailed Godwit is present in internationally important numbers, I will consider this first. It is quite clear from the TTTCs and the WeBS counts for 2010/11 (see my Appendix IV Table 1), that August to October plus July (to a much smaller extent from the TTTCs) and November (based on the average WeBS data 2004/05-2008/09) (HRA Table 6.6), is the critical time. So, any compensation has to replicate that autumn function in order to properly compensate for the loss of their feeding grounds plus the long-term presence of a secure roost nearby. Considering its relevance by averaging it over the whole year would be inappropriate.

5.4. Although the most important species detrimentally affected by the inter-tidal loss is the Black-tailed Godwit, specifically its autumn functional requirements, there are also seven other species which are included in the Assemblage which would be adversely affected by the Application (HRA section 3 and p3-1, Table 5.7). It is important that their requirements are not overlooked.

5.5. For Curlew, individuals displaced would need to find additional field feeding close to their inter-tidal area in order to achieve their required food intake. This has been shown by many studies (e.g. Durell, S.E.A. dit *et al* 2006 – see Appendix VI Tab 4, Stillman,R.A. *et al* 2005 – see Appendix VI Tab 19).

5.6. For many of the species there is the broad requirement of winter feeding grounds with some at other times of the year.

<u>Defining the number of birds to be accommodated by the compensation</u>

5.7. I have covered the uncertainties in relation to what is presented in the Application documents in Appendix III (attached). Getting the numbers right is critical to understanding the ecological function which is lost. Unfortunately, the HRA does not present its assessment of numbers in the context providing that function. This is a fundamental problem as it is then not easy to identify the targets which the compensation has to meet. Without working through all of the data, my starting point has to be the data in the HRA and supporting documents and this is used without prejudice to any clarification or corrections needed. So the data provided would have to be that which appears in HRA 6.3.

5.8. Annex 35.6 Table 1 (p21) has summarised data for NKM, apparently in respect of the whole year, to look at the density of birds displaced by the Application. The figure given on this basis is a mean of 62.3 birds[b] at a density of 183.9/km^2. In this Annex, the estimate is made of the comparative density on Paull Holme Strays and this is given as 29/km^2. Based on those data, this would indicate that the density is 6.3 x greater on the Application site than on the comparator realignment site. However, I do not accept that looking at the whole year is appropriate - the key function is the use made of the site in autumn. If one takes the numbers provided in HRA Table C2.9 (pC-34) for the seven autumn counts (July-October) the mean count would be 882 Black-tailed Godwits on the Application site. This would be on 33.9ha (Annex 35.6, p21, Table 1) and would mean they were present in autumn at a density of 26.0/ha or 2,602/km^2. On Paull Holme Strays (Table 16 of Mander *et al* 2010 – see Appendix VI Tab 12) it is recorded that Black-tailed Godwit mean density in autumn 2008/09 in Area D was 94.43/km^2 (0.94/ha on 10.59ha[c]) and in Area F was 8.49/km^2 (0.08/ha on 6.31ha[c]). Over the whole site of c80ha this would be 12 birds[c] or 0.15/ha. If, however, the peak count is used for the Application site in autumn, in my view this should be taken for the replication of the full

[b] How this figure was obtained is not shown in the Annex and I cannot accept it without that information but as it is given in the Application, I have used it here as the only figure put forward.

[c] Data supplied by IECS.

autumn function, the count would be of 2,566 and the density would be 7,569/km^2. The data to calculate the comparative figure from the latest Paull Holme Strays monitoring (2008/09, Mander *et al* 2010 – see Appendix VI Tab 12) are not presented. Which ever way one looks at it the density at PHS is dramatically lower than at NKM.

<u>Ecological implications of the Cherry Cobb managed realignment site</u>

5.9. The RSPB has only seen the Application documents. However, we recognise that there are a number of key issues which relate to this compensation. The experience gathered from other realignments especially on the Humber Estuary will be highly pertinent in considering these issues. The key ecological issue is the ability of those mudflats to replace the functions lost to the development in the long term.

<u>The ability of those mudflats to replace the functions lost</u>

5.10. I will describe the issues relating to this with reference to the most important species, the Black-tailed Godwit.

5.11. The first requirement is to look at the autumn numbers in relation to targets for ecological delivery. There is a problem here in that the TTTC and the related NKHP roost counts are for a single year but these may have to be the relevant targets for the realignment delivery. The maximum count on NKM at this time in 2010/11 is given as 2,566 (Annex 11.9, p41, 3.27.3.3) and this should be the target for the foraging compensation capacity. The five-year average maximum on NKHP from WeBS counts is 3,338 (HRA, p41, Table 5.2) and the maximum by the BTO WeBS counts for autumn 2010 is 3,555 (see my Appendix IV Table 1) or 3,800 by the TTTCs (Annex 11.9, 3.27.3.3). So for roosting birds, my view is that the last (3,800) should be the second target. As I have serious concerns about the data gap in September, it would be inappropriate to take this down to bird days on the data provided and in any case the maximum should be for what we are designing the compensation. The period covered should at least be August to October and probably the second half of July and the first half of November as well.

5.12. The second issue is the long-term ability of the site to cater for birds in appropriate numbers. As Mr Dixon describes (para 5.4), the RSPB has serious concerns that the high accretion rates will lead to a substantial loss of inter-tidal mud in the medium and long term. The lack of an assessment of this critical aspect makes it very difficult to make an ecological judgement as to its capacity to deliver this autumn function. However, the detailed bird counts from nearby Paull Holme Strays, Chowder Ness and Welwick realignments (ES Annex 35.6, p12, Fig 5) provide some important guidance.

5.13. The first observations are from the Chowder Ness and Welwick sites where detailed counts of birds have been undertaken since their seawalls were breached or removed in 2006. Chowder Ness is small, 15ha, and the objective was to provide 0.8ha of saltmarsh and 10.5ha of inter-tidal mud while Welwick is larger at 54ha and had the wide expectations for 8-32ha of saltmarsh and 7-37ha of inter-tidal mud (ABP realignment web database - www.**abpmer**.net/omreg/ - see Appendix V). The birds have been counted annually since then. On Chowder Ness (Shepherd 2007, 2008, 2009 and 2010 – see Appendix VI Tabs 15-18) the only feeding Black-tailed Godwits were 2 on one occasion in 2009/10; there were four roosting birds on one occasion in 2007/08 and 31 roosting on one occasion in 2008/09. So, Chowder Ness provides little confidence that Black-tailed godwits can be accommodated.

5.14. At Welwick, IECS (2007, 2008, 2009 and 2010 – see Appendix VI Tabs 8-11) have monitored the site. No Black-tailed Godwits were noted in the first two years despite the site becoming a major wader roost. However, on one occasion in 2008 110 roosted and 51 of them fed. In 2009/10, up to 380 roosted and up to 200 fed occasionally in the site's borrow pits, not on the mudflats. So, this site shows they maybe occasional but in moderate numbers and may feed occasionally; this is in contrast to the suggestion in Annex 35.6 (p14) that the site is 'used extensively…for both roosting and feeding'.

5.15. However, a more extensive set of data has been obtained at Paull Holme Strays. This c80ha site close to the proposed site of Cherry Cobb (see Appendix I Map 4), had the objective of providing 45ha of saltmarsh, 35ha of mudflat and 10ha of transitional habitat, was breached in 2003. In several aspects (the Black-tailed Godwit use, the benthic invertebrate populations, the general bird use and the rate of habitat change) it has been used extensively in the HRA and ES as a comparative example for what would or is likely to happen at Cherry Cobb. I believe it is important to examine the comparative comments made particularly as they relate to the first three or four years of the development of Paull Holme Strays and how that relates to the autumn functions lost at NKM and NKHP. The longer set of data now available means that some of the conclusions drawn after the first few years are no longer valid.

The Black-tailed Godwit numbers

5.16. In the HRA 9.2.4 (p9-5), it is noted that monitoring at Paull Holme Strays, by year 3, shows that Black-tailed Godwits were increasing markedly. Mander *et al* (2010) (see Appendix VI Tab 12) provides the only information on bird numbers for the first six years of Paull Holme Strays realignment. Annex 35.6 takes this further and notes from Mander *et al* (2010) (see Appendix VI Tab 12) that '*over the first four years since breaching….has developed as a major roosting/loafing site … on many occasions flocks of national importance in autumn, as well as increasing numbers of foraging birds*'. However, the full data in Mander *et al* (2010) (see Appendix VI Tab 12), particularly that which is relevant to the lost autumn foraging function at NKM, is not presented for evaluation. The data for the first six years are provided in the report and are presented in Appendix IV Table 3 appended to this evidence.

5.17. From this one can see the figures 377, 72 and 26 presented in Annex 35.6 (p14 and 20) relate to all Back-tailed Godwits, not foraging birds. Secondly when considering foraging birds only, the numbers are much lower. For foraging birds, tests were carried out to see if there were trends in the data but for all seasons, there was no significant trend but it is important to note that the authors (in para 3.3) stated '*That the lack of significant results is therefore believed to be an artefact of the survey frequency*.' The variability of data is also likely to be a cause of this as well. However, it is worth examining the actual series in Table 2 for autumn. In 2006/07 only a mean of 10 birds was found while in 2008/09 just 12 feeding Black-tailed Godwits were present during the autumn. So we have 10, 153, and 12 as the counts for the last three years. Hardly convincing evidence that the lost autumn feeding function can be replaced by the Cherry Cobb proposed realignment if it has any similarity to Paull Holme Strays.

The benthic invertebrate populations

5.18. Franco and Mazik (2011) (see Appendix VI Tab 5) have produced the latest report for Halcrow and this brings the data up to 2010. Even with this, only considering the results for the first seven years of a managed re-alignment site might not give a true picture of the medium and long term viability of that site. They show that there have been considerable variations over time in the invertebrate populations of Paull Holme Strays and the early years may not be typical of the longer term. The sampling took place in September 2010, a date when one would expect the maximum biomass of invertebrates. I have considered just the three species which could be Black-tailed Godwit food (though it is known that they do not take the smaller sized individuals, it was not possible to determine the actual available biomass from the sampling) – *Hediste diversicolor* and the bivalves *Abra tenuis* and *Macoma balthica* and the overall biomass of the benthic fauna.

5.19. This report shows that the biomass peaked in 2008 when 49.6 g/m^2 wet wt was present; by 2010 it had decreased to 21.3 g/m^2 wet wt (para 3.3.2 & Figure 9). It is relevant to note that the calculations made in Annex 35.6 (p 25-26) were based on 40 g/m^2 wet wt and that this number has not been shown to be regular and seven years after breach it was down to half that. However, importantly, while the biomass was predominantly composed of the three potential food species and the density of *Hediste* was 203/m^2, of *Abra* 84/m^2 and *Macoma* 19/m^2, only a mean of 12 Black-tailed Godwits fed on the site during the autumn that year. It is highly likely that the food depletion and departure of Black-tailed Godwits from the inter-tidal in the Paull Holme Strays compensation site is operating in much the same way as it is on NKM (see para 3.4 above). So, despite a moderate biomass of prey species being present, the site is not chosen by godwits as a feeding zone.

5.20. Thus the detail provided in Annex 35.6 (p25-26) which underpins the concept that the Cherry Cobb realignment will work has no foundation in practice and has to remain a set of theoretical calculations, some of which are based on flawed assumptions. The absence of birds yet the presence of their food in Paull Holme Strays, shows that the promotion of Cherry Cobb realignment as a compensatory option for Black-tailed Godwits is an inappropriate functional compensation mechanism for this development. It provides me with no scientific confidence that it will deliver the claimed benefits.

Ecological implications of the Old Little Humber Farm compensation

5.21. The compensation here is aimed at providing temporary (though there may be a need for that to be longer term if the realignment fails to deliver the objectives) wet grassland compensation for feeding Black-tailed Godwits while Cherry Cobb inter-tidal compensation through realignment matures (HRA 9.5.1, p9-15).

5.22. Here I comment on the proposals in the Application documentation but following several helpful meetings with the Applicant we know that further consideration is being given to this area and that new designs and management are being considered, so the comments will be brief in this submission.

5.23. The layout of the site shown in Chapter 28 (p 28-3, Figure 28.2) and management proposals briefly noted in various places in the Application documents in particular in HRA 9.2.11-16 (p9-7 and 8), HRA 9.4.1-4.5 (p9-14 and 15), Chapter 28 2.14-15 (p28-8).

5.24. The RSPB, with its extensive knowledge of developing wet grassland for birds, has very severe doubts that this particular site has any potential to achieve the objective set. Our concerns are summarised below:

5.24.1. No critical assessment as to the suitability of the site to achieve its objective has been tabled – this contrasts with the detailed site assessment for the Cherry Cobb realignment.

5.24.2. The site's location, about 1.5km away from the inter-tidal and the Cherry Cobb realignment, is very poor; a site close to the inter-tidal is required.

5.24.3. The site's entire water budget will be dependent on rainwater and given its need to provide the key function of compensatory feeding for the autumn birds from NKM, this is likely to prove severely limiting.

5.24.4. The site will have no substantial excavations on it, due partly to the six pipe lines crossing the fields, to achieve substantial bodies of permanent water with islands for security; minor surface furrows are proposed.

5.24.5. The invertebrate, mostly earthworm, population of arable fields is severely depleted and cannot be increased rapidly to achieve the target now identified via Annex 35.6 (p25) as 74.2 g/m^2 formaldehyde preserved (wet) weight for dry pasture and 6.5g/m^2 wet weight for wet pasture. This has been rounded to 40g/m^2 wet weight.

5.24.6. Even if measures were taken to improve fertility of the site, it is extremely unlikely that the target biomass would be able to be reached within two to four or so years.

5.24.7. The very dry soil in autumn over a large part of the site would mean that earthworm accessibility would be very difficult for Black-tailed Godwits – the silty clay tends to dry very hard indeed.

5.25. The calculations referred to in HRA 9.2.13 (p9-8) based on Annex 35.6 p25-27 are just theoretical concepts with no basis for the practical assumptions being made for the sites in question or indeed the ability for the Black-tailed Godwits to completely extract all of the biomass from the 38.5ha site. They do not provide any confidence that the autumn functionality of Black-tailed Godwit feeding on wet grassland can be achieved at this site. The time required to bring earthworm biomass up to the required level is such that this site has no potential to act in the way considered by the Application i.e. to provide short term feeding resource while the Cherry Cobb realignment matures.

5.26. However, there is an aspect which has not been addressed and may be critical. The HRA 9.2.12 (p9-7) notes that wet grassland is an important component of the feeding requirements of Black-tailed Godwits and quotes two sources; from my extensive experience in southern Britain and Ireland, I would agree with that. I agree that grassland can be important as has also been identified by Gill *et al* (2007) (see Appendix VI Tab 7). However, far from a piece of temporary grassland being important, it is critical that this is permanent grassland and is present to enable the species to have supplementary feeding at all times of the year. Permanent grassland with associated extensive pools and islands is the important habitat association with suitable close estuarine habitat that is required. This aspect has not been addressed at all in the Application.

6. APPENDICES

Appendix I

Map 1 Application site in relation to the Special Protection Area
Map 2 Application site in relation to the Special Area of Conservation
Map 3 Application site in relation to the Ramsar site
Map 4 Paull Holme Strays and Cherry Cobb Compensation Site

Appendix II

Black-tailed Godwit Fact Sheet

Appendix III

Issues relating to the counts undertaken

Appendix IV

Table 1 Counts of Black-tailed Godwits from WeBS data 2010-2011 for the Humber Estuary

Table 2 Data used to assess density of Macoma balthica and Hediste diverscolor on NKM from Table 4 in Annex 10.1

Table 3 Black tailed godwit numbers by season at Paull Holme Strays

Appendix V

ABP Realignment Web Database Reports

- Chowder Ness
- Welwick

Appendix VI

References

Tab 1 Atkinson-Willes, G.L., Scott, D.A. and Prater, A.J. (1982) Criteria for selecting wetlands of international importance. Proceedings of the Conference on the conservation of wetlands of international importance especially as waterfowl habitat: 1017-1042. Cagliari, Italy 24-29 November 1980.

Tab 2 Calbrade, N., Holt, C., Austin, G., Mellan, H., Hearn, R., Stroud, D., Wotton, S. and Musgrove, A. (2010) Waterbirds in the UK 2008/09. The Wetland Bird Survey. BTO, RSPB & JNCC

Tab 3 Catley, G.P. (2009) Black-tailed Godwits *L.l.islandica* on the Humber estuary: Status, distribution and behaviour 1989-2009. Grimsby Ro-Ro Berth Environmental Statement Supplementary Note 1: Response to Consultees. 2010. ABPMer.

Tab 4 Durell, S.E.A. Le V. dit, Stillman, R.A., Caldow, R.W.G., McGrorty, S., West, A.D. and Humphreys, J. (2006) Modelling the effect of environmental change in shorebirds: A case study on Poole Harbour, UK. Biological Conservation 131: 459-473

Tab 5 Franco, A. and Mazic, K. (2011) Paull Holme Strays Monitoring Programme 2010: Benthic Invertebrate Monitoring. IECS report to Halcrow Group

Tab 6 Gill, J.A., Norris, K. and Sutherland, W.J. (2001) The effects of disturbance on habitat use by black-tailed godwits *Limosa limosa*. Journal of Applied Ecology 38: 846-856

Tab 7 Gill, J.A., Langston, R.H.W., Alves, J.A., Atkinson, P.W., Bocher, P., Cidraes Vieira, N., Crockford, N.J., Gélinaud, G., Groen, N., Gunnarsson, T.G., Hayhow, B., Hooijmeijer, J., Kentie, R., Kleijn, D., Lourenço, P.M., Masero, J.A., Meunier, F., Potts, P.M., Roodbergen, M., Schekkerman, H., Schröder, J., Wymenga,E. and Piersma, T. (2007) Contrasting trends in two Black-tailed Godwit populations: a review of causes and recommendations. Wader Study Group Bulletin 114: 43-50

Tab 8 IECS (2007) Welwick Managed Realignment Site: Ornithological Survey Results, September 2006 to May 2007. Report to ABP Marine Environmental Research

Tab 9 IECS (2008) Welwick Managed Realignment Site: Ornithological Survey Results, September 2007 to March 2008. Report to ABP Marine Environmental Research

Tab 10 IECS (2009) Welwick Managed Realignment Site: Ornithological Survey Results, September 2008 to March 2009. Report to ABP Marine Environmental Research

Tab 11 IECS (2010) Welwick Managed Realignment Site: Waterbird Monitoring Survey Results, September 2009 to March 2010. Report to ABP Marine Environmental Research

Tab 12 Mander, L., Phelps, A., Thomson, S. and Cutts, N. (2010) Waterbirds Monitoring at Paull Holme Strays: Annual Report #7 September 2008 to August 2009. IECS report to Halcrow Group

Tab 13 Moreira, F. (1994) Diet, prey-size selection and intake rates of Black-tailed Godwits Limosa limosa feeding on mudflats. Ibis 136: 349-355

Tab 14 Pollitt, M., Hall, C., Holloway, S., Hearn, R., Marshall, P., Musgrove, A., Robinson, J. and Cranswick, P. (2003) The Wetland Bird Survey 2000-01: Wildfowl and Wader Counts. BTO, WWT, RSPB & JNCC

Tab 15 Shepherd. I. (2007) Habitat Creation Measures at Chowder Ness/Barton Cliff. Monthly Bird Monitoring, September 2006 to March 2007.

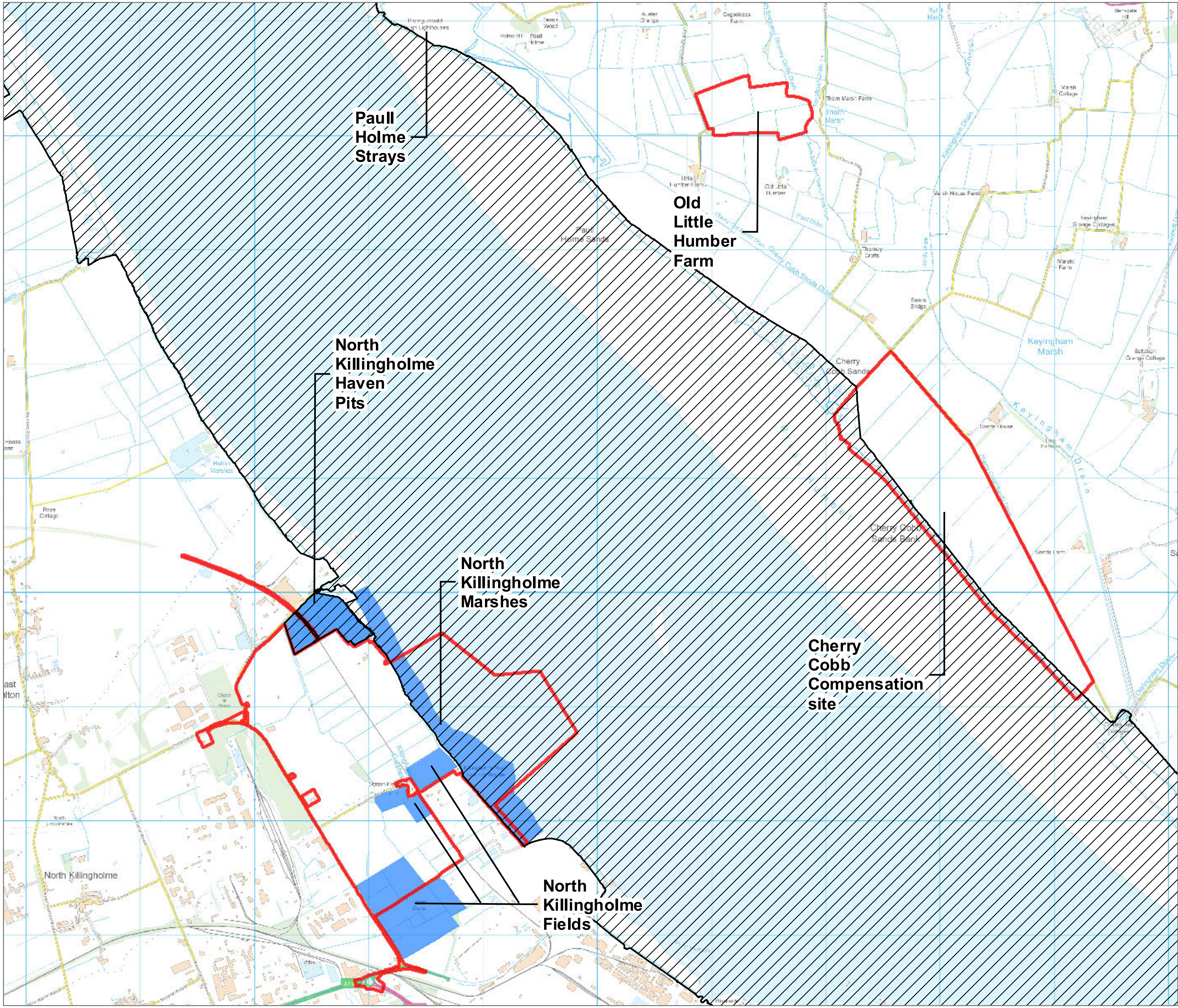
Tab 16 Shepherd. I. (2008) Habitat Creation Measures at Chowder Ness/Barton Cliff. Monthly Bird Monitoring, September 2007 to March 2008.

Tab 17 Shepherd. I. (2009) Habitat Creation Measures at Chowder Ness/Barton Cliff. Monthly Bird Monitoring, September 2008 to March 2009.

Tab 18 Shepherd. I. (2010) Habitat Creation Measures at Chowder Ness/Barton Cliff. Monthly Bird Monitoring, September 2009 to March 2010.

Tab 19 Stillman, R.A., West, A.D., Goss-Custard, J.D., McGrorty, S., Frost, N.J., Morrisey, D.J., Kenny, A.J. and Drewitt, A.L. (2005) Predicting site quality for shorebird communities: a case study on the Humber estuary, UK. Marine Ecology Progress Series 305: 203-217

Map 1: Application site showing extent of SPA and other wildlife sites



Key:

- SPA
- Development Consent Order boundary
- other sites

Notes:

1:43,000

Scale on A4 paper

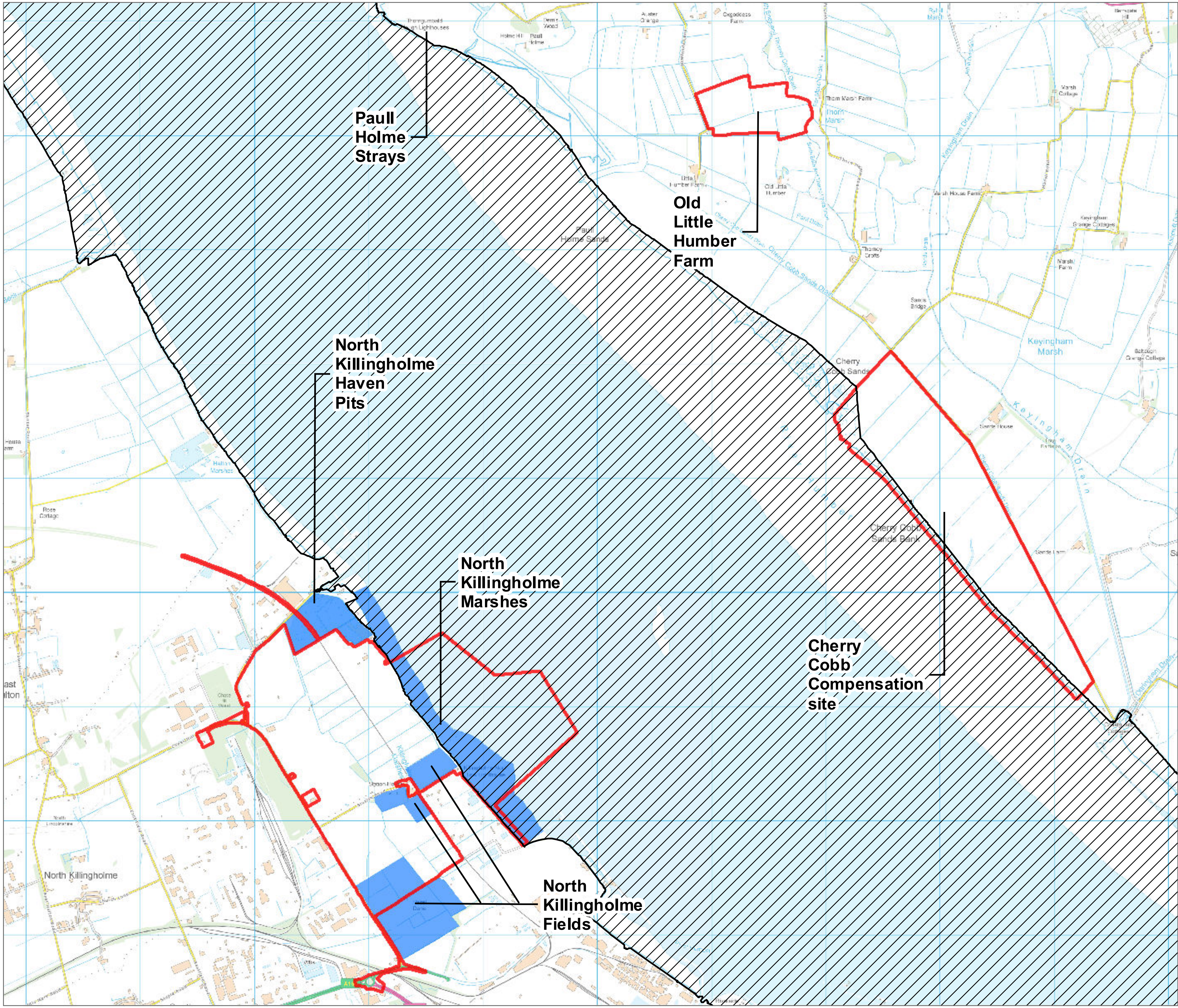
Acknowledgements:

Created by: Paul Britten 28 June 2012

0 0.5 1 Km

RSPB

Data sourced from Ordnance Survey



Map 2: Application site showing extent of SAC and other wildlife sites

Key:

- SAC
- Development Consent Order boundary
- other sites

Notes:

1:43,000

Scale on A4 paper

N

Acknowledgements:

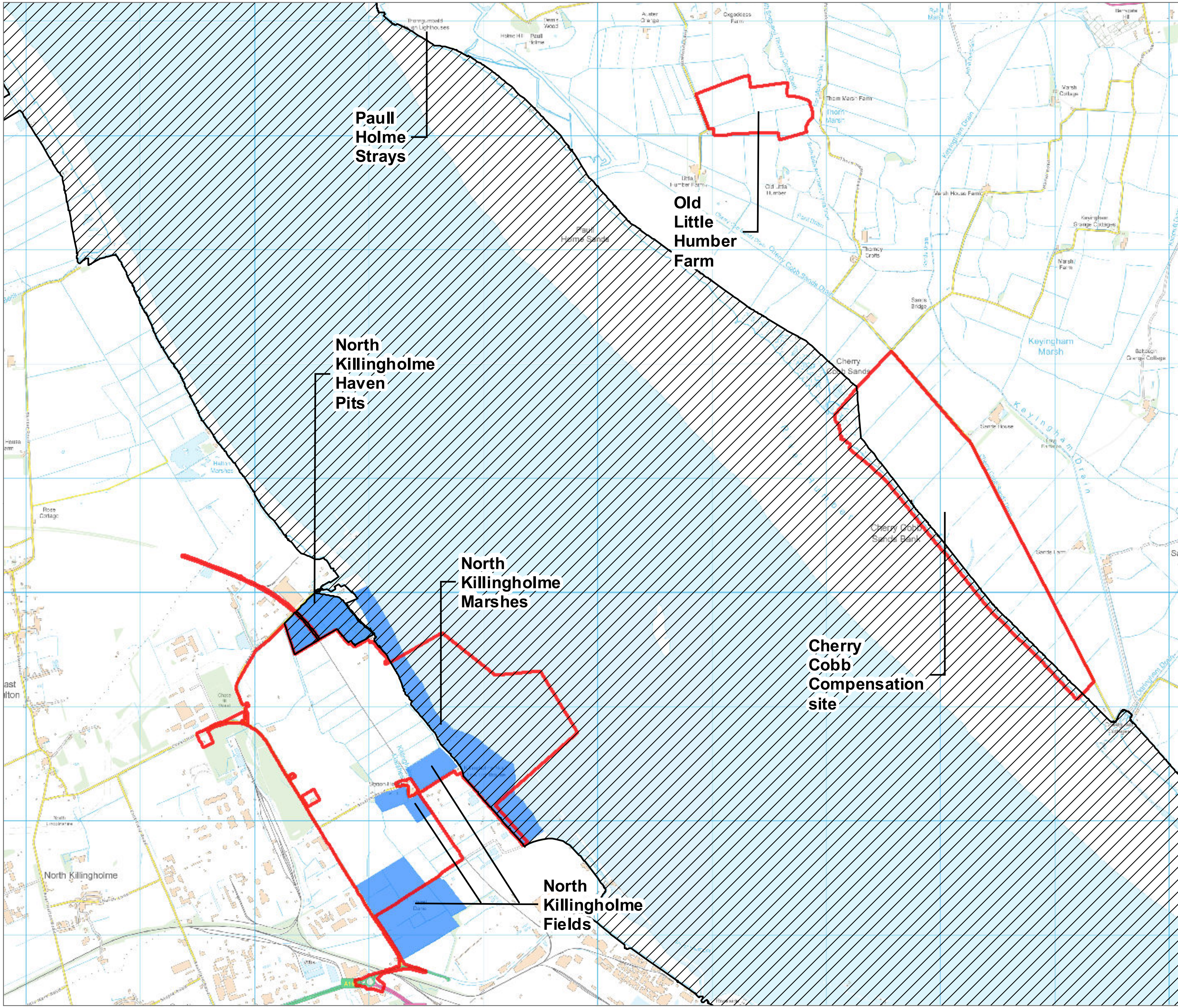
Created by: Paul Britten 28 June 2012

0 0.5 1 Km

RSPB

Data sourced from Ordnance Survey

Map 3: Application site showing extent of Ramsar and other wildlife sites



Key:

- RAMSAR
- Development Consent Order boundary
- other sites

Notes:

1:43,000

Scale on A4 paper

N

Acknowledgements:

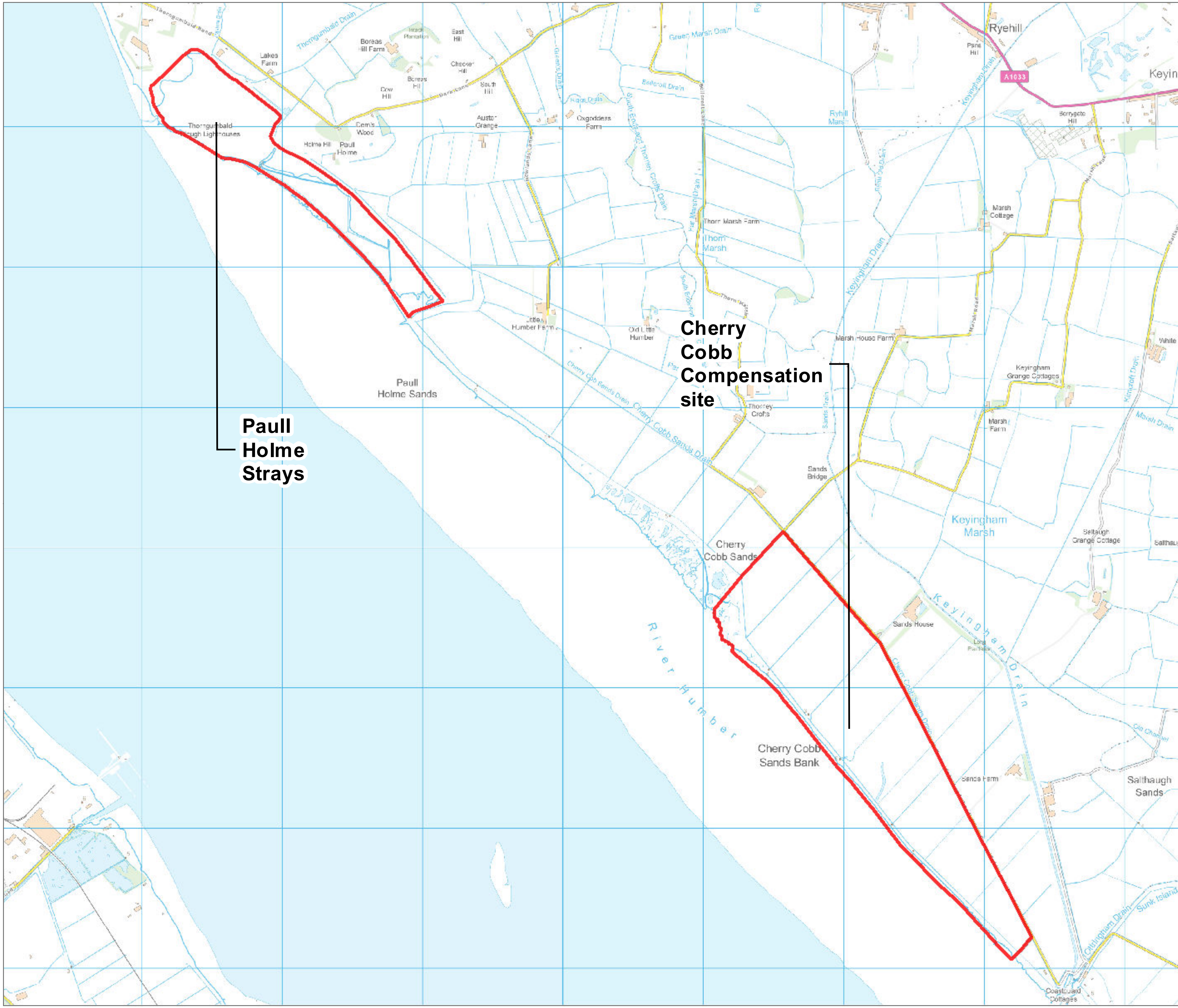
Created by: Paul Britten 28 June 2012

0 0.5 1 Km

RSPB

Data sourced from Ordnance Survey

Map 4: Paull Holme Strays and Cherry Cobb Compensation Site



Key:

Notes:

1:35,000

Scale on A4 paper

N

Acknowledgements:

Created by: Paul Britten 29 June 2012

0 0.5 1 Km

RSPB

Data sourced from Ordnance Survey

Appendix II

The Black-tailed Godwit in autumn at North Killingholme Marshes

Migration: The Icelandic population (which is the one on the Humber) is an early migrant with birds arriving in Britain and Ireland from mid July onwards. They build up to a maximum between August and October, there are slightly different timings each year. From the North Norfolk coast, through the Wash and to the Humber, numbers then drop steadily through November as birds relocate to sites especially south to Iberia but also widely around the southern/western estuaries of Britain.

Areas chosen: Black-tailed Godwits, other than the occasional birds, are restricted to a few sites even within the estuaries they favour. In autumn, the main numbers on the Humber are on North Killingholme Marshes (NKM) and the North Killingholme Haven Pits (NKHP) roosting area but as autumn progresses into winter, they move more widely especially moving to Pyewipes near Grimsby to the east. Throughout their range the Icelandic Black-tailed Godwit is essentially a feeder on mudflats though it makes use of grassland especially in winter and spring when estuarine food is depleted. Some will feed on wet permanent pasture in autumn.

The daily pattern of activity: Their activity patterns are based around the tidal cycle – at high water they roost/preen/loaf inland on NKHP with a few remaining on the narrow fringing saltmarsh especially on neap tides. As the tide drops, they tend to move out onto the mudflats to feed after an hour or two. However, individually, they feed for only a short period; two-three hours is a typical feeding period, then they rest/loaf etc mostly on the mudflats but a few may go back onto the NKHP. As the season progresses and adults start to complete their moult and more juveniles arrive (juveniles tend to be a little later arriving), these birds start to move more widely around the Humber.

Moult patterns: The adults which are on the NKM in autumn, the majority of the birds present, undergo a full moult. This includes the flight feathers and so is an energy demanding activity. Juveniles only moult body feathers and are not so constrained. By early November moult is effectively complete. Then the birds disperse widely within and from the Humber. Like many birds, fresh or brackish water is important for bathing particularly during moult.

The use of NKHP: The screening of the pits is generally a positive aspect for Black-tailed Godwits which require a safe refuge; the combination of openwater and islands is ideal. Sometimes, however, the cover given for avian predators or if there is other significant disturbance, means the pits are not used for a day or two. The use in autumn when the birds are in moult and being in close proximity to excellent feeding grounds, provides the ideal combination of food availability and secure roosting area. Once moult has been completed, they are less likely to be important, especially if the adjacent food has been depleted.

Food chosen: There are only really two species which would be expected to be taken by Black-tailed Godwits on NKM – the polychaete worm *Hediste diversicolor* and small bivalve mollusc *Macoma balthica*. Elsewhere, especially at Paull Holme Strays another bivalve, *Abra tenuis*, is probably taken. *Hediste* is principally found on the upper shore (so also common in realignment sites) while *Macoma* is a mid- and low-shore species. Medium and larger sized individuals would be taken of these species. When feeding inland, they take a range of earthworms. When food levels drop below a certain level (150m^2 for bivalves), the feeding grounds for those species are vacated.

Appendix III

There are a number of areas where the number of birds counted may not represent the full picture. These are:

Data inconsistency between the documents

For Black-tailed Godwits the September count shown in HRA Table 6.6 (p6 - 12) is of 57 birds, yet in HRA Annex C, pC-34, Table C2.9 it is shown as 0.

For clarity, I cannot make sense of Table C2.10 (Annex C, pC-34) (and the similar table for all other species) as the table title does not seem to match the repeated data included within it. No reasons are given for these discrepancies so, if taken at face value, they could have material implications for any assessment of the numbers of birds using the Application site and therefore needing to be compensated for.

Data for a single year were obtained with the detailed Through The Tide Counts for North Killingholme Marshes and North Killingholme Haven Pits

The issue here is exemplified by two specific problems. They are:

The 5 September 2010 count found only 57 Black-tailed Godwits (HRA Table 6.6, page 6-12) present despite this traditionally (Catley 2009) (see Appendix VI Tab 3) being one of the months when normally large numbers are present. There were also just 86 roosting on North Killingholme Haven Pits (NKHP) then. The cause for the near absence of birds is not known; there could be many reasons why they were not there on that day, not necessarily that they had chosen to leave to feed elsewhere as the HRA suggests. Indeed, when the BTO WeBS count took place on 19 September there were 2,304 on NKHP and 42 on North Killingholme Marshes (NKM) (data supplied by the BTO, my Appendix IV Table 1). The very low figures on that one day seem to have been taken as the result for the month in assessing the number of Black-tailed Godwits days displaced by the loss of NKM.

The counts for November and December found no Black-tailed Godwits on NKM. The text on the maps e.g. Figures 36 and 37 of Annex 11.9 (p43) state that ‘Due to adverse weather conditions, they became inaccessible through certain weeks of November and December’ and ‘birds (Black-tailed Godwits) were only absent in November and December on the inter-tidal zone though this may be due to adverse weather condition’ (para 3.27.3.4, Annex 11.9, p41). Indeed, Table 6.6 (page 6-12) of the HRA identifies that the five year mean peak count in November for NKHP is 2710 – of course all the WeBS count data relate to the high tide roost but it is likely that some at least would have been feeding on NKM. The inclusion of counts, without further justification, under these conditions is also likely to understate the average number of birds present. The dismissal of any problems that these data gaps or data aberrancies may cause in ES 11.5.63 (p11-40) is a serious misjudgement.

The use of up to date data

It is not a criticism of the counts undertaken but inevitably data will be used which relates to different time periods. Here the BTO WeBS data for 2009/10 and obviously for 2010/11 would not have been available when the ES and HRA were written, but there is a danger that comparisons between data gathered in 2010/11 when compared with data from 2004/05-2008/9 may lead to inappropriate conclusions. The 2010/11 WeBS data for Black-tailed Godwits for the sites relevant to this Application are set out in Appendix IV Table 1.

Appendix IV

Table 1: Counts of Black-tailed Godwits from WeBS data 2010-2011 for the Humber Estuary

Four areas are shown – North Killingholme Haven Pits (NKHP), North Killingholme Marshes (NKM), Paull to Cherry Cobb (P/CC) and the rest of the Humber Estuary. Data supplied by BTO and relate to non-feeding birds counted at high water.

Month	NKHP	NKM	P/CC	Rest Humber	Total	% on NKHP and NKM
July	0	0	1	182	183	0
August	3345	337	0	70	3752	98.1
September	2304	42	12	211	2569	91.3
October	3555	0	402	86	4043	87.9
November	0	0	0	171	171	0
December	0	0	138	18	156	0
January	0	0	49	715	764	0
February	0	51	2	307	360	14.2
March	0	3	0	205	208	1.4
April	123	0	0	187	310	39.7
May	9	0	14	89	112	8.0
June	0	0	0	27	27	0

The importance of NKHP and NKM's function in autumn is emphasised and particularly noticeable is the count in September when 91.3% of the Humber Estuary SPA's Black-tailed Godwits were at NKHP and NKM.

Table 2: Data used to assess density of *Macoma balthica* and *Hediste diverscolor* on NKM from Table 4 in Annex 10.1

Note numbers in the table have been multiplied by 100 to give numbers m^2.

Transect	***Macoma***				***Hediste***		
	upper	mid	lower		upper	mid	lower
2	0	400	400		0	0	0
3	0	900	200		2,600	0	0
4	100	200	0		0	0	0
5	0	0	0		500	0	0
6	0	400	100		0	0	0
7	300	300	0		0	0	0
average	67	367	117		517	0	0

Table 3: Black-tailed godwit numbers by season at Paull Holme Strays

From Mander *et al* (2010) tables 1, 2, 3, 20, 21 and 6 (on p41) (see Appendix VI Tab 12). The numbers are mean number of birds for the season and foraging birds are for low water. F = foraging, NF = non-foraging.

	03/04	**04/05**	**05/06**	**06/07**	**07/08**	**08/09**	**mean**
F and NF combined							
Autumn	378	406	977	32	199	270	377
Winter	67	159	60	32	36	82	72
Spring	4	81	31	0	39	1	26
Foraging only							
Autumn	42	183	147	10	153	12	
Winter	0	99	13	23	29	12	
spring	2	79	31	0	11	1	

Details for Chowder Ness | Humber

Name	Chowder Ness
Location	Humber
County/Region	North Lincolnshire (North East England)
Country	UK
Implementation date	2006
Area (ha)	15
Longitude & Latitude (Deg)	Long: 53.6916845889468 Lat: -0.48153194261883
Type	Defence removal
Years Embanked	97
Previous landuse	Arable
Main Reasons	Compensation
Cost	~£1,500,000 (3million for Welwick & Chowder Ness)
Habitats created/ expected (ha)	0.8 saltmarsh, 10.5 mud flats, 2.3 grassland
Components (incl. dimensions)	Defence removal over 570m
Length difference new/old defence (% of old)	152
Site preparation	Reprofiling
Elevation (m national datum)	average: 2.4 OD; range: 1.6-4.5 OD
Tidal Range (m)	6.9
Accretion/erosion (mm/year)	~90 in first year
Management post-realignment	Unknown
Monitoring - details & duration	Accretion/erosion on site; bathymetry; invertebrates; birds Duration: 5 years
Summary lessons learned	Natalie Frost, ABPmer: Chowder Ness was created as compensation for port development on the Humber Estuary. Early discussion with stakeholders was highly beneficial throughout the whole process including the selection of a potentially suitable site, design issues, the EIA and subsequnet implementation of the scheme.
Views of participants re. drivers, constraints & success	Natalie Frost, ABPmer: Chowder Ness was created in compensation for port developments on the Humber. An Environmental Steering Committee met at regular intervals to discuss issues relating to the site. Although there was no planned timetable, it took considerably longer than anticipated to get all the approvals from the regulatory bodies (incl. Environment Agency and Local Authorities). The scheme was breached in June 2006 and appears to be performing as predicted at this early stage with saltmarsh development and bird usage already evident. In the medium to long term the monitoring results will be compared with the objectives of the site to determine the success of the scheme.
Extra text available	Yes
Media available	Yes

References for Chowder Ness | Humber
ABPmer, 2004. Environmental Statement for a Managed Realignment Scheme at Chowder Ness. ABP Marine Env
Institute of Estuarine & Coastal Studies (IECS), 2008. Managed Realignment in the Humber Estuary, UK. HARBAS http://www.harbasins.org/fileadmin/inhoud/pdf/Final_Products/WP2/Products__Reports_and_Publications_by_IEC
Personal communication with Natalie Frost, ABPmer

Details for Welwick | Humber		
Name	Welwick	
Location	Humber	
County/Region	East Riding of Yorkshire (North East England)	
Country	UK	
Implementation date	2006	
Area (ha)	54	
Longitude & Latitude (Deg)	Long: 53.6471718836982 Lat: 0.00954951150096	
Type	Defence removal	
Years Embanked	~35	
Previous landuse	Arable	
Main Reasons	Compensation	
Cost	~£1,500,000 (3million for Welwick & Chowder Ness)	
Habitats created/ expected (ha)	8-32 saltmarsh, 7-37 mud flats, very small saline lagoon, 9-15 grassland	
Components (incl. dimensions)	Defence removal over 1,400m	
Length difference new/old defence (% of old)	130	
Site preparation	Reprofiling, 2 breaches through fronting saltmarsh	
Elevation (m national datum)	1.75-4 OD	
Tidal Range (m)	6	
Accretion/erosion (mm/year)	Unknown	
Management post-realignment	Unknown	
Monitoring - details & duration	Accretion/erosion on site; bathymetry; invertebrates; birds Duration: 5 years	
Summary lessons learned	Natalie Frost, ABPmer: Welwick was created as compensation for port development on the Humber Estuary, Early discussion with stakeholders was highly beneficial throughout the whole process including the selection of a potentially suitable site, design issues, the EIA and subsequnet implementation of the scheme.	
Views of participants re. drivers, constraints & success	Natalie Frost, ABPmer: Welwick was created in compensation for port developments on the Humber. An Environmental Steering Committee met at regular intervals to discuss issues relating to the site. Although there was no planned timetable, it took considerably longer than anticipated to get all the approvals from the regulatory bodies (incl. Environment Agency and Local Authorities). The scheme was breached in June 2006 and appears to be performing as predicted at this early stage with saltmarsh development and bird usage already evident. In the medium to long term the monitoring results will be compared with the objectives of the site to determine the success of the scheme.	
Extra text available	Yes	
Media available	Yes	

References for Welwick | Humber
ABPmer, 2004. Record of Appropriate Assessment for a Managed Realignment Scheme at Welwick. ABP Marine I
Institute of Estuarine & Coastal Studies (IECS), 2008. Managed Realignment in the Humber Estuary, UK. HARBAS http://www.harbasins.org/fileadmin/inhoud/pdf/Final_Products/WP2/Products__Reports_and_Publications_by_IEC
Personal communication with Natalie Frost, ABPmer
Pontee, N.I., Hull, S. C., and Moore, J.R., 2006. Banked realignment: a case study from the Humber Estuary, UK. I Engineering Sustainability 159(ES3), 99-108.

Annex C1

Summary Proof of Evidence
of Mr Mark Dixon
for the
Royal Society for the Protection of Birds

29 June 2012

Planning Act 2008

In the matter of:

Planning Application for construction of the Able Marine Energy Park on the South Bank of the River Humber at Immingham, North Lincolnshire

Planning Inspectorate Ref:	**TR030001**
Registration Identification Ref:	**10015550**

1. SUMMARY

1.1. The Applicant's proposal to create a sustainable mudflat of up to 76ha in a 100ha site by conventional realignment design on the Humber is very difficult given that the natural sediment loading is 300g/m^3.

1.2. The Environmental Statement (ES) Volume 2 appear to demonstrate that meeting the prime objective of recreating a sustainable inter-tidal area of mainly mudflat has relied on an unconventional shallow V shaped breach design of 250 m width and an invert level (lowest point) of +2 m ODN (Ordnance Datum Newlyn).

1.3. Although this design will assist with limiting accretion over the immediate adjacent landward area in the short term, this objective will not be achieved in the medium to long term.

2. QUALIFICATIONS AND EXPERIENCE

2.1. I am Mr Mark Dixon. Since 2009 I have been a self employed consultant providing advice on sustainable wetlands. My clients include the RSPB, Environment Agency, Dredging International, Thames Gateway Development, Bristol Ports Ltd, Centre for Environment, Fisheries, and Aquaculture Science, Natural England, BBC and Department of Energy and Climate Change.

2.2. Over the previous twenty years I worked within flood management, coastal flood defence schemes (e.g. project manager for the 800ha Wallasea Project for the RSPB and Crossrail, quantity surveyor for the Thames flood defences) and for ten years (1992-2002) I was a senior coastal engineer and project manager to the Environment Agency and National Rivers Authority.

3. WHAT IS REQUIRED

3.1. As described in the ES, Chapter 28 the compensation site proposal is to replace protected habitats that will be destroyed by the Application and require to provide a sustainable compensation area for, in particular, feeding waders and wildfowl. I refer you to Dr Prater's evidence (paras 5.2-5.6) which describes the ecological function that will be lost and therefore needs replacing.

4. WHAT IS PROPOSED

4.1. Chapter 28 describes a managed realignment at Cherry Cobb Sands, by the removal of a section of an existing sea defence to allow flooding onto the historic flood plain to recreate the original habitat. The site would be some 3km long with a width varying between approximately 250m to the south and 900m to the north, with a V shaped breach to the south of the site of 250m width at the crest and a lowest level of +2m ODN at the bottom of the V. Immediately to landward of the breach the existing land level would be lowered to an area of 30ha to provide by its lower level, for a new mudflat. It should be noted that high water on Neap tides will not flood into the site as the bottom of the V breach is higher than these tides, and that the water in the site cannot all drain out on any tide as the landward level is lower than the bottom of the V breach.

Proposal for the creation of the compensation site

4.2. Chapter 28, paragraph 28.2.10 explains that the ground level profiles by lowering are to "maximise the provision of long term inter-tidal mudflat...The actual finished ground levels will be determined following further detailed modelling studies in consultation with Natural England (NE)." But these need to be available now to ensure that an effective habitat can be created.

4.3. In addition paragraph 28.2.11 and Figure 28.3 estimated the ground level after 5 years "...though this will be refined by further detailed modelling…." The modelling must be undertaken now and the results known and presented before any conclusions can be reached on the viability of the Compensation Site proposal.

4.4. The design appears to be based on the theory that strong tidal flows of between 2.4m/sec (metres per second) and 2.6m/sec (Chapter 32, para 32.6.7) through the breach and 1.6m/sec to 1.8m/sec close to the breach (para 32.6.18) will prevent or limit sedimentation to the lowered breach landward adjacent areas. However, current strengths of this speed will only be present in the early stages post breaching. As the site responds to these forces so a new creek will be eroded and form through the breach, which will result in lower current speeds which will not be strong enough to limit siltation over a wide area.

4.5. My site visit on Wednesday 6 June 2012 showed that there appeared to be a very vigorous accretion to the immediate foreshore and onto Foul Holme Sands with aggressive saltmarsh plant colonisation, which further demonstrates that the location for the proposed realignment will accrete rapidly post breaching.

5. POTENTIAL DESIGN PROBLEMS

The breach design

5.1. Although the breach width of 250m is correct for the estimated water volume of 1.26 million cubic metres (my approximate calculation based on the figures provided by the Applicant's consultants) by having a V shaped cross section with invert, the tidal current through that breach will be accelerated because the V shape presents a smaller cross section. Although this increase in current speed will no doubt assist in the short term in limiting accretion (Chapter 28, para 28.2.27) by washing away settled sediments and hence maintaining mudflat, the Applicant's consultants indicate that these same current speeds will erode through the breach within 5 years to form a creek to the north of the breach cross section (Chapter 28, para 28.2.25, Chapter 32, paras 32.6.8 and 32.6.18) and as that creek forms so the breach cross section will become larger and as a consequence current speeds will reduce and the impact on limiting siltation diminish.

5.2. The invert level of the breach is higher than the adjacent lowered area meaning that not all the water can drain off the site and this will create an area of still water that will actually accelerate the accretion process by enabling fine sediments a longer settling time. The other major impact of the V shape and invert level will be to accelerate ebb tide currents seaward having detrimental impacts to both Foul Holme Sands and Cherry Cobb Sands Creek (both these areas are within the Humber Estuary SPA/Ramsar/SAC in front of existing sea wall) within six months to one year.

5.3. A lot of care and attention has been given to predicted siltation (Chapter 28, para 28.2.11 and Figure 28.3, Chapter 32, paras 32.6.19, 32.6.24, Annex 32.4, paras 4.1.6 and 4.2.5) with siltation rates estimated for the first 5 years post breach from 800mm to the north of the site to 400mm in Year 1 at points of ground levels +1.50m AOD and 150mm at +2.50m AOD, with Annex 32.4, page 25, Table 11 showing 400mm at year 5 for low points. This same Annex at page 33, at 5.1.14 states "the predicted changes in ground levels probably have an uncertainty of +/- 50%" which is a very honest statement.

5.4. Annex 32.5 has a summary that indicates that the site will rapidly accrete and form saltmarsh and compares siltation rates at other realigned sites on the Humber, with Paull Holme Strays showing 420mm at Year 5 and states in paragraph 2.4.6 for the Cherry Cobb site "…there remains a high probability that a stable saltmarsh will develop on any managed realignment site on the north bank of the Humber opposite Immingham". This is again a very honest conclusion reflecting that the background suspended sediments are $300g/m^3$ of tidal water. Basically the site as designed will not provide the required long or even medium term quantity of mudflat that will be destroyed by the Application.

6. CONCLUSIONS

6.1. Due to the very high natural sediment loadings in the Humber of $300g/m^3$ of tidal water and consequent accretion, any conventional managed realignment design is unlikely to result in large areas of sustainable mudflat in the medium term.

6.2. The proposed design will assist in the short term only with maintaining adjacent mudflat habitat. As the enhanced tidal flows through the V breach erode and cut a new creek, so the flow speeds through the breach will reduce and their impact on reducing accretion diminish.

6.3. The invert level of the proposed breach is higher than the landward realigned lowered area therefore not all of the tide will be able to drain from the site, which will create an area of still water at low tide to enable enhanced accretion.

6.4. As the site accretes the swept tidal volume flooding and ebbing from the site will reduce, further accelerating the accretion process.

6.5. The V shaped breach and related enhanced ebb tide current speeds will have a greater impact to seaward to both Foul Holme Sands and Cherry Cobb Sands Creek in the short term.

6.6. The Applicant's consultant's reports have been very thorough and honest in their assessment of the potential accretion process and therefore it has been recognised that the site location and the design of the managed realignment has limitations on achieving the required habitat.

Lessons Learned from 20 Years of Managed Realignment and Regulated Tidal Exchange in the UK

Colin Scott, ABP Marine Environmental Research (ABPmer), Southampton, England.
Dr Susanne Armstrong, ABPmer, Southampton, England.
Prof. Ian Townend, HR Wallingford Ltd, Wallingford, England.
Mark Dixon (MBE), self-employed consultant, Mersea Island, England.
Dr Mark Everard, University of the West of England, Bristol, England.

Introduction

In certain coastal and estuarine locations, the best and most sustainable way to enhance flood protection is to realign the primary sea defences in a landward direction. This typically involves building new sea walls at the back of a site and then either breaching the old wall to fully open up the land to tidal waters ('managed realignment' (MR)) or inserting tidal exchange structures such as sluices into the old wall to enable greater control of the new tidal flows ('regulated tidal exchange' (RTE)). Alongside sediment recharge, such 'soft' engineering measures can be used to respond to sea level rise, improve the cost effectiveness of coastal defences and create new intertidal habitat. Over the last 20 years, some 50 individual MR and RTE schemes have been implemented in the UK. Cumulatively, these have created/restored over 1,300ha of coastal habitat. Therefore, there is now a significant (and expanding) amount of accumulated knowledge about how best to implement these schemes, how habitats develop in these sites and how they provide socio-economic functions beyond their core objectives. This increasingly large evidence base can be used to supplement earlier, fairly generic, design and assessment guidance which was based on relatively few implemented schemes (e.g. Leggett *et al.*, 2004). Ensuring that the practical lessons are communicated and disseminated is essential for underpinning the effective implementation of future schemes. This paper therefore summarises these lessons across six topics, namely: scheme implementation costs, project management and communication, key issues in MR design and assessment, ecological development of the schemes (with particular consideration given to fish and shellfish), and concluding with some consideration of the socio-economic benefits. The paper is informed by the authors' practical experiences, as well as consultation and literature used for the creation and ongoing updating of the Online Managed Realignment Guide (OMReG) database (www.abpmer.net/omreg). The paper also draws upon the main issues raised by delegates at a bespoke MR conference in November 2010 hosted by ABPmer.

Costs of implementation

Frequently, one of the main hurdles to undertaking MR/RTE projects is the cost of their implementation as well as the risk of these costs increasing where obstacles are encountered during the various phases (i.e. scheme design, impact assessment, planning and construction).

Lessons from the past

A review of the implementation cost for 35 of the completed UK schemes has shown that the average cost of a scheme is just under £30,000/ha (2010 prices) (see OMReG). However, these costs have ranged greatly from £6,950/ha for the Pillmouth scheme (Torridge estuary) to just over £100,000/ha for the Trimley Marsh (Orwell) and Paull Holme Strays (Humber) schemes. Such variability is to be expected given the distinct challenges and constraints faced at the individual schemes. In general there has been a clear shift over the course of two decades from initial low-cost, small-scale, and relatively inexpensive trial projects to high-cost, larger, projects that were designed to meet specific targets for habitat creation and flood alleviation. This change is not unexpected, but what is much less intuitive is that many of the recent larger projects were not accompanied by improved unit costs (i.e. 'economies of scale'), and thus did not secure enhanced efficiencies in the light of the lessons learned from previous projects. This is illustrated in Figure 1, which demonstrates that schemes implemented after 2000 had higher unit costs. A contributory factor here will be increasing land prices, but also greater costs are being incurred for licensing, assessment, engineering and mitigation requirements. Project objectives are also a factor, with compensatory scheme costs (e.g. those undertaken to offset impacts from port developments such as Welwick (Humber)) being typically much higher, at £70,000/ha on average, than others. It is furthermore clear that the amount and scale of set-back defences is also a critical consideration; where large new defences needed to be constructed these accounted for a large percentage (c. 44%) of the total cost. Therefore, it is unsurprising that five of the six most expensive MR schemes required extensive new defence construction.

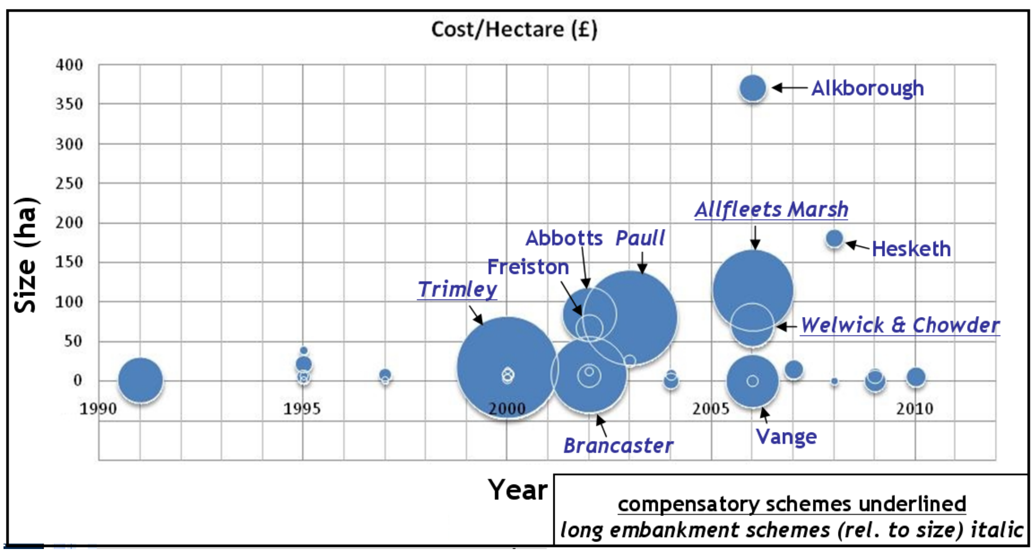


Figure 1: Unit costs of implemented realignments plotted against size and year

The future – need to review and identify cost efficiencies

At this stage there is no sign that the trend of larger projects incurring higher unit costs is likely to change. A number of large-scale projects are in the pipeline at present (e.g. Medmerry (near Selsey) and the Wallasea Island Wild Coast project (Crouch)), which will be relatively high cost projects due to their large size and/or novel complexities associated with their design and build. On an ongoing basis however, there is a need to identify where cost savings can be made with reference to the fees incurred in the past. This could include taking account of the flood protection benefits of intertidal morphology, applying past assessment, mitigation and monitoring regimes to new MRs and designing out the need for future maintenance.

Project management and communication

In general, MR projects should be viewed in the same way as any other engineering development with their implementation requiring careful planning and project management. However, it needs to be noted that, unlike typical infrastructure developments, MRs need to integrate into changing, sensitive, coastal zones and must themselves become adaptive rather than fixed systems.

Lessons from the past

As noted above, there has been a shift from relatively straightforward, smaller MRs to larger, more complex and costly sites that require significant project management to bring them to fruition. For example, the successful realisation of the Allfleet's Marsh site (Crouch; formerly Wallasea) can be attributed to good project management, the competency of the contractors and a clear understanding of the process to be followed (Dixon *et al.*, 2008, p.68). Key documents produced for this project included a clear business case as well as a detailed business plan (setting clear achievable objectives and time lines, outlining robust procurement and cash control). A review of the lessons learned provided for implemented schemes on OMReG also revealed the importance of having committed and enthusiastic implementers on board who learn from previous experience and ensure good cooperation with regulators and wider stakeholders. It is important to note that, once underway, a myriad of issues can cause significant project delays if not completed to specific timeframes. Obtaining planning consent can be a long and complicated process, especially for larger scale projects, and a variety of additional consents/licences are required. Furthermore, construction can be constrained by many factors (weather, tides and protected species windows), and embankments and mitigation habitats may need time to settle and develop. Significant contingencies should be incorporated to allow for aspects such as landowner negotiations, unexpected concerns and issues becoming unexpectedly complex (e.g. the presence of footpaths caused delays at several projects, including at Walborough (Axe)).

Having an effective, clear, honest and early, stakeholder communication strategy emerged as the most important lesson learned from schemes contained in OMReG. This is especially the case as MR is relatively complex and entails largely irreversible land use and visual change. The issue of change from arable land to intertidal has become a more prominent one over recent years, and in 2010, the Donna Nook MR on the Humber was denied planning consent largely for this reason. Based on experience at recent large-scale projects, including Alkborough Flats (Humber) and Medmerry, stakeholder engagement incorporating liaison groups, public exhibitions and individual meetings with interested parties is highly beneficial. This should enable genuine input into areas the public can actually influence and extol the wider benefits of schemes beyond the immediate objectives (focussing on aspects people can relate to, e.g. flood protection).

The future

The requirements and resources needed for project management and consultation are unlikely to diminish in the future, particularly as in some areas, more straightforward sites may have already been realigned. Also, local communities and authorities increasingly demand significant planning gains from MR implementers (e.g. improved flood protection and public access). Cuts in government spending may also make obtaining funding more difficult, so project managers may need to allocate more time to obtaining resources from more diverse sources. Factors which have proven useful during recent consultation experiences, and which are recommended for future schemes, include the 'marketing' of a scheme by providing information on the multiple benefits of MR, and using photorealistic 3D Geographical Information System (GIS) visualisations to demonstrate how a site will look and function.

Design and assessment

It is important at the very earliest stages of implementing a MR to understand the hydrodynamic functionality of a site and the physical interaction it will have with the adjacent estuary or coastal zone. Indeed this element needs to underpin the process of selecting a site in the first instance before then also forming the cornerstone of the majority of the design and assessment work that follows. There is a need to consider both short-term effects likely to arise from introducing a new inundation area as well as longer-term effects given that estuaries can take decades to centuries to respond. However, short-term considerations often dominate the consulting process, with immediate impacts a prominent issue when seeking the necessary consents.

Lessons from the past

Designing and assessing MR projects is a complex process, and can vary greatly in scope between projects. Two issues are crucial to the successful design of MR sites. Firstly, the hydrology and hydraulics within the site have to be designed to support the target habitats. Secondly, the physical changes which occur along adjacent estuaries or coasts following the introduction of a new inundation area need to be assessed; particularly as these can in turn affect other interests, such as designated habitats or flood protection. Understanding such changes often requires detailed hydrodynamic, sediment and wave modelling/assessment exercises. Listing each of these considerations is beyond the scope of this review. However, it is instructive to focus briefly on three of the best-understood and most accurately-quantifiable aspects of the physical changes which occur. These are:

- the amount by which a scheme increases an estuary's tidal prism (which is a simple surrogate indicator of the scale of a scheme's potential near-field and far-field effects);
- the channel formations that occur in front of a site as an indication of its near-field effects;
- the anticipated rate of accretion of sediments within a site, which influence how a site functions and also the rate at which the tidal prism effect reduces over time.

The available guidance on MRs suggests that changes in tidal prism amounting to more than 5% are likely to have significant impacts on the morphology of the adjacent system (e.g. Leggett *et al.*, 2004). However, this has not actually been tested and any schemes implemented to date have at most had a minor effect on the adjacent estuary's prism. For example, the Allfleet's Marsh MR led to a 2% change to the Crouch estuary prism and evidence from this and other projects with comparable changes (incl. Abbotts Hall, Blackwater/Salcott Creek) indicate that this has not led to significant external hydrodynamic effects. With respect to near-field morphological changes, some changes will always necessarily occur along the drainage channel from a site. However, such effects can be minimised by effective site and breach design, drawing on lessons from sites where the breach design was perhaps sub-optimal and thus led to unwanted (largely temporary) effects on fronting habitats (e.g. Freiston, Wash; Symonds & Collins, 2007). Experience from UK sites is that they tend to accrete, thus leading to a gradual reduction in tidal prism over time. The accretion rates differ greatly depending on site design and location. In the turbid Humber estuary initial lower-elevation accretion has been rapid at more than 10cm per year at all of the four Humber MRs. At Allfleet's Marsh, accretion was less rapid at 3-5cm per year; in the four years since implementation, this accretion has already led to a 10% prism reduction. It is interesting to note that at flood storage RTE projects such as Lippenbroek (Belgium), accretion and the consequent reduction in prism are seen as negative. This demonstrates that it is critical that these sites are not seen as static environments but as evolving and changing from day one.

When approaching the assessment and design of MR projects, an iterative and phased process is recommended, whereby there is a building up of evidence about the scale of changes and the functioning of a site. A site visit should be seen as an essential first step in this process. During the next phase, a preliminary design should be developed and its implications assessed on a high level. At the same time, the Environmental Impact Assessment (EIA) process should be commenced, and relevant ecological surveys undertaken to ensure on-site constraints are known (and mitigated for). The final phase should involve the detailed assessment of the scheme's hydrodynamic effects, which will then inform both the finalisation/enhancement of the design and the assessment of the individual EIA topics. This may need to be supported by wave and sediment transport modelling. Design aspects requiring the most careful consideration include tidal prism, breach design (and breach flow speeds), the role of site morphology in delivering particular habitats, and how future accretion may influence site development. Breach placement should be based on insights gained from a site visit, and a review of historic charts, current elevation maps and estuarine/coastal processes. For example, at Allfleet's Marsh, the breaches were largely placed in locations that minimised the losses of fronting saltmarsh habitat. The optimum breach dimensions can be calculated using recognised equations outlined by Townend *et al.* (2010), with a key input being a site's tidal prism. A breach needs to be sufficiently large and deep to avoid unwanted stability issues, a lesson learned from implemented schemes such as Freiston and Hesketh Out Marsh (Ribble). At Allfleet's Marsh, the breaches were deliberately over-designed to ensure that they were in 'regime' with the volumes of water exchanged and, to date, no morphological changes to the breach channels have been observed. Regarding site morphology, the extent of any landform manipulation must be justified with due consideration to project objectives, the potential gains and the likely cost. It has often been the case that materials for new walls need to be sourced on site (e.g. at Medmerry), which provides valuable opportunities for environmental optimisation (e.g. on-site fish lagoons or landward ditches enhanced for freshwater species). At the majority of the implemented MR sites, internal creeks were excavated to facilitate the effective flooding and draining of the site which, in turn, helps to ensure effective habitat creation. In some instances, field drains were already available for this function (e.g. Alkborough, Allfleet's Marsh) whilst, in others, tidal waters were allowed to create their own creek network (e.g. Tollesbury (Blackwater)).

The future

Future projects need to follow and further develop best practices established in the past, particularly with respect to following an iterative approach in which key questions are addressed early. It is recommended that early feasibility studies are carried out that address the key hydrodynamic issues but also begin the EIA scoping process by identifying the relevant impacts based on past experience. Where possible the guiding principles of scheme design work should be to minimise land manipulation and work with the existing topography. However, interventions should be undertaken to facilitate the efficient drainage of a site, maximise the stability of the breach(es) and optimise a site's ecological value from the opportunities presented by wall build excavations. These design principles were for instance applied to design the consented Medmerry scheme (breach anticipated in 2012).

Ecological development (benthos, saltmarsh and birds)

The ecological development of MRs is well studied, particularly where these were implemented as compensatory measures under the EU Habitats Regulations. For these sites there is a requirement to understand whether the created/restored habitats have offset the impacts of the plan or project which they have been designed to compensate. This monitoring usually focuses on mudflat benthos, marsh vegetation and overwintering birds. Some key findings from this work are set out below.

Lessons from the past

With regards to benthos, mudflat invertebrate monitoring undertaken at several MR sites has shown that, where the tidal elevation and physical conditions are appropriate, benthic invertebrates can colonise the accreting mudflat fairly rapidly (e.g. Tollesbury, Allfleet's Marsh and the Humber sites). Site species composition generally becomes more complex and stable over time. Early colonisers such as ragworm, mud snail and mud shrimp often dominate the biomass over the first few years. For example, rapid colonisation was observed at Allfleet's Marsh where there have been 10,000 to 20,000 organisms/m^2 in each year since its breaching. The species composition, abundance and diversity can vary greatly with differences in site elevation and location, and this makes comparison between schemes very difficult. At Chowder Ness for instance, between 500-15,000 organisms/m^2 have been observed, while at the Welwick site, ca. 37km downstream on the Humber, numbers ranged from 700-7,000 organisms/m^2. However, the species diversity at Welwick is still typically lower when compared to fronting, pre-existing mudflats, whereas at Chowder Ness, these figures are already very similar (three years post realignment). Judging assemblages in the context of fronting habitats provides an interesting context but will not necessarily allow the effectiveness of the schemes to be determined given how different the internal conditions can be from those outside (e.g. Nigg Bay (Cromarthy Firth) and Allfleet's Marsh).

Saltmarsh plant colonisation follows a similar successional pattern as that observed for mudflat invertebrates. Rapid colonisation occurs if the conditions are right, especially in relation to drainage and elevation (e.g. Welwick, Chowder Ness). Pioneer vegetation such as glasswort typically colonises within one year, and it may then take several years or decades to achieve a species composition similar to that of adjacent mature marshes. At Freiston, particularly rapid pioneer colonisation was observed; 70% of the area was covered in vegetation within three years. A similar 'exponential' rate was observed at Allfleet's Marsh, where the percentage plant coverage increased over four years from 1% to 6% to 60% and then 100%. At Freiston, the expectation was that the site's species abundance and community types would be equivalent to those outside the site within 10 years of breaching (Brown *et al.*, 2007).

MR sites can rapidly develop into important roosting and feeding sites for waterbirds. At Freiston, Badley and Allcorn (2006) concluded after four years that the site supported 'large numbers of wintering waterbirds, several species in nationally important numbers' (p. 105).

Some sites (e.g. Welwick, Allfleet's Marsh) may initially mainly be utilised as roost sites but, as prey diversity and biomass increases, so should the proportion of feeding birds. Allfleet's Marsh for example supported very good, increasing, numbers of waterbirds in the first three years of its existence; with some 7,000, 10,000 and 12,000 waterbirds observed respectively. At the Tollesbury and Orplands MRs (Blackwater), communities were found to be largely similar to those of surrounding mudflats within five years of the initial breach (Atkinson *et al.*, 2001).

The future –need to clarify site success criteria

With regards to compensatory MRs, one of the most important future objectives will be to clarify the issues associated with measuring a site's ecological performance and, where relevant, addressing the extent to which it has offset the predicted and actual impacts arising from the project which it has compensated. Clearly, appropriately-designed MRs can deliver high ecological and biodiversity value even in a short space of time (weeks/months) alongside a wide range of other gains. However, the process of achieving full equivalency with mature habitat, saltmarsh in particular, may take much longer. The relevance of this needs to be better understood, agreed and communicated amongst coastal managers. In this context it should be noted that measuring value is not simple and different approaches are often taken to review monitoring data. It is also clear that most sites accrete sediments, often very rapidly, and their habitats are therefore inherently adapting from day one. Hence, quantitatively measuring the value and extent of the created habitats will never be a simple task. Each case will probably need to be judged on its own merits, but some kind of auditable framework that addresses the role that new sites play in maintaining the coherence of the Natura 2000 network may be warranted. The most obvious issue is whether designation requirements are met. However, it may be more useful to evaluate the 'functional equivalence' of the new habitats using ecosystem services analysis, particularly given that judgements are made in a non-stationary climate. In 2011, several major schemes will reach the end of their first five-year monitoring cycle and conclusions on their success will need to be reached in the context of these dynamics (and lessons disseminated).

Fish and Shellfish

In general, intertidal habitats are known to be valuable feeding and nursery grounds for many fish species such flounder, herring and bass (Dixon *et al.*, 2008). Hence, the value of managed MR for fish and shellfish populations, as well as for associated commercial and recreational fishing activities, is an important consideration when seeking to understand the socio-economic and ecological gains/benefits that can be achieved. In the UK to date, this has never been a key motive for habitat creation and is typically no more than a tertiary consideration if it is addressed at all. However, there is increasing recognition of the potential importance of MR sites for commercial fishing and food-production in their own right as well as in mitigation for losses of at-risk arable land and as a means to enhance the recruitment of fish and shellfish stocks.

Lessons from the past

Work undertaken at several MRs has confirmed that they are capable of providing suitable habitat within a relatively short space of time. At Allfleet's Marsh, fish sampling undertaken just 1 and 2 months after breaching showed that even though plants and algae had yet to colonise, the lagoonal scrapes in the developing mudflat had high numbers of crustacea and were refuge and feeding areas for juvenile sea bass and herring (amongst others). Fish were feeding on marine zooplankton, crustacea and polychaetes and were leaving the site with fuller stomachs than when they entered (L. Fonseca PhD, pers comm). Longer term surveys undertaken at Freiston and Paull Holme Strays confirmed the value of MRs as nursery areas for economically important fish. At Freiston, high numbers of bass, sprat and herring were observed (Brown *et al.*, 2007). At Paull, eel, flounder, bass and sand goby were abundant, and species composition and density was judged to be largely similar to that of adjacent areas (Hemingway *et al.*, 2008). Of particular note is that sites are of higher value if they provide fish habitat throughout the entire tidal cycle by including channels and ponds which remain flooded at low water. The value of such deep ponds/lagoons has been demonstrated at Abbotts Hall where up to 2000 herring/sprat were once found in one pool alone (along with 10 other species including bass, flounder and eel) (Colclough *et al.*, 2005). Comparative surveys at Brancaster (Norfolk) and Freiston confirmed the value of both sites for fish with the former site having a greater species diversity that was attributed to more diverse habitats and the presence of deep channels (Deaney, 2010). It is also known that fish use RTE areas. At Goosemoor (Exe), for instance, mullet pass through the control device to graze within the site; at Beltringharder Koog (Germany) fish pass through a culvert where average speeds are 4m/s; and at Lippenbroek, fish mostly utilise the outlet sluice.

Increasing work is also being done to understand the use of MRs by shellfish species and the potential for their commercial exploitation. Environment Agency-funded trials of cockle growth undertaken at Allfleet's Marsh demonstrated that this species grows as well within the site as it does outside (Dirt Consultants, pers. comm.). Subsequent RSPB-funded trials at Allfleet's Marsh concluded that MR sites could be used for the initial growing on of juveniles/spat. Benthic monitoring in this site has also shown that bivalve species are thriving more generally. The breach areas now have large rock oyster aggregations as well as occurrences of native oyster and mussels, while the mudflat supports high numbers of clams and occasional cockles. It seems likely that shellfish are feeding on both autochthonous nutritional inputs (internally generated from marsh and algae) and allochthonous organics (imported from external sources).

The future – the importance of environmental optimisation and commercial trials

There is now evidence that MR s are valuable for fish/shellfish populations and certainly that they are important places for the development of juveniles. However, the commercial potential of these sites has yet to be fully realised. In large part this is because these sites are not designed with this as a core objective. Adopting a process of 'environmental optimisation' when designing projects should allow this deficiency to be addressed. It is clear that even modest design changes, often undertaken at limited (if any) extra cost, enable a site to be enhanced in biodiversity terms. The inclusion of ponded areas retaining water at low tide is particularly valuable and also brings about additional benefits for bird species. It will be important to further investigate the commercial exploitability of MRs and to understand how the fish objective can be elevated as part of future scheme design work. This has particular resonance when dealing with the loss of productive (but often at risk) agricultural land and addressing how this can be offset by opportunities in new coastal habitat creation projects.

Socio-Economic Benefits

As discussed above, the main reasons for MR are to enhance flood defences and/or create new coastal habitat. In addition to these objectives, which need to be clearly laid out, secondary benefits can accrue providing additional socio-economic benefits. These can relate to tourism, recreational and commercial fisheries, carbon sequestration and water quality improvements.

Lessons from the past

Although the potential and theoretical benefits of MR have always been well understood, new lessons are being learned about the socio-economic gains that can realistically arise and also, in the light of new guidance from Defra (2007), about how to value ecosystems generally. The RSPB site at Freiston is a good practical example of a site that has been justified on economic and social grounds, having led (among other aspects) to reduced sea wall maintenance and increased visitor numbers (56,000 in 2003) that have boosted the local economy. Anecdotally, businesses near the site have reported increased trade from the visitors to the site and a guesthouse has opened immediately adjacent to the reserve. Separate, ecosystem services review work has also informed the Alkborough scheme (Everard, 2009) as well as projects that have not yet been completed such as the Medmerry and the Wallasea Island Wild Coast projects during their developmental phases. The Alkborough review identified an approximate aggregate benefit of £23m. The Wallasea Island Wild Coast scheme was predicted to lead to the creation of 16 to 21 full-time equivalent jobs in the local economy, and to flood defence-related cost savings of between £0.5 and 10million over the next 10 years (Eftec, 2008).

The future

Projects such as Freiston indicate the clear economic gains that can arise from a scheme, while ecosystem valuation also regularly demonstrates that these projects can have a sound economic rationale. There is a need to obtain more accurate valuation data on the ecosystem services to better understand and quantify these benefits. There is also a need for clarity on how ecosystem valuation will influence future coastal management decisions, because were it to do so, it could shift the balance in favour of coastal habitat creation. In the near future, however, it seems more likely that project valuation will need to be based primarily on the more obvious market services (e.g. reduced defence cost or greater tourism) that are more easily evaluated and communicated to local communities. However, less tangible services (such as local ‘sense of place’) must mot be overlooked as they can be a source of friction with local residents. Separately, there is a need to use these findings to seek out new funding sources, for instance from commercial organisations that can use such schemes as part of their carbon budgeting or from other as yet unexploited ‘paying for ecosystem services’ markets. This, if achieved, would help to address one of the key problems of funding MR implementation.

Conclusion

Our understanding about how to implement schemes has been greatly advanced through practical experience. This includes aspects such as how to design MRs, assess their impacts, secure planning consents and construct them, as well as how to engage stakeholders. Knowledge sharing has yet to be achieved adequately, and some projects still do not build upon well-known design opportunities. Major problems still exist in moving from the strategic level (shoreline management planning), which says what should be done, to ground-level implementation which indicates what can be done. Key difficulties include: securing landowner involvement, obtaining appropriate funding (especially when the costs of schemes increase) and communicating the potential socio-economic benefits (carbon sequestration, commercial fisheries productivity, green tourism, etc.). Ultimately, a long-term vision for scheme implementation is required in which a ‘conveyor-belt’ of future schemes is identified, some of which may not be implemented for decades. Within such a long-term vision there may well be a need to consider whether very large–scale (>>1000ha) projects can now be implemented to help achieve national habitat creation targets and provide services of economic value. It will, however, continue to be difficult to communicate the rationale for this work and to convey the relevant principles of future site and shoreline evolution, when shorter-term visions inherently prevail.

Key References

Large sections of this review are based on the primary and secondary data contained in the OMReG database (incl. many references). This site can be accessed at: www.abpmer.net/omreg

Atkinson, P.W., Crooks, S., Grant, A. & Rehfish, M.M., 2001. The success of creation and restoration schemes in producing intertidal habitat suitable for waterbirds. English Nature, Peterborough, 167p.

Badley J. & Allcorn R.I., 2006. Changes in bird use following the managed realignment at Freiston Shore RSPB Reserve, Lincolnshire, England. Conservation Evidence (2006) 3, 102-105.

Brown, S.L., Pinder, A., Scott, L., Bass, J., Rispin, E., Brown, S., Garbutt, A., Thomson, A., Spencer, T., Moller, I. & Brooks, S.M., 2007. Wash Banks Flood Defence Scheme - Freiston Environmental Monitoring 2002-2006. Centre for Ecology and Hydrology, Dorchester, 374p.

Colclough, S., Fonseca, L., Astley, T., Thomas, K. & Watts, W., 2005. Fish utilisation of managed realignments. Fisheries Management and Ecology 12, 351-360.

Defra, 2007. An introductory guide to valuing ecosystem services. Department for Environment, Food and Rural Affairs, London, 68p.

Dixon M., Morris R.K.A, Scott C. R. Birchenough A. & Colclough S., 2008. Managed coastal realignment: lessons from Wallasea. ICE Proceedings - Maritime Engineering, 161(2), 61-71.

Eftec, 2008. Wallasea Island Economic Benefits Study Report for the East of England Development Agency 24 October 2008. Eftec, London, 35p.

Everard, M., 2009. Ecosystem services case studies. Environment Agency Science Report SCHO0409BPVM-E-E. Environment Agency, Almondsbury, 101p.

Hemingway, K.L., Cutts, N.C. & R. Pérez-Dominguez., 2008. Managed Realignment in the Humber Estuary, UK. University of Hull, Hull, 44p.

Leggett, D.J., Cooper, N. & Harvey, R., 2004. Coastal and estuarine managed realignment – design issues. Construction Industry Research And Information Association, London, 215p.

Symonds, A.M. & Collins, M.B., 2007. The establishment of a temporary creek system in response to managed realignment. Earth Surface Processes and Landforms, 32(12), 1783-1796.

Townend I.H., Scott C.R. & Dixon M., 2010, Managed Realignment: A Coastal Flood Management Strategy, In: Pender G, et al. (Eds.), Flood Risk Science and Management, Blackwell Publishing Ltd, Oxford, pp. 60-86.

Proceedings of the Institution of Civil Engineers
Maritime Engineering 161
June 2008 Issue MA2
Pages 61–71
doi: 10.1680/maen.2008.161.2.61

Paper 700016
Received 04/09/2007
Accepted 21/07/2008

Keywords:
coastal engineering/environment/management

Mark Dixon
RSPB Project Manager, c/o Environment Agency, Kelvedon, Essex, UK

Roger K. A. Morris
Natural England, Policy Team, Northminster House, Peterborough, UK

Colin R. Scott
ABP Marine Environmental Research Ltd (ABPmer), Southampton, UK

Andrew Birchenough
Centre for Environment, Fisheries and Aquaculture Science (Cefas), Burnham on Crouch, Essex, UK

Steve Colclough
Environment Agency, Thames Region, London, UK

Institution of Civil Engineers

Managed realignment – lessons from Wallasea, UK

M. Dixon MBE, FIMS, R. K. A. Morris BSc, CEnv, FIEEM, FRES, AMICE, C. R. Scott MSc, A. Birchenough BSc, PhD and S. Colclough BSc, CEnv, MIFM

Managed realignment often involves the construction of new sea walls at a location behind existing sea walls to create parcels of land that can be flooded to create new inter-tidal environments. It is employed in the UK to improve flood risk management within the context of flood risk management strategies, but so far most emphasis has focused upon creation of new wildlife habitat because this has been where the opportunities and funding have been found. Initial projects were relatively small in scale, but recent projects have been much larger. Scaling up the size of realignments introduces a variety of additional engineering and social challenges and the realignment of Wallasea Island in 2006 is one of the largest. There were a variety of issues encountered during the development of the Wallasea Island realignment that make it a good platform for exploring the issues and some of the solutions that have been found to date. This account describes the project and some of the measures taken to give it as high a level of social acceptability as possible. Such measures include design features for fish nurseries, provision of public access and careful liaison with affected communities.

1. INTRODUCTION

Climate change and sea level rise have been recognised as requiring a new approach to flood risk involving the creation of accommodation space for higher tides.[1] One part of this approach is the use of managed realignment to secure more sustainable flood management solutions. Similar solutions are also employed to deliver new coastal habitat as compensatory measures linked to strategically important commercial projects such as new ports and upgraded navigation channels. In the UK, managed realignment was trialled at Northey Island (Blackwater estuary) in 1991.

Since then, there have been 23 further projects as listed in Table 1 and depicted in Fig. 1. Of these, three have solely been on flood defence grounds, five involve compensation for loss of habitat to major flood defence and port projects, seven provide a combination of flood risk management and habitat creation benefits and seven were solely for nature conservation purposes. So far, the bigger projects have largely been undertaken as compensation for habitat loss and small ones have addressed habitat creation.

Conceptually, managed realignment involves breaching sea walls to allow the sea to cover uninhabited land as far inland as the nearest high ground.[2,3] Most suitable land would have formerly been saltmarsh that was enwalled at some point to prevent tidal flooding and to create more viable agricultural land. Examples of this approach include Abbotts Hall Farm (Blackwater estuary, Essex) and Alkborough (Humber estuary, North Lincolnshire). There are also numerous examples of unmanaged realignment arising from breaches that were judged uneconomic to repair. In practice, however, most estuary floodplains are too extensive to make such an approach technically or socially acceptable. It is more usual for new flood banks to be built behind existing sea walls and once the new walls have consolidated and vegetated the old walls are breached. Inter-tidal habitats subsequently form in the space between old and new walls.

The rate of accretion depends upon the supply of suspended sediment entering the site and the hydrodynamics of the site, especially its position within the tidal frame and the widths of the breaches.[4] If suspended sediment levels are low, the rate of deposition will also be low, whereas higher levels of suspended sediments will result in commensurately higher levels of deposition; sites whose position in the tidal frame is low will also take longer to accrete to the point where saltmarsh develops. If the widths of the breaches are too small, the volume of water entering and departing the site may be constrained and the rate of egress may lead to erosion and net export of sediment. This is clearly demonstrated by Garbutt and Reading[5] who also show that there is a fine separation between open mudflats and the development of early successional stages of saltmarsh.

Any proposal to interfere with existing flood defences causes concern among coastal stakeholders, many of whom regard realignment as giving up land to the sea. In addition, there are interest groups for whom realignment can have significant implications. Concerns arise from such disparate interests as shellfisheries and navigation to public access and protected wildlife. As a result, new realignment projects still encounter extensive problems and require competent project management if they are to progress through the consents process and proceed to the construction phase.

This paper draws upon experience of managed realignment in the UK gained over the past 16 years and in particular focuses upon the lessons learned during the recently created

Site name	Estuary	Size: ha	Year	Main purpose
[1] Northey Island	Blackwater	0·8	1991	Reduced defence costs and habitat creation
[2] Pawlett Hams	Parrett	4·8	1994	Existing bank could not be maintained
[3] Orplands	Blackwater	38·0	1995	Reduced defence costs
[4] Tollesbury	Blackwater	21·0	1995	Reduced defence costs
[5] Thornham Point	Chichester harbour	6·9	1997	Habitat creation
[6] Lantern Marsh	Alde-Ore	29·0	1999	Reduced defence costs and habitat creation
[7] Annery Kiln	Torridge	3·8	2000	Habitat creation
[8] Trimley Marsh	Orwell estuary	16·5	2000	Compensation for impacts of Harwich Haven capital dredge
[9] Watertown Farm	Yeo	1·5	2000	Habitat creation
[10] Pillmouth (1 and 2)	Torridge	12·9	2000/01	Habitat creation
[11] Bleadon Levels	Axe	13·0	2001	Reduced defence costs and habitat creation
[12] Abbotts Hall	Blackwater	84·0	2002	Reduced defence costs and habitat creation
[13] Brancaster West Marsh	North Norfolk Coast	7·5	2002	Reduced defence costs and habitat creation
[14] Brandyhole	Crouch	12·0	2002	Compensation for a flood defence project
[15] Freiston Shore	Wash	66·0	2002	Multiple benefit scheme for flood risk management and habitat creation
[16] Nigg Bay	Cromarty Firth	25·0	2003	Habitat creation and advocacy/demonstration site
[17] Paull Holme Strays	Humber	80·0	2003	Compensation for impacts of upgrading of flood banks along the Humber
[18] Thorness Bay	The Solent	6·0	2004	Habitat creation
[19] Alkborough	Humber	180·0 (tidal)	2006	Multiple benefit scheme for flood risk management and habitat creation
[20] Alnmouth	Alne	8·0	2006	Habitat creation
[21] Chowder Ness	Humber	12·2	2006	Compensation for Immingham outer harbour
[22] Wallasea Island	Crouch-Roach	115·0	2006	Compensation for port developments at Fagbury Flats and Lappel Bank
[23] Welwick	Humber	54·0	2006	Compensation for Immingham outer harbour

Superscript numbers refer to site locations presented in Fig. 1. More details of these and related tidal exchange projects can be found at www.abpmer.net/omreg

Table 1. Managed realignment sites in England since 1991

realignment site at Wallasea Island near the mouth of the Crouch and Roach estuary in Essex.

2. WALLASEA ISLAND MANAGED REALIGNMENT SITE

The Wallasea Island realignment project was undertaken to compensate for the loss of inter-tidal habitats at Fagbury Flats (port of Felixstowe) and Lappel Bank (port of Sheerness) that should have been designated for its bird interest under the EC Birds Directive (79/409/EEC).[6] The project was undertaken by the Department for Environment, Food and Rural Affairs (Defra), the UK government's department responsible for environmental matters. Government policy is to ensure that where detrimental impacts are anticipated, the developer is responsible for compensatory measures. The locations of the Wallasea realignment scheme and the two sites it is designed to offset are shown in Fig. 2.

The design criteria for compensatory measures therefore took particular account of specific habitat losses (22 ha of mudflat at Lappel Bank and 32 ha of saltmarsh and mudflats at Fagbury Flats). This meant that the package was expected to comprise both saltmarsh and mudflat and was an important factor as the choice of realignment site(s) would have to be capable of yielding both mudflat and saltmarsh. The process of finding suitable sites for possible realignment involved detailed examination of the coastlines of Kent and Essex, within the greater Thames natural area.[7] An initial study by English Nature and the Environment Agency between 1996 and 1998 identified 193 possible locations, of which nine were believed to meet overall requirements.

Further detailed studies were commissioned to determine the suitability of the shortlist against the following criteria.

(*a*) Provision of intertidal habitat capable of supporting the number and range of bird species displaced as a result of the loss of Lappel Bank and Fagbury Flats.
(*b*) Impacts to the originally proposed Medway estuary special protection area (SPA) and Stour and Orwell estuaries SPA are offset.
(*c*) Compensatory measures do not have an adverse impact on the geomorphological and ecological functioning of the area in which they are based.
(*d*) Construction of a self-sufficient system which can evolve in response to natural, physical, chemical and biological changes.
(*e*) Construction of a site that is able to maintain the bird populations for which it was created for a period of at least 50 years.
(*f*) To provide compensatory measures for loss of wetland function that cannot be adequately replaced.

This selection exercise[8] initially identified a location at Weymarks, close to Bradwell on the Blackwater estuary in Essex that most closely met the design criteria. This option was explored in more detail, including liaison with local stakeholders. Unfortunately, although it was a highly suitable site, it proved to be too contentious to make progress with certainty of gaining consent for necessary engineering. Local opposition was considerable and included concerns that the project would *inter-alia*

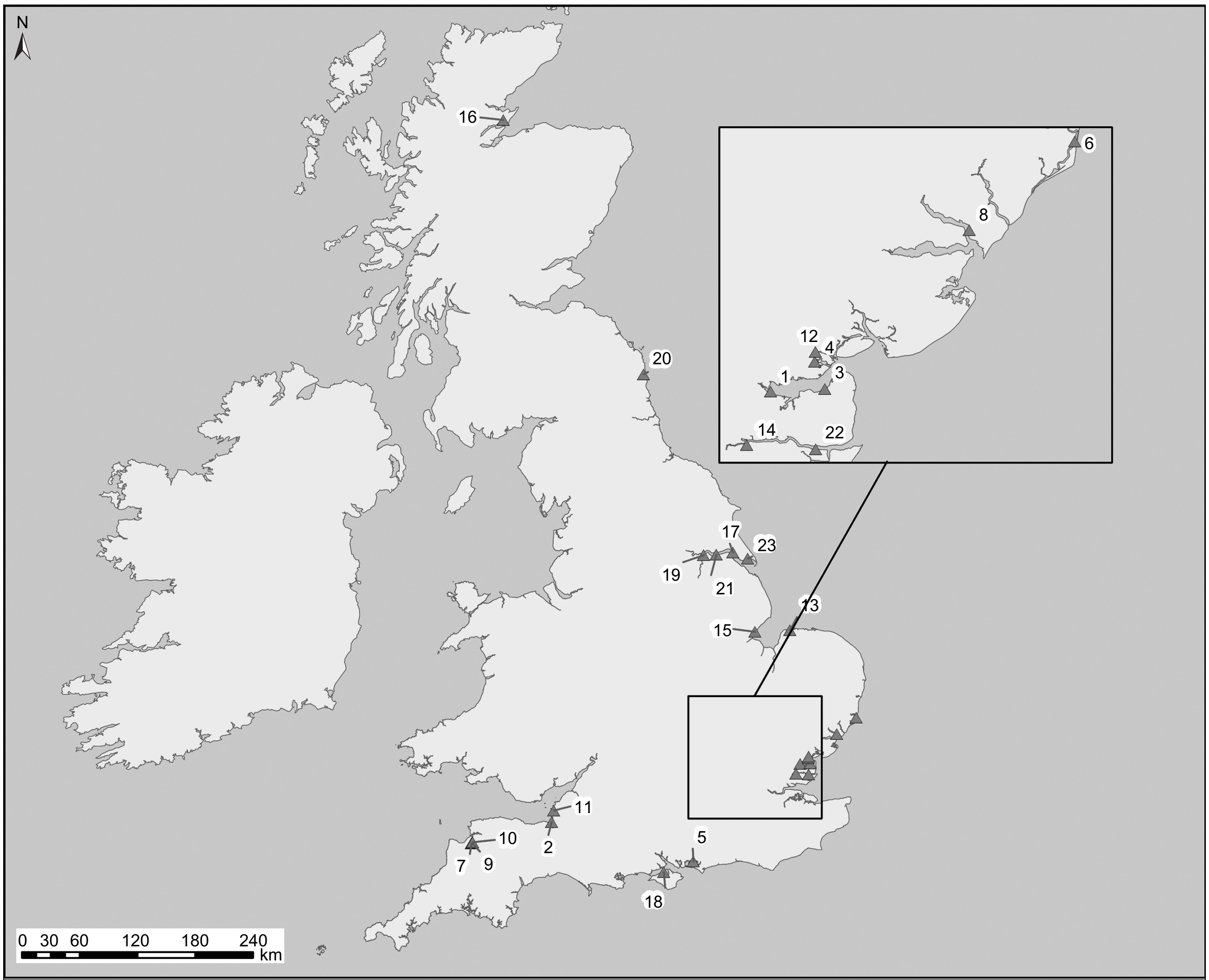


Fig. 1. The location of managed realignment schemes in the UK to 2007

(*a*) adversely affect the local economy through loss of visitors, or conversely could result in increased visitor pressure
(*b*) cause damage to local wildlife interest (on arable fields)
(*c*) prevent access to a small shingle beach
(*d*) affect possible archaeological interest.

Public opposition by local residents and their elected representatives meant that chances of securing planning permission were too uncertain to make the project viable. It resulted in a substantial delay and the need to re-assess the options and look for an alternative site: a process that took several months. Such experience clearly shows that managed realignment will not always be possible and that there are limits to the costs that can be incurred in taking forward such an option. This may of course mean that alternative approaches such as no active intervention[9] of defences are adopted.

Further reviews were undertaken to reconsider alternative sites and to determine whether there were any suitable alternatives to Weymarks. Thirty-one possible sites were investigated and a shortlist of five was identified.[10] The Wallasea Island site held several advantages.

(*a*) The owner, Wallasea Farms, was aware that its flood protection was in a parlous state in places and it had already taken the precaution of creating a new floodbank and potential realignment site amounting to some 54 ha.[11]
(*b*) There was positive public consultation feedback.
(*c*) There was little evidence of archaeological interest and protected species.
(*d*) Provision of more accommodation space met important flood risk management benefits identified within the Crouch and Roach flood management strategy, which was developed with extensive public consultation.

3. SITE SELECTION: KEY CONSIDERATIONS

In its ideal form, managed realignment should involve a minimum of engineering apart from breaches in the sea walls. Such scenarios are rare because flood cells in key realignment areas are often too big to realistically realign, or contain elements of infrastructure that cannot readily be moved. Consequently, there is a strong likelihood that a new sea wall will be required. Options that significantly reduce the length of sea wall that require maintenance are therefore the most logical solution, although this cannot be established as an over-riding rule.

Depending upon the time between sea wall construction and the decision to realign, land behind sea walls will often be lower in

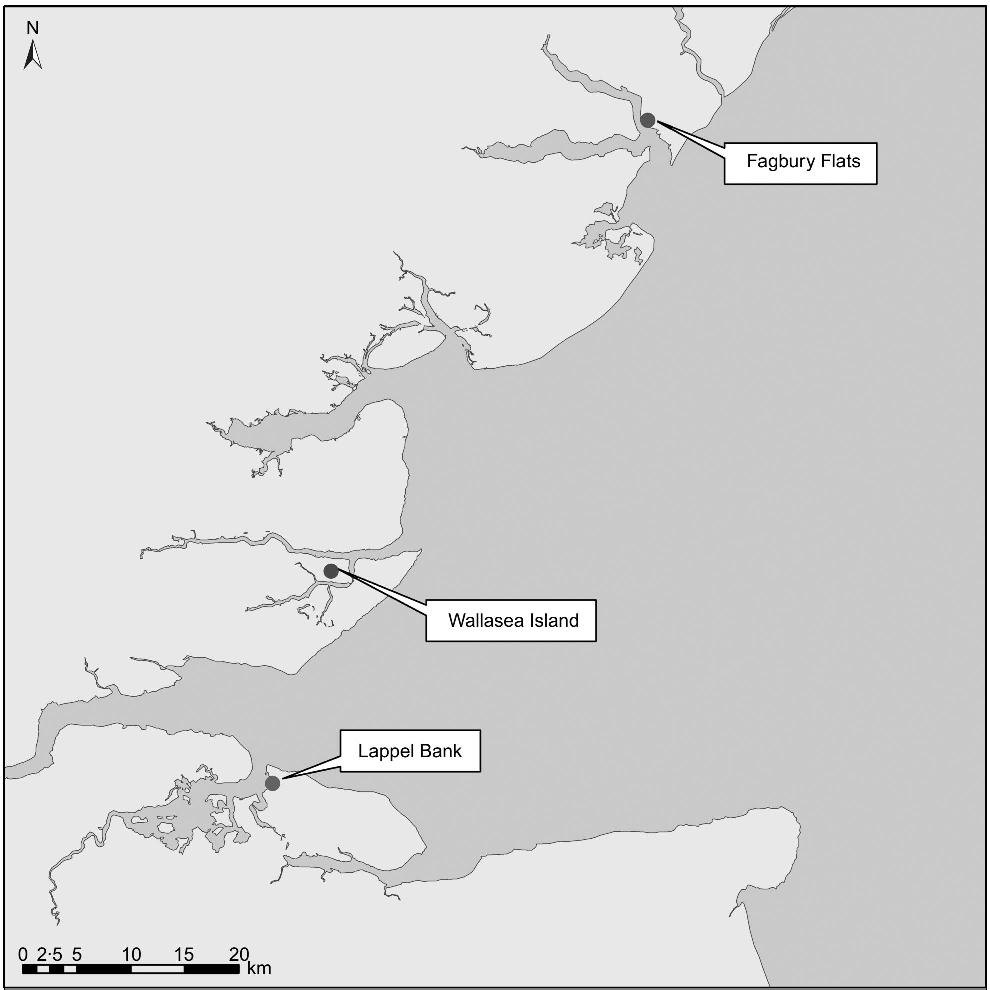


Fig. 2. The locations of Fagbury Flats, Lappel Bank and Wallasea Island (south-east England)

the tidal frame than existing saltmarsh and mudflat. There are several reasons for these differences.

(*a*) Saltmarsh removed from tidal influences shrinks through de-watering and oxidation of organic elements.
(*b*) Saltmarshes and mudflats continue to accrete on the seaward side of the wall in conjunction with sea level rise.
(*c*) When grazing marsh was converted into arable, it was flattened and former channels (reens) within the marsh were in-filled by re-distribution of soils.

Not infrequently the topography actually slopes landwards the further it lies behind the sea wall. This is because land-take often happened at different times and the older sections have been exposed to change for a much longer period. Thus, if multiple land-take occurs the furthest inland points will be lower-lying. Meanwhile, saltmarshes still subjected to tidal influences will continue to increase in elevation as sediment is deposited. A good example of this phenomenon is the Alkborough realignment where the land closest to rising land is the lowest lying.

The position of possible realignment sites in relation to the tidal frame is of considerable importance both to engineering design and to potential nature conservation outcomes.[12,13] It also has possible implications for estuarine morphological evolution, navigation channels, sea wall stability and in some cases to local economies.

(*a*) *Potential nature conservation outcomes*. The position of realignment in the tidal frame will be the key factor behind the nature of habitat created. Lower-lying land will form mudflats or possibly even ponds, whereas the highest level land may rarely be inundated and will not form the mid- and upper-zone saltmarshes that are often desired. These outcomes will provide different habitats such as inter-tidal mudflats for feeding birds, tidal lagoons, creeks and stable ponds for fish feeding and nursery areas, and upper zone marshes for roosting and nesting birds, reptiles and mammals.
(*b*) *Engineering design*. Where sea walls are not fronted by saltmarsh they are far more vulnerable to erosion, especially during the early period of establishment. Ideally, a realignment site should have the profile that allows saltmarsh to develop in front of the new wall (i.e. land rising towards the point of the new wall with heights commensurate with the levels of tidal inundation that favour saltmarsh development). This marsh will absorb wave energy (as illustrated in Fig. 3). If it is not possible to create saltmarsh early on, armouring walls is likely to be necessary; which involves a significant increase in costs. Where realignments are lower in the tidal frame they will take much longer to accrete towards the desired result of saltmarsh fronting the sea wall, even where sufficient sediment is available. Creating creeks and dendritic systems can help mudflat development by increasing drainage and habitat complexity, but ultimately the morphology will change as the mudflats evolve. Deeply incised channels should be avoided because the lack of gradual slopes and reduced plant growth at margins provide fewer refugia and are less favourable for fish populations.
(*c*) *Estuarine morphological evolution*. The size and position in the tidal frame will dictate the volume of water entering a realignment site. This can affect sediment availability and can lead to lower rates of accretion. Extreme examples include bank failures within the Blyth estuary in Suffolk during the twentieth century. In this extreme example an estuary that was effectively a canal has assumed the form of a ‘bladder’ as a consequence of bank failures, with a very narrow canalised mouth now opening into a considerable expanse of open water that has accreted slowly and supports very little saltmarsh.[14] It is worth bearing in mind that a big

Fig. 3. A former sea wall at Tollesbury. The eroding side is within the realignment site and illustrates the impact of internal wind-driven waves. On its outer face there is no erosion because of the energy absorption of adjacent saltmarsh

realignment site on a relatively small estuary could increase the tidal prism by several million cubic metres and this has the potential to shift the duration of flood and ebb tide durations. Were this to happen, the overall regime of sediment deposition and erosion could be affected, with potentially important and detrimental consequences for existing habitats and, of course, for other infrastructure such as flood banks. In such situations, there may also be a need to widen the estuary at key pinch-points and this is something that must be addressed as part of an estuary-wide flood risk management strategy.

(*d*) *Sea wall stability*. A realignment that significantly changes tidal prisms, or affects the position and speed of major flood or ebb channels has the potential to erode mudflats/saltmarshes fronting other sea walls. In such situations, there is a risk of bank failure elsewhere.

(*e*) *Economic implications*. Many estuaries support small but viable oyster fisheries; there is one example of a realignment, at Freiston in Lincolnshire, that led to significant damage to an oyster farm. This is a frequent matter of concern to local fishermen and is best resolved by regular communication, sound modelling and breach design geared to minimising currents on flood and ebb tides (bigger breaches also help to establish flood dominance over new mudflats). Similar concerns may also be encountered from the sailing community, especially in relation to the impacts on swinging moorings and buoys that are important Harbour Authority responsibilities.

The site selection process for the Wallasea site was very unusual but is illustrative of the efforts required to identify a location that meets particular design criteria. Other projects have not encountered the same level of difficulty, but compensation sites must meet clear design parameters that may also involve the need to create mudflat rather than saltmarsh. Where critical design criteria limit the range of options for suitable sites, projects can be vulnerable to commercial pressure such as the value an owner might demand for suitable land. Historically, this has occasionally resulted in very costly packages in which the benefits to wildlife have been achieved at a disproportionately high price per hectare of habitat created (there is sensitivity about these cases and consequently they are not quoted). Examples of this nature can lead to higher project costs that inevitably reduce the scope for habitat creation from what is often a limited budget for direct intervention.

4. DESIGN: PHYSICAL PARAMETERS

Realignment sites requiring significant engineering of new floodbanks are highly reliant upon a sound knowledge of the topography of the site and identification of critical ground conditions such as the presence of relict creeks that might cause structural instability to new walls. Even where surveys are exhaustive, problems will occur, as was experienced at Wallasea when a section of the new wall slumped because it crossed a relict creek that was totally obscured by surface conditions. Problems of this nature are most likely to arise where deep creeks have been infilled to create surfaces suitable for arable production. Where problems do occur, they can be costly and there is a need to factor the risk into cost estimates for the project.

Prior to project planning, design and construction, it is also important to have clearly identified the locations and sizes of proposed breaches. The size of breaches is inevitably a compromise between the practicalities of breaching along a long length of wall or at various locations along the wall and the implications such breaches will have on current velocities. A key to this is the need to undertake hydrodynamic modelling[15] to determine current velocities and to achieve optimal breach sizes. In the case of Wallasea Island, modelling outputs were ground-truthed against natural features and drew on local knowledge. This helped to reassure sceptics that the outputs were realistic and believable.

When breaches are first created, it is important to ensure that they are significantly wider than the projected regime width of the ebb channel. This is because past experience has shown that modelled current speeds can be misleading and the greatest risks lie in the creation of excessive ebb currents that may cause scour and changes to the position of main channel currents in the adjacent estuary. Over time, sedimentation should reduce the tidal prism and the breach width is likely to adjust to reflect these changes.

At Wallasea Island, the new walls were created from material won on-site. This is not always possible, but is the cheapest source of materials. The best engineering clays were confined to particular horizons within the site and thus a very large area was explored for suitable materials. The walls were constructed in a two-stage process, with initial placements to 50% of the design height before being allowed to settle and consolidate post-compaction before a second period of construction commenced. During this period, the gain in strength of the founding material was monitored using piezometers installed at 400 m intervals along the 2 km length of the construction but this may vary elsewhere according to ground conditions. Wall integrity was further assisted by the use of Enkamat, a geotextile used to stabilise the seaward face of the wall that is bound into the fabric of the wall once vegetation cover has been established. This approach contrasts with other projects such as the realignment at Chowder Ness, which was prepared in a shorter time-frame and used pre-cast concrete revetment to secure wall integrity.

During the design and construction process attention to risk is fundamental, with particular concerns surrounding the breach event. At Wallasea, the site was divided into three compartments for a number of reasons, many of which relate to risk management.

(*a*) The length of wall to be breached and the size of the site meant that there would have been significantly greater risks to people involved, had the design involved a single compartment.
(*b*) Three units allowed the earthwork team to gain in experience and meant that sufficient machinery was available.
(*c*) The compartmentalised site allowed for the inclusion of sufficient escape routes for construction machinery, people and animals.
(*d*) A requirement to maintain access points on existing sea walls for sports fishermen.

Breaches were developed by peeling down the walls over a 2 week period following the peak of the spring tide, leading to completion of the breach on the weakest neap tide. This was achieved over 2 months, with separate breach events in June and July 2006.

Design of the topography at Wallasea Island involved the creation of a clay bund (Figs 4 and 5) to create conditions suitable for saltmarsh development and provision of energy attenuation in front of the new sea walls. The bunds were designed to contain 550 000 m^3 of dredged material supplied by Harwich Haven Authority derived from the maintenance of approach channels to the port of Felixstowe and supplied as fluid mud pumped from a dredger moored offshore. This bund was required to maintain its integrity until the dredged material had consolidated, but was also expected to be allowed to erode in due course. It was made of less suitable engineering clays and as a result did present problems with risks of failure. The first stage where failure was anticipated was during the placement of dredged material and in the final event the volume of material placed in the bund differed according to the estimated strength of the retaining bund. Each bund section was constructed to a height of 130 mm above design height to allow for compaction, and included shallow grips (channels approximately 1 m wide cut to allow water run-off) at 50 m intervals along the lip of the bund to allow run-off of water as the dredged materials consolidated. Subsequent experience showed that there was a need for gripping at 25 m intervals. Remedial action was necessary and it was also necessary to lower the lip of the bund.

Bearing in mind the current novelty value of realignments and their high wildlife potential, it is also worth considering the need to build into the overall design provisions for visitors and car parking. For example, the realignment at Wash Banks (Freiston Shore) in North Lincolnshire has generated over 50 000 visitors in 2002 and 2003, respectively, and is perceived to have been a significant generator of income to the local economy.[16] Although the numbers visiting Wallasea are not yet known, it has proved to be such an attraction that the landowner (Wallasea Farms Ltd.) and Defra have constructed bespoke parking facilities.

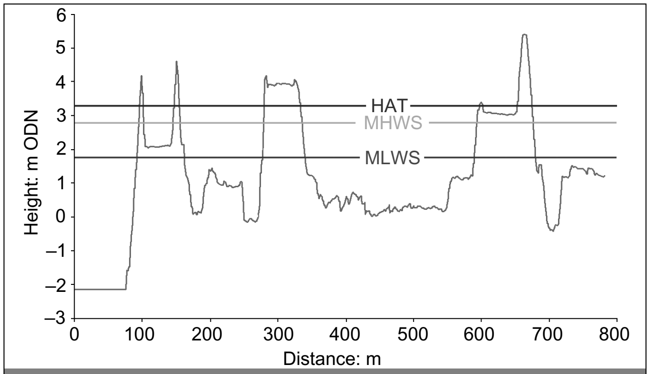


Fig. 4. Cross-section of the managed realignment site at Wallasea based on light detection and ranging (Lidar) profiles: HAT, highest astronomical tide; MHWS, mean high water springs; MLWS, mean low water springs

5. DESIGN: ENVIRONMENTAL PARAMETERS

Wallasea Island, in keeping with most other sites created as compensation for habitat loss, was designed specifically to create sufficient habitat to offset that used by birds at Lappel Bank and Fagbury Flats. Thus, the over-riding concern was to create a system that comprised saltmarsh and actively accreting mudflats for a specific assemblage of birds (Tables 2 and 3).

Where sites lie too low in the tidal frame, it is possible to use placements of dredged material to raise the levels of sediment to heights that are sufficient to create saltmarsh. The construction of a bund, as described earlier, is likely to be necessary, however, except where a site is relatively small. This is because the volumes of material required are such that it is unlikely to be possible to import sufficient sediment at a realistic cost. Experience at Wallasea Island suggests that if sediment is imported it will colonise quickly; here the signs of colonisation by glasswort *Salicornia* sp., *Spartina* and sea aster, *Aster tripolium*, were evident within the same year where the bunded areas sat at the right point in the tidal frame. As colonisation occurred *before* the site was breached, the seeds of these species must have arrived in the dredged material, as the optimum time for colonisation by saltmarsh plants is in the autumn[17] and there are no obvious alternative ways that they might have been transported.

Large realignment sites can offer a variety of additional advantages based on varying their topography. Deliberate sculpturing to provide proto-channels[17] for water movement through otherwise compacted soils is highly beneficial but not always essential. Low-points will undergo temporary ponding until sedimentation creates even more mudflats, but such ponds can be beneficial to fish fry and can accelerate the value of the site as a fish nursery. In eastern England, flounder (*Platichthys flesus*), herring (*Clupea harengus*), sand smelt (*Atherina presbyter*), thick-lipped mullet (*Chelon labrosus),* common goby (*Pomatoschistus microps*) and bass (*Dicentrarchus labrax*) are the principal beneficiaries. In addition, higher ground topped with shingle can provide important roosts for wintering waders and breeding sites for terns (*Sternus* sp.) and ringed plovers (*Charadrius hiaticula*).

At Wallasea Island, material excavated from the breaches in the old sea walls was also placed within the realignment site as unconsolidated island features which are expected to erode (as a

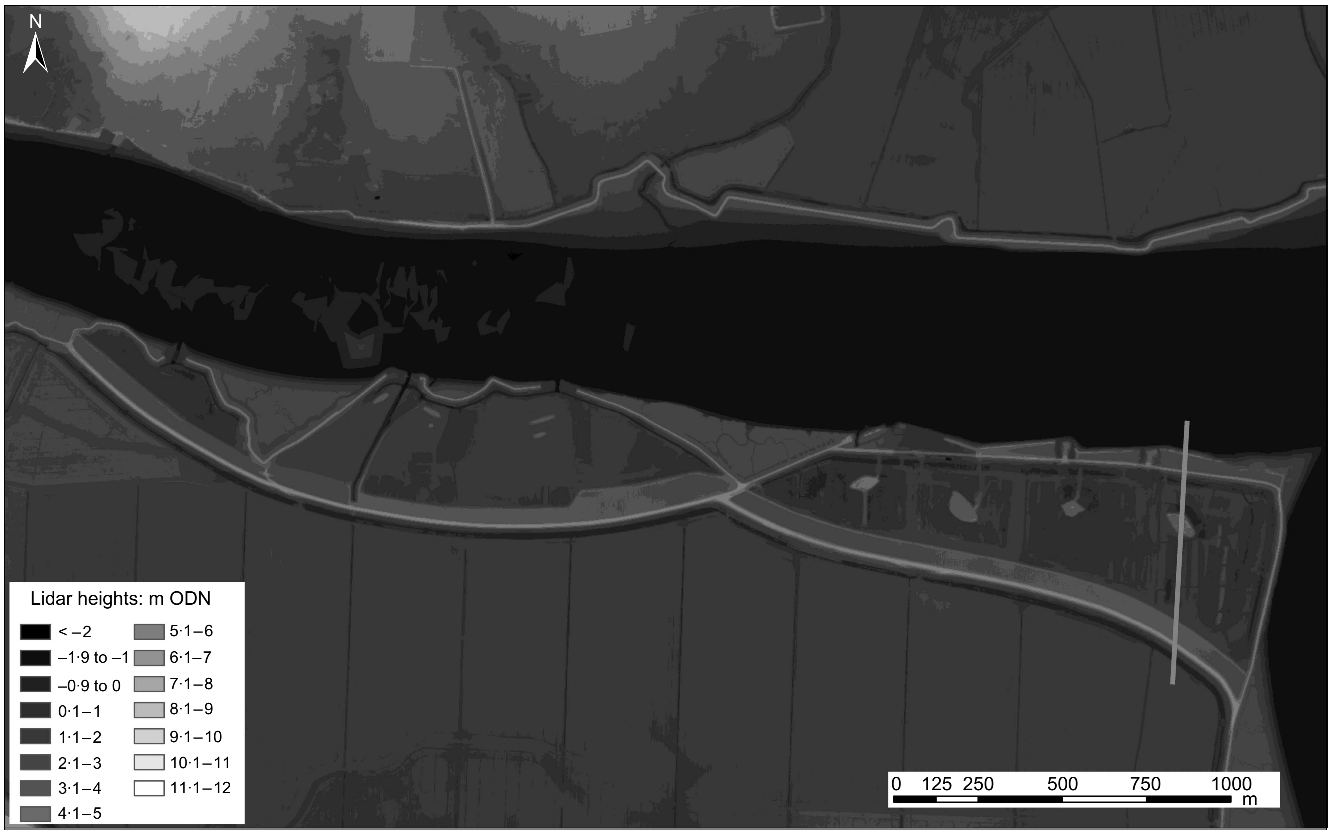


Fig. 5. Light detection and ranging (Lidar) image of the Wallasea realignment site showing the location of the cross-section depicted in Fig. 2

result of wind-driven internal waves) and contribute sediment to the evolution of the site. Remains of concrete revetment have been placed such that these islands are likely to remain in situ for some while. The choice of location for the islands was based on the need to optimise the distance over which material from the breaches was transported and to make temporary use of the features as a roosting and possible breeding site for waterfowl. Their location, close to the mouth of the breaches also serves to intercept and deflect wave activity that might otherwise cause internal erosion during the early stages of the evolution of the site; that is, before saltmarsh has developed on the walls to the rear of the site.

Many former sea walls were created by excavating a borrow-dyke (ditch) to the rear of the sea wall to provide material for the wall. The resulting dykes are now important linear features along much of the coast of eastern England. There are a variety of reasons for this importance, but a major factor is that most are brackish. This salinity is a result of several factors, including percolation through/under sea walls, leakage of saline water

Primary objectives

(*a*) An assemblage of roosting waterbirds, comprising, on a 5 year mean peak basis, at least 3600 waterbirds in similar proportions to those historically supported by Fagbury Flats, in particular ringed plover, grey plover, dunlin and turnstone.
(*b*) An assemblage of feeding waterbirds, comprising, on a 5 year mean peak basis, at least 2800 waterbirds in similar proportions to those historically supported by Lappel Bank and Fagbury Flats, in particular shelduck, dunlin and redshank.

Secondary objective

(*c*) The habitat characteristics that provide the opportunity for the full assemblage of waterbirds to feed and roost within the site
(i) Soft inter-tidal mudflats
(ii) Saltmarsh: this should be higher saltmarsh generally suitable for roosting waterbirds
(iii) A range of islands with appropriate capping material; that is, shingle, cockles and mud, to provide suitable habitat for roosting waterbirds
(iv) Limited disturbance: for example, through the prevention of wildfowling, casual access; speed boating on or over the intertidal areas created.

Table 2. Key objectives for birds and habitats at Wallasea Island

Species	Lappel Bank	Fagbury Flats	Lappel Bank and Fagbury Flats (combined)
Cormorant	2	3	5
Dark-bellied Brent goose	3	80	83
Shelduck	108	3	111
Mallard	5	4	9
Oystercatcher	70	23	93
Ringed plover	15	9	24
Grey plover	6	34	40
Lapwing	0	467	467
Knot	—	9	9
Snipe	0	9	9
Dunlin	1012	325	1337
Curlew	288	1	289
Redshank	192	100	292
Turnstone	8	22	30
Total	1709	1089	2798

Table 3. Waterbird count data for Lappel Bank and Fagbury Flats

Process	Timescales
Site selection and purchase	Unusually this took several years due to the project's size, novelty and complexity. More typically, it took about 12 months in the latter stages of the process (which was greatly facilitated by having an emerging Environment Agency flood management strategy). Generically, this stage is highly variable and depends on several factors of which the most critical are the availability of strategic flood management guidance; land owner responses/involvement and the views of the local population
Site investigations, project design and environmental impact assessment (EIA) preparation	12 months
Seeking consents	12 months (about half of which can be concurrent with the EIA process)
Major earthworks for new coastal defence and recharge bund	3 months per km
Placement of dredged material to elevate ground levels	4 months in two separate tranches that avoid reduced day-light and poor conditions of mid-winter November/ December and February/March
Settlement, consolidation and vegetation of walls	12 months (ideally) but can be accelerated by engineering
Breaching window	2 weeks (between top of spring tide and bottom on neap tide) in two separate tranches at Wallasea
Post-breach hydrodynamic studies for impact verification monitoring	6 months (minimum) to validate hydrodynamic predictions and evaluate channel morphological changes
Post-breach hydrodynamic studies for site success monitoring	5 years (ideal minimum) ornithological/ecological monitoring to confirm the site has met pre-determined waterbird compensation targets (where relevant)

Table 4. Indicative timescales involved in creating managed realignment schemes (based on Wallasea Island scheme)

through flap valves and saline leaching from surrounding soils. Today, this network of linear lagoons supports an important suite of aquatic invertebrates, especially flies, water beetles and true bugs that are specialists of brackish conditions. Furthermore, many support animals and plants that are usually regarded as denizens of saline lagoons, an annex 1 habitat under the EC Habitats Directive.

At Wallasea Island, however, borrow dykes are of even greater importance because they are wide and lie within a strip of uncultivated land some 50 m wide. The uncultivated strips of rough grassland have proven to be important breeding grounds for a variety of wading birds such as redshank (*Tringa tetanus*) and oystercatcher (*Haematopus ostralegus*). The project design therefore sought to re-create lost borrow dykes and to design them with breeding birds in mind.

Central islands have also been created with surrounding channels of variable depth and bank profiles that provide shallow water and rising ground. This habitat, which supports a wide range of emergent and submerged vegetation, is important for water voles (*Arvicola terrestris*); a protected species that is under severe threat from habitat loss and predation by North American mink (*Mustela vison*),which have colonised after escaping from fur farms.

6. PROJECT MANAGEMENT

The safe delivery of a successful realignment project centres upon good project management, the competency of the contractors and a clear understanding of the process to be followed. At Wallasea, a clear business case was written to set clear objectives and to maintain business continuity in the event of the loss of the project manager. In addition, a business plan defined responsibility for particular actions and when they should be delivered. The Wallasea project also benefited from the establishment of a project team drawn from regulators, advisors and the voluntary sector. This team helped to provide appropriate skills when required and could be called upon to help to resolve particular problems relating to their organisation or specialist area. Responsibility for decisions on the final design, day-to-day operations and liaison with contractors was solely the responsibility of the project manager.

Once underway, realignment projects are also vulnerable to a variety of key pinch-points within the critical pathway, including clearing of consents in time for weather windows for groundwork, consolidation times for earthworks and coincidence of neap tides with fine weather windows. A description of the windows within the Wallasea project is provided in Table 4 which identifies the timescales involved in the overall process, based on the Wallasea experience. This information should also provide indications of where the major expenditure can be expected and how cash-flow may be planned.

7. POTENTIAL PITFALLS

Although the majority of pitfalls can be readily predicted and resolved through project planning, risk identification and analysis, there are some that cannot always be identified in advance.

(*a*) *Archaeology*. No significant archaeological problems were encountered because the land for realignment had largely been recently reclaimed; but in some catchments with land-claim going back to Roman times, the potential for archaeological interest is greater. Site investigations can be costly and time-consuming and may significantly reduce a project's cost-effectiveness.

(*b*) *Protected species*. The presence of water voles and reptiles such as grass snakes (*Natrix natrix*) and common lizards (*Lacerta vivipara*) may require rescue programmes and habitat recreation to re-accommodate them. Trapping water voles requires licences and the creation of new habitat, and involves the use of skilled operatives. It can therefore be extremely expensive (e.g. at Brancaster the total cost of water vole rescue was £50 000).

(*c*) *Invertebrates*. At Wallasea Farm, the fly *Dorycera graminum*, a Biodiversity Action Plan species,[18] was found during site surveys and this raised concern from the non-governmental organisation 'Buglife' about the need for the project and alternative options. In reality, the extent of breaches on the existing sea wall was such that these concerns could be allayed, but delays were incurred as a result.

(*d*) *Navigation and shellfisheries*. Concerns about impacts on commercial and recreational navigation have been raised on various occasions and although they are generally resolvable they can involve significant tension with local communities. As discussed earlier, the Freiston Shore realignment encountered problems when it was found that an unconsented and therefore unknown oyster fishery was partly washed away by ebb tides that were greater than predicted (parts were also negatively affected by increased sedimentation). In this respect it is important to get the design right to minimise the velocity of ebb tides.

(*e*) *Visitor interest*. During construction, a realignment site can be a dangerous place, especially where dredged material is placed in bunded settling lagoons. It is important to take account of the likely public interest and the risk that individuals may stray into the most dangerous areas. Fencing, signposting and way-marking are essential.

8. WIDER BENEFITS OF REALIGNMENT

The Wallasea Island scheme provides some useful insights into the commercial justification for the construction of new floodbanks. The economic case for creating new flood banks is low in terms of the use of government funds because the site fails to meet priority scores for funding according to current guidance.[19] However, of the 17 km of floodbanks that surround Wallasea Island, 2 km were in a particularly parlous state. The most vulnerable 2 km of flood banks safeguard over 800 ha owned by a single landowner who found it economically viable to invest in the construction of a secondary defence that would have become the primary defence in the event of a breach; the cost was over £1·8 million. Landowners with this approach are the most likely to be receptive to the concept of realignment and to be interested in a partnership approach, as we found at Wallasea.

In eastern England, recent realignments have benefited from the work of the Environment Agency on estuary shoreline management plans (ESMP) and related flood defence strategies. This is particularly noteworthy on the Humber[20,21] where the highest concentration of realignments has occurred in recent years. These programmes have included significant levels of modelling that are a considerable aid to understanding the factors influencing options for realignment. Examples on the Humber are particularly illustrative and consequently they are worth considering in a little more detail.

The realignment at Alkborough on the Humber was not dissimilar to Wallasea Island because the majority of landowners recognised (as a result of the ESMP) that there were advantages to working positively with the Environment Agency. They therefore agreed to sell their land at acceptable rates. Not all landowners take a similar approach. To date it has proved very difficult to encourage landowners to accept realignment as a desirable option; this too is a general public perception as realignment is seen as giving land up to the sea rather than as a realistic economic response to the cost of flood risk management.

Although the over-riding driver for managed realignment was originally promoted to secure coastal stability,[19] the arguments in favour of individual realignment have often concentrated upon habitat creation and nature conservation benefits. The one exception is the Humber estuary shoreline management plan,[21] which includes provisions for managed realignment and has succeeded because the socio-economic benefits of realignments have been identified. Improved flood storage responses to surge tides have been identified and the recent realignment at Alkborough includes spillways to absorb surge tides. This is one of three flood storage schemes that are predicted to reduce surge tides by up to 100 mm.[22]

The Alkborough project and the response of Yorkshire Forward (the region's Regional Development Agency) to the demonstrable economic benefits of realignment are illustrative of the gulf between public perceptions and the economic realities facing flood risk managers. In this case, a contribution to funding for the Alkborough project was provided by Yorkshire Forward because it was seen to deliver long-term flood risk management benefits to the wider catchment of the Humber estuary.[23,24] Realignment geared solely towards nature conservation is likely to meet with resistance because the benefits to the individual and to the community are not clear and are not generally viewed positively whereas projects that reduce flood risk gain much wider support. If realignment is to become a more regularly used instrument then its wider economic and social benefits need to be captured and disseminated without heavy emphasis on nature conservation benefits that will emerge incidentally.

ComCoast (http://www.comcoast.org/) has investigated the wider economic and social benefits of managed realignment and other multifunctional flood risk management techniques. Social and recreation benefits, the contribution of realignment to carbon sequestration, and benefits to commercial fisheries have been given particular attention. In addition, the potential for coastal farm diversification options has been considered. Most emphasis has concentrated on the realignments in Essex, especially within the Blackwater estuary, and in particular fish usage.

Colclough *et al.*[25] describe studies on a number of the early managed realignment sites in Essex, including Tollesbury, Orplands and Abbotts Hall. Further work (unpublished) indicates similar high utilisation of extant marshes at several UK locations. All of this work tends to confirm earlier studies in Mont St. Michel Bay, France[26] that saltmarshes present the preferred nursery grounds for juvenile fish species such as bass. Wallasea Island is the first realignment in the UK in which this understanding was taken into account at the design phase to maximise fisheries benefits. There are now semi-quantitative studies underway elsewhere to further refine our understanding of the roles of saltmarshes and mudflats as nursery areas.

The implications of this work on fish populations are that in many coastal and estuarine waters, water quality impacts are less of an impediment to fish productivity than the absence of suitable saltmarsh habitat. It is now possible that the EU Water Framework Directive (20/60/EC)[27] will become an important driver for creation of new intertidal marshes if 'good ecological status' is to be achieved. It is also possible that if the value of fish productivity can be more clearly defined, future saltmarsh creation projects may be eligible for European Fisheries Fund support.

9. COMMUNICATION AND PUBLIC LIAISON

Realignment is still a relatively unknown quantity amongst the public at large and is likely to evoke concerns for some years to come. There is therefore a need for the project's management to remain accessible and to meet concerned parties. From the onset, it is worth bringing up to speed the officers and elected members of the local authority who will determine consents. At Wallasea, the project manager (M.D.) not only held public meetings but also met concerned individuals on a one-to-one basis. This approach paid dividends as various detractors subsequently became positively supportive of the project.

A communication strategy is essential. Consider when and how information is to be disseminated. At Wallasea, it was found that clear visual aids and computer-generated graphics that showed how the site would behave were highly beneficial in explaining what was proposed and what was expected to happen. Elsewhere, regular newsletters have proved to be helpful and the Alkborough project also benefited from the creation of a liaison group that has met regularly with local representatives throughout the duration of the project; it is important to remember that construction can involve a lot of plant and machinery with potential disruption to communities. Furthermore, this approach is beneficial in developing after-use strategies which may be essential in the case of larger sites that are likely to be developed in future.

10. MONITORING

Monitoring is an essential part of any managed realignment scheme, making it possible to determine whether project success criteria have been met. At Wallasea the purpose has been to determine whether the site meets its compensation targets (site success monitoring), and to verify the findings of modelling work (impact verification monitoring). This work is needed to ensure that the physical and ecological changes in the adjacent Crouch and Roach estuaries conform to the limits predicted in the environmental impact assessment.

A comprehensive 5 years monitoring programme is underway. It commenced in February 2006 (5 months prior to the breaching work to establish a baseline dataset) and will continue until December 2012. Monitoring includes bird populations, benthic, aquatic and terrestrial invertebrates, juvenile fish and saltmarsh vegetation. Benthic invertebrate monitoring within the realignment site focuses upon biomass, which is fundamental to bird usage; feeding bird data will also provide confirmation that benthic communities are developing as expected. Sufficient information already exists on the process of benthic recolonisation and this was not pursued further (as a cost reduction measure). Other parts of the monitoring programme are designed to help to provide a better understanding of the overall evolution of a new site and its relevance both to ecosystem function and to colonisation of newly created habitats.

Physical monitoring at Wallasea comprises inter-tidal and sub-tidal morphology, current speeds and tide heights. It also involves issues such as stability and integrity of breaches, sea walls and clay bunds. Current speed data to confirm the rate of water flow through the breaches and changes to current speeds in the estuary are particularly valuable in validating the hydrodynamic studies and also to allay stakeholder concerns about potential effects on navigation channels in the estuaries.

If lessons are to be learnt from past realignments, it is important that the results from monitoring studies are fed back into the design and implementation of future schemes. As realignment is still in its infancy, and as no two sites are ever the same, schemes still require monitoring on a site-specific basis. The Wallasea realignment scheme has benefited from the knowledge and experience of those members of the project management group who have worked on previous realignments. After completion of the 5 years monitoring period, the performance of the site will be re-assessed to determine whether any further work is needed. This learning process has been opened to a wider audience through the establishment of a website http://www.abpmer.net/wallasea/, which is also intended to act as a collection point for wider managed realignment information.

ACKNOWLEDGEMENTS

During the development of this paper the authors have drawn upon the experience of colleagues and partners involved in realignment projects. They would like to thank Juliet Austin (Defra), Sarah Coles, Chris Davis, Audrey Jones and Steve Parker (Natural England), Trazar Astley-Reid (Environment Agency), Andrew Bell (Devon County Council) and Susanne Rupp-Armstrong (ABPmer) for providing relevant information and helpful comments on the text. They also thank two unnamed referees whose comments have helped greatly to refine this account.

REFERENCES

1. Department for Environment Food and Rural Affairs. *Making Space for Water: Taking Forward a New Government Strategy for Flood & Coastal Erosion Risk Management.* Defra, London, 2005. See http://www.defra.gov.uk/environ/fcd/policy/strategy/firstresponse.pdf. Accessed 03/09/2008.
2. Burd F. *Managed Retreat: a Practical Guide.* English Nature, Peterborough, 1995.
3. Leggett D. J., Cooper N. and Harvey R. *Coastal and Estuarine Managed Realignment—Design Issues.* CIRIA, London, 2004, pp. 215.
4. Morris R. K. A., Reach I. S., Duffy M. J., Collins T. S. and Leafe R. N. On the loss of saltmarshes in south-east England and the relationship with *Nereis diversicolor*. *Journal of Applied Ecology*, 2004, **41**, No. 5, 787–791.
5. Garbutt R. A. and Reading C. J. *Managed Realignment at Tollesbury Annual Report 2006–2007.* Centre for Ecology and Hydrology, Monks Wood, 2007, CEH Project C 00356 (Defra Project Number 1922).
6. The Council of the European Communities. Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds. *Official Journal of the European Communities*, 1979, L103.
7. English Nature. *Greater Thames Estuary Coastal Natural Area Profile.* English Nature, London, 1997. See http://www.english-nature.org.uk/science/natural/profiles/naProfile 67.pdf. Accessed 03/09/2008.
8. ABP Marine Environmental Research Ltd and British Trust for Ornithology. *Lappel Bank and Fagbury Flats Compensatory Measures: Phase 1. 2002.* ABP Marine Environmental Research Ltd, Southampton, 2003.

9. Department for the Environment, Food and Rural Affairs. *Shoreline Management Plan Guidance Volume 1: Aims and Requirements*. Defra, London, 2006. See http://www.defra.gov.uk/environ/fcd/guidance/smpgvol1.pdf. Accessed 03/09/2008.
10. ABP Marine Environmental Research Ltd. *Lappel Bank and Fagbury Flats Compensatory Measures: Phase 1 Site Selection Revisited*. ABP Marine Environmental Research Ltd, Southampton, 2003.
11. ABP Marine Environmental Research Ltd. *Wallasea Island North Bank Realignment: Environmental Statement*. ABP Marine Environmental Research Ltd, Southampton, 2002. See http://www.abpmer.net/wallasea/media/reports/R1114%20Final%205%20Nov%2004%20-%20%20Wallasea%20ES.pdf. Accessed 03/08/2008.
12. Wolters M., Bakker J. P., Bertness M. D., Jefferies R. L. and Möller I. Saltmarsh erosion and restoration in south-east England: squeezing the evidence requires realignment. *Journal of Applied Ecology*, 2005, **42**, No. 5, 844–851.
13. Wolters M., Garbutt A. and Bakker J. P. Saltmarsh restoration: evaluating the success of de-embankments in north-west Europe. *Biological Conservation*, 2005, **123**, No. 2, 249–268.
14. Morris R. K. A. Sustainable estuary management for the 21st century. *Proceedings of 'Dunes and Estuaries 2005': International Conference on Nature Restoration Practices in European Coastal Habitats, Koksijde, Belgium, 19–23 September 2005* (Herrier J.-L., Mees J., Salman A., Seys J. van Nieuwenhuyse H. and Dobbelaere I. (eds)). Vlaams Instituut vor de Zee (VLIZ), Oostende, Belgium, 2005, Special Publication, 19, pp. 569–579.
15. Townend I. H. Breach design for managed realignment sites. *Maritime Engineering*, 2008, **161**, No. 1, 9–21.
16. East Midlands Regional Assembly. *Wash Banks Flood Defence Scheme*. EMRA, Melton Mowbray, 2003. See http://www.emra.gov.uk/what-we-do/regional-communities-policy/success-stories/lincolnshire/flood-defence-scheme. Accessed 03/08/2008.
17. Wolters M., Garbutt A. and Bakker J. P. Plant colonisation after managed realignment: the relative importance of diaspore dispersal. *Journal of Applied Ecology*, 2005, **42**, No. 4, 770–777.
18. UK Biodiversity Group. *Tranche 2 Action Plans—Volume IV: Invertebrates*. UK Biodiversity Group, 1999. See http://www.ukbap.org.uk/UKPlans.aspx?ID=271. Accessed 03/09/2008.
19. Defra. *Flood and Coastal Defence Project Appraisal Guidance FCDPAG3 Economic Appraisal: Supplementary Note to Operating Authorities*. Defra, London, 2004. See http://www.defra.gov.uk/environ/fcd/pubs/pagn/fcdpag3/pag3suppjuly04.pdf. Accessed 03/08/2008.
20. Pethick J. Estuarine and tidal wetland restoration in the United Kingdom: policy versus practice. *Restoration Ecology*, 2002, **10**, No. 3, 431–437.
21. Environment Agency. *Planning for the Rising Tides: The Humber Estuary Shoreline Management Plan*. Environment Agency, Leeds, 2000. See http://www.hull.ac.uk/coastalobs/media/pdf/humberestuarysmp.pdf. Accessed 03/08/2008.
22. Environment Agency. *The Humber Estuary Flood Risk Management Strategy: Consultation Document*. Environment Agency, Leeds, 2005.
23. Yorkshire Forward. *Board Meeting Minutes*. Yorkshire Forward, Leeds, November 2001. See http://www.yorkshire-forward.com/www/view.asp?content_id=508&parent_id=503. Accessed 03/08/2008.
24. Environment Agency, Countryside Agency, English Nature and North Lincolnshire Council. *The Alkborough Flats Project*. Environment Agency, Leeds, undated. See http://www.english-nature.org.uk/about/teams/team_photo/alkborough.pdf. Accessed 03/09/2008.
25. Colclough S., Fonseca L., Astley T., Thomas K. and Watts W. Fish utilisation of managed realignments. *Fisheries Management and Ecology*, 2005, **12**, No. 6, 351–360.
26. Laffaille P., Feunteun E. and Lefeuvre J. C. Composition of fish communities in a European saltmarsh (the Mont Saint-Michel Bay, France). *Estuarine, Coastal and Shelf Science*, 2000, **51**, No. 4, 429–438.
27. European Parliament and Council of the European Union. Directive 2000/60/EC of the European Union and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy. Official Journal of the European Communities, 2000, L327/1.

What do you think?
To comment on this paper, please email up to 500 words to the editor at journals@ice.org.uk

Proceedings journals rely entirely on contributions sent in by civil engineers and related professionals, academics and students. Papers should be 2000–5000 words long, with adequate illustrations and references. Please visit www.thomastelford.com/journals for author guidelines and further details.

Annex C2

Proof of Evidence
of Mr Mark Dixon
for the
Royal Society for the Protection of Birds

29 June 2011

Planning Act 2008

In the matter of:

Planning Application for construction of the Able Marine Energy Park on the South Bank of the River Humber at Immingham, North Lincolnshire

Planning Inspectorate Ref:	**TR030001**
Registration Identification Ref:	**10015550**

CONTENTS

1. SUMMARY

1.1. This is the critical analysis of the Applicant's Cherry Cobb Sands managed realignment compensation site proposal.

1.2. The Applicant's proposal to create a sustainable mudflat of up to 76ha in a 100ha site by conventional realignment design on the Humber is very difficult given that the natural sediment loading is 300g/m^3.

1.3. The Environmental Statement (ES) Volume 2 appear to demonstrate that meeting the prime objective of recreating a sustainable inter-tidal area of mainly mudflat has relied on an unconventional shallow V shaped breach design of 250 m width and an invert level (lowest point) of +2 m ODN (Ordnance Datum Newlyn – national standard for tidal heights).

1.4. Although this design will assist with limiting accretion over the immediate adjacent landward area in the short term, this objective will not be achieved in the medium to long term.

2. QUALIFICATIONS AND EXPERIENCE

2.1. I am Mr Mark Dixon. Since 2009 I have been a self employed consultant providing advice on sustainable wetlands. My clients include the RSPB across the UK, Environment Agency, Dredging International, Thames Gateway Development, Bristol Ports Ltd, Centre for Environment, Fisheries, and Aquaculture Science, Natural England, BBC and Department of Energy and Climate Change and include being a consultant on wetland design, environmental impacts and marine coastal engineering. In 2010 I was appointed as the RSPB's main advisor and consultant on coastal issues.

2.2. Before this I was a project manager for the 800ha Wallasea Wild Coast Project for the RSPB and its project partner Crossrail, for feasibility, design, hydrodynamics, Environmental Impact Assessments (EIA), consents and licences, including Business Case, Project Plan, risk assessment and communication strategy.

2.3. I was also the project manager for the DEFRA 120ha managed realignment site to replace and construct a saline wetland of mainly mudflat in the UK following the original wetland being destroyed by development, including purchase of suitable arable land, design, hydrodynamic assessment, EIA, Business Case, Project Plan, risks, communication to government standard and approval, dealing with all media, obtaining all licences and consents, contract letting, construction and monitoring.

2.4. Over the previous twenty years I worked within flood management, coastal flood defence schemes (eg quantity surveyor for the Thames flood defences) and for ten years (September 1992-2002) I was a senior coastal engineer and project manager to the Environment Agency and National Rivers Authority. During this period I was responsible for developing the concept of “soft engineering”; the use of saline wetland by managed realignment and foreshore recharge to use natural design systems and habitats (beach, mudflat, saltmarsh and transition zones) to manage increasing tidal energies from climate change induced sea level rise and storm surges. The work involved design and construction of twelve realignment sites and the use of 2 million cubic metres of port and harbour navigation dredgings. The role included an international perspective working closely with southern North Sea basin countries, the USA and relationships with Japan, New Zealand, South Africa, Australia and included R&D with major UK universities on coastal issues, working with UK and EU environmental economists. Part of the remit was to manage the change in mindsets by use of the media eg TV programmes including Panorama, Newsnight, national and local news stations, for example “Flooded Britain” produced over a six month period with the BBC Wildlife Unit.

2.5. I was awarded the MBE in 2006 for my role in developing design work for new wetlands and construction on soft engineering.

3. WHAT IS REQUIRED

3.1. As described in the ES Volume 2, Chapter 28 – Description of the Project – the compensation site proposal is to replace protected habitats that will be destroyed by the Application to the north of Immingham and will require the creation of 76ha of mudflats and 14ha of saltmarsh to provide a sustainable compensation area for, in particular, feeding waders and wildfowl. I refer you to Dr Prater’s evidence (paras 5.2-5.6) which describes the ecological function that will be lost and therefore needs replacing.

4. WHAT IS PROPOSED

4.1. Again as described in Chapter 28, a managed realignment of some 100ha at Cherry Cobb Sands on the north of the Humber directly opposite the Application site is proposed. Managed realignment is the removal of a section of an existing sea defence to allow flooding onto the historic flood plain to recreate the original habitat. The Cherry Cobb compensation site is proposed by the Applicant as one of the compensation sites for the direct and indirect losses of inter-tidal areas arising from the Application. The site would be some 3km long with a width varying between approximately 250m to the south and 900m to the north, with a V shaped breach to the south of the site of 250m width at the crest and a lowest level of +2m ODN at the bottom of the V. Immediately to landward of the breach the existing land level of +2.50m ODN would be lowered by 1m to +1.50m ODN to an area of 30ha to provide both a donor area for the new landward sea wall construction and provide by its lower level, for a new mudflat. It should be noted that MHWST (Mean High Water Spring Tide) is +3.40m ODN, MHWNT (Mean High Water Neap Tide) is +1.90m ODN, with existing land levels +2.50m ODN for the majority of the site. This means that high water on Neap tides will not flood into the site as the bottom of the V breach is higher than these tides, and that the water in the site cannot all drain out on any tide as the landward level is lower than the bottom of the V breach.

4.2. As a result of the breach a new sea wall of 3km length will have to be built to limit the proposed managed realigned compensation area and to ensure a 1:200 flood defence standard is still provided (Chpt 28, para 28.2.3 states that the Environment Agency requires this defence standard). It is proposed that the 300k m^3 excavated material from the 30ha lowered area be mixed with lime and cement to overcome potential weakness in this material from high water content before it is finally placed to form the new sea wall. Landward of the new sea wall an existing trapezoidal cross section drainage ditch will be incorporated into the design for land drainage continuity. The new landward sea wall will use 300k m^3 of material excavated from within the realigned area.

Proposal for the creation of the compensation site

4.3. Chapter 28 Description of Project – paragraph 28.1.3 states "The site should also maximise the long term creation of inter-tidal mudflat….creating in excess of 38ha of sustainable mudflat... with a target of developing 76ha….(a 2:1 ratio of creation:loss)… to create substantially in excess of 38ha".

4.4. At paragraph 28.2.10 it is explained that the ground level profiles by lowering are to "maximise the provision of long term inter-tidal mudflat...The actual finished ground levels will be determined following further detailed modelling studies in consultation with Natural England (NE)." But these need to be available now to ensure that an effective habitat can be created.

4.5. In addition paragraph 28.2.11 and Figure 28.3 estimated the ground level after 5 years "...though this will be refined by further detailed modelling…." The modelling must be undertaken now and the results known and presented before any conclusions can be reached on the viability of the Compensation Site proposal.

4.6. The design appears to be based on the theory that strong tidal flows of between 2.4m/sec (metres per second) and 2.6m/sec (Chapter 32 Hydrodynamic and Sedimentary Regime, para 32.6.7) through the breach and 1.6m/sec to 1.8 m/sec close to the breach (para 32.6.18) will prevent or limit sedimentation to the lowered breach landward adjacent areas. However, current strengths of this speed will only be present in the early stages post breaching. As the site responds to these forces so a new creek will be eroded and form through the breach, which will result in lower current speeds which will not be strong enough to limit siltation over a wide area.

4.7. The concept of the breach design takes particular account of potential impacts to seaward to Foul Holme Sands and Cherry Cobb Sands Creek (see location plan at ES Annex 30.2, p16, Figure 1), its location to the south of the realignment area being chosen where the fronting saltmarsh was at its narrowest and therefore there would be less impact on that habitat. It is worth noting that NE assessment of the location states, Chapter 32 Hydrodynamic and Sedimentary Regime, paragraph 32.5.3 "...saltmarsh [at the proposed site including the breach location] is undergoing a period of expansion and encroachment downshore". My site visit on Wednesday 6 June 2012 showed that there appeared to be a very vigorous accretion to the immediate foreshore and onto Foul Holme Sands with aggressive saltmarsh plant colonisation, which further demonstrates that the location for the proposed realignment will accrete rapidly post breaching.

5. POTENTIAL DESIGN PROBLEMS

The breach design

5.1. I refer you to Colin Scott et al (2011) *Lessons Learned from 20 Years of Managed Realignment and Regulated Tidal Exchange in the UK* (attached as Appendix I) and Wallasea paper (attached as Appendix II) as two useful papers in relation to managed realignment sites. Although the tidal conditions and in particular the high sediment loads of the Humber (Annex 32.4 Model Testing of a 90ha Layout, para 4.1.6) at 300g/m^3 are very different from the Wallasea site, the basics of the direct relationship between breach *cross section area and invert level* (as opposed to just *breach width and invert level* – Annex 32.3 - Breach Design, para 3.3.2 - the invert level is the lowest point of the breach where water can flow in or out) and the volume of water to pass through that breach are very pertinent. Basically the smaller the breach the faster the tide will have to flow through it to fill the site.

5.2. Although the breach width of 250m is correct for the estimated water volume of 1.26 million cubic metres (my approximate calculation based on the figures provided by the Applicant's consultants) by having a V shaped cross section with invert, the tidal current through that breach will be accelerated because the V shape presents a smaller cross section. Although this increase in current speed will no doubt assist in the short term in limiting accretion (Chapter 28 Description of Project, para 28.2.27) by washing away settled sediments and hence maintaining mudflat, the Applicant's consultants indicate that these same current speeds will erode through the breach within 5 years to form a creek to the north of the breach cross section (Chapter 28, para 28.2.25, Chapter 32, paras 32.6.8 and 32.6.18) and as that creek forms so the breach cross section will become larger and as a consequence current speeds will reduce and the impact on limiting siltation diminish.

5.3. It is the combination of the V breach cross section with an invert level of +2 m AOD (Above Ordnance Datum) that seems to form the design basis of maintaining a sustainable mudflat (Chapter 28, para 28.2.22, Annex 32.3, paras 3.6.1 to 3.6.3), albeit at a reduced area from the original objective of 76ha to an estimated maximum of 50ha after 5 years (Chapter 28, para 28.2.28, Annex 32.4, para 4.2.5 and Chapter 32, para 32.6.22) including mudflat areas below +2.50m AOD formed within the breach channel itself.

5.4. The invert level of the breach at +2m AOD is higher than the adjacent lowered area at +1.50m AOD. This will mean that not all the water can drain off the site and this will create an area of still water that will actually accelerate the accretion process by enabling fine sediments a longer settling time. The other major impact of the V shape and invert level will be to accelerate ebb tide currents seaward having detrimental impacts to both Foul Holme Sands and Cherry Cobb Sands Creek, since both these areas are within the Humber Estuary SPA/Ramsar/SAC in front of existing sea wall. The Applicant's consultants (as mentioned above and set out in Chapter 28, para 28.2.24) have chosen a creek design system to try and minimise the losses to the designated sites and its features including saltmarsh. Hence one of the reasons for the location of the breach is to minimise the impacts of that existing protected saltmarsh and therefore choosing the area where the saltmarsh is narrowest but actually there is very little difference in the width of the saltmarsh and clarity is therefore sought as to why the proposed breach location is thought to be better for the existing protected saltmarsh compared to other possible locations.

5.5. In addition the proposed design of a V shaped breach within six months to one year will actually accelerate the impacts outside of the Cherry Cobb realignment site (Annex 32.3, para 3.4.9) "major effect … latter part of ebb…high velocity while the water held on the site drains out…" One of the major reasons for the breach design and extreme southern breach location was to limit this impact (Annex 32.3, paras 2.2.1, 2.2.3 to 2.2.5, 3.4.9 and 3.5.7), but in actual fact the V shape and consequent stronger currents will increase detrimental seaward impacts, not decrease them.

5.6. A lot of care and attention has been given to predicted siltation. (Chapter 28, para 28.2.11 and Figure 28.3, Chapter 32, paras 32.6.19, 32.6.24, Annex 32.4, paras 4.1.6 and 4.2.5) with siltation rates estimated for the first 5 years post breach from 800mm to the north of the site to 400mm in Year 1 at points of ground levels +1.50m AOD and 150mm at +2.50m AOD, with Annex 32.4, page 25, Table 11 showing 400mm at year 5 for low points. This same Annex, at page 33, paragraph 5.1.14 states "the predicted changes in ground levels probably have an uncertainty of +/- 50%" which is a very honest statement.

5.7. Annex 32.5 Sedimentation Erosion Saltmarsh Growth, has a summary that indicates that the site will rapidly accrete and form saltmarsh and compares siltation rates at other realigned sites on the Humber, with Paull Holme Strays showing 420mm at Year 5 and states in paragraph 2.4.6 for the Cherry Cobb site "…there remains a high probability that a stable saltmarsh will develop on any managed realignment site on the north bank of the Humber opposite Immingham". This is again a very honest conclusion reflecting that the background suspended sediments are 300g/m^3 of tidal water. Basically the site as designed will not provide the required long or even medium term quantity of mudflat that will be destroyed by the Application.

5.8. The siltation problem and hence less mudflat, may well accelerate with time if the site has been designed to maintain mudflat by enhanced current speed. As the area accretes so the water volume flooding and ebbing from the site will decrease i.e. more mud and therefore less water flowing into and out of the site, and as a consequence current speeds reduce and accretion accelerates. Taking the immediate post breach water volume at 1.26 million m^3 and allowing for an average minimum accretion after 5 years of say 400mm, will give a water volume reduction of some 40%.

6. CONCLUSIONS

6.1. Due to the very high natural sediment loadings in the Humber of 300g/m^3 of tidal water and consequent accretion, any conventional managed realignment design is unlikely to result in large areas of sustainable mudflat in the medium term.

6.2. The proposed design using a 250m V shaped breach with invert level of +2 m ODN will assist in the short term only with maintaining adjacent mudflat habitat. As the enhanced tidal flows through the V breach erode and cut a new creek, so the flow speeds through the breach will reduce and their impact on reducing accretion diminish.

6.3. The invert level of the proposed breach at +2 m ODN is higher than the landward realigned lowered area at +1.50 m ODN therefore not all of the tide will be able to drain from the site, which will create an area of still water at low tide to enable enhanced accretion.

6.4. As the site accretes the swept tidal volume flooding and ebbing from the site will reduce, further accelerating the accretion process.

6.5. The V shaped breach and related enhanced ebb tide current speeds will have a greater impact to seaward to both Foul Holme Sands and Cherry Cobb Sands Creek in the short term than a conventional breach cross section.

6.6. The Applicant's consultants have been very thorough and honest in their assessment of the potential accretion process and therefore it has been recognised that the site location and the design of the managed realignment has limitations on achieving the required habitat.

ISTITUTO NAZIONALE DI BIOLOGIA DELLA SELVAGGINA
BOLOGNA

Atti della Conferenza sulla conservazione delle zone umide di importanza internazionale specialmente come habitat degli uccelli acquatici

Cagliari 24-29 novembre 1980

Supplemento alle Ricerche di Biologia della Selvaggina

Volume VIII   Novembre 1982   Numero Unico

CRITERIA FOR SELECTING WETLANDS OF INTERNATIONAL IMPORTANCE*

Proposed amendments and guidelines on use.

INTRODUCTION

1. The Ramsar Convention is essentially a statement of intent. The Contracting Parties accept the ethics expressed in the preamble, and confirm their good intentions by subscribing to the conditions set out in Articles 2-5. Most of the undertakings are couched in general terms, their purpose being to guide the Parties towards a common policy of wetland conservation and research. A more precise requirement is that «each Party shall designate suitable wetlands within its territory for inclusion in a List of Wetlands of International Importance» (Article 2.1) and shall promote the conservation of the sites concerned (Article 3.1).

2. The purpose of this paper is to expound upon the methods of identifying wetlands of international importance, and of selecting ones which are suitable for inclusion in the List.

3. *Summary of proposals*

a) Quantitative criteria should be used, wherever possible, to determine whether or not a wetland is of international importance. (These are not at present available for interests other than waterfowl).

b) The current criteria for identifying wetlands of international importance to waterfowl require some amendment and expansion, but are otherwise effective.

c) The subjective criteria used to evaluate the importance of

---

* Prepared for the International Union for the Conservation of Nature and Natural Resources (IUCN) by the International Waterfowl Research Bureau (IWRB). Text prepared by G.L. Atkinson-Willes, D.A. Scott and A.J. Prater.

(see 1 (ii) below)	a) regularly supports either 10000 ducks, geese and swans; or 10000 coots; or 20000 waders.
i) regularly supports 1% (being at least 100 individuals) of the flyway or biogeographical population of one species of waterfowl	or b) regularly supports 1% of the individuals (being at least 100) in a biogeographical population of one species or subspecies of waterfowl.
or ii) regularly supports either 10000 ducks, geese and swans; or 10000 coots; or 20000 waders.	(see 1 (a) above)
(no existing criterion)	or c) regularly supports 1% of the breeding pairs in a biogeographical population of one species or subspecies of waterfowl.
(heading not previously used).	2. General criteria for identifying wetlands of importance to plants or animals. A wetland should be considered internationally important if it:
or iii) supports an appreciable number of an endangered species of plant or animal.	a) supports an appreciable number of a rare, vulnerable or endangered species or subspecies of plant or animal
or iv) is of special value for maintaining genetic and ecological diversity because of the quality and peculiarities of its flora and fauna	or b) is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna
or v) plays a major role in its region as the habitat of plants and of aquatic and other animals of scientific or economic importance.	or c) is of special value as the habitat of plants or animals at a critical stage of their biological cycles.
2. Criteria concernend with the selection of representative or unique wetlands.	3. Criteria for assessing the value of representative or unique wetlands.

Waterbirds in the UK 2008/09
The Wetland Bird Survey

**Neil Calbrade, Chas Holt, Graham Austin,
Heidi Mellan, Richard Hearn, David Stroud,
Simon Wotton & Andy Musgrove**

WeBS

Published by

**British Trust for Ornithology,
Royal Society for the Protection of Birds
and Joint Nature Conservation Committee
in association with
Wildfowl & Wetlands Trust**

July 2010

BTO RSPB JNCC Joint Nature Conservation Committee in association with WWT

CONTENTS

Details of WeBS Core Count survey methods, Analysis and Presentation of data, and Interpretation of Waterbird Counts, are now available via the WeBS website at ***www.bto.org/webs/websdownloads/methods***

Table 6 below lists the principal sites for non-breeding waterbirds in the UK as monitored by WeBS. All sites supporting more than 10,000 waterbirds are listed, as are all sites supporting internationally important numbers of one or more waterbird species. Naturalised species (*e.g.* Canada Goose and Ruddy Duck) and non-native species presumed to have escaped from captive collections have been excluded from the totals, as have gulls and terns since the recording of these species is optional (see *Analysis*). Table 7 lists other sites holding internationally important numbers of waterbirds, which are not routinely monitored by standard WeBS surveys but rather by the Icelandic Goose Census and aerial surveys.

A total of 240 sites are listed in tables 6 and 7. Of these 223 supported one or more species in internationally important numbers and 82 held a five-year mean peak of 10,000 or more birds. Typically there are few changes to the top twenty sites listed in the principal sites table, with the order of the top ten changing little each year.

The Wash remains as the key waterbird site in terms of absolute numbers, but in 2008/09 held figures 8% lower than the five-year average (attributable to apparent redistribution of Knots to North Norfolk Coast; see page xxx). The Ribble Estuary consolidated second place in the table following a further increase. Totals at both Morecambe Bay and North Norfolk Coast returned to over 200,000 birds; the Morecambe total being the highest since 2003/04. Total numbers at both Thames Estuary and Humber Estuary were approximately 20% lower than the averages for recent years, those on Dee Estuary were typical, whereas the total from Breydon Water & Berney Marshes was the highest ever from there. Totals at the two most important non-estuarine sites, Somerset Levels and Ouse Washes, were representative of the trends at those two sites in recent years.

Overall, five-year averages of sites holding 10,000 or more waterbirds were relatively similar compared to the previous year, with 69 of the 82 sites undergoing changes of less than 10%. The greatest increases were at Eden Estuary (36%), Slains Lochs (32%), Blyth Estuary (25%) and Dengie Flats, Camel Estuary and Ythan Estuary (all 14%). The greatest decreases were seen at Moray Firth (23%), Loch Spynie (17%) and Mersey Estuary (15%).

Table 6. Total number of waterbirds at principal sites in the UK, 2004/2005 to 2008/09 (includes data from all available sources) and species occurring in internationally important numbers at each. (Species codes are provided in Table 8.)

Site	04/05	05/06	06/07	07/08	08/09	Average	Int.Imp.Species
The Wash	369,627	398,373	380,003	372,405	344,411	372,964	PG DB SU PT OC RP GP GV L. KN SS DN BW BA RK
Ribble Estuary	242,686	220,693	214,279	263,180	274,248	243,017	WS PG WN T. PT OC RP GV KN SS DN BW BA RK
North Norfolk Coast	221,337	241,410	215,396	142,870	206,843	205,571	PG DB PT RP KN BW BA
Morecambe Bay	204,114	205,571	194,375	131,200	219,070	190,866	MS PG SU PT OC RP KN DN BW BA CU RK
Thames Estuary	172,491	186,385	226,127	186,982	149,746	184,346	DB SV OC AV RP GV KN DN BW BA RK
Humber Estuary	163,357	187,065	167,461	145,783	125,257	157,785	PG DB SU RP GP GV KN DN BW BA RK
Dee Estuary (England and Wales)	115,307	130,362	125,640	103,875	123,880	119,813	SU PT OC KN DN BW RK
Breydon Water & Berney Marshes	110,759	106,453	96,850	100,555	128,151	108,554	PG WN SV AV GP L. BW
Solway Estuary	140,091	103,053	118,198	89,947	88,008	107,859	WS PG YS SU PT OC RP KN RK
Somerset Levels	99,789	87,827	108,162	114,246	104,340	102,873	MS WN GA T. SV GP L.
Ouse Washes	112,818	133,474	72,202	66,975	76,765	92,447	MS BS WS WN GA T. PT SV BW

Table 7. Other sites in the UK holding internationally important numbers of waterbirds in 2008/09 which are not routinely monitored by standard WeBS surveys. (Species codes are provided in Table 8.)

Site	Int.Imp.species
Benbecula	JH
Berney Marshes	PG
Bute	JI,JH
Caithness Lochs	NW,JI
Colonsay/Oronsay	YN
Cromarty Firth	JI
Dingwall Bay	JI
Nigg Bay	JI
Dalreoch	WS,JI
East Mains Flood	JI
Floodwater South Of Braco	PG
Forth Estuary	PG
Aberlady Bay	PG
Forth Grangemouth to Kincardine	PG
Hule Moss (West)	PG
Read`s Island Flats	PG
Inner Moray and Inverness Firth	PG,JI
Beauly Firth	JI
Easterton - Fort George	PG,JI
Findhorn Bay	PG
Island of Islay	NW,JH,YN
Isle of Oronsay	YN
Isle of Lismore	NW
Loans of Tullich	WS
Loch Eye and Cromarty Firth	WS,JI
Loch Fleet	JI
Lune Estuary	PG
Martin Mere and Ribble Estuary	WS
Morecambe Bay	PG
Wyre to Cockerham	PG
Wyre Estuary	PG
Wyre Estuary to Arm Hill	PG
North Norfolk Coast & The Wash	PG
Holkham Bay Roost	PG
Holkham & Burnham Marshes	PG
Holme and Thornham	PG
Norton Marsh	PG
Scolt Head Roost	PG
Snettisham Roost	PG
Wells-next-the-Sea	PG
North Uist	JH,YN
Baleshare and Carinish (Grimsay)	JH
Balmartin To Vallay	JH
Balranald Clettraval and Tigharry	JH
Berneray	JH,YN
Boreray and Lingay	JH
Clachan Na Luib to Bayhead	JH
Malaclate To Grenitote	JH,YN
Oronsay	JH
Paible	JH
Trumisgarry to Newton	JH
Orkney	JI, YN
Isle of South Ronaldsay	JI
South Walls (Hoy)	YN
Ribble Estuary	PG
Banks Marsh Central	PG
Hesketh Out-Marsh	PG
Simonswood Peat Moss	PG
Solway Firth	YS
South Uist	
Askernish To Smerclate	JH
Bornish To Askernish	JH
Drimore To Howmore	JH
Howbeg To Bornish	JH
Lochdar, Gerinish and Drimsdale	JH
Southwest Lancashire	PG
Tayinloan	NW,JH
Winter Loch, St Fergus Gas Term.	PG
Ythan Estuary and Slains Lochs	PG

Table 8. Species codes for species listed in tables 6., 7. and 9.

AV	Avocet
BA	Bar-tailed Godwit
BS	Bewick's Swan
BV	Black-throated Diver
BW	Black-tailed Godwit
CA	Cormorant
CO	Coot
CU	Curlew
CX	Common Scoter
DB	Dark-bellied Brent Goose
DN	Dunlin
E.	Eider
EW	European White-fronted Goose
GA	Gadwall
GG	Great Crested Grebe
GK	Greenshank
GP	Golden Plover
GV	Grey Plover
JH	Greylag Goose Northwest Scotland population
JI	Greylag Goose Icelandic population
KN	Knot
L.	Lapwing
LG	Little Grebe
MA	Mallard
MS	Mute Swan
ND	Great Northern Diver
NW	Greenland White-fronted Goose
OC	Oystercatcher
PG	Pink-footed Goose
PO	Pochard
PS	Purple Sandpiper
PT	Pintail
QN	Light-bellied Brent Goose Nearctic population
QS	Light-bellied Brent Goose Svalbard population
RH	Red-throated Diver
RK	Redshank
RM	Red-breasted Merganser
RP	Ringed Plover
RU	Ruff
SP	Scaup
SS	Sanderling
SU	Shelduck
SV	Shoveler
SZ	Slavonian Grebe
T.	Teal
TT	Turnstone
WN	Wigeon
WS	Whooper Swan
YN	Barnacle Goose Nearctic population

Black-tailed Godwits *L l islandica* on the Humber estuary

Status, distribution and behaviour 1989 - 2009

Graham P Catley BSc Env
NYCTEA Ltd December 2009

Nyctea Ltd.

Contents

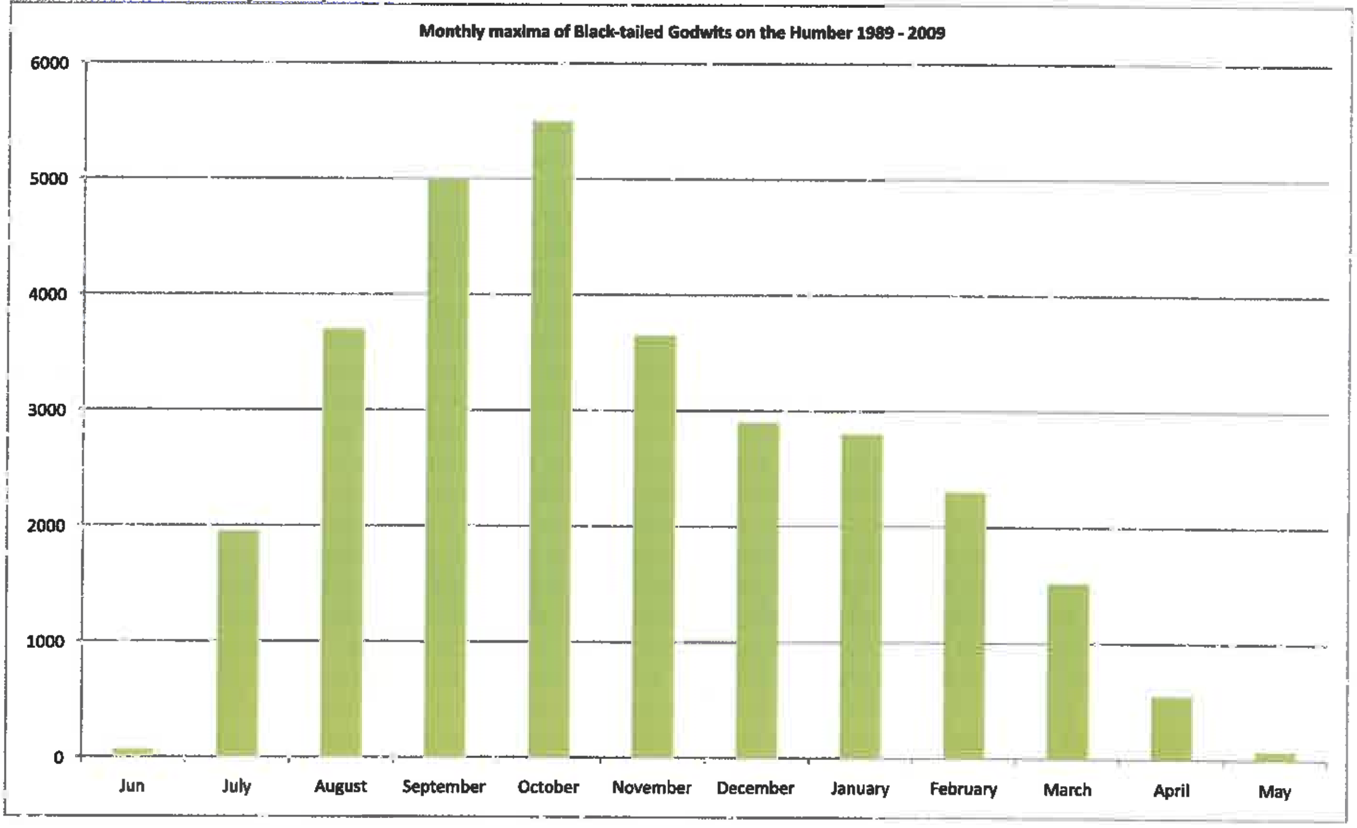
Importance of the Humber population:

In the latest Wetland Bird Survey (WeBS) report for the 2006-2007 autumn – winter the international threshold for Black-tailed Godwit is 470 birds. The latest five-year mean for the Humber estuary is calculated at 3361 and thus the species easily qualifies as being of **International Importance**. Some of the maximum counts included for the Humber are below the totals obtained from the North Killingholme Haven pits roost alone in some of these winters so the five-year mean should be higher. The threshold is derived from an estimate of the Icelandic population size suggested at 50,000 birds up to 2002. In a more recent paper Gunnarson T G et al estimate that the population may be in the region of 50-75,000 birds. With a minimum Humber peak count of 5500 birds in October 2009 this flock formed 7% to 11% of the total *islandica* population on one date. Taking into account the turnover of birds in the autumn and winter populations on the estuary the Humber may well hold up to 15% of the entire Icelandic Black-tailed Godwit population in the course of an autumn – winter period.

Status and distribution on the Humber:

Autumn arrivals

Black-tailed Godwits have occurred on the Humber in all months of the year but the main occurrence period is between late June and mid-March with a variable spring movement involving passage flocks that may occur at any time during the March to mid-May time period.



The first returning *islandica* of the 'autumn' appear during June still in their striking summer plumage. Flocks at this time can be scattered around the estuary with regular feeding/roosting sites being on the upper estuary at Blacktoft Sands (RSPB), Alkborough Flats, Winteringham Haven - Read's Island and on the middle estuary from Barton to North Killingholme on the south bank and on the north bank from Saltend and Cherry Cobb to Patrington Haven and the Spurn basin. The most favoured areas have changed over the time period involved in this paper as new sites have been developed mainly through managed realignment. The major developments at Paul, Alkborough Flats and Welwick have all attracted Black-tailed Godwits in their early stages of development. During the early autumn period, June to August there is considerable movement between sites as newly arrived birds swell the population. The turnover of birds at this time is also important as birds arrive and feed before moving to moulting areas in the Wash while others join the birds already in autumnal residence. Observations of individual colour ringed birds have proven the speed with which birds move from different sites around the estuary over short time periods. The distance from sites at the head of the estuary to those on the middle estuary is relatively small at 40 kms following the estuary; a distance that a godwit can cover in

40 minutes so daily movements between different feeding areas and favoured roost sites is well within the expected ergonomics of the species. Following the coast it is only 100 kms to the south-west corner of the Wash a distance that godwits could easily cover in two hours so it is to be expected that birds could move between the two major locations over the course of a few days if needed.
On spring tides most of the birds in the early autumn still roost at Alkborough Flats / Blacktoft and North Killingholme Haven pits but smaller numbers have adopted the newly created sites at Paul and Welwick. Movements of birds between these different areas of the estuary are confirmed by sightings of colour-ringed individuals at differing locations over short periods of time. Other colour-ringed birds seen on the estuary in the early autumn have however, never been seen again on the Humber in spite of extensive observations of the wintering flock which confirms that some of the flocks seen on the estuary during the early autumn are transient groups that subsequently move on to winter in other parts of the species range. This is also of significance with regard to the importance of some of the sites on the estuary that are used during the autumn but do not hold regular flocks of wintering birds.

The upper Humber has been in a very dynamic state throughout the 1990's and 2000's with extensive erosion and deposition occurring between Blacktoft and Barton-on-Humber, in particular, and this could have affected the suitability of the area for feeding Black-tailed Godwits. In addition major developments with regard to managed realignment schemes around the estuary have also affected the distribution of the species through the creation of new feeding and roosting sites.
As the species very much a recent addition to the estuarine wader population there have thus been considerable differences in the number of birds recorded at some of the sites around the estuary during the past twenty years. On the upper estuary the Blacktoft Sands reserve has attracted passage flocks of varying size in both spring and autumn throughout with numbers being quite variable between years. At Winteringham/Read's Island a flock of 40 birds that occurred in September 1990 was the largest flock recorded in that part of the estuary. Subsequently autumnal peak counts varied between seven and 28 birds between 1991 and 1996 inclusive. There was then a sudden increase in the importance of the area with autumn peaks reaching 193 in 1997 and 167 in 1998 before falling again to a maximum of 36 during 1999 to 2001. The construction of saline lagoons on Read's Island in 1997 had a profound effect upon the status of the site as a staging area for passage waders but as these lagoons disappeared through erosion in the early 2000's the site lost its attraction to godwits. More recently the development of the managed realignment site at Alkborough Flats has again altered the areas available to feeding waders on the upper estuary and the site has attracted growing numbers of Black-tailed Godwits on passage with a more stable wintering population now becoming apparent. At Saltend a maximum of 148 birds was feeding in 1995 with 356 in 1996 and 725 in 1997. These birds were part of the same flock that roosted at North Killingholme Haven pits during the same period. Subsequently few birds from this flock have been recorded from Saltend but as Paul Holme Strays was developed that site also attracted birds from the North Killingholme pits roost. On the outer estuary managed realignment schemes at Welwick / Patrington Haven have also attracted feeding and roosting Black-tailed Godwits and these may be the birds that have started to feed in the Spurn basin. Morris (1990) suggested that the distribution of feeding birds within the Dee estuary may have altered due to changes in the sand-flats and mud-flats on that estuary. Clearly there have been obvious reasons for some of the changes in distribution around the Humber estuary but the increasing number of birds that now use the site in the autumn and winter also appear to be forcing birds to use a wider range of sites a round the estuary.
By mid September and increasingly through October the bulk of the Humber population becomes concentrated in the area adjacent to North Killingholme Haven pits where the birds roost. Feeding birds concentrate on the inter-tidal mudflats to the south of the roost between the Haven and Immingham Docks but also start to move further south-east to the mudflats around the Oldfleet Drain outfall between Immingham Docks and Pywipe. The birds return to the roost at North Killingholme pits during this period at high tide and if undisturbed will remain in the roost for up to four to five hours around high tide. With long hours of daylight and generally mild conditions the energy requirements of the birds seems to be met through a concentrated period of about two hours feeding between each tide. The number of birds remaining at Alkborough Flats has steadily increased in recent years during this period of the year but still remains small compared to the number recorded at Killingholme. From late October passage birds leave the estuary and the wintering population becomes more stable although there is still some possible interchange between other wintering areas on the East coast. Up to 2007 from mid November the wintering birds abandoned the North Killingholme roost site and moved to the inter-tidal mudflats between Immingham Docks and Grimsby Docks roosting on the inner Pywipe basin. In the last three autumn periods birds have tended to remain longer in the North Killingholme area using the roost through to late November but feeding more extensively in the Pywipe area. By December the vast majority of the wintering birds are generally found in the Pywipe area feeding on the inter-tidal mudflats and roosting on the upper inter-tidal around Doig's Creek. Wintering birds start to depart from the Humber as early as mid December with the total number of birds falling rapidly during January and typically few remaining in February. From repeated observations of colour ringed birds it has been shown that many of these wintering birds move south and south-east to areas in East Anglia and Cambridgeshire where they feed on grasslands prior to spring departures for Iceland.
An explanation for the early departure of wintering birds is found in the paper by Gill et al 2007 where they address the conservation of the two European Black-tailed Godwit populations. The issue of food depletion in the inter-tidal feeding areas could also be implicated in the change of feeding areas from the Killingholme area to Pywipe from the autumn to winter.

BIOLOGICAL CONSERVATION 131 (2006) 459–473

available at www.sciencedirect.com

SCIENCE DIRECT®

journal homepage: www.elsevier.com/locate/biocon

Modelling the effect of environmental change on shorebirds: A case study on Poole Harbour, UK

Sarah E.A. Le V. dit Durell[a,*], *Richard A. Stillman*[a], *Richard W.G. Caldow*[a], *Selwyn McGrorty*[a], *Andrew D. West*[a], *John Humphreys*[b]

[a]*Centre for Ecology and Hydrology (CEH) Dorset, Winfrith Technology Centre, Dorchester, Dorset DT2 8ZD, UK*
[b]*Vice Chancellor's Office, University of Greenwich, Old Royal Naval College, Greenwich, London SE10 9LS, UK*

A R T I C L E I N F O

Article history:
Received 28 November 2005
Received in revised form
15 February 2006
Accepted 28 February 2006
Available online 18 April 2006

Keywords:
Individuals-based model
MORPH
SPAs
Shorebirds
Climate change

A B S T R A C T

An individuals-based model, MORPH, was used to assess the quality of Poole Harbour, UK, for five overwintering shorebirds: dunlin *Calidris alpina*, redshank *Tringa totanus*, black-tailed godwit *Limosa limosa*, oystercatcher *Haematopus ostralegus* and curlew *Numenius arquata*. Site quality, and the effect of environmental change, was measured as predicted overwinter survival. Dunlin had the highest prey biomass densities and were the least likely to be affected by reductions in their food supply, lower temperatures or loss of terrestrial habitats. Black-tailed godwits and curlew had the lowest prey biomass densities and were the most likely to be affected by reductions in their food supply, lower temperatures and loss of terrestrial habitats. All five shorebird species were seriously affected by simulated sea-level rise. Conservation issues identified for the Poole Harbour SPA were the relatively low densities of larger size classes of polychaete worms, the importance of maintaining and managing surrounding terrestrial habitats and the effect of sea-level rise on the length of time for which intertidal food supplies are available.

1. Introduction

One of the main conservation priorities for inter-tidal estuaries in north-west Europe is to protect and maintain internationally important numbers of overwintering shorebirds. To this end, many estuaries have been designated Special Protection Areas (SPAs) and European Marine Sites under the EU Directive 79/409/EEC for the conservation of wild birds. Statutory bodies are required by such Directives to monitor the quality of a site for particular bird species and to assess how potential changes may affect site quality.

In most instances, estuary SPA quality is measured in terms of bird numbers. This approach has two main drawbacks, particularly for migratory shorebirds. The first drawback is that the number of birds using a site depends not only on conditions at that site, but also conditions at other sites during both the breeding and the non-breeding seasons (Goss-Custard, 1993; Goss-Custard et al., 1995b). A change in numbers at any particular site may not be due to change within that site but to a change in quality at other sites or to a change in the total population size resulting from altered reproductive rates and/or overall mortality rates. The second drawback is that bird numbers are not predictive: if bird numbers go down it is often too late to take remedial action once any change has been detected.

Another way of measuring habitat quality is to determine, either directly or indirectly, the demographic rates that govern population size, i.e. reproduction and mortality. For migratory shorebirds during the non-breeding season, this means the number of birds that starve to death during the winter (Goss-Custard et al., 2002). If it can be shown that feeding conditions on a site are sufficient to maintain present-day

* *Corresponding author:* Tel.: +44 1305 213569; fax: +44 1305 213600.
E-mail address: sld@ceh.ac.uk (Sarah E.A. Le V. dit Durell).
0006-3207/$ - see front matter
doi:10.1016/j.biocon.2006.02.022

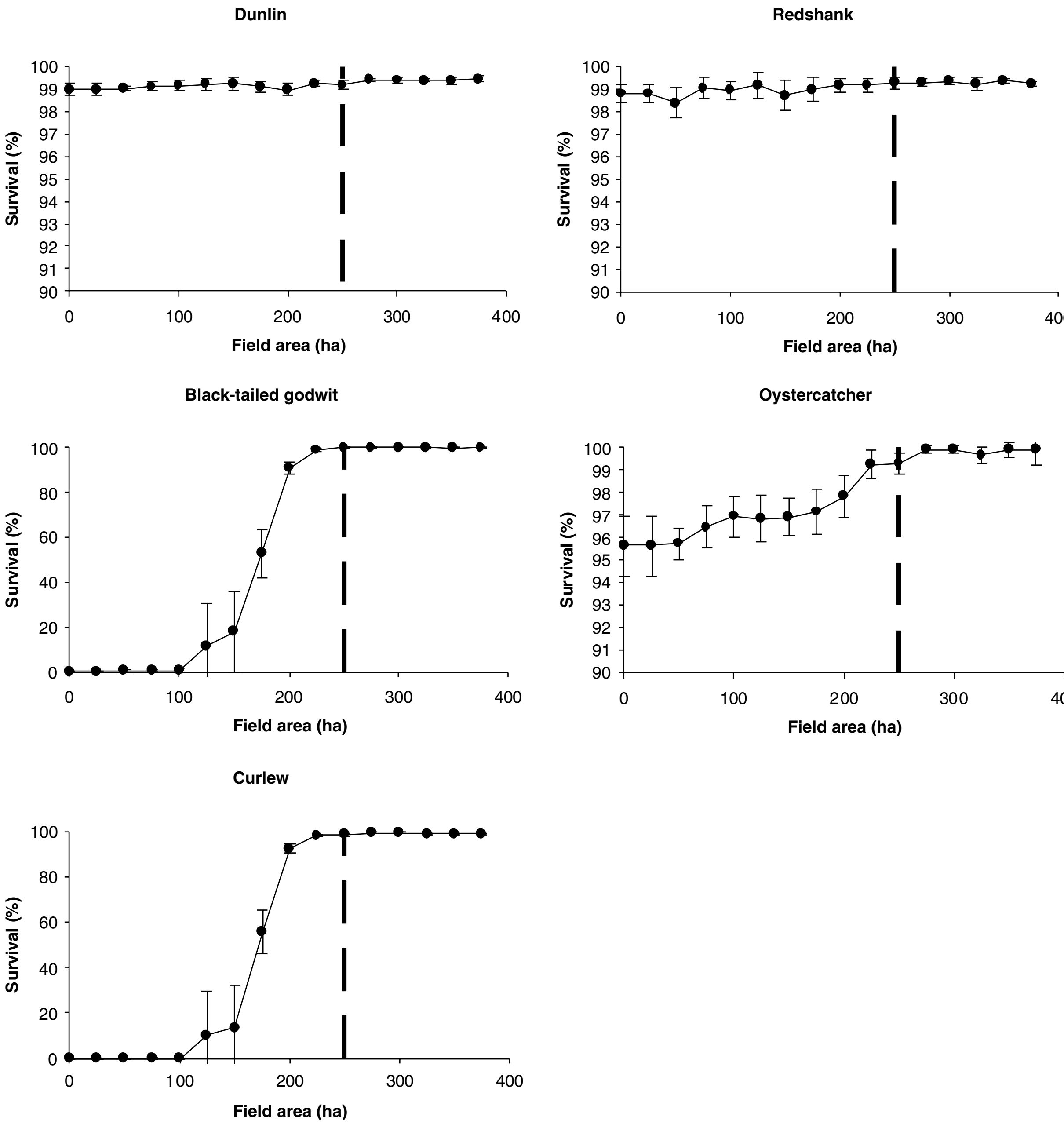


Fig. 5 – The predicted effect of reducing field feeding habitats on shorebird overwinter survival rates. The vertical dashed lines show area used in baseline runs. Error bars show 95% confidence limits. Note different scales used for different species.

10 cm reduced survival rates in all five shorebird species and a reduction of 40 cm meant that no birds at all survived the winter.

4. Discussion

In this paper, we have measured the site quality and predicted the effect of environmental change in Poole Harbour in terms of the survival rates of five species of overwintering shorebirds. To do this, we have parameterised an individuals-based model using survey data collected by CEH and data collected from the literature. We used an individuals-based model to predict shorebird survival rates because (a) shorebird survival rates have not been measured directly in Poole Harbour and (b) direct measurement of survival rates would be of little use in predicting the effect of future environmental changes.

We calibrated the model so that overwinter survival for all five shorebirds was between 98.6% and 99.9%. Actual survival rates are probably lower than this, so the results we present here represent a 'best-case' scenario. If baseline survival rates had been set lower, the effect of environmental deterioration would have been even greater. Conversely, any improvement in the environment, such as increased prey biomass, higher temperatures or longer exposure times, would have increased shorebird survival.

The model predicted well the present-day distribution of dunlin, redshank and black-tailed godwit around Poole Harbour at low water. However, oystercatcher and curlew distri-

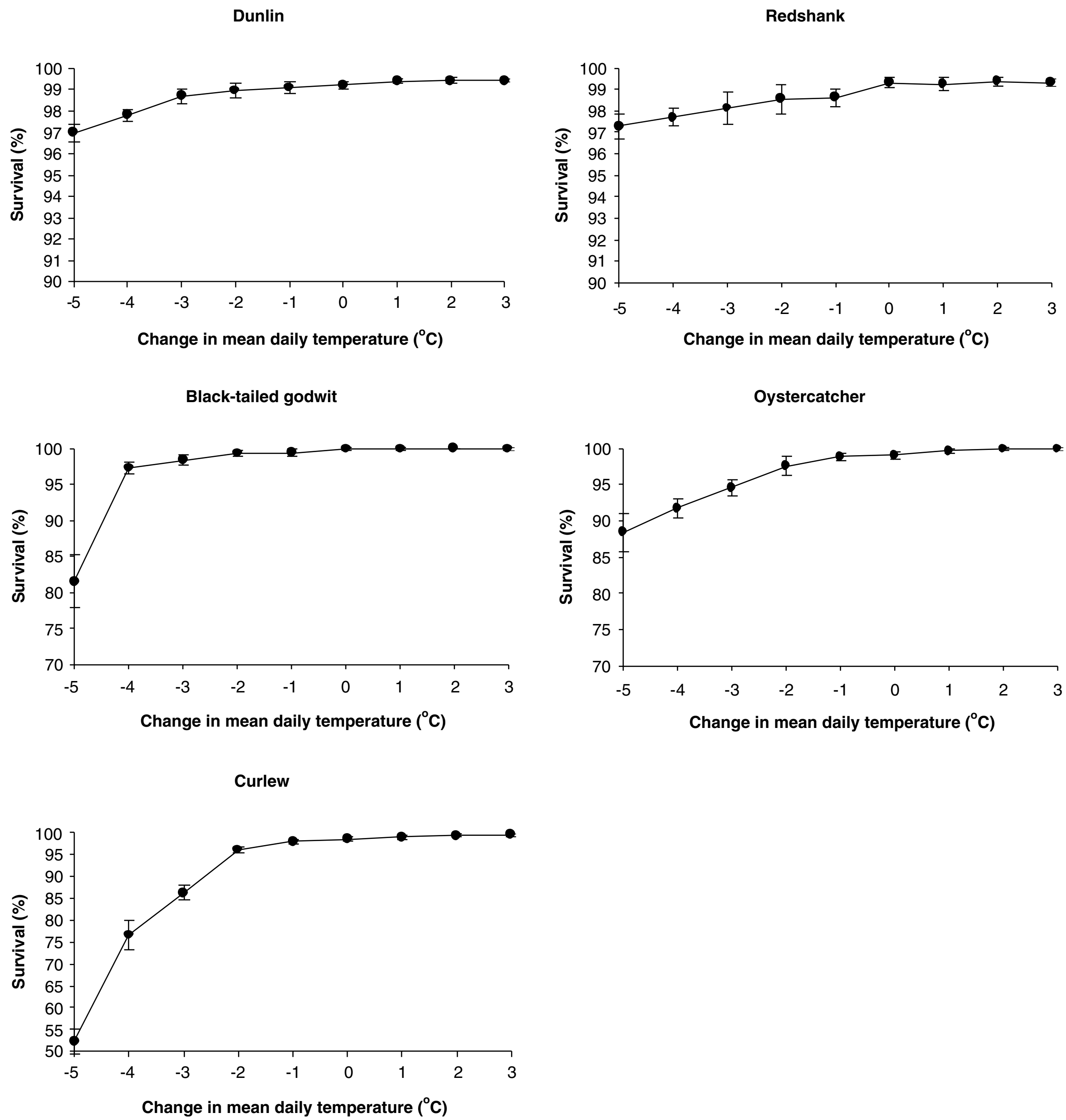


Fig. 6 – The predicted effect of mean daily temperature change on shorebird overwinter survival rates. Note different scales used for different species.

butions were less well predicted, with more model birds feeding in the north-east of the Harbour (Sand) and fewer in the Wareham Channel and South Bays patches. Oystercatchers and curlew in the model did use the Wareham Channel and South Bays patches as the tide receded and advanced but moved to the Sand patch when it exposed at low tide. One possible explanation for the discrepancy in oystercatcher and curlew distributions may, therefore, be due to the timing of bird counts in relation to how much of the intertidal area had been uncovered by the tide. Alternatively, it is possible that the quality of the food supply for oystercatchers and curlew, i.e. the larger size classes of polychaete worms, in the Wareham Channel and South Bays patches have deteriorated since the period of the bird counts.

As with any model, the accuracy of the model predictions will depend on the accuracy with which its parameters have been measured. One of the key model parameters, which is also very time-consuming to measure, is the distribution and abundance of the invertebrate food supply. In this study, we have shown how a range of simulations can be run to incorporate the full range of possible prey biomass densities.

Using the model, we were able to predict which shorebird species might be the most vulnerable to environmental changes in Poole Harbour. Dunlin had the highest prey biomass densities and were the least likely to be affected by reductions in their food supply, lower temperatures or loss of terrestrial habitats. Black-tailed godwits and curlew, on the other hand, had the lowest prey biomass densities and

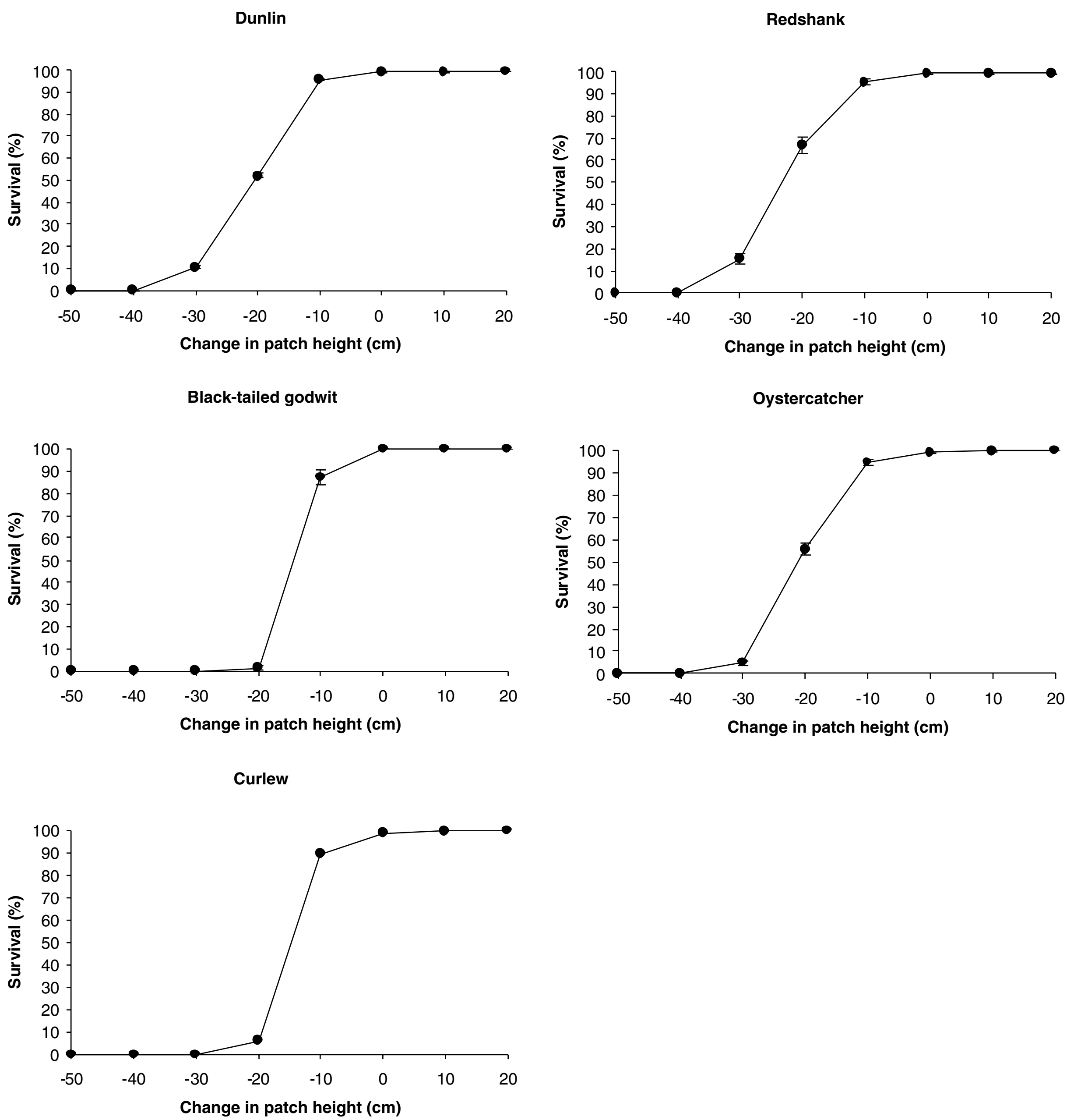


Fig. 7 – The predicted effect of mean patch heights (sea level rise) on shorebird overwinter survival rates.

were the most likely to be affected by reductions in their food supply, lower temperatures and loss of terrestrial habitats. All five shorebird species were seriously affected by a decrease in the height of intertidal areas i.e. the time they can spend feeding in the Harbour.

Our simulations suggest that there are three main conservation issues for shorebirds in Poole Harbour: (1) the low densities of larger size classes of benthic polychaete worms, (2) the importance of terrestrial habitats for the larger shorebirds and (3) the effect of sea-level rise or sediment dynamics on intertidal exposure times. Our surveys showed that, whilst densities of smaller (<60 mm) polychaete worms were high, densities of larger size classes were very low compared with other estuaries (Appendix A) (Caldow et al., 2005; Stillman et al., 2005b). It is these larger worms which constitute the main prey of black-tailed godwit and curlew. It is not clear why densities of large worms should be low, but possible reasons include disturbance from pump-scoop dredging for shellfish (Jenson et al., 2005; Parker and Pinn, 2005), bait dragging for ragworms (Jenson et al., 2005) or pollution from toxic contaminants (MPMMG, 1998; Wardlaw, 2005). Whatever the reason, we suggest that densities of large polychaete worm species in Poole Harbour should be closely monitored and actions taken to regulate any activities which may depress their abundance.

Black-tailed godwit and curlew were also the two species that made the most use of terrestrial habitats around Poole Harbour and were the most vulnerable to any loss of suitable fields. It is clear that the presence of internationally and nationally important numbers of these birds is due as much to suitable terrestrial habitats as to the quality of intertidal habitats. Managers need to monitor carefully the availability of suitable terrestrial habitats (permanent grassland with short swards) around Poole Harbour and be aware of their vulnerability to extremes of flooding, drought, disturbance and changes in management regime. Terrestrial habitats are not included in SPAs, even though they are of vital importance for shorebirds, such as the black-tailed godwit, and for wildfowl, such as the Brent goose *Branta bernicula* (Rowell and Robinson, 2004). We suggest that the inclusion of terrestrial habitats in SPAs such as Poole Harbour should be seriously considered.

Finally, the quality of SPAs for shorebirds depends not only on the biomass of prey, but also on prey availability. Intertidal exposure times in Poole Harbour are already brief and likely to be reduced still further by sea-level rise or sediment loss. Reductions in exposure times may be mitigated by changes in upper-shore habitats, such as erosion of the *Spartina* marsh (Raybould, 2005) or increased sedimentation rates resulting from higher winter rainfall (Watkinson et al., 2004). However, in the event of sea-level rise, conservation managers should also consider managed retreat of reclaimed saltmarsh areas around the Harbour to offset coastal squeeze and increase the availability of high-level feeding areas for shorebirds.

Acknowledgement

Most of the work undertaken for this study was funded by English Nature.

Appendix A – Resource variables

Resource		Initial density (n m^{-2})						Winter mortality (%)	Resource component	
Species	Size class (mm)	Wham-Chan	North-Bays	South-Bays	South-Deep	Sand	Fields		Initial AFDM (g)	Overwinter change in AFDM
LittleWorms	All	8626.93	7539.18	5549.90	6369.05	2257.78	0.00	20	0.0015	0
Worms	5–14.99	394.61	519.55	419.10	203.20	2638.78	0.00	25	0.00118	0
Worms	15–29.99	190.50	46.18	139.70	25.40	84.67	0.00	25	0.00698	+(0.000037 × Day)− (0.0000 × Day × Day)
Worms	30–44.99	195.04	34.64	88.90	76.20	0.00	0.00	40	0.02131	+(0.0001 4Day)− (0.000001 × Day × Day)
Worms	45–59.99	45.43	28.45	0.10	22.20	13.11	0.00	40	0.04446	+(0.000323 × Day)− (0.000002 × Day × Day)
Worms	60–74.99	18.14	0.00	0.00	0.00	0.00	0.00	50	0.07699	+(0.000598 × Day)− (0.000003 × Day × Day)
Worms	75–89.99	4.54	11.55	0.00	0.00	0.00	0.00	85	0.11937	+(0.000973 × Day)− (0.000005 × Day × Day)
Worms	90–104.99	0.00	0.00	0.00	0.00	0.00	0.00	85	0.17195	+(0.001 456 × Day)− (0.000008 × Day × Day)
Worms	105+	14.11	0.00	0.00	0.00	14.11	0.00	85	0.29594	+(0.002662 × Day)− (0.000014 × Day × Day)
Cyathura	5+	498.93	242.45	76.20	106.95	0.00	0.00	0	0.0012	0
Crustacea	3+	167.82	334.82	2425.70	1076.16	451.56	0.00	0	0.00193	0
Bivalves	5–9.99	18.57	3.64	13.60	0.60	0.00	0.00	6	0.00277	0
Bivalves	10–14.99	1.00	0.73	0.40	1.20	0.00	0.00	6	0.01511	0
Bivalves	15-19.99	1.71	2.55	1.60	4.40	0.00	0.00	6	0.04611	0
Bivalves	20–24.99	4.14	5.82	3.20	7.40	1.33	0.00	6	0.10609	−(0.000036 × Day)
Bivalves	25–29.99	2.86	8.36	2.00	4.60	0.89	0.00	6	0.20634	−(0.000138 × Day)
Bivalves	30–34.99	1.43	5.82	0.00	3.00	1.33	0.00	6	0.35899	−(0.000322 × Day)
Bivalves	35–39.99	0.86	3.64	0.80	1.40	3.11	0.00	6	0.57691	−(0.000615 × Day)
Bivalves	40–44.99	0.14	1.09	0.00	0.80	1.78	0.00	6	0.87358	−(0.001046 × Day)
Bivalves	45–49.99	0.00	0.36	0.00	0.00	1.78	0.00	6	1.26309	−(0.001645 × Day)
Bivalves	50–54.99	0.14	0.00	0.00	0.00	0.00	0.00	6	1.76004	−(0.002443 × Day)
Hydrobia	3+	217.71	334.82	812.80	311.15	0.00	0.00	53	0.00202	0
Earthworms	5–14.99	0.00	0.00	0.00	0.00	0.00	0.00	0	0.0009	0
Earthworms	15–29.99	0.00	0.00	0.00	0.00	0.00	4.66	0	0.0054	0
Earthworms	30–44.99	0.00	0.00	0.00	0.00	0.00	22.13	0	0.0165	0
Earthworms	45–59.99	0.00	0.00	0.00	0.00	0.00	39.21	0	0.0346	0
Earthworms	60–74.99	0.00	0.00	0.00	0.00	0.00	26.79	0	0.0601	0
Earthworms	75–89.99	0.00	0.00	0.00	0.00	0.00	16.69	0	0.0935	0
Earthworms	90–104.99	0.00	0.00	0.00	0.00	0.00	10.87	0	0.135	0
Earthworms	105+	0.00	0.00	0.00	0.00	0.00	4.66	0	0.194	0

the INSTITUTE of ESTUARINE and COASTAL STUDIES

THE UNIVERSITY OF HULL

Institute of Estuarine and Coastal Studies (IECS)

Paull Holme Strays Monitoring Programme 2010: Benthic Invertebrate Monitoring

Report to Halcrow Group Ltd.

Institute of Estuarine and Coastal Studies
University of Hull

19 May 2011

Author(s): A. Franco & K. Mazik

Report: ZBB757-DBenth-2011

Institute of Estuarine & Coastal Studies (IECS)
The University of Hull
Cottingham Road
Hull
HU6 7RX
UK

Tel: +44 (0)1482 464120
Fax: +44 (0)1482 464130

E-mail: iecs@hull.ac.uk

Web site: http://www.hull.ac.uk/iecs

TABLE OF CONTENTS

Table 2. (Cont.)

OUTSIDE (Ref)										
Sector	**Station**	**Median phi**	**Mean phi**	**Sand (%)**	**Silt/Clay (%)**	**Water %**	**Organic %**	**Kurtosis**	**Skew.**	**Sorting coeff.**
Ref1	2D_10	4.85	5.27	26.00	74.00	35.50	2.65	0.87	0.34	1.82
	5C_10	6.08	6.15	7.98	92.02	50.44	6.65	0.86	0.04	1.67
	7C_10	5.87	6.01	9.80	90.20	47.86	5.88	0.83	0.11	1.70
Ref2	2F_10	4.26	4.50	41.53	58.47	50.91	5.38	1.38	0.35	1.46
	5D_10	4.44	4.81	36.43	63.57	30.29	3.01	1.11	0.36	1.68
	7D_10	4.27	4.63	42.15	57.85	26.81	3.64	1.19	0.35	1.64
Ref1 Total	**MEAN**	**5.60**	**5.81**	**14.59**	**85.41**	**44.60**	**5.06**	**0.85**	**0.16**	**1.73**
	SD	**0.66**	**0.47**	**9.92**	**9.92**	**7.99**	**2.12**	**0.02**	**0.16**	**0.08**
	%CV	**11.82**	**8.07**	**67.98**	**11.62**	**17.91**	**41.94**	**2.08**	**96.39**	**4.59**
Ref2 Total	**MEAN**	**4.32**	**4.65**	**40.04**	**59.96**	**36.00**	**4.01**	**1.23**	**0.35**	**1.60**
	SD	**0.10**	**0.16**	**3.14**	**3.14**	**13.03**	**1.23**	**0.14**	**0.00**	**0.12**
	%CV	**2.39**	**3.38**	**7.83**	**5.23**	**36.19**	**30.57**	**11.50**	**1.00**	**7.45**
Ref Total	**MEAN**	**4.96**	**5.23**	**27.32**	**72.68**	**40.30**	**4.53**	**1.04**	**0.26**	**1.66**
	SD	**0.82**	**0.71**	**15.41**	**15.41**	**10.75**	**1.65**	**0.22**	**0.14**	**0.12**
	%CV	**16.46**	**13.57**	**56.42**	**21.20**	**26.68**	**36.44**	**21.44**	**55.66**	**6.97**

3.2 Biological parameters (2010)

3.2.1 UNIVARIATE INDICES

The distribution of the number of species, abundance, biomass and diversity inside the site appears to be related to elevation and tidal inundation with minimum values typically being recorded from high elevation areas which are infrequently inundated. These areas are typically located at the internal margins of the site, comprising stations in the south eastern area of the site (5A, 6A and 7A) and those in the north western corner (1B and 2C) (Appendix 2).

The greatest number of species was observed at stations 3A, 8A, 4B and 10A where mean values ranged 8-13 (Table 3). These stations are located in proximity of the western breach. In contrast, the mean number of species at stations 5A, 6A, 1B, and 7A, in less frequently inundated areas, ranged 3.3–5.3. Similarly, the lowest mean values were recorded at stations 5A, 6A, 7A and 1B, ranging from 637 to 3353 individuals m^{-2}, whereas the highest values were observed at stations 2A, 2B and 4B, ranging from 49020 to 53264 individuals m^{-2}. Shannon Weiner diversity (H') ranged from 0.9 at station 5A to 3.1 at station 10A, the highest values again being recorded at stations close to the western breach. High values of benthic biomass were also observed in stations from this area (8A, 9A, 10A, ranging 43-64.3 g m^{-2} respectively), although a high biomass was recorded also at station 5B (62.6 g m^{-2}) located in the south eastern area of the site. The minimum biomass value (0.8 g m^{-2}) was recorded at stations 6A and 2B. It is of note that this latter station showed relatively high species abundance hence the very low biomass is likely ascribed to the dominance of small benthic species, like the enchytraeid worms, nematodes, and collembola, accounting for 86.5% of the community (Appendices 2 and 3). Pielou's Evenness (J') values were generally between 0.5 and 0.9 and were not indicative of extreme dominance at any station.

Outside the site, the distribution of the biological parameters was, in part, but not exclusively, a function of shore height. Stations 2D and 5C, located on the upper shore, showed the highest diversity (Shannon-Weiner index>2) and evenness (Pielou's index>0.7) which indicate a reasonable spread of individuals between the species (Table 3). Station 2D showed also the lowest mean abundance (2207 individuals m^{-2}) and biomass (0.2 g m^{-2}). In turn station 5C, besides the relatively low abundance detected with respect to the other reference stations (36287 individuals m^{-2}), showed the highest biomass (72.8 g m^{-2}). This is likely ascribed to the abundance of larger species like the nereid worm *Hediste diversicolor* which occurred among the dominant species in the community (Appendices 2 and 3). Stations 5D and 2F, located in the mid shore, and station 7C, in the upper shore, showed the highest mean number of species, ranging 8.7-10.7, and relatively high abundance (>88500 individuals m^{-2}), and biomass (>25 g m^{-2}). Diversity at these stations was relatively low, with the lowest values of the Shannon-Wiener diversity index (1.3) and Pielou's evenness index (0.39) recorded at station 2F. This is likely ascribed to the high dominance enchytraeid worms accounting for 66% of the community in this station (Appendix 3).

Both inside and outside the site, the high abundance ratio values (A/S) are typical of estuarine areas, indicating high numbers of organisms represented by a small number of species. Similarly, the low biomass ratio values are indicative of a community composed of large numbers of small bodied organisms in most of cases.

The number of species differed significantly among sectors ($p<0.05$), mainly due to differences occurring between sectors inside the realignment site rather than to a difference between the inside and outside areas. In fact, a low mean number of species (5) was detected in the sector with higher tidal elevation (MR3) compared to the other sectors inside the site (8.7 and 7.4 in MR1 and MR2, respectively). A difference among sectors was also detected in terms of mean abundance ($p<0.05$), but, in this case, the difference was ascribed to the significantly higher abundance detected in reference sectors with respect to those inside the realignment site, as confirmed by the comparison of the two areas on the whole ($p<0.01$). The difference was particularly evident when considering sector Ref2 (with 87132 individuals m^{-2}) and the sectors inside the site (with mean values <31000 individuals m^{-2}), as sector Ref1 (with around 50000 individuals m^{-2}) showed intermediate abundance between these two groups. The other community parameters did not differ between the areas inside and outside the realignment site or among sectors (Table 3).

Table 3. Biological parameters (means, 2010) for each station inside and outside the managed realignment site with mean values for the different sectors identified according to tidal elevation, and for the areas inside and outside the site.

INSIDE (MR)								
Sector	**station**	**S**	**A**	**B**	**H'**	**J'**	**A/S**	**B/A**
MR1	2A_10	6.7	49019.7	21.6	1.7	0.62	7436.6	0.0004
	3A_10	8.0	26907.8	14.0	1.7	0.58	3302.0	0.0008
	8A_10	8.0	18249.8	43.0	1.9	0.65	2189.3	0.0026
	9A_10	7.3	9294.6	36.5	2.2	0.79	1265.8	0.0039
	10A _10	13.3	20117.2	64.3	3.1	0.82	1495.7	0.0033
MR2	1C_10	7.7	11756.2	8.5	2.1	0.72	1520.5	0.0008
	2B_10	6.7	52457.5	0.8	2.0	0.73	7595.2	0.0000
	2C_10	6.3	5772.0	15.7	1.9	0.74	840.5	0.0062
	4A_10	7.7	31449.0	6.7	1.3	0.45	3805.9	0.0003
	4B_10	8.7	53263.9	19.3	1.6	0.51	6146.3	0.0004
MR3	1B_10	4.0	1612.8	11.4	1.4	0.73	407.4	0.0058
	5A_10	3.3	2419.2	7.5	0.9	0.66	585.7	0.0055
	5B_10	6.7	30557.7	62.6	1.3	0.47	4795.9	0.0021
	6A_10	3.3	636.6	0.8	1.6	0.95	182.5	0.0008
	7A_10	5.3	3352.9	24.7	2.1	0.87	643.7	0.0076
	7B_10	7.3	33231.6	3.8	1.7	0.60	5277.9	0.0001
MR1 Total	**MEAN**	**8.7**	**24717.8**	**35.9**	**2.1**	**0.69**	**3137.9**	**0.0022**
	SD	**2.7**	**14968.8**	**19.6**	**0.6**	**0.11**	**2530.2**	**0.0015**
	%CV	**30.75**	**60.56**	**54.71**	**26.91**	**15.39**	**80.63**	**69.92**
MR2 Total	**MEAN**	**7.4**	**30939.7**	**10.2**	**1.8**	**0.63**	**3981.7**	**0.0015**
	SD	**0.9**	**22153.2**	**7.4**	**0.3**	**0.14**	**2902.5**	**0.0026**
	%CV	**12.73**	**71.60**	**72.14**	**18.38**	**22.02**	**72.90**	**170.17**
MR3 Total	**MEAN**	**5.0**	**11968.5**	**18.5**	**1.5**	**0.71**	**1982.2**	**0.0037**
	SD	**1.7**	**15483.8**	**23.2**	**0.4**	**0.18**	**2376.5**	**0.0031**
	%CV	**34.81**	**129.37**	**125.46**	**27.00**	**24.74**	**119.89**	**83.80**
MR Total	**MEAN**	**6.9**	**21881.2**	**21.3**	**1.8**	**0.68**	**2968.2**	**0.0025**
	SD	**2.4**	**18435.8**	**20.3**	**0.5**	**0.14**	**2564.6**	**0.0025**
	%CV	**34.6**	**84.3**	**95.1**	**27.6**	**20.8**	**86.4**	**100.1**

Table 3. (Cont.)

OUTSIDE (Ref)								
Sector	**station**	**S**	**A**	**B**	**H'**	**J'**	**A/S**	**B/A**
Ref1	2D_10	5.3	2206.9	0.2	2.1	0.93	378.9	0.0003
	5C_10	8.3	36287.3	72.8	2.2	0.71	4715.2	0.0022
	7C_10	8.7	111323.6	40.1	1.5	0.49	12397.1	0.0004
Ref2	2F_10	10.7	88702.4	55.8	1.3	0.39	8196.1	0.0011
	5D_10	10.3	95493.0	29.9	1.6	0.46	9771.8	0.0004
	7D_10	6.3	77200.8	7.1	1.4	0.55	11957.5	0.0001
Ref1 Total	**MEAN**	**7.4**	**49939.3**	**37.7**	**1.9**	**0.71**	**5830.4**	**0.0010**
	SD	**1.8**	**55824.7**	**36.4**	**0.4**	**0.22**	**6086.2**	**0.0011**
	%CV	**24.7**	**111.8**	**96.5**	**18.7**	**30.6**	**104.4**	**110.5**
Ref2 Total	**MEAN**	**9.1**	**87132.0**	**30.9**	**1.5**	**0.47**	**9975.2**	**0.0005**
	SD	**2.4**	**9246.7**	**24.4**	**0.1**	**0.08**	**1888.9**	**0.0005**
	%CV	**26.5**	**10.6**	**78.8**	**7.4**	**16.6**	**18.9**	**100.0**
Ref Total	**MEAN**	**8.3**	**68535.7**	**34.3**	**1.7**	**0.59**	**7902.8**	**0.0008**
	SD	**2.1**	**41179.4**	**27.9**	**0.4**	**0.20**	**4625.8**	**0.0008**
	%CV	**25.6**	**60.1**	**81.4**	**21.2**	**33.5**	**58.5**	**106.6**

***S = number of species; A = total abundance / m^2; B = total biomass (g m^{-2}); H' = Shannon-Weiner diversity; J' = Pielou's evenness; A/S = abundance ratio; B/A = biomass ratio.**

3.2.2 COMMUNITY ANALYSIS

A total of 22 benthic taxa were recorded from the area as a whole. Also 2 epibenthic taxa occurred in the samples from inside the realignment site (*Carcinus maenas* and *Neomysis integer*), but these were not considered in the benthic faunal analysis. Of the benthic taxa, 19 taxa were typically estuarine with 3 terrestrial / freshwater taxa (Collembola, Diptera and Acarina). Two estuarine taxa, Ostracoda and *Cyathura carinata*, were found exclusively inside the site, although the latter was found with very low abundance (1 individual at station 10A). All the other taxa occurred both inside and outside the site.

In terms of abundance, the community inside the site (as a whole) was dominated by the annelid worms Enchytraeidae and *Manayunkia aestuarina*, accounting for 28% and 27% of the abundance, respectively (Table 4). These taxa dominated the benthic assemblages also when distinguishing the different sectors inside the site, although also Collembola proved to be quantitatively important (26% of the total abundance) in sector MR2 (Appendix 3). When considering biomass, the dominant species was always the large nereid worm *H. diversicolor*, which accounted for more than 70% of the total biomass inside the site (as a whole and in the different sectors) (Table 4 and Appendix 3). Removing the terrestrial / freshwater species from the analysis increased these values, particularly in sector MR2 (Appendix 3). These species, in fact, were important components of the community at certain stations located at the inner margins of the site, such as stations 4A (78% of the total abundance), 1C (32%) and 2B (26%) in sector MR2, but also stations 3A (63%), 6A (33%), 7B (24%), 1B (21%) and 7A (19%) (Appendix 3). Together with nematodes, Collembola were another significant taxa present inside the site, in terms of abundance (Table 4 and Appendix 3). Together with Enchytraeidae and *M. aestuarina* these species collectively accounted for 90% of the total abundance. The bivalve *Abra tenuis* accounted for 11% of the biomass overall inside the site, mainly reflecting its dominance (with *H. diversicolor*) in sector MR1 (20% of the abundance). In turn, the gastropod *Hydrobia ulvae* accounted for just 10% of the biomass in sector MR2, whereas its contribution to the biomass inside the site as a whole was reduced to 2.5% (s 4 and Appendix 3).

The community outside the realignment site was dominated by Enchytraeidae, nematodes and *M. aestuarina*, collectively accounting for 94% of the total abundance as a whole and 89% and 97% in sectors Ref1 and Ref2 respectively (Table 4 and Appendix 3). In terms of biomass, *H. diversicolor* dominated the community outside the realignment site (69% of the biomass as a whole and 88% and 47% in sectors Ref1 and Ref2 respectively). Another key species was *M. balthica* (18% of the biomass) mainly due to its dominance in mid shore sector (Ref2, 40% of the biomass). Together with Enchytraeidae, these two species collectively accounted for >90% of the total biomass (on the whole and in each sector) (Table 4 and Appendix 3). Removing the terrestrial / freshwater species from the analysis did not significantly change these values, mainly due to the very small dimensions characterising the individuals of these taxa indicating that these species are not a significant part of the community outside the realignment site overall (Appendix 3). However, a local high contribution of these species to the community (30% of the total abundance) was observed at station 2D (though the actual number of individuals of these taxa was comparatively lower than in the other sectors) (Appendix 3).

Table 4. Species dominance in terms of abundance and biomass for sites inside (collectively) and outside (collectively) the managed realignment site (asterisk denotes species of terrestrial/freshwater origin).

INSIDE (MR) - ALL SPECIES							
	Total A	%Dom	Cum%		Total B	%Dom	Cum%
Enchytraeidae	2305	27.94	27.94	*Hediste diversicolor*	6.477	80.55	80.55
Manayunkia aestuarina	2243	27.19	55.13	*Abra tenuis*	0.8642	10.75	91.30
Collembola*	1539	18.66	73.79	*Hydrobia ulvae*	0.2535	3.15	94.45
Nematoda	1356	16.44	90.23	Diptera larvae*	0.1024	1.27	95.73
Hediste diversicolor	203	2.46	92.69	Enchytraeidae	0.1003	1.25	96.97
Diptera larvae*	173	2.10	94.79	*Macoma balthica*	0.076	0.95	97.92
Hydrobia ulvae	130	1.58	96.36	*Manayunkia aestuarina*	0.0601	0.75	98.67
Abra tenuis	84	1.02	97.38	*Tubificoides benedii*	0.0369	0.46	99.13
Tubificoides benedii	58	0.70	98.08	*Eteone flava/longa*	0.0262	0.33	99.45
Pygospio elegans	40	0.48	98.57	Collembola*	0.0147	0.18	99.63
Acarina*	25	0.30	98.87	*Pygospio elegans*	0.0097	0.12	99.75
Eteone flava/longa	21	0.25	99.13	Nematoda	0.0076	0.09	99.85
Macoma balthica	19	0.23	99.36	Acarina*	0.0059	0.07	99.92
Streblospio shrubsolii	14	0.17	99.53	*Corophium volutator*	0.0024	0.03	99.95
Copepoda	12	0.15	99.67	*Cyathura carinata*	0.001	0.01	99.97
Ostractoda	11	0.13	99.81	*Streblospio shrubsolii*	0.0007	0.01	99.97
Paranais litoralis	5	0.06	99.87	Copepoda	0.0007	0.01	99.98
Heterochaeta costata	3	0.04	99.90	*Paranais litoralis*	0.0004	0.005	99.99
Corophium volutator	3	0.04	99.94	Ostracoda	0.0004	0.005	99.99
Nemertea	2	0.02	99.96	*Heterochaeta costata*	0.0003	0.004	100.00
Tellinoidea	2	0.02	99.99	Tellinoidea	0.0002	0.002	100.00
Cyathura carinata	1	0.01	100.00	Nemertea	0.0001	0.001	100.00

Table 4. (Cont.).

OUTSIDE (Ref) - ALL SPECIES							
	Total A	%Dom	Cum%		Total B	%Dom	Cum%
Enchytraeidae	5000	51.60	51.60	*Hediste diversicolor*	3.3696	69.48	69.48
Nematoda	2815	29.05	80.66	*Macoma balthica*	0.8816	18.18	87.66
Manayunkia aestuarina	1260	13.00	93.66	Enchytraeidae	0.2396	4.94	92.60
Tubificoides benedii	111	1.15	94.81	*Hydrobia ulvae*	0.1083	2.23	94.83
Hediste diversicolor	107	1.10	95.91	*Tubificoides benedii*	0.0682	1.41	96.24
Heterochaeta costata	107	1.10	97.02	Diptera larvae*	0.039	0.80	97.04
Collembola*	95	0.98	98.00	*Manayunkia aestuarina*	0.0344	0.71	97.75
Hydrobia ulvae	44	0.45	98.45	Nematoda	0.0303	0.62	98.38
Streblospio shrubsolii	43	0.44	98.90	*Heterochaeta costata*	0.0272	0.56	98.94
Diptera larvae*	40	0.41	99.31	*Pygospio elegans*	0.0132	0.27	99.21
Pygospio elegans	25	0.26	99.57	*Eteone flava/longa*	0.011	0.23	99.44
Macoma balthica	17	0.18	99.74	*Abra tenuis*	0.0093	0.19	99.63
Copepoda	9	0.09	99.83	*Streblospio shrubsolii*	0.0079	0.16	99.79
Eteone flava/longa	6	0.06	99.90	Tellinoidea	0.0039	0.08	99.87
Corophium volutator	3	0.03	99.93	Collembola*	0.0028	0.06	99.93
Nemertea	2	0.02	99.95	Nemertea	0.0025	0.05	99.98
Tellinoidea	2	0.02	99.97	Copepoda	0.0005	0.01	99.99
Paranais litoralis	1	0.01	99.98	*Corophium volutator*	0.0002	0.004	100.00
Abra tenuis	1	0.01	99.99	*Paranais litoralis*	0.0001	0.002	100.00
Acarina*	1	0.01	100.00	Acarina*	0.0001	0.002	100.00

Table 5. R-values derived from the one-way ANOSIM test and percentage dissimilarities from the SIMPER analysis (in italics) between communities in the sectors inside (MR) and outside (Ref) the realignment. Values in red indicate significant differences between communities.

	MR1	MR2	MR3	Ref1	Ref2
MR1	-	*44%*	*59%*	*51%*	*47%*
MR2	0.07	-	*57%*	*53%*	*46%*
MR3	0.16	0.13	-	*62%*	*67%*
Ref1	0.05	0.35	0.02	-	*47%*
Ref2	0.35	0.43*	0.41	0.15	-

* denotes a significant difference at $p<0.05$.

The stations located at higher tidal elevation levels inside the site (sector MR3) showed the highest dissimilarities (always >55%) with respect to the other sectors inside and outside the realignment site (Table 5, Figure 2). This was mainly due to the low number of individuals recorded at these stations overall, and particularly for the dominant taxa Enchytraeidae, Nematoda and *M. aestuarina*. Low numbers of Collembola and Diptera were also found at sector MR3 compared to the other sectors inside the site, and low numbers of *H. ulvae* were also recorded in this sector compared to the others (Appendices 2 and 3). A relatively high dissimilarity (>50%) was also detected between the communities inside the site and those at stations in the upper shore outside (Ref1) (Table 5). This was mainly due to the general high abundance of Enchytraeidae, Nematoda, *Tubificoides benedii*, *H. diversicolor*, *Heterochaeta costata* and *Streblospio shrubsolii*, and the low abundance of Collembola and

On average, the sand content in the sediments showed a significant increase at stations inside the site, particularly between 2004 (4.7% of sand) and 2008-2010 (16.1% and 11.6% of sand, respectively) ($p<0.001$) (Figure 4B). This pattern was evident particularly at stations 1B, 2B, 2C, 4A and 5B, located both in the western and eastern areas of the realignment site. In turn, a marked decrease in sand content between 2008 and 2010 was observed at stations 4B, 5A, 6A, 7A and 7B, possibly due to their location at the marsh margins, as explained above. No significant differences between years were detected outside the realignment site (Figure 4B). Sand content was significantly higher ($p<0.05$) outside the site than inside in 2004 and 2010 (Figure 4B) whereas the opposite pattern was noted for silt (Figure 4C).

Inside the site, the average sediment organic content decreased significantly from 9% in 2004 to 7% and 6% in 2008 and 2010 respectively (Figure 4D), this pattern being detected at most of the stations. Outside the site, organic content showed a progressive, but non significant, decrease over time (Figure 4D). Comparison between areas showed a significant different between the sediments inside and outside the site only in 2004 ($p<0.01$), with higher organic content recorded inside the site (Figure 4D). In turn, in later years this gap was reduced by the higher decreasing rate observed inside the site, leading to non significant differences in organic content between sediments at MR and Ref areas in 2008 and 2010.

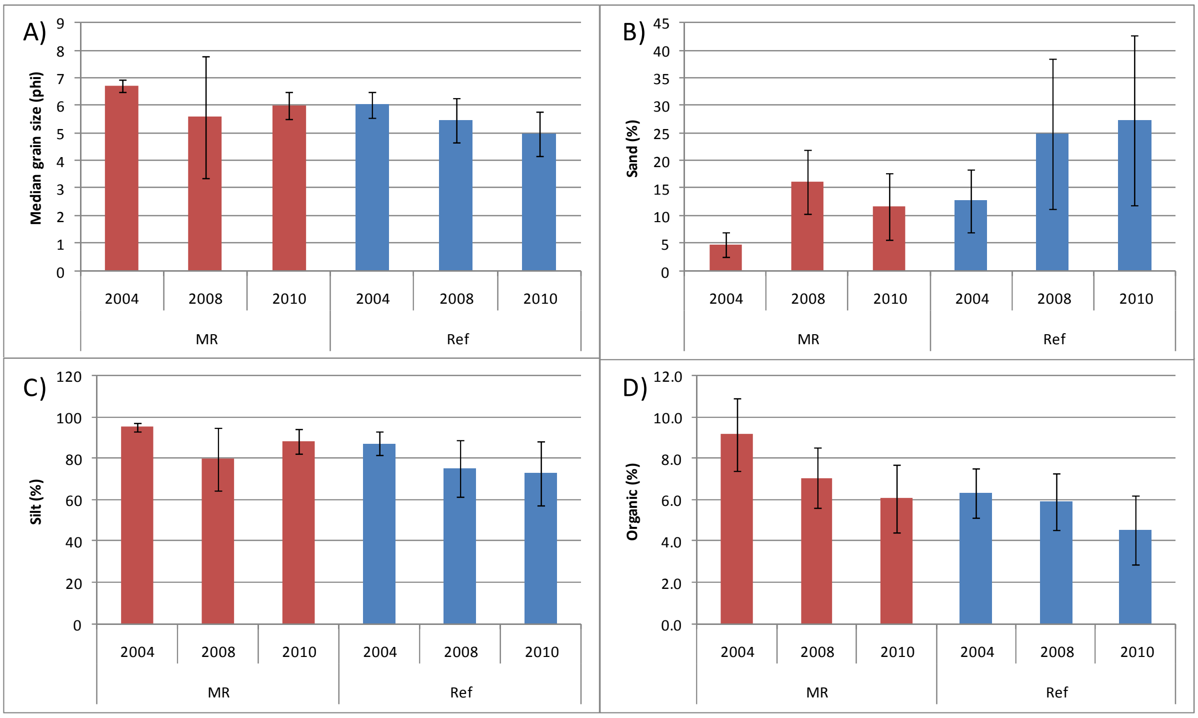


Figure 4. Temporal changes in sediment properties (mean ±SD) between 2004, 2008 and 2010 for stations (collectively) inside (MR) and outside (Ref) the realignment site. A = median grain size; B = sand content; C = silt content; D = organic content.

3.3.2. Variation in biological properties

Since 2004, the number of species has increased overall at most stations inside the site (Figure 5, Appendix 4). Outside the site, the number of species has been subject to some degree of variation but has remained relatively stable. The total abundance has increased at most stations since 2004. The most notable increase inside the site was observed in 2010 at stations 2A, 2B, 3A, 4A, 4B, 5B and 7B (Figure 6, Appendix 4). However, abundance remained low in comparison to stations outside the site, where a large increase was also observed in 2010. Station 2D was an exception, with the highest total abundance observed in 2004, mainly due to the occurrence of very high numbers of Enchytraeidae and nematodes accounting for 80% of the total abundance in this station.

Considering the stations inside the site collectively, there has been a statistically significant increase in all parameters since 2004 ($p<0.001$) (Figure 9). The mean number of species has increased from 1.8 in 2004 to 3.9 in 2008 and 6.9 in 2010, with significant changes being recorded between all years (Figure 9A). The number of species outside the site has remained stable over time, with mean values ranging 7.5 to 9. These remained significantly higher than those recorded inside the site ($p<0.05$) until 2008. The further increase inside the site in 2010 reduced the gap between the two areas, leading to non significant differences between them in this year (Figure 9A).

The total abundance has increased inside the site from 1462 individuals m^{-2} in 2004 to 4202 in 2008 and 21881 in 2010, the difference between 2004 and 2008 not being of significance (Figure 9B). These values were always low compared to mean values of over 14,000 individuals m^{-2} found outside the site, given also the substantial increase in total abundance (to more than 60000 individuals m^{-2}) observed in this area in 2010 compared to previous years (Figure 9B).

Inside the site, Shannon Weiner diversity (H') increased from 0.5 in 2004 to 1.1 in 2008 and 1.8 in 2010 with significant differences being recorded between all years ($p<0.001$) (Figure 9C). Values outside the site showed an opposite trend, with a significant decrease ($p<0.01$) being detected particularly between 2004 (2.3) and 2010 (1.7). The opposite trends observed inside and outside the site led to a reduction in the gap between the two areas, with significant differences observed only in 2004 and 2008 (with higher mean diversity being recorded in communities outside the site).

Biomass showed a substantial and significant increase inside the site between 2004 (3.5 g m^{-2}) and 2008 (49.6 g m^{-2}), followed by a decrease in 2010 (to 21.3 g m^{-2}), when mean biomass still remained higher than in 2004 ($p<0.001$) (Figure 9D). In turn, a decrease in biomass was recorded outside the site from 88.3 g m^{-2} in 2004 to 65.6 g m^{-2} in 2008 and 34.3 g m^{-2} in 2010, but this trend was not statistically significant due to the high variability in the data set. Biomass values were always higher outside than inside the site, but the difference between the two areas remained significant only in 2004 (Figure 9D).

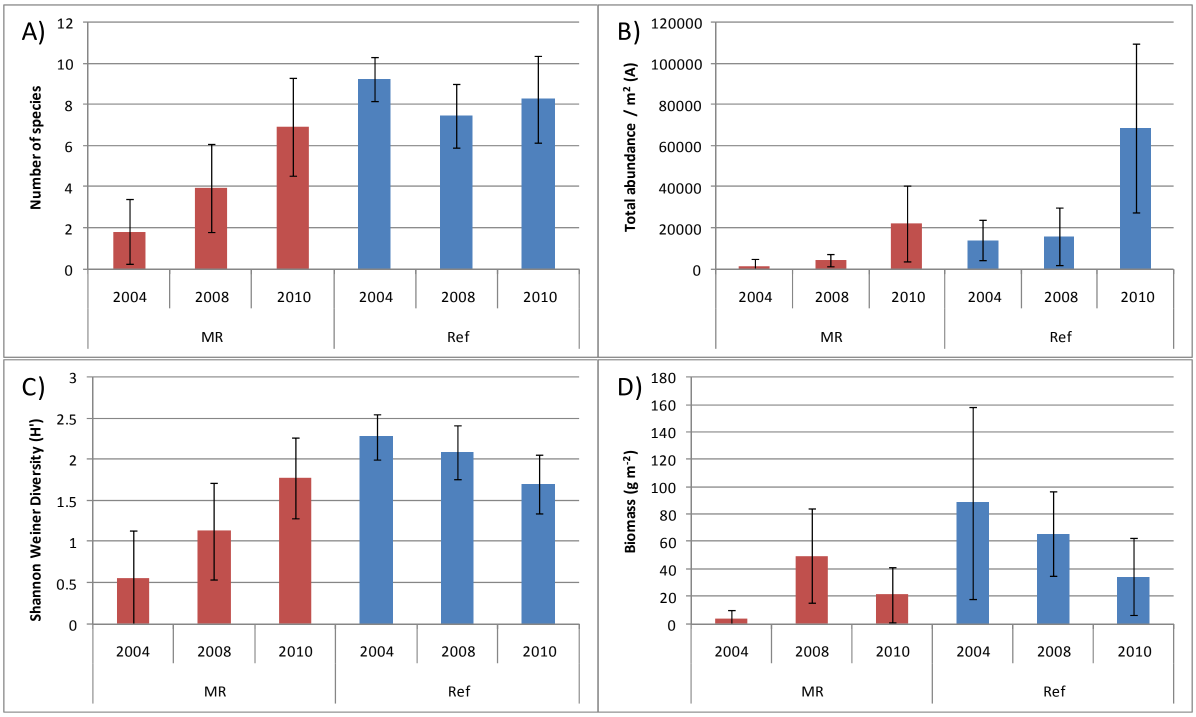


Figure 9. Temporal changes in the community parameters (mean ±SD) between 2004, 2008 and 2010 for stations (collectively) inside (MR) and outside (Ref) the realignment site. A = number of species; B = abundance; C = diversity; D = biomass.

3.3.3. VARIATION IN COMMUNITY STRUCTURE

The difference between the upper and mid shore communities outside the realignment site and those inside the site has reduced considerably over time (Figure 10 and 11, Appendix 4). In 2004, the community inside the site was heavily dominated by the oligochaete *Paranais litoralis*, accounting for 53% of the community and 79% in combination with the terrestrial organisms Collembola and Diptera. In 2008, this species had largely been replaced by *H. diversicolor*, dominating the community along with Enchytraeidae, nematodes, *S. shrubsolii* and *H. ulvae*. In 2010, Enchytraeidae still dominated the community inside the site along with *M. aestuarina*, Collembola and nematodes, accounting altogether for 62% of the community (Table 6). Whilst the abundance remained comparatively low inside the site, the differences between these communities and those on the established mudflats outside the site have reduced considerably over time. This is highlighted by the decrease in the dissimilarity values obtained from SIMPER analysis between the two areas, from 79% in 2004 to 57% in 2008 and 41% in 2010 (Table 7). This increased similarity in community structure between the two areas is also evident in Figures 10 and 11 which show a gradual convergence of the areas inside and outside the site, in terms of community structure, over time. ANOSIM confirmed these results by revealing significant differences between the communities inside and outside only in 2004 and 2008 (Table 7).

Both ANOSIM and SIMPER analysis indicated significant differences in the community structure inside the site between years, for all years. Only a slight decrease in the difference over time was observed, suggesting that substantial changes in the community structure inside the site occurred also over the last two years. Comparison between communities

Journal of Applied Ecology 2001
38, 846–856

The effects of disturbance on habitat use by black-tailed godwits *Limosa limosa*

JENNIFER A. GILL, KEN NORRIS* and WILLIAM J. SUTHERLAND
*Tyndall Centre, School of Biological Sciences, University of East Anglia, Norwich NR4 7TJ, UK; and *School of Animal and Microbial Sciences, University of Reading, Whiteknights, PO Box 228, Reading RG6 6AJ, UK*

Summary

1. Human disturbance of wildlife is widely considered to be a serious conservation problem. However, despite many qualitative studies, little attempt has been made to assess whether human presence limits the number of animals that sites can support. This can be quantified by incorporating measures both of human presence and of resource distribution into analyses of population distribution. The effects of disturbance can then be measured from any reduction in resource use at disturbed sites, which in turn indicates any reduction in the number of animals supported.
2. Shorebirds are often considered highly susceptible to disturbance because of their very obvious flight responses to humans and because they use areas that are generally subject to high levels of human recreational use.
3. This study addressed the effect of human presence on the distribution of black-tailed godwits *Limosa limosa islandica* on coastal areas in eastern England. We identified the prey types selected by godwits and related their depletion to different levels and types of human disturbance at a range of spatial scales.
4. Three methods of analysis are described: simple regressions of the effect of human activity on the number of godwits supported; multiple regression analyses of the effect of human presence and prey density on godwit numbers; and analyses of the effect of human presence on prey density at the end of the season. The latter method assumes that godwits are responsible for the majority of resource depletion. None of the analyses showed any effect of human presence on the number of godwits supported by the food supply at any of the spatial scales examined.
5. Many species may appear to avoid human presence but this may not reduce the number of animals supported in an area. Assessing the influence of disturbance on the relationship between animal distribution and resource distribution provides a means of assessing whether numbers are constrained by disturbance.

Key-words: bivalves, estuaries, human presence, prey selection, waders.

Journal of Applied Ecology (2001) **38**, 846–856

Introduction

The effect of human disturbance on animal distribution has received considerable attention in recent years (Owens 1977; Stalmaster & Newman 1978; Bélanger & Bédard 1989; Keller 1991; Stockwell, Bateman & Berger 1991; Pfister, Harrington & Lavine 1992; Reijnen *et al*. 1995; Madsen 1998). Assessing the severity of the effects of disturbance has important practical consequences; if it has serious impacts, conservationists are justified in recommending that access to wildlife areas be limited (Burger 1981; Tuite, Hanson & Owen 1984; Klein, Humphrey & Percival 1995). However, if the impacts of disturbance are trivial, then such measures cannot be justified. Restricting human access to the countryside can be expensive and time-consuming but, more importantly, it goes against the increasing view that rural access should be increased. Moreover, access to areas of conservation value can be the best way to protect them, as it increases the value placed on them by society (Adams 1997). There is therefore a need to quantify the extent to which disturbance adversely affects animal populations, in the context of a wider debate of how much human access to wildlife areas should be sanctioned or discouraged.

Correspondence: J.A. Gill, Tyndall Centre, School of Biological Sciences, University of East Anglia, Norwich NR4 7TJ, UK (fax 01603 592250; e-mail j.gill@uea.ac.uk).

activity (< 10 people h^{-1}); and sites with no footpaths (mean index of activity at high use: 1·19 ± 0·13; low use: 0·45 ± 0·09; no footpath: 0·31 ± 0·14; $F_{2,15} = 14{\cdot}78$, $P < 0{\cdot}001$). Each of the six estuaries in this survey had one of each of the three footpath categories. At each of the marina and footpath sites, prey samples were collected in the autumn (16 October–1 November 1995) and again in the spring (26 February–12 March 1996). The samples were collected from transects running out from the shoreline, with eight replicate cores of 6·4 cm diameter and 15 cm depth taken at 0 m (as close as possible to the shore), 20 m, 40 m, 60 m and 80 m, totalling a maximum of 40 replicates for each site [the width of some sites was less than 80 m, in which case transects were only run to 60 m (one marina + reference site and two footpaths) or 40 m (three marinas + reference sites and one footpath)]. This allowed disturbance to be examined both as a direct comparison of sites with and without a source of disturbance, and as an effect of distance away from the shoreline, where the majority of the human activity occurs.

Results

LEVELS OF HUMAN ACTIVITY BETWEEN AND WITHIN ESTUARIES

Across the 20 small sites studied intensively in 1996–97, the level of disturbance on each site could be characterized by taking the mean value of the index of disturbance recorded every 2 weeks. This index varied significantly between sites ($H_{19} = 165{\cdot}6$, $P < 0{\cdot}0001$).

The mean disturbance indices also varied significantly across the five estuaries (Fig. 3). The Deben, Orwell and Colne estuaries had significantly higher levels of human activity than the Alde and the Blackwater (Kruskal–Wallis test: $H_4 = 28{\cdot}9$, $P < 0{\cdot}0001$). Figure 3 also shows the relative importance of each of the four constituent components of the index on each of the estuaries. The majority of human activity on each of the estuaries was due to shore-based activities. Water-based activities were more common on the Alde, Deben and Orwell than on the Colne and Blackwater.

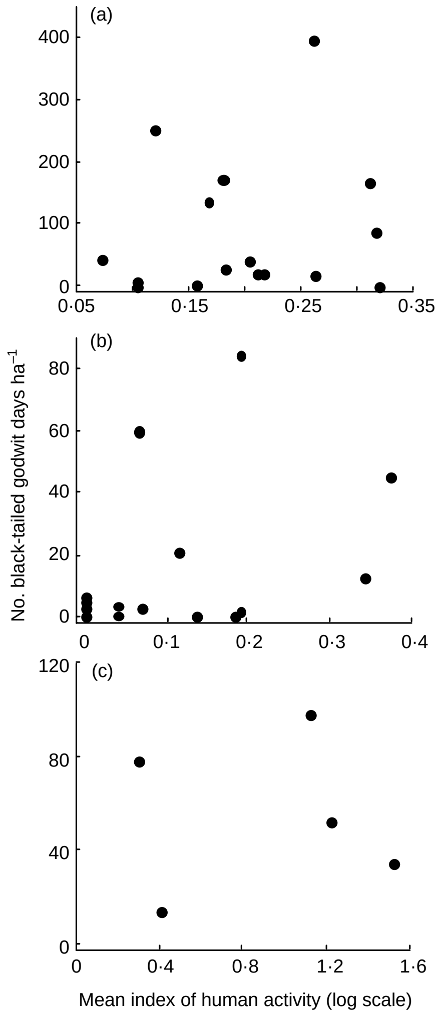


Fig. 4. The relationship between the mean level of human activity and the total number of black-tailed godwit days per hectare over the winter on (a) patches ($r^2 = 0{\cdot}02$, NS); (b) mudflats ($r^2 = 0{\cdot}1$, NS); (c) estuaries ($r^2 = 0{\cdot}001$, NS).

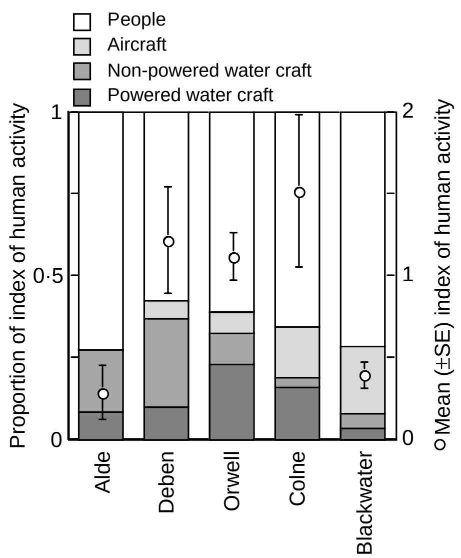


Fig. 3. The mean index of human activity on each of the five estuaries studied in 1994–95 and the relative contribution of each of the four constituent components of the index, on each of the estuaries.

HUMAN ACTIVITY AND GODWIT NUMBERS

At none of the three scales was there a significant relationship between numbers of godwits and human activity (Fig. 4a–c).

HUMAN ACTIVITY, BIRD NUMBERS AND RESOURCE ABUNDANCE

Over the 20 sites studied in 1996–97, black-tailed godwits showed a strong aggregative response, with the total density of godwits consuming bivalves (summed

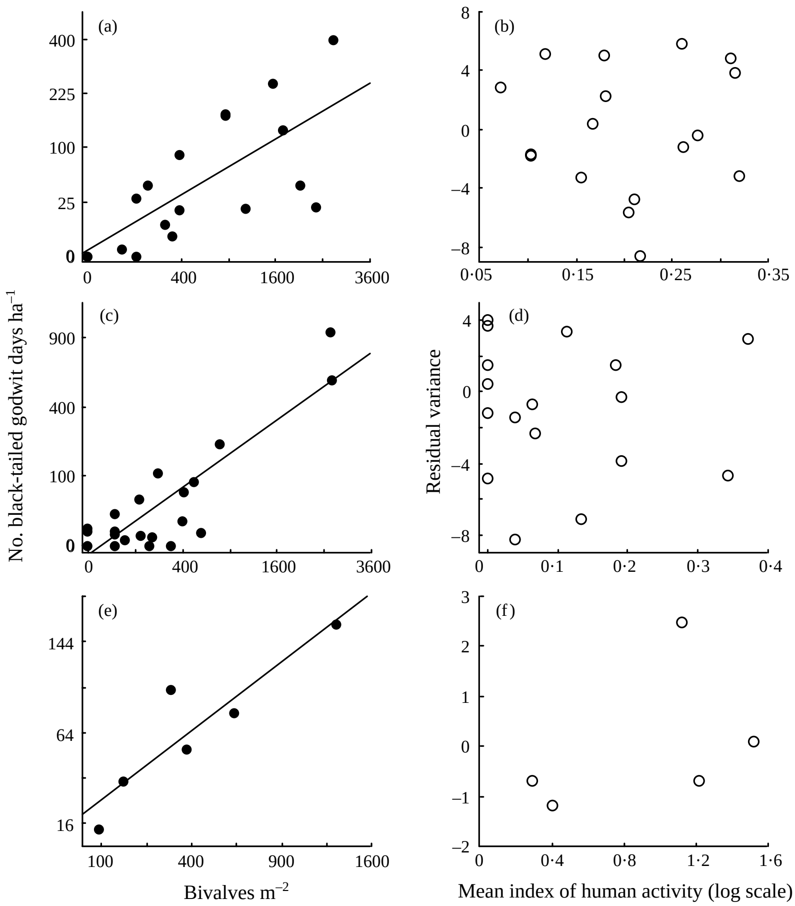


Fig. 5. The relationships between the initial density of available bivalves in October and the total number of black-tailed godwit days feeding on bivalves on (a) patches of mudflat over the winter 1996–97 ($y = 0{\cdot}256x + 0{\cdot}63$; $r^2 = 0{\cdot}46$, $P < 0{\cdot}003$); (c) whole mudflats over the winter 1994–95 ($y = 0{\cdot}49x - 1{\cdot}60$; $r^2 = 0{\cdot}76$, $P < 0{\cdot}0001$); (e) estuaries over the winter 1994–95 ($y = 0{\cdot}36x - 1{\cdot}03$; $r^2 = 0{\cdot}79$, $P < 0{\cdot}02$) (all axes were normalized by square-root transformation) and the relationships between the residual variance in these responses and the mean index of human activity on (b) patches, (d) mudflats and (f) estuaries (see text for analysis).

from counts every 2 weeks) over the winter increasing significantly with the initial density of available bivalves (Fig. 5a). Sites containing less than 150 bivalves m^{-2} in October were never used by godwits. When the mean index of human activity on these sites was included with initial bivalve density in a stepwise multiple regression analysis of the factors affecting total over-winter godwit density, the index of human activity was non-significant (partial correlation coefficient = 0·07, $P < 0{\cdot}79$) but available bivalve density was retained (coefficient = 0·25 ± 0·06, $r^2 = 0{\cdot}53$, $P < 0{\cdot}0001$). This could be illustrated by relating the residual variance of the patch-scale aggregative response presented in Fig. 5a to the index of human activity (Fig. 5b). This indicated that human activity had no effect on the number of godwits supported on these sites.

The distribution of black-tailed godwits was also strongly related to available bivalve density across larger mudflats (Fig. 5c). In a stepwise multiple regression analysis of the effect of bivalve density and human activity on total over-winter godwit density across mudflats, the index of human activity was again non-significant (partial correlation coefficient = 0·3, $P < 0{\cdot}7$) and bivalve density was retained (coefficient = 0·36 ± 0·09, $r^2 = 0{\cdot}79$, $P < 0{\cdot}017$). There was therefore no relationship between human activity and the residual variance of the mudflat-scale aggregative response (Fig. 5d).

At the whole estuary scale, the total number of godwits over a winter was again significantly related to the initial bivalve density (Fig. 5e). The index of human activity was again rejected in a stepwise multiple regression analysis (partial correlation coefficient = 0·16, $P < 0{\cdot}83$), whereas bivalve density significantly affected godwit density at this scale (coefficient = 0·80 ± 0·11, $r^2 = 0{\cdot}93$, $P < 0{\cdot}002$). There was therefore no relationship between human activity and the residual variance of the estuary-scale aggregative response (Fig. 5f).

HUMAN ACTIVITY AND RESOURCE ABUNDANCE

As bivalve populations on these estuaries undergo severe over-winter depletion, and as black-tailed godwits are the major cause of depletion of the available bivalves (Gill, Sutherland & Norris 2001b), it was possible to examine the relationship between levels of human activity and the abundance of bivalves remaining at the end

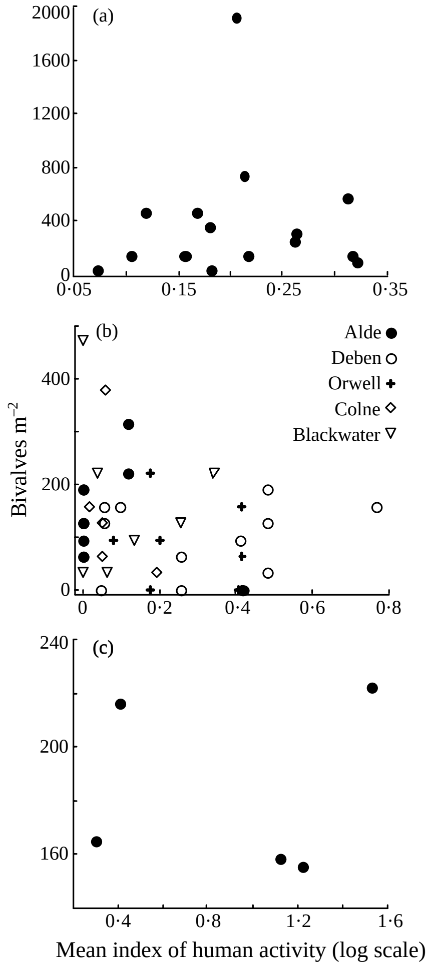


Fig. 6. The relationship between the mean index of human activity and the density of available bivalves in spring on (a) small patches of mudflat (r^2 = 0·02, NS); (b) mudflats across five estuaries (see Table 1 for analysis); (c) whole estuaries (r^2 = 0·004, NS). Only sites with more than 150 bivalves m^{-2} in autumn are included.

of the season. This method assumes that initial prey density at the start of the season is not related to levels of disturbance. At the 20 sites in which levels of human activity and prey abundance were recorded every 2 weeks throughout the winter of 1996–97, the prey abundance at which the godwits stopped consuming bivalves at each site was therefore known. On sites with available bivalve

Table 1. Summary of two-way analyses of variance of the effect of the index of disturbance on the density of available bivalves (*Scrobicularia plana*, *Macoma balthica* and *Mya arenaria* of less than 20 mm length) on five different estuaries in autumn and spring. Only sites with more than 150 bivalves m^{-2} in autumn are included

Source	d.f.	Autumn *F*	Spring *F*
(a) Index of human activity	1	1·81	2·08
(b) Estuary	4	0·69	2·49
a × b	4	0·56	0·58
Error	33		

densities high enough to attract godwits (> 150 m^{-2}; Fig. 5a), the initial density of available bivalves was not related to the mean index of human activity (r^2 = 0·00001, P < 0·99). There was no relationship between the mean index of human activity and the abundance of bivalves after godwits had stopped using the sites (Fig. 6a). The level of human activity also had no effect on the abundance of bivalves at the end of the season at either the larger mudflat-scale (Fig. 6b; Table 1) or the whole estuary scale (Fig. 6c).

At the patch-scale, the index of human activity could also be broken into its constituent components, but none was significantly related to the over-winter depletion of the available bivalves on these sites (Table 2). Disturbance could also be estimated from factors such as the distance to the nearest road or footpath, but again neither affected over-winter depletion of the available bivalves on these sites (Table 2). Human activity may not have affected the overall use made of the sites but may have affected the temporal pattern of use by the godwits. If the godwits used undisturbed sites preferentially, rates of prey depletion should have been higher in these sites than in undisturbed sites. However, the index of human activity had no significant effect on the rates of depletion of available bivalves ($y = 0{\cdot}04x - 0{\cdot}14$, r^2 = 0·03, P < 0·6).

At all of these scales, almost all of the sites were depleted from a wide range of initial densities down to approximately 100–500 bivalves m^{-2} (Fig. 6). If human activity was restricting the use made of this food supply by the godwits, it would be unlikely that the spring densities would be so consistent.

Table 2. Summary of linear regression analyses of the effect of seven disturbance variables on the density of available bivalves on patches of mudflat in autumn and spring. Only sites with more than 150 bivalves m^{-2} in autumn are included

	Autumn		Spring	
Disturbance variable	Slope	r^2	Slope	r^2
Mean number of people h^{-1}	–ve	0·03	+ve	0·08
Mean number of PWC h^{-1}	–ve	0·10	–ve	0·03
Mean number of NPWC h^{-1}	–ve	0·08	–ve	0·11
Mean number of aircraft h^{-1}	–ve	0·07	+ve	0·01
Distance to road (m)	–ve	0·041	–ve	0·01
Distance to footpath (from shore edge) (m)	–ve	0·20	–ve	0·14
Distance to footpath (from centre of mudflat) (m)	+ve	0·10	+ve	0·10

Journal of Applied Ecology, **38**, 846–856

Contrasting trends in two Black-tailed Godwit populations: a review of causes and recommendations

JENNIFER A. GILL[1], ROWENA H.W. LANGSTON[2], JOSÉ A. ALVES[1], PHILIP W. ATKINSON[3], PIERRICK BOCHER[4], NUNO CIDRAES VIEIRA[5], NICOLA J. CROCKFORD[2], GUILLAUME GÉLINAUD[6], NIKO GROEN[7], TÓMAS G. GUNNARSSON[1,8], BECCA HAYHOW[1], JOS HOOIJMEIJER[7], ROSEMARIE KENTIE[7], DAVID KLEIJN[9], PEDRO M. LOURENÇO[7], JOSÉ A. MASERO[10], FRANCIS MEUNIER[11], PETER M. POTTS[12], MAJA ROODBERGEN[7,9], HANS SCHEKKERMAN[13], JULIA SCHRÖDER[7], EDDY WYMENGA[14] & THEUNIS PIERSMA[7]

[1] School of Biological Sciences, University of East Anglia, Norwich, NR4 7TJ, UK j.gill@uea.ac.uk
[2] Royal Society for the Protection of Birds, The Lodge, Sandy, Beds, SG19 2DL, UK
[3] British Trust for Ornithology, The Nunnery, Thetford, IP24 2PU, UK
[4] Laboratoire Littoral Environnement et Sociétés, Pôle Sciences et Technologies, University of La Rochelle, 17042 La Rochelle, France
[5] Sociedade Portuguesa para o Estudo das Aves, Av. Liberdade 105, 2º Esq., 1250-140 Lisboa, Portugal
[6] Bretagne Vivante – SEPNB, Réserve Naturelle Des Marais De Séné. Brouel Kerbihan- 56860 Séné, France
[7] Animal Ecology Group, Centre for Ecological and Evolutionary Studies, University of Groningen, PO Box 14, 9750 AA Haren, The Netherlands
[8] Snæfellsnes Research Centre, University of Iceland, Hafnargata 3, IS-340 Stykkishólmur, Iceland
[9] Alterra, Centre for Ecosystem Studies, PO Box 47, 6700 AA, Wageningen, The Netherlands
[10] Grupo de Investigación en Biología de la Conservación, Área de Zoología, Universidad de Extremadura, Avenida de Elvas s/n, 06071 Badajoz, Spain
[11] Ligue pour la Protection des Oiseaux, Corderie Royale, BP90263, 17300 Rochefort, France
[12] Farlington Ringing Group, Solent Court Cottage, Chilling Lane, Warsash, Southampton, Hampshire, SO31 9HF, UK
[13] Dutch Centre for Avian Migration and Demography, PO Box 40, 6666ZG Heteren, The Netherlands
[14] Altenburg & Wymenga Ecological Consultants, PO Box 32, 9269 ZR Veenwouden, The Netherlands

---

Gill, J.A., Langston, R.H.W., Alves, J.A., Atkinson, P.W., Bocher, P., Cidraes Vieira, N., Crockford, N.J., Gélinaud, G., Groen, N., Gunnarsson, T.G., Hayhow, B., Hooijmeijer, J., Kentie, R., Kleijn, D., Lourenço, P.M., Masero, J.A., Meunier, F., Potts, P.M., Roodbergen, M., Schekkerman, H., Schröder, J., Wymenga, E. & Piersma, T. 2007. Contrasting trends in two Black-tailed Godwit populations: a review of causes and recommendations. *Wader Study Group Bull.* 114: 43–50.

Keywords: Black-tailed Godwit, *Limosa limosa*, subspecies *limosa*, subspecies *islandica*, population size, population trend, habitat, conservation

In recent decades, the West European population of Black-tailed Godwits, *Limosa limosa limosa*, has declined in size at a quite alarming rate, while the Icelandic population, *L. l. islandica*, has undergone a rapid increase in population size. These two populations have been the subject of a great deal of research, much of which has been focused on understanding the causes and consequences of the contrasting population trends. In 2007, a workshop was held during the annual conference of the International Wader Study Group at La Rochelle, France, with the aims of identifying the likely causes of the population changes and providing recommendations for future actions to improve the conservation of both populations. The available evidence strongly suggests that changes in productivity as a consequence of agricultural intensification are the most likely driver of the decline in *L. l. limosa,* although the concentration of much of the population in just a few sites in winter and spring is likely to exacerbate their vulnerability to future habitat changes. Agricultural and climatic changes are implicated in the expansion of *L. l. islandica*, and the availability of both intertidal mudflats and wet grasslands as foraging habitats appears to be very important across much of the winter range of this population. A series of recommendations for actions to conserve both populations are provided, including improving agricultural land management and protecting key passage and winter sites and habitats.

The last three decades have seen widespread declines in the population size of many species of shorebird (International Wader Study Group 2003). While research has strongly implicated the loss and degradation of breeding habitats in these declines, largely through drainage of wetlands and conversion to intensive agriculture (Thorup 2006), efforts to reverse declining population trends have met with little success. The West European population of Black-tailed Godwits, *Limosa limosa limosa*, provides one of the clearest examples of this problem. The great majority of this population breed in the Netherlands where, after increasing in the first half of the 20th century (Bijlsma *et al.* 2001), it was a widespread and common meadow bird in the 1960s, numbering up to 250,000 individuals (Mulder 1972, Piersma 1986). However, since then this population has declined severely, and now numbers only around 50,000 breeding pairs (BirdLife International 2004).

Attempts to reverse this population decline (and similar declines in many other meadow-breeding bird species) have focused on implementing agri-environment schemes (AES) on farmland in breeding areas to improve breeding success (Beintema *et al.* 1997, Kleijn *et al.* 2001, van Brederode & Laporte 2006, Verhulst *et al.* 2007). Despite the area covered by AES aimed at conserving meadow birds increasing from *c.*20,000 ha to *c.*150,000 ha of farmland in the Netherlands by 2006, and schemes costing in excess of 30 million Euro per year, no discernible improvement in the population so far has been apparent (Kleijn *et al.* 2001). In fact, the national population trends of meadow birds in the period 2000–2004 have declined even more rapidly (by approximately 3.5%) than trends in the period 1990–2000 (Teunissen & Soldaat 2006). In addition to agri-environment initiatives, the creation and management of nature reserves for meadow birds has also occurred but on relatively small areas (*c.*18,000 ha, Schekkerman *et al.* subm. b). Although population declines are less steep in reserves than in the wider countryside, there is much variability between reserves (Teunissen & Soldaat 2006).

By contrast, the population of Black-tailed Godwits that breeds in Iceland, *Limosa limosa islandica*, has undergone a rapid increase over the same time period, from an estimated 2,000–3,000 individuals around 1900 to *c.*50,000–75,000 at present. This population has expanded from breeding locations in south-west Iceland and now occurs virtually throughout lowland Iceland (Gunnarsson *et al.* 2005a).

Both the *limosa* and *islandica* subspecies of Black-tailed Godwits have been the subject of extensive research studies in recent years, mostly focused on the causes and consequences of population changes (e.g. Beintema 2007, Both *et al.* 2006, Gill *et al.* 2001a, Groen & Hemerik 2002, Gunnarsson *et al.* 2005b, Roodbergen *et al.* subm., Schekkerman *et al.* 2005, subm. a,b, Schekkerman & Verhulst *et al.* 2007). In order to bring together the available information on both populations, a workshop was held at the International Wader Study Group conference at La Rochelle, France in 2007. This workshop aimed to:

- compare current knowledge of the Icelandic and West European *L. limosa* populations
- inform potential explanations for the divergent population trajectories
- highlight research gaps and potential future collaborations
- recommend conservation measures.

Here we report on the findings of this workshop, particularly focusing on identifying the likely drivers of changes in demography and distribution of both populations, highlighting the key issues influencing each population and providing a series of recommendations for future conservation and research efforts. The workshop attracted *c.*100 participants with a wide range of expertise and knowledge of these birds and their habitats. This meeting was therefore a unique and exciting opportunity to compare two subspecies with widely diverging population trajectories, and to discuss causes of changes and prioritise future actions.

The workshop comprised a series of comparative talks which detailed current knowledge of the key processes influencing breeding and non-breeding season distribution and demography, and patterns of connectivity between seasons and sites, for the two populations. During the workshop, information from each talk was used to complete a summary table of current status, drivers of change and potential impact for a series of demographic, distribution and habitat issues (Tables 1 & 2). The key issues arising from this summary are discussed below.

CURRENT DISTRIBUTION AND HABITAT USE OF *L. L. LIMOSA*

The West European breeding population of Black-tailed Godwits breeds throughout the Netherlands, with smaller numbers in Germany, Belgium, Denmark, France and the UK, and migrates via France and Iberia to winter grounds in Senegal, Guinea-Bissau and Guinea in sub-Saharan West Africa (Beintema & Drost 1986, Kuijper *et al.* 2006).

Key breeding season issues

This population depends on grasslands with high groundwater levels as breeding sites, and on wetlands as passage and winter foraging sites (Wymenga *et al.* 2006). Over the last 50 years, both of these habitats have undergone extensive modification. The core of the recent breeding range of this population is on clay-on-peat and peat soils, but the historical distribution also included blanket bogs and wet moorland, which were abandoned as the population expanded into agricultural habitats in the first half of the 20th century (Bijlsma *et al.* 2001). Since then, drainage, urbanisation and conversion of grasslands to arable crops have created drier and highly fragmented breeding habitats (SOVON 2002). The remaining grasslands are generally farmed very intensively, with mowing dates having advanced by one month over the last century, most grasslands now being mown more than twice per year, and livestock number per unit grassland area being the highest of all European countries (Statistics Netherlands, Statline). In addition, there is evidence that changes in predator control and environmental contamination, and landscape changes such as road-building and tree-planting, have altered predator abundance and distribution, and consequently increased nest and chick predation rates (Schekkerman *et al.* subm. a, Teunissen *et al.* 2006, Teunissen & Willems 2004).

When the population size was higher, godwits bred on grasslands in areas of peat, clay and sandy soils. The population decline has been characterised by a contraction into largely peat areas, although levels of degradation now appear similar across all soil types. AES initiatives to reverse the population decline have focused on delaying mowing dates and improving nest protection. However, there is no strong evidence that these schemes have improved breeding densities (Kleijn *et al.* 2001, Kleijn & van Zuijlen 2004, Verhulst *et al.* 2007, Willems *et al.* 2004), despite evidence that delayed mowing saves nests and improves chick survival (Schekkerman & Müskens 2000, Schekkerman *et al.* 2005, subm b). Godwits preferentially choose areas with high groundwater levels as breeding sites (Kleijn & van Zuijlen

2004, Verhulst *et al.* 2007); although clay soils with relatively low ground water levels can also be used. Current AES do not, however, include management of groundwater levels, as this is a contentious issue for farmers. Successful management is also likely to require fields with tall, open and structurally diverse swards within the matrix of more intensively farmed fields throughout the breeding season. This provides chicks hatched throughout an area with access to high quality foraging sites as well as shelter from predators (Schekkerman *et al.* subm. b).

Key non-breeding season issues

On passage and at wintering sites in Iberia and West Africa, wetlands have been extensively drained and dammed since the 1960s, to facilitate energy production, water storage and agriculture (Kuijper *et al.* 2006). Rice production is now widespread, and rice fields provide an alternative habitat which, when flooded, is wet enough to allow birds such as godwits to forage. Godwits have been reported foraging on rice fields in winter since at least the 1970s (Altenburg *et al.* 1985, Tréca 1984, van der Kamp *et al.* 2007), and recent studies of godwits in Iberia and Africa have shown that the birds primarily consume rice seeds (along with smaller amounts of invertebrate food) during the months in which rice fields are used (Tréca 1994). Godwits typically forage on molluscs, worms and other invertebrates, and the consequences of this largely plant-based diet through much of the winter and spring are currently unknown.

Godwits begin to arrive in West Africa in July, and they use rice fields extensively, particularly during planting (Jul–Aug) and harvest (Nov–Dec) (Kuijper *et al.* 2006, van der Kamp *et al.* 2007). When the African rice fields are dried out and harvested during December, the birds begin to migrate north to use rice fields in Spain and Portugal (Sanchez-Guzman *et al.* 2007, Zwarts *et al.* in press). At this time they can be highly concentrated, with up to 50,000 birds in the Doňana National and Natural Park, SW Spain, in December, up to 25,000 in Extremadura, W Spain, by early February and up to 45,000 around the Tagus and Sado estuaries, W Portugal, by late February. Passage sites in Morocco were formerly used in autumn and spring but few birds use these sites now. Drainage of Moroccan wetlands may have influenced this shift in passage site use, as may recent increases in rice production in Spain. Similarly, use of French sites on spring migration may have declined in recent years, although overlap

Table 1. Summary of the current status of the demography, distribution and habitat use of the West European Black-tailed Godwit population, *Limosa limosa limosa*, together with likely drivers of changes and estimates of the proportion of the population experiencing these conditions.

	Status of *limosa* population	Drivers of changes	Potential population impact
Population size	*c.*60,000 breeding pairs		
Population trend	Severe decline at *c.*5%p.a.	Primarily due to declining productivity	Population-wide
Nest survival	Intermediate to low and variable.	Earlier mowing and increased predation	Population-wide
Chick survival	Low. Declines since 1980s	Earlier mowing, reduced habitat heterogeneity and increased predation	Population-wide
Productivity trend	Decline since 1980s from *c.*0.7 to 0.2 fledged young /pair	Loss of grasslands with high water tables, intensification of remaining grasslands	Population-wide
Juvenile survival	Estimates from 40% to 68%	Hunting of juveniles on migration could be significant	Higher estimate from one site only (Workumerwaard)
Adult survival	Annual estimates = 81–96%	Unknown	Probably population-wide
Breeding habitat	Grasslands with high ground water levels in open landscapes	26% loss to urbanisation and arable conversion since 1960s. Severe decline in quality through drainage and intensification	Population-wide
Breeding locations	Grassland in Netherlands, Germany, Belgium and Denmark	Unknown as degradation of all soil types appears similar	Population wide
Breeding trend	Declining and contracting in range	Declining habitat quality, fragmentation	Population-wide
Autumn habitat	Wetlands, mudflats, saltpans, rice fields	Unknown	Unknown
Autumn locations	France (Jun–Nov), Iberia (Jun–Nov) and W Africa (Jul–Nov)	Reduced wetland area in Morocco and S Europe and/or changes in site quality	Most adults fly direct to Africa. Juveniles may use European sites
Autumn trend	Earlier departure and reduced use of Morocco	Early departure correlated with poor breeding success and deferral of breeding	Unknown
Winter habitat	Rice fields and wetlands	Increased use of rice following widespread conversion of wetlands	Population-wide
Winter locations	Senegal and Guinea Bissau (Nov–Dec), Iberia (Dec–Feb)	Large-scale damming, drainage, water storage and agriculture in Senegal delta	Population-wide
Winter trend	Possible earlier departure from Africa for Iberia	Departure follows drying of rice fields – changing rainfall patterns may be involved	Population-wide
Spring habitat	Rice fields, saltpans and wetlands	Conversion of wetlands to rice fields	Population-wide
Spring locations	Iberia (Dec–Feb), France (Feb–Mar) and Netherlands (Mar–Apr), reduced use of Morocco and France	Reduced wetland area in Morocco and France and/or changes in site quality Switch to rice-seed diet	Population-wide
Spring trend	Possible earlier departure from Iberia but arrival in Netherlands unchanged	Unknown	Unknown

between the two subspecies at this time of year makes this difficult to assess.

POSSIBLE CAUSES OF THE POPULATION DECLINE IN *L. L. LIMOSA*

These extensive habitat changes throughout the range of *L. l. limosa* allow several plausible causes of the severe population decline to be identified:

- declining habitat quality and availability in the breeding season may have resulted in reductions in productivity;
- changes in winter and spring diet may have altered the body condition or survival probability of fully-grown birds;
- habitat and climatic changes in the Sahel region may have altered habitat availability, and consequently body condition or survival of fully-grown birds.

The demographic evidence presented at this workshop strongly suggests that reductions in productivity are the most likely driver of the population decline. Changes in productivity through the period of breeding habitat change have been severe, declining from *c.*0.7 chicks per pair (range: 0.5–1) in the 1980s to *c.*0.2 chicks per pair (range: 0.1–0.7) at present (Schekkerman *et al.* 2005, subm b). Changes in the timing and frequency of mowing, affecting both direct nest and chick losses and the foraging conditions for chicks (Schekkerman & Beintema 2007), are strongly implicated in driving these declines. In addition, the abundance of nest and chick predators and their impact on an increasingly fragmented and exposed (through loss of cover by early mowing) population appears to be growing. In recent years, there has also been evidence from one site for deferral of breeding by up to half of the adults returning to the breeding grounds.

The widespread use of rice as food in winter and spring may affect adult body condition but there is currently no evidence for any declines in adult survival rates, in fact adult survival appears to have increased in recent decades (Zwarts *et al.* in press). Recent colour-ring studies suggest high adult annual survival rates of *c.*81–96% (Both *et al.* 2006, Roodbergen *et al.* subm., J. Schröder in prep.), though national estimates from ring-recoveries suggest annual survival rates of *c.*80% (van Noordwijk & Thomson subm.). Recent reductions in the length of the hunting season in France are likely to have reduced hunting pressure, and numbers of hunting recoveries of ringed birds have declined in recent years (Zwarts *et al.* in press). Mortality of juveniles on autumn migration may

Table 2. Summary of the current status of the demography, distribution and habitat use of the Icelandic Black-tailed Godwit population, *Limosa limosa islandica*, together with likely drivers of changes and estimates of the proportion of the population experiencing these conditions.

	Status of *islandica* population	Drivers of changes	Potential population impact
Population size	*c.*50,000–75,000 individuals		
Population trend	Rapid increase, from *c.*2600 around 1900	Warmer temperatures and agricultural expansion in Iceland	Population-wide
Nest survival	50–75% of nests hatch	Unknown	Unknown
Chick survival	20–80% pairs fledge at least one chick. Productivity likely to be *c.*0.5–0.8 chicks/pair	Population expansion may have reduced average productivity	Unknown
Productivity trend	Unknown	Unknown	Population-wide
Juvenile survival	*c.*60% from ringing to fledging and *c.*50% post-fledging to first autumn	Unknown	Population-wide
Adult survival	Annual estimates = 87–99%, highest in winter and lowest during spring migration	Survival increased in late 1990s. Some evidence of recent declines	Probable regional variation in survival trends
Breeding habitat	Lowland marshes and dwarf-birch bogs	Suitability of dwarf-birch bogs as breeding sites may have increased	Population-wide
Breeding locations	Expansion from SW to NE Iceland	Expansion into colder parts of Iceland with more dwarf-birch bog	Population-wide
Breeding trend	Increasing and expanding distribution	Average productivity likely declined but number of pairs increased	Population-wide
Autumn habitat	Estuarine mudflats, occasional use of river valleys and gravel pits	None	Most use of freshwater habitats by juveniles
Autumn locations	Most in UK, Ireland and France (Jul–Sep).	None	Population-wide
Autumn trend	Expansion into E and NW England moulting sites	Population size increase	*c.*30% of population in new sites
Winter habitat	Estuarine mudflats and grasslands. Saltpans in Iberia	Grassland use more extensive in recently occupied sites	*c.*80% on mudflats and *c.*20% on grasslands
Winter locations	UK, Ireland, France and Iberia (Oct–Feb)	Population size increase	Population-wide
Winter trend	Recent expansion into E and NW England	Population size increase	*c.*10% of population in new sites
Spring habitat	Estuarine mudflats and grasslands. Some use of saltpans (France & Iberia) and rice fields (Iberia)	Grassland use more extensive in recently occupied sites	*c.*30% on mudflats and *c.*70% on grasslands
Spring locations	Netherlands (Iberian and French birds), Ireland (Irish birds), UK (UK and Irish birds) (Mar–Apr)	Increase in use of Netherlands and E England grasslands	*c.*50–60% of the population uses Netherlands and E England sites
Spring trend	Increasing use of grasslands on spring passage. Earlier arrival in Iceland	Changing rainfall. Population increase and/or warmer springs	Earlier arrival trend may be more apparent in the earliest birds

be higher as they appear to use European passage sites more than adults, and may thus be exposed to hunting pressures in France. The available national ringing recovery data, together with a recent colour-ringing study from one site, suggest that juvenile survival is not particularly low, but these estimates may not be representative of the whole population.

Habitat structure and composition in Iberia and West Africa have clearly changed dramatically since the 1950–1960s, especially in the Senegal delta, but again there is little evidence for negative impacts on survival rates, at least in recent years. Mortality rates do appear to be a little higher in years with low rainfall in the Sahel, possibly as a consequence of birds occurring at high densities in the remaining wet areas, especially during the post-breeding arrival period when conflict with rice farmers can make the godwits vulnerable to hunting pressure (Zwarts *et al.* in press). However, although there is no strong evidence for climatic or habitat changes in the non-breeding season driving the population declines, there is clear concern that these processes could exacerbate the declines, as such a high proportion of the population is dependent upon relatively small areas of rice fields at key times of year.

CURRENT DISTRIBUTION AND HABITAT USE OF *L. L. ISLANDICA*

The Icelandic population of Black-tailed Godwits breeds primarily in Iceland, with small numbers in the Faeroes, Lofoten and Shetland Islands. In Iceland they breed in lowland areas, primarily on coastal marshes and dwarf-birch bogs (Gunnarsson *et al.* 2006a).

Key breeding season issues

In both marshes and dwarf-birch bogs, Icelandic Black-tailed Godwits are strongly associated with shallow pools, often surrounded by sedges, which support foraging adults. Chicks feed mostly on invertebrates gleaned from vegetation, and seek out tracts of grassland which are rarer in the dwarf-birch bog habitats. The expansion from SW Iceland (around 1900) to the major basins in the north and west (1920s–1940s) and then the east and north-east of Iceland (1970s–1980s) was characterised by an increase in the proportion of dwarf-birch bog sites occupied (Gunnarsson *et al.* 2005a). The most recently occupied sites are also colder than the traditionally occupied southerly sites (Gunnarsson *et al.* 2006b). The lowland areas of Iceland have seen widespread drainage of wetlands and increases in numbers of hayfields since the 1960s, and godwits are now frequently recorded feeding on hayfields during the breeding season.

Key non-breeding season issues

After the breeding season, Icelandic godwits migrate south to the UK, Ireland and France. Small numbers of birds also appear to migrate directly to Portugal from Iceland. The moulting sites in the north-west and east of England have seen particularly large increases in use in recent decades, especially the Wash, Humber and Dee estuaries. The vast majority of Icelandic godwits use estuarine mudflats during the autumn months. By winter many birds have moved south to estuaries in France and Portugal and, in Ireland and England, they start to forage on grasslands. The number of Icelandic godwits wintering in the UK, Ireland and France is well reported, but the number wintering in Iberia is difficult to assess because the subspecies overlap there, particularly during January and February when both wintering and migratory continental godwits are present.

In spring, most godwits from Portugal and France migrate to the Netherlands or eastern England, where they forage primarily on grasslands. At the same time, many birds from coastal sites around the UK move inland to forage on flooded grasslands. Studies of energetic intake rates on mudflats and grasslands suggest that godwits move to grasslands when estuarine food supplies are no longer sufficient to support them, and that they frequently use both mudflats and grasslands throughout winter and spring. This seems to be particularly common in the northern part of their range, where estuarine prey are often subject to strong seasonal depletion (e.g. Gill *et al.* 2001b) and where grassland foraging appears to be a necessary addition to compensate for insufficient estuarine food supplies.

POSSIBLE CAUSES OF THE POPULATION INCREASE IN *L. L. ISLANDICA*

The drivers of the population increase in Icelandic godwits are not fully identified, but there are several plausible candidates:

- climatic amelioration in Iceland may have improved breeding conditions and increased the area available for breeding godwits;
- changes in habitat structure in Iceland may have improved breeding conditions;
- climatic and habitat changes in the non-breeding range may have improved survival and condition for breeding;
- changes in hunting pressures may have improved survival rates.

The initial increase in godwit numbers around the 1920s coincided with a period of rapid warming in Iceland, suggesting that climatic amelioration may have been involved, at least in the early stages of population growth. From the 1930s to the 1980s, the rate of colonisation of Iceland is correlated with the number of drainage ditches installed, indicating that large-scale habitat changes may have positively influenced godwit breeding distribution. The common observation of godwits foraging in hayfields, especially those close to dwarf-birch bogs, suggests that the presence of hayfields as foraging habitats may have improved the quality of dwarf-birch bogs as breeding sites.

In recent decades, the primary habitat change in lowland Iceland has been the development of afforestation schemes, many of which are focused on marsh habitats, in addition to house-building in lowland areas. Since the 1980s, there has been a strong positive correlation between Iceland spring temperatures and the index of Icelandic godwits wintering in the UK (as recorded by the Wetland Bird Survey, Banks *et al.* 2006). Colour-ring information has shown that the majority of the UK population increase has involved birds from the recently occupied east and north-east of Iceland (Gunnarsson *et al.* 2005b); strongly suggesting that recent climatic amelioration has allowed these coldest parts of the country to be occupied.

In the non-breeding range, there are few indications of improvements to habitat quality, but changing rainfall patterns may be altering the timing of availability of grassland foraging sites. This may be particularly true of sites in eastern England and the Netherlands, use of which has increased substantially in recent years (Gerritsen & Tijsen 2003, Gill *et al.* 2001). The reduced frequency of cold winters in NW Europe also may be influencing survival rates.

The role of hunting pressure in driving population changes in Icelandic godwits is difficult to assess. Historically, there are records of godwits being considered a delicacy, having been described as "highly esteemed for the table" and "both shot and taken by snares" (Morris 1897). It is possible that reductions in hunting pressure, and the associated disturbance levels, may have influenced the population changes, but there are currently no data with which to explore this issue. At present, the only country in which Icelandic godwits are shot is France, and the lack of accurate bag statistics precludes calculation of the impact of this hunting pressure. Although the Icelandic population is increasing, it is still small and restricted in range, and the impact of hunting is therefore difficult to predict should conditions change.

CONTRASTING *LIMOSA* AND *ISLANDICA* POPULATIONS

Despite the current contrast in the fortunes of these two populations, comparison of their demography and distribution has revealed intriguing similarities, which we hope will help to focus current and future conservation and research efforts. In both Iceland and the Netherlands, it seems evident that agricultural intensification has played a role in driving population expansions and contractions over the last century. Wetlands and heathlands have been converted into agricultural habitats in which productivity has increased through fertilisation and reduction of flooding intensity, while frequent cutting and mowing maintains an open sward structure. This seems to have benefited several large, ground-nesting shorebird species, probably through higher abundances of soil macrofauna and improved access to these resources (Beintema 1986, Beintema *et al.* 1987). Throughout Europe this process began in the first half of the twentieth century, but so far the area converted and the level of intensification have been much greater in the more populated countries of NW Europe than in Iceland. In both Iceland and the Netherlands, there is evidence that populations of Black-tailed Godwit, along with other similar species, may have been able initially to increase and expand their distribution in response to this habitat conversion and increase in productivity.

In the Netherlands, the agricultural landscape is now so intensively managed that the area suitable for breeding godwits has declined dramatically, such that the population is now probably lower than it was prior to the 1950s. By contrast, the Icelandic population appears to be still benefiting from changes in agricultural practice that have created a landscape in which grass production and moderate levels of horse grazing have given rise to the complex sward structure necessary for breeding, alongside areas suitable for foraging. The extent to which these habitat changes have driven the population increase in Iceland is not currently clear, and there may yet be scope for further population expansion in Iceland. However, the Netherlands experience would strongly suggest that further intensification, such as increasing grazing intensities, are likely to be very detrimental to godwits and other ground-nesting birds. In addition, land-use changes in Iceland, such as the current widespread afforestation programmes, are a major threat to the internationally important shorebird populations of lowland habitats.

While habitat changes may be the primary driver of population changes over the last century, climatic changes have the potential to be an equally important issue in the near future. Temperature increases and changing precipitation patterns are both implicated in the *islandica* population increase, and there is some recent evidence for deferral of breeding in *limosa* in particularly dry years, although warm conditions are also likely to improve chick growth and survival. The timing of spring rainfall and the magnitude of temperature changes in the future are therefore likely to be very important in determining the impact of climate change on breeding success. The dependence of most of the *limosa* population on relatively small areas of flooded rice fields in Africa and Iberia is also likely to make them highly vulnerable to changing rainfall patterns. The recent drought in the Sahel region (Dai *et al.* 2004) is of particular concern for the maintenance of suitable foraging areas for these birds. Rice production is also dependent upon global markets and, in Iberia, on European Union agricultural support mechanisms, further increasing concern over the persistence of these key habitats.

A more immediate threat to the godwits that depend on rice fields and mudflats in Portugal is the proposed development of a new airport near Lisbon. One potential location for this airport is in the vicinity of the Tagus Estuary Nature Reserve, with approach routes that are likely to cross the main rice field areas in the Tagus and Sado estuaries, which are used by tens of thousands of godwits during January and February, and the corridor linking the Tagus and Sado mudflats which are used by godwits throughout the non-breeding season. Such a development could seriously impact on a very large proportion of the godwit population at a critical time of year, and would therefore be very likely to exacerbate already severe population declines.

The historical context of the population changes, and concern about future conditions for godwits and other similar bird species, led the workshop participants to identify the key recommendations that we believe it will be necessary to implement in order to conserve Black-tailed Godwits effectively in Iceland and W Europe.

CONSERVATION RECOMMENDATIONS FOR *L. L. LIMOSA*

1. Improve prescriptions and targeting of AES in the breeding range, focusing efforts in areas with high groundwater levels and open landscapes to attract godwits and avoid high predator densities, in order to have the potential to improve overall productivity. Include raising groundwater levels in the Netherlands AES prescriptions (as is the case in the UK, Denmark and Germany)
2. Incorporate the creation of small-scale habitat mosaics into management prescriptions, to provide both foraging and predator avoidance options throughout the season.
3. Improve conservation of key wetland habitats in Iberia and Africa, either through maintenance of support for rice production or restoration of wetlands, as well as designation of more sites under relevant national legislation and international treaties (EU Birds and Habitats Directives, Ramsar Convention etc.).
4. In view of the severe continuing declines of this population, take a precautionary approach and ban hunting of godwits, at least temporarily, where there is any risk that birds from

this population could be involved (especially late migrating juveniles in autumn), until productivity is increased to a level that can sustain a certain amount of additional mortality of adults and immatures.

CONSERVATION RECOMMENDATIONS FOR *L.L. ISLANDICA*

1. Improve conservation of winter habitat mosaics, particularly in areas, such as Ireland, England and France, where grasslands, coastal lagoons and salinas may be necessary to maintain populations when estuarine food supplies are depleted.
2. Reduce impact of afforestation and building developments in Iceland on godwits and other shorebird species, by conserving key breeding areas.
3. Improve protection of coastal habitats in areas where development and associated disturbance levels are high (especially in Ireland).

KEY RESEARCH GAPS FOR *L. L. LIMOSA*

1. Improve estimates of juvenile survival, causes of mortality and distribution prior to recruitment.
2. Improve survey information on the distribution and abundance of Black-tailed Godwits in the West African wintering grounds.
3. Improve understanding of the importance of the Doňana National and Natural Park area for protecting *L. l. limosa* during spring migration.
4. Explore the potential impact of hunting on the *limosa* population, and work with hunting organizations to develop better methods of recording accurate bag statistics in France.
5. Explore the impact of the increasing time-lag between godwit arrival in the Netherlands and the commencement of breeding, and the frequency of deferral of breeding attempts.
6. Improve understanding of the location, timing and duration of use of passage sites in Europe and Africa, and habitat use and diet within these sites.

KEY RESEARCH GAPS FOR *L. L. ISLANDICA*

1. Improve understanding of the role of agricultural intensification in Iceland.
2. Identify the key drivers of productivity in different habitats in Iceland.
3. Improve survey data for Iberia and France during the passage period of January to March, when there is the greatest overlap between the subspecies.
4. Explore the factors influencing the quality and availability of grassland habitats.
5. Explore the consequences of seasonal matching (individual use of similar quality habitat in both breeding and wintering areas) for population processes and identification of key areas for conservation.
6. Explore the potential impact of hunting on the *islandica* population.

FINAL COMMENT

The workshop provided an exciting and hopefully very valuable means of exploring the causes of population change in two closely related subspecies. The large group of experts provided an ideal forum for both highlighting key issues and using expert opinion to identify and prioritise the conservation recommendations. This process would undoubtedly have been helped were information available on the eastern population of *L. l. limosa* and the eastern subspecies, *L. l. melanuroides*. Our final recommendation is therefore to encourage the collation and presentation of information on these two populations.

ACKNOWLEDGEMENTS

Many thanks to all the workshop participants who contributed so willingly and helpfully to the whole day, Bill Sutherland for historical godwit recipes, Richard Chandler for helpful comments and to the organising committee of the IWSG conference for providing such excellent conditions for eating, drinking, colour-ring reading and discussion.

REFERENCES

Altenburg, W., van der Kamp, J. & Beintema, A. 1985. The wintering grounds of the black-tailed godwit in West Africa. *Wader Study Group Bull.* 44: 18–20.

Banks, A.N., Collier, M.P., Austin, G.E., Hearn, R.D. & Musgrove, A.J. 2006. Waterbirds in the UK 2004/05. The Wetland Bird Survey. BTO/WWT/RSPB/JNCC, Thetford.

Beintema A.J. 1986. Man-made polders in the Netherlands: a traditional habitat for shorebirds. *Colonial Waterbirds* 9: 196–202.

Beintema, A.J. & Drost, N. 1986. Migration of the Black-tailed Godwit. *Gerfaut* 76: 37–62.

Beintema A.J., Dunn, E. & Stroud, D. 1997. Birds and wet grasslands. In. D.J. Pain & M.W. Pienkowski (eds.). *Farming and birds in Europe: the Common Agricultural Policy and its implications for bird conservation*. Academic Press, San Diego.

Beintema, A.J. & Müskens, G.J.D.M. 1987. Nesting success of birds breeding in Dutch agricultural grasslands. *J. Appl. Ecol.* 24: 743–758.

Bijlsma R., Hustings, F. & Camphuysen, C.J. 2001. *Common and scarce birds of the Netherlands*. Avifauna of the Netherlands 2. GMB / KNNV, Haarlem.

BirdLife International. 2004. *Birds in Europe: population estimates, trends and conservation status*. BirdLife Conservation Series. Cambridge, BirdLife International.

Both, C., Schroeder, J., Hooijmeijer, J., Groen, N. & Piersma, T. 2006. The balance between reproduction and death of Black-tailed Godwits. *De Levende Natuur* 107: 126–129.

Dai, A.G., Lamb, P.J., Trenberth, K.E., Hulme, M., Jones, P.D & Xie, P.P. 2004. The recent Sahel drought is real. *Int. J. Climatology* 24: 1323–1331.

Gerritsen, G.J. & Tijsen, W. 2003. De betekenis van Nederland als pleisterplaats voor IJslandse Grutto's *Limosa limosa islandica* tijdens de voorjaarstrek in 2001 en 2002. *Limosa* 76: 103–108.

Gill, J.A., Norris, K., Potts, P.M., Gunnarsson, T.G., Atkinson, P.W. & Sutherland, W.J. 2001a. The buffer effect and large-scale population regulation in migratory birds. *Nature* 412: 436–438.

Gill, J.A., Sutherland, W.J. & Norris, K. 2001b. Depletion models can predict shorebird distribution at different spatial scales. *Proc. Royal Soc. Lond. B*. 268: 369–376.

Groen, N.M. & Hemerik, L. 2002. Reproductive success and survival of black-tailed godwits *Limosa limosa* in a declining local population in the Netherlands. *Ardea* 90: 239–248.

Gunnarsson, T.G., Gill, J.A., Petersen, A., Appleton, G.F. & Sutherland, W.J. 2005a. A double buffer effect in a migratory population. *J. Anim. Ecol.* 74: 965–971.

Gunnarsson, T.G., Gill, J.A, Newton, J., Potts, P.M. & Sutherland, W.J. 2005b. Seasonal matching of habitat quality and fitness in migratory birds. *Proc. Royal Soc. Lond. B.* 272: 2319–2323.

Gunnarsson, T.G., Gill, J.A., Appleton G.F., Gíslason H., Gardarsson, A., Watkinson, A.R. & Sutherland, W.J. 2006a. Large-scale habitat associations of birds in lowland Iceland: implications for conservation. *Biol. Conserv.* 128: 265–275.

Gunnarsson, T.G., Gill, J.A., Atkinson, P.W., Gélinaud, G., Potts, P.M., Croger, R.E., Gudmundsson, G.A., Appleton, G.F. & Sutherland, W.J. 2006b. Population-scale drivers of individual arrival times in migratory birds. *J. Anim. Ecol.* 75: 1119–1127.

International Wader Study Group. 2003. Waders are declining worldwide. *Wader Study Group Bull.* 101/102: 8–12.

Kleijn, D. & van Zuijlen, G.J.C. 2004. The conservation effects of meadow bird agreements on farmland in Zeeland, the Netherlands, in the period 1989–1995. *Biol. Conserv.* 117: 443–451.

Kleijn, D., Berendse, F., Smit, R. & Gilissen, N. 2001. Agri-environment schemes do not effectively protect biodiversity in Dutch agricultural landscapes. *Nature* 413: 723–725.

Kuijper, D.P.J, Wymenga, E., van der Kamp, J. & Tanger, D. 2006. Wintering areas and spring migration of the Black-tailed Godwit: bottlenecks and protection along the migration route. Altenburg & Wymenga ecological consultants, A & W report 820, Veenwouden, the Netherlands (*www.altwym.nl*)

Morris, Rev. F.O. 1897. *A History of British Birds*, 4th edition. John C. Nimmo, London.

Mulder, T. 1972. *De grutto in Nederland*. Wetenschappelijke Mededelingen KNNV 90, Hoogwoud.

Piersma, T. (ed.) 1986. Breeding waders in Europe. *Wader Study Group Bull.* 48 Suppl. 1–116.

Roodbergen, M., Klok, C. & Schekkerman, H. (submitted). Adult survival of Black-tailed Godwits (*Limosal l. limosa*) in the Netherlands 2002–2005 does not explain the ongoing decline of the breeding population. *Ardea.*

Sanchez-Guzman, J.M., Moran, R., Masero, J.A., Corbacho, C., Costillo, E., Villegas, A. & Santiago-Quesada, F. 2007. Identifying new buffer areas for conserving waterbirds in the Mediterranean basin: the importance of the rice fields in Extremadura, Spain. *Biodiv. & Conserv.* 16: 3333–3344.

Schekkerman, H. & Beintema, A.J. 2007. Abundance of invertebrates and foraging success of Black-tailed Godwit *Limosa limosa* chicks in relation to agricultural grassland management. *Ardea* 95: 39–54.

Schekkerman, H. & Müskens, G. 2000. Do black-tailed godwits *Limosa limosa* produce sufficient young to sustain populations in agricultural grasslands? *Limosa* 73: 121–134 [in Dutch with English summary].

Schekkerman, H., Teunissen, W. & Oosterveld, E. 2005. Breeding productivity of Black-tailed Godwits under 'mosaic management' a new agri-environment scheme. Alterra-report 1291, Alterra, Wageningen [in Dutch with English summary].

Schekkerman, H., Teunissen, W. & Oosterveld, E. (submitted a). Mortality of shorebird chicks in lowland wet grasslands: influences of predation and agricultural practice. *J. Ornithol.*

Schekkerman, H., Teunissen, W. & Oosterveld, E. (submitted b). Can 'mosaic management' improve breeding success and halt the population decline of Black-tailed godwits *Limosa limosa* in agricultural grasslands? *J. Appl. Ecol.*

SOVON. 2002. *Atlas van de Nederlandse broedvogels 1998–2000*. Nationaal Natuurhistorisch Museum Naturalis, Leiden.

Teunissen, W.A. & Soldaat, L.L. 2006. Recent population development of meadow birds in the Netherlands. *De Levende Natuur* 107: 70–74. [in Dutch]

Teunissen, W.A. & Willems, F. 2004. *Bescherming van weidevogels*. SOVON-onderzoeksrapport 04/06. SOVON, Beek-Ubbergen.

Teunissen, W., Schekkerman, H. & Willems, F. 2006. Predation on meadowbirds in the Netherlands – results of a four-year study. In: *Ökologie und Schutz von Wiesenvögeln in Mitteleuropa* (eds H. Düttman, R. Ehrnsberger & R. Akkermann), Osnabrücker Naturwissenschaftlige Mitteilungen, 32: 137–143.

Thorup, O. 2005. *Breeding Waders in Europe 2000*, International Wader Studies 14. International Wader Study Group, UK.

Tréca, B. 1984. La barge à queue noire (*Limosa limosa*) dans le Delta du Sénégal: regime alimentaire, donées biométriques, importance économique. *L'Oiseax et R.F.O.* 54: 247–262.

Tréca, B. 1994. The diet of ruffs and black-tailed godwits in Senegal. *Ostrich* 65: 256–263.

van Brederode, L. & Laporte, H.M. 2006. Weidevogelverbond werkt aan actieplan. *De Levende Natuur* 107: 146–147.

van der Kamp, J. & Ndiaye, I. 2006. Post-breeding exploitation of rice habitat in the Senegal delta by migrating Black-tailed Godwit *Limosa limosa*. Altenburg & Wymenga ecological consultants, A & W report in prep., Veenwouden, the Netherlands.

van Noordwijk, A.J. & Thomson, D.L. (submitted). Survival rates of Black-tailed Godwits breeding in the Netherlands estimated from ring recoveries. *Ardea.*

Verhulst, J., Kleijn, D. & Berendse, F. 2007. Direct and indirect effects of the most widely implemented Dutch agri-environment schemes on breeding waders. *J. Appl. Ecol.* 44: 70–80.

Willems, F., Breeuwer, A., Foppen, R., Teunissen, W., Schekkerman, H., Goedhart, P., Kleijn D. & Berendse, F. 2004. Evaluation of agri-environment schemes: effects on meadow bird breeding densities. Sovon-onderzoeksrapport 2004/02. Sovon/WUR/Alterra, Beek-Ubbergen. [In Dutch]

Wymenga, E., Oosterveld, E. & Bruinzeel, L. 2006. Management of meadow bird communities in Fryslân: bottlenecks and solutions in the core areas of the Black-tailed Godwit. Altenburg & Wymenga ecological consultants, A & W report 911, Veenwouden, the Netherlands (*www.altwym.nl*)

Zwarts, L., Bijlsma, R.G., van der Kamp, J. & Wymenga, E. (in press) *Living on the edge: Wetlands and birds in a changing Sahel.* KNNV publishers, Utrecht.

Welwick Managed Realignment Site: Ornithological Survey Results, September 2006 to May 2007

Report to ABP Marine Environmental Research

Institute of Estuarine
and Coastal Studies
University of Hull

12 June 2007

Institute of Estuarine & Coastal Studies (IECS)
The University of Hull
Cottingham Road
Hull
HU6 7RX
UK

Tel: +44 (0)1482 464120
Fax/Tel: +44 (0)1482 464130

E-mail:
iecs@hull.ac.uk

Web site:
http://www.hull.ac.uk/iecs

Author(s): L Mander, R Eades & N Cutts

Report: ZBB686-F-2007

TABLE OF CONTENTS

2.2.2 REALIGNMENT SITE (EX AREA A)

Area A: This realignment site has developed as a major roosting site at high water over the current monitoring period. The site was found to be highly attractive to roosting wading birds, in particular Red Knot (*Calidris canutus*) (up to 10,000), Dunlin (*Calidris alpina*) (up to 4,000), European Golden Plover (*Pluvialis apricaria*) (up to 3,600), Northern Lapwing (up to 1,800), Common Redshank (up to 450), Grey Plover (*Pluvialis squatarola*) (up to 440), Eurasian Curlew (up to 340), Bar-tailed Godwit (*Limosa lapponica*) (up to 270) and Eurasian Oystercatcher (up to 180 individuals).

After high water, although European Golden Plover and Northern Lapwing were observed to linger in the area for longer than other waders, the majority of wading birds moved onto the fronting or adjacent intertidal areas as the tide receded. As the site developed over the survey programme, increasing numbers of Grey Plover, Common Redshank, Dunlin and Eurasian Curlew were observed to forage from high to low water, with the greatest usage within a two hours period after high water. Around low water, in comparison to the fronting intertidal area, abundance in the realignment site was low, with species maxima in single figures.

Wildfowl species were also well represented in the realignment site, especially Common Shelduck *(Tadorna tadorna*) present from high to low water. Maximum foraging counts of 385 foraging at high water and 170 birds at low water were made during the current reporting period.

Foraging wading birds and Common Shelduck were generally distributed in the lowest part of the realignment site. By contrast, the main roosting sites were established along the old flood defence, which despite having been flattened is still the highest area within the realignment site.

2.2.3 MUDFLAT FRONTING THE REALIGNMENT SITE

The mudflat fronting the realignment site is covered on spring tides, with an area of high saltmarsh remaining uncovered (Area C). During the initial ebb phase, Eurasian Curlew, Eurasian Oystercatcher, Dunlin, Common Redshank, Grey Plover and Bar-tailed Godwit were observed to generally disperse onto the fronting intertidal mudflats from their high tide roost sites, mainly from the Welwick saltmarsh and the realignment site. Red Knot were found to be particularly abundant on this mudflat with the dispersal of large roost flocks from the realignment site.

Red Knot feeding distribution was generally on the mid shore but smaller flocks were also observed regularly feeding on the upper shore, close to the banks. The flocks of Red Knot were usually highly mobile within the survey area with regular movements up and down the shore as well as laterally along it.

Dunlin, Grey Plover and Bar-tailed Godwit flocks were associated with the Knot on the initial ebb phase, but then gradually dispersed onto the mid shore with concentrations frequently observed on the mudflat immediately to the west of Patrington Channel creek.

Welwick Managed Realignment Site: Ornithological Survey Results, September 2007 to March 2008

Report to ABP Marine Environmental Research

Institute of Estuarine and Coastal Studies University of Hull

17 June 2008

Institute of Estuarine & Coastal Studies (IECS)
The University of Hull
Cottingham Road
Hull
HU6 7RX
UK

Tel: +44 (0)1482 464120
Fax/Tel: +44 (0)1482 464130

E-mail:
iecs@hull.ac.uk

Web site:
http://www.hull.ac.uk/iecs

institute of estuarine & coastal studies THE UNIVERSITY OF HULL

Author(s): L Mander, R Eades & N Cutts

Report: ZBB703-F-2008

TABLE OF CONTENTS

2.2.2 REALIGNMENT SITE (EX AREA A)

Monthly surveys carried out between September 2007 and March 2008 indicated the site to support large roosts of wading birds around high water. Counts of up to 17,000 Red Knot (*Calidris canutus*), 3,800 Lapwing (*Vanellus vanellus*), 2,000 Dunlin (*Calidris alpina),* 1,700 European Golden Plover, 490 Eurasian Curlew (*Numenius arquata*), 410 Bar-tailed Godwit (*Limosa lapponica*), 300 Grey Plover (*Pluvialis squatarola*), 200 Common Redshank, and Eurasian Oystercatcher (up to 150 individuals) were made during the current reporting period. Shelduck were also present in important numbers in the realignment site with a count of up to 1,200 individuals at high water. Mallard *(Anas platyrhynchos)*, Eurasian Wigeon (*Anas penelope*), Eurasian teal (*Anas crecca*) and Northern Pintail (*Anas acuta*) were occasionally recorded in single figures across the site. The largest roosts of waders were noted on intermediate to spring tides, with waders favouring the old flood defence to roost or loaf. Shelduck were generally widely spread across the realignment site with both foraging and loafing activities observed around high water period.

As the tide receded, waders dispersed on the mudflat fronting the realignment site, although occasionally large numbers of waders were observed to forage around high water on the exposed mudflats within the realignment site. The December survey featured counts of to 2,500 Knot, 1,700 Dunlin, 250 Grey Plover, 209 Redshank and 130 Bar-tailed, all foraging around the high water period. It is believed that the realignment site provides a supplementary feeding habitat for waders when the fronting mudflats are covered at high water.

Within the realignment site, with the exception of Shelduck which remained to feed until low water, numbers of foraging waders declined rapidly as the tide receded. Numbers of foraging Shelduck peaked at 180 individuals at low water, whilst numbers of waders were rarely seen in double figures during this period. Occasionally, influx of European Golden Plover and Lapwing occurred around the low water period, with the area predominantly use as a loafing/roosting grounds by these two species.

2.2.3 MUDFLAT FRONTING THE REALIGNMENT SITE

The mudflat fronting the realignment site is covered on intermediate to spring tides. As such, during the initial ebb phase, Eurasian Curlew, Eurasian Oystercatcher, Red Knot, Dunlin, Common Redshank, Grey Plover and Bar-tailed Godwit were observed to generally disperse onto the fronting intertidal mudflats from their high tide roost sites, mainly the realignment site on spring tides (> 7.0m) and the Welwick saltmarsh on lower tides.

Red Knot largely dominated the avifaunal assemblage on the mudflats fronting the realignment site. Colonisation of the mudflats occurred generally two hours after high water; as the mudflats became exposed. Red Knot feeding distribution was generally on the mid shore but smaller flocks were also observed regularly feeding on the upper shore, close to the embankment. A count of up 5,000 individuals was made around low water in October 2007 on the mudflat fronting the realignment site. The flocks of Red Knot were usually highly mobile within the survey area with regular movements up and down the shore as well as laterally along it.

Welwick Managed Realignment Site: Ornithological Survey Results, September 2008 to March 2009

Report to ABP Marine Environmental Research

Institute of Estuarine and Coastal Studies
University of Hull

27 March 2009

Institute of Estuarine & Coastal Studies (IECS)
The University of Hull
Cottingham Road
Hull
HU6 7RX
UK

Tel: +44 (0)1482 464120
Fax/Tel: +44 (0)1482 464130

E-mail:
iecs@hull.ac.uk

Web site:
http://www.hull.ac.uk/iecs

Author(s): L. Mander & R. Eades

Report: ZBB712-F-2009

TABLE OF CONTENTS

tadorna) roosting/loafing along the lower part of the saltmarsh. However, the creation of the new habitat resulted in a displacement of the roost in the following winter (September 2006 to March 2007), with roosting/loafing waterbirds absent from Area C.

Area D: This area contained a well drained winter cereal field. No roosting or loafing flocks of waterbirds were recorded during the monitoring programme. As with the 2007/08 monitoring programme, the presence of Greylag Geese (*Anser anser*) was noted late in the survey programme (11 individuals in March). It is possible that these individuals were early breeders prospecting the adjacent Haverfield Gravel Pits for suitable nesting sites.

2.2.2 REALIGNMENT SITE (EX AREA A)

A total of 31 waterbird species were recorded during the 2008/09 monitoring programme, of which 14 were wader species and eight wildfowl species (i.e. ducks, geese and swans). Herons (two species), Great Cormorant (*Phalacrocorax carbo*) and gulls (four species) accounted for the rest of the avifaunal assemblage. The monthly surveys carried out between September 2008 and March 2009 continued to indicate that the site supported large roosts of waterbirds around the high water period (Table 1).

Table 1: Maximum counts of roosting/loafing waterbirds recorded at high water in the realignment site during the 2008/09 monitoring programme

Species	Abundance	Date
Common Shelduck *(Tadorna tadorna)*	748	13/03/2009
Eurasian Wigeon (*Anas penelope)*	45	15/01/2009
Eurasian teal (*Anas crecca*)	10	31/10/2008
Mallard *(Anas platyrhynchos)*	26	15/01/2009
Northern Pintail (*Anas acuta*)	8	17/12/2008
Eurasian Oystercatcher (*Haematopus ostralegus)*	280	17/12/2008
European Golden Plover (*Pluvialis apricaria)*	10,000	15/01/2009
Grey Plover (*Pluvialis squatarola*)	510	15/01/2009
Lapwing (*Vanellus vanellus*)	2,000	15/01/2009
Red Knot (*Calidris canutus*),	3,500	17/11/2008
Dunlin (*Calidris alpina)*	500	17/11/2008
Black-tailed Godwit *(Limosa limosa)*	110	17/11/2008
Bar-tailed Godwit (*Limosa lapponica*)	650	15/01/2009
Eurasian Curlew (*Numenius arquata*)	405	27/02/2009
Common Redshank (*Tringa totanus)*	330	18/09/2008

On high tide exceeding 7.0m CD, the realignment site was covered and the waders preferred to roost along the old sea defence (Figure 3). Below 7.0m CD, with the exception of Eurasian Curlew and Eurasian Oystercatcher which continued to roost along the sea defence, other species of waders such as Bar-tailed Godwit (*Limosa lapponica*), Grey Plover

(*Pluvialis squatarola*), Red Knot (*Calidris canutus*) and Dunlin (*Calidris alpina*) were seen to established roosts in the centre of the realignment site. On these tides (<7.0 CD) a large proportion of the Bar-tailed Godwit and Dunlin flocks were also observed foraging in the realignment site at high water This was however limited to the winter months when energy demands are at the highest for wading birds. For instance, there were 500 Dunlin and 110 Bar-tailed Godwit foraging in January 2009 within the realignment site. As for wildfowl species, Common Shelduck was the most abundant at high water and the species was generally widely spread across the realignment site with both foraging and loafing activities observed around the high water period.

Figure 3: Flock of Red Knot roosting along the old sea defence on a high spring tide. Photo taken by IECS on 13th March 2009.

As the tide receded, waders generally dispersed first on the mudflat fronting the Welwick saltmarsh, although large numbers lingered in the realignment to either roost/loaf or forage until approximately high water + 2. It is believed that the realignment site provides on intermediate to spring tides a supplementary feeding habitat for waders when the outside mudflats are covered until approximately high water + 2.

By high water + 3, numbers of waders foraging in the realignment site are very low and the avifaunal assemblage is mainly dominated by Common Shelduck. The number of foraging waders tended to decline further as the tide receded until low water, and only Common Shelduck remained to feed in large numbers around low water. For instance, up 293 Common Shelduck were recorded foraging in November 2008 whilst maximum counts of waders at low water over the monitoring period included a total of: 51 Black-tailed Godwit (*Limosa limosa*), 27 Redshank, 20 Dunlin, 12 Grey Plover, 11 Curlew, 11 Ringed Plover and

5 Red Knot. Occasionally, influxes of European Golden Plover and Lapwing occur around the low water period, with the area predominantly used as a loafing/roosting grounds by these two species.

2.2.3 MUDFLAT FRONTING THE REALIGNMENT SITE

The mudflat fronting the realignment site was covered on intermediate to spring tides until high water + 2. At this time, small numbers of Brent Geese (*Branta bernicla*) and Eurasian Wigeon (*Anas penelope*) were found to be loafing on the Humber estuary along the old flood defence, whilst Common Shelduck were present in small flocks further out on the river. Overall abundance continued to be very low at high water in comparison that of the surveys conducted prior the habitat creation. As discussed in previous report, the creation of the new habitat in 2006 resulted in a shift in wildfowl usage around high water, with the Common Shelduck, Mallard and Northern Pintail populations now preferring to loaf in the realignment site rather than the adjacent Humber river. After high water + 2, the wading birds started to colonise the fronting intertidal mudflats with a large majority of birds originating from the mudflat fronting Welwick Saltmarsh which is exposed at high water +1. During the initial ebb phase, Eurasian Curlew, Eurasian Oystercatcher, Red Knot, Dunlin, Common Redshank, Grey Plover and Bar-tailed Godwit were observed feeding on the upper shore. After high water + 3, Red Knot feeding distribution was generally on the mid shore but smaller flocks were also observed regularly feeding on the upper shore, close to the embankment. A count of up 3,912 individuals was made around low water in March 2009 on the mudflat fronting the realignment site. The flocks of Red Knot were usually highly mobile within the survey area with regular movements up and down the shore as well as laterally along it. Dunlin, Grey Plover and Bar-tailed Godwit flocks were associated with the Red Knot on the initial ebb phase, but then gradually dispersed onto the mid shore with concentrations frequently observed on the mudflat immediately to the west of Patrington Channel creek. At low tide, Common Shelduck showed a widespread distribution although concentrations were found along the Patrington Channel area. Loafing Mallard were also often present along the channel and creek system.

2.3 Other Observations

Other observations in the realignment site included Ruddy Turnstone (up to 15 individuals) and Ringed Plover *(Charadrius hiaticula)* (up to 18 individuals). In late autumn, up to five Common Greenshank (*Tringa nebularia*) were observed foraging in the realignment site. The realignment site also held a population of Little Egret (*Ardea garzetta)* in September with a count of six birds made at high water. As the tide receded two individuals were observed to forage in the realignment site at low water whilst the rest dispersed on the adjacent Welwick Saltmarsh. Raptors were regularly seen in the area, in particular a single Merlin (*Falco columbarius*) was observed hunting the realignment site. There were also sightings of Peregrine (*Falco peregrinus*) in September and Hen Harrier (*Circus cyaneus*) in December. Additionally, Short-eared Owl (*Asio flammeus*) were regularly seen hunting over the Welwick Saltmarsh where at least two individuals were present over the winter 2008/09. On a few occasions, this species was observed to hunt over the old flood defence within the realignment site causing disturbance to the wader population. The colonising pioneer saltmarsh within the realignment site also attracted a number of passerines including

Welwick Managed Realignment Site: Waterbird Monitoring Survey Results, September 2009 to March 2010

Report to ABP Marine Environmental Research

Institute of Estuarine and Coastal Studies
University of Hull

26th May 2010

Institute of Estuarine & Coastal Studies (IECS)
The University of Hull
Cottingham Road
Hull
HU6 7RX
UK

Tel: +44 (0)1482 464120
Fax/Tel: +44 (0)1482 464130

E-mail:
iecs@hull.ac.uk

Web site:
http://www.hull.ac.uk/iecs

institute of estuarine & coastal studies
THE UNIVERSITY OF HULL

Author(s): L. Mander

Report: ZBB738-F-2010

TABLE OF CONTENTS

Area C: The current reporting period (2009/10) continued to show the absence of roosting waterbirds in Area C. Until the completion of the realignment site in July 2006, this area was regularly used as a roosting site for Eurasian curlew (*Numenius arquata*) and Eurasian oystercatcher (*Haematopus ostralegus)*, with occasional flocks of common redshank (*Tringa totanus*), ruddy turnstone (*Arenaria interpres*) and common shelduck (*Tadorna tadorna*) roosting/loafing along the lower part of the saltmarsh. However, the restoration of the habitat resulted in a displacement of the roost in the following winter (September 2006 to March 2007), with roosting/loafing waterbirds absent from Area C.

Area D: This area contained a well drained winter cereal field. No roosting or loafing flocks of waders were recorded during the monitoring programme. As with the 2007/08 and 2008/09 monitoring programme, the presence of greylag geese (*Anser anser*) were noted later in the survey programme (four individuals in March). An additional two mute swans were recorded in March. It is possible that the greylag geese were early breeders prospecting the adjacent Haverfield Gravel Pits for suitable nesting sites.

2.2.2 Realignment Site (Ex Area A)

A total of 31 waterbird species were recorded during the 2008/09 monitoring programme, of which 17 were wader species and seven wildfowl species (i.e. ducks, geese and swans), herons (two species), great cormorant (*Phalacrocorax carbo*) and gulls (four species) accounted for the rest of the avifaunal assemblage. The monthly surveys carried out between September 2009 and March 2010 continued to indicate that the site supported large roosts of waterbirds around the high water period (Table 2).

Table 2: Maximum counts of roosting/loafing waders recorded at high water in the realignment site during the 2009/10 monitoring programme

Species	**Total Number 2008/09**	**Total Number 2009/10**
Eurasian oystercatcher (*Haematopus ostralegus)*	280	60
European golden plover (*Pluvialis apricaria)*	10,000	300
Grey plover (*Pluvialis squatarola*)	510	480
Lapwing (*Vanellus vanellus*)	2,000	40
Red knot (*Calidris canutus*),	3,500	3,500
Dunlin (*Calidris alpina)*	1,700	1,700
Black-tailed godwit *(Limosa limosa)*	380	380
Bar-tailed godwit (*Limosa lapponica*)	650	2,200
Eurasian curlew (*Numenius arquata*)	405	255
Common redshank (*Tringa totanus)*	330	400

On high tide exceeding 7.0m CD, the realignment site was covered and the waders preferred to roost along the old sea defence (Figure 3). Below 7.0m CD, with the exception of Eurasian curlew and Eurasian oystercatcher which continued to roost along the sea defence, other species of waders such as bar-tailed godwit (*Limosa lapponica*), grey plover

(*Pluvialis squatarola*), red knot (*Calidris canutus*) and dunlin (*Calidris alpina*) were seen to establish roosts in the middle of the realignment site.

As for wildfowl species, common shelduck was the most abundant at high water and the species was widely spread across the realignment site with both foraging and loafing activities observed around the high water period. A count of 1,350 birds was made during the September survey. Other species of wildfowl recorded during the monitoring programme included mallard (*Anas platyrhynchos)* (55 birds), Eurasian wigeon (*Anas penelope*) (100 birds), Eurasian teal (*Anas crecca*) (40 birds), northern pintail (*Anas acuta*) (four birds), pink footed goose (*Anser brachyrhynchus)* (11 birds), greylag goose (115 birds), and brent goose (*Branta bernicla*) (145 birds).

As the tide receded, waders generally dispersed first on the mudflat fronting the Welwick saltmarsh, although large numbers lingered in the realignment to either roost/loaf or forage until approximately high water + 2.

By high water + 3, numbers of waders foraging in the realignment site were very low and the avifaunal assemblage is mainly dominated by common shelduck and several wader species. The number of foraging waders tended to decline further as the tide receded until low water, and only common shelduck and common redshank regularly remained in numbers exceeding 25 birds. Occasionally, influxes of bar-tailed godwit (up to 230 birds) and black-tailed godwit (up to 200) occurred around the low water period, with the borrow pits at the north eastern part of the site used predominantly as foraging grounds by these two species. In contrast to previous years, there was no noticeable influx of European golden plover and northern lapwing around the low water period. Generally, both species come onto the area to loaf at low water.

2.2.3 Mudflat Fronting the Realignment Site

The mudflat fronting the realignment site was covered on intermediate to spring tides until high water + 2. At this time, small numbers of brent geese and Eurasian wigeon were found to be loafing on the Humber estuary along the old flood defence, whilst common shelduck were present in small flocks further out on the river. Overall abundance continued to be very low at high water in comparison to that of the surveys conducted prior to the habitat restoration. As discussed in previous reports, the restoration of the habitat in 2006 resulted in a shift in wildfowl usage around high water, with the common Shelduck, mallard and northern pintail populations now preferring to loaf in the realignment site rather than the adjacent Humber estuary.

Waterbirds Monitoring at Paull Holme Strays: Annual Report #7 September 2008 to August 2009

Report to Halcrow Group Ltd.

Institute of Estuarine and Coastal Studies
University of Hull

21 April 2010

Institute of Estuarine & Coastal Studies (IECS)
The University of Hull
Cottingham Road
Hull
HU6 7RX
UK

Tel: +44 (0)1482 464120
Fax: +44 (0)1482 464130

E-mail:
iecs@hull.ac.uk

Web site:
http://www.hull.ac.uk/iecs

Author(s): L Mander, A Phelps, S Thomson & N Cutts

Report: ZBB634-Draft 7 Orni-2010

TABLE OF CONTENTS

3. RESULTS

3.1 Waterbirds importance of the realignment site

The national and international importance of the site was assessed using the 1% criterion level (Holt *et al.,* 2009). If the site holds more than 1% of the national population of a species, it is conventionally considered to be of national significance. For each species, the annual mean and the six-year peak mean (2003/09) are given. Foraging and non-foraging birds are combined to assess the importance of the site.

The present surveys continued to highlight the importance of the site for Golden Plover. Mean numbers over the winter period peaked above the threshold of national importance (4,000 birds) (Table 1). The Humber Estuary is currently of international importance for Golden Plover, and is the most important wintering site for the species in the UK. The latest Wetland Bird Survey (WeBS) estimates that a total of 42,373 individuals wintered over the last five years in the Humber Estuary (Holt *et al.,* 2009).

The mean numbers of Black-tailed Godwit was also close to the level of national importance and highlighted the importance of the site for this species over the winter (Table 1). The Humber is of significance importance for Black-tailed Godwit, with the five-year average (03/04 to 07/08) rising close to 4,000 individuals and therefore exceeding the level of national and international importance.

Table 1: Key species annual mean and 6-year mean during winter (Nov to March) at Paull Holme Strays

	Annual Mean Abundance						6 - year mean	Threshold of importance	
	03-04	04-05	05-06	06-07	07-08	08-09	03-09	International	National
Shelduck	30	169	173	84	148	203	135	***3,000***	***782***
Wigeon	2	87	82	85	110	88	75	***15,000***	***4,060***
Teal	198	331	124	153	396	502	284	***4,000***	***1,920***
Mallard	115	52	37	45	67	58	62	***20,000***	***3,520***
Oystercatcher	2	13	1	5	2	2	4	***10,200***	***3,200***
Avocet	0	0	1	11	1	0	2	***730***	***35***
Ringed Plover	0	3	1	0	1	13	3	***730***	***330***
Golden Plover	**4,880**	3,364	**6,312**	2,711	**4,804**	**4,000**	**4,345**	***9,300***	***4,000***
Grey Plover	1	200	28	11	85	138	77	***2,500***	***530***
Lapwing	3,750	690	407	550	2,645	1505	1592	***20,000***	***6,200***
Knot	37	32	13	0	27	0	18	***4,500***	***2,800***
Dunlin	65	54	277	252	528	1000	363	***13,300***	***5,600***
Black-tailed Godwit	67	**159**	60	32	36	82	72	***470***	***150***
Bar-tailed Godwit	0	29	38	35	191	247	90	***1,200***	***620***
Curlew	3	63	39	79	99	151	72	***8,500***	***1,500***
Redshank	39	63	95	133	368	295	165	***2,800***	***1,200***

Although Black-tailed Godwit did not exceed the level of national importance during the winter, the species passed through the site in large numbers in autumn. The 5-year mean indicated the site to be of national importance in autumn, and close to the level of international importance (Tables 2). The spring featured a lower number of black-tailed godwit passing through the Humber Estuary (Table 3).

Table 2: Key species annual mean and 6-year mean during autumn (July to October) at Paull Holme Strays

	Annual Mean Abundance						6 - year mean	Threshold of importance	
	03-04	04-05	05-06	06-07	07-08	08-09	03-09	International	National
Shelduck	62	239	166	95	20	48	105	***3,000***	***782***
Wigeon	15	11	47	85	71	47	46	***15,000***	***4,060***
Teal	8	105	104	71	99	71	76	***4,000***	***1,920***
Mallard	4	32	36	50	43	83	41	***20,000***	***3,520***
Oystercatcher	1	4	5	2	10	1	4	***10,200***	***3,200***
Avocet	23	31	24	5	1	1	14	***730***	***35***
Ringed Plover	11	12	14	4	0	62	17	***730***	***330***
Golden Plover	76	30	87	1,261	406	3,463	887	***9,300***	***4,000***
Grey Plover	0	58	38	19	28	33	29	***2,500***	***530***
Lapwing	0	19	25	40	7	1	15	***20,000***	***6,200***
Knot	115	0	274	218	796	100	250	***4,500***	***2,800***
Dunlin	69	266	455	308	410	284	299	***13,300***	***5,600***
Black-tailed Godwit	**378**	**406**	**977**	32	**199**	**270**	**377**	***470***	***150***
Bar-tailed Godwit	0	2	1	5	5	6	3	***1,200***	***620***
Curlew	23	108	54	58	21	103	61	***8,500***	***1,500***
Redshank	61	76	134	287	361	280	200	***2,800***	***1,200***

The importance of the site for Avocet has declined in recent years following the failure of the breeding colony in the last two years (Table 3). This is considered to be most likely to be habitat related impact with the increasing frequency of flooding of high spring tides in the realignment site.

Table 3: Key species annual mean and 6-year mean during spring (April to June) at Paull Holme Strays

	Annual Mean Abundance						6 - year mean	Threshold of importance	
	04	05	06	07	08	09	04-09	International	National
Shelduck	347	223	234	79	63	59	167	***3,000***	***782***
Wigeon	0	0	0	0	0	0	0	***15,000***	***4,060***
Teal	0	2	11	0	8	2	4	***4,000***	***1,920***
Mallard	17	5	19	7	15	25	15	***20,000***	***3,520***
Oystercatcher	3	5	17	5	4	6	7	***10,200***	***3,200***

Avocet	**36**	**51**	**51**	**53**	4	3	33	***730***	***35***
Ringed Plover	11	98	0	32	8	38	31	***730***	***330***
Golden Plover	0	2	0	0	0	0	0	***9,300***	***4,000***
Grey Plover	2	1	3	2	55	8	12	***2,500***	***530***
Lapwing	0	0	1	0	0	0	0	***20,000***	***6,200***
Knot	0	0	0	3	19	0	4	***4,500***	***2,800***
Dunlin	0	298	33	14	165	10	85	***13,300***	***5,600***
Black-tailed Godwit	4	81	31	0	39	1	26	***470***	***150***
Bar-tailed Godwit	0	0	12	0	36	0	8	***1,200***	***620***
Curlew	5	44	24	3	12	20	18	***8,500***	***1,500***
Redshank	6	28	82	3	84	20	37	***2,800***	***1,200***

3.2 Spatial variation in the utilisation of the realignment site and adjacent intertidal areas.

3.2.1 SHELDUCK

Shelduck predominantly use the realignment site to forage at low and mid water, whilst at high water they generally loaf/roost across the realignment site. As with the previous year, foraging densities were low over the autumn period but increase notably over the winter period, with further increase reported in spring. Numbers of non-foraging birds remained very low in the realignment site when compared to the adjacent intertidal area (Table 4).

Table 4: Mean density of foraging birds at low water and mean number of non-foraging birds at high water.

		Autumn		Winter		Spring	
Area	**Sectors**	**No. foraging / km^2**	**No. non-foraging**	**No. Foraging / km^2**	**No. non-foraging**	**No. foraging / km^2**	**No. non-foraging**
Adjacent intertidal area	A	0	1	45.68	0	3.57	0
	B	34.59	10	100.70	24	17.51	7
Realignment site	C	0	0	0	0	0.75	0
	D	0	0	3.78	1	30.69	4
	E	0	0	19.01	13	31.68	2
	F	0	1	0	10	41.03	0
	G	0	0	0	5	0	1
	H	0	0	0	0	0	0
	I	0	0	0	6	56.14	13
	J	0	0	0	3	0	0
	K	0	0	45.01	5	70.33	6

3.2.13 Black-tailed Godwit

Over the first four years since breaching, the Paull Holme Strays site has developed as a major roosting/loafing site for Black-tailed Godwit on the Humber, supporting on many occasions flocks of national importance in autumn, as well as increasing numbers of foraging birds. Density values of foraging birds in the realignment site were greater than on the adjacent intertidal in autumn and winter. Figure 14 indicates the foraging densities to be the highest in winter. The winter surveys also indicate the distribution to extend to other sectors in the realignment site. The largest roost of birds continued to be located in Sector I where a mean of 123 non-foraging birds congregated in autumn.

Table 16: Mean density of foraging birds at low water and mean numbers of non-foraging birds at high water.

		Autumn		Winter		Spring	
Area	Sectors	No. foraging / km^2	No. non-foraging	No. Foraging / km^2	No. non-foraging	No. foraging / km^2	No. non-foraging
Adjacent intertidal area	A	37.47	0	32.83	0	0	0
	B	1.09	0	0	0	0	0
Realignment site	C	0	0	0	0	0	0
	D	94.43	6	1.89	0	0	0
	E	0	33	31.68	1	0	0
	F	8.49	2	28.30	16	0	0
	G	0	0	0	0	0	0
	H	0	0	0	0	0	0
	I	0	123	37.37	30	8.02	0
	J	0	0	0	0	0	0
	K	0	0	6.75	0	0	0

3.3 Inter annual variation in foraging abundance at Paull Holme Strays

As in 2008, only a significant difference was found in Shelduck foraging abundance ($p < 0.01$). This species was absent from the present autumn surveys. This pattern followed a declining trend in the numbers of foraging Shelduck at the site after the level of abundance had peaked to 176 birds in Year 2 (2004/05). Although numbers of foraging Teal and Wigeon recovered slightly in Year 6 with respectively 15 and 10 birds, the analysis over the autumn period continued to show no significant difference of abundance between years (Table 20). Between years comparison of waders abundance show no significance difference during the autumn period (Table 20). In autumn, due to the rapid turnover of the wader population during migration, there are often large fluctuations of waders between years across the estuary. The lack of significant results is therefore believed to be an artefact of the survey frequency.

Table 20: Inter-annual comparison of foraging abundance during autumn. Values relate to mean of foraging birds at low water for each year and level of significance between years in P column *** P<0.001, ** P<0.01, * P<0.05, NS P>0.05.

Species	1st autumn (2003/04)	2nd autumn (2004/05)	3rd autumn (2005/06)	4th autumn (2006/07)	5th autumn (2007/08)	6th autumn (2008/09)	P
Wildfowl							
Shelduck	4	176	104	23	4	0	**
Wigeon	0	0	20	46	7	15	**NS**
Teal	0	42	80	14	6	10	**NS**
Mallard	0	2	22	3	1	**0**	**NS**
Waders							
Oystercatcher	0	3	0	0	0	**1**	**NS**
Avocet	11	12	3	0	1	**1**	**NS**
Ringed Plover	0	0	3	4	0	**1**	**NS**
Golden Plover	0	24	0	0	0	**0**	**NS**
Grey Plover	0	0	1	4	3	**6**	**NS**
Lapwing	0	0	0	3	1	**0**	**NS**
Knot	59	0	0	1	11	**0**	**NS**
Dunlin	20	55	28	34	36	**19**	**NS**
Black-tailed Godwit	42	183	147	10	153	**0**	**NS**
Bar-tailed Godwit	0	1	0	1	0	**0**	**NS**
Curlew	9	25	26	15	10	**16**	**NS**
Redshank	44	24	80	46	111	**54**	**NS**

Similarly to the autumn period, foraging Shelduck continued to fall into Year 6 with only six birds recorded (albeit the result was not significant). Teal followed a similar trend in Year 6. Both species have shown a rapid rise in the first two years, but numbers have since declined. Mallard was the only species of wildfowl to show a significant difference of abundance between winters. After a peak of 23 birds in Year 3, numbers have since fell sharply. The mean of foraging Mallard was of one in the winter 2008/09 (Table 13).

With the exception of Bar-tailed Godwit which continued to show a significant rise in foraging individuals (p <0.05), other species have shown their numbers to stabilise or fall over the winter 2008/09. Analysis over the winter period continued to show a significant difference of abundance between years in several specialist intertidal feeders: Grey Plover (p <0.001), Dunlin (p <0.01). These species have however showed a net drop in Year 6 after an increasing trend since the creation of the realignment site in 2003. The numbers of Grey Plover and Dunlin recorded during the present surveys were back to a level similar to that Years 3 and 4. Significance difference in the mean number of foraging Redshank and Curlew continued to be recorded between winters. These two specialist intertidal feeders were not recorded foraging at low water during the first winter (2003/2004), but increased considerably since. In Year 6, the level of abundance appeared to have stabilised (Table 21).

Table 21: Inter-annual comparison of foraging abundance during winter. Values relate to mean of foraging birds at low water for each year and level of significance between years in P column *** P<0.001, ** P<0.01, * P<0.05, NS P>0.05.

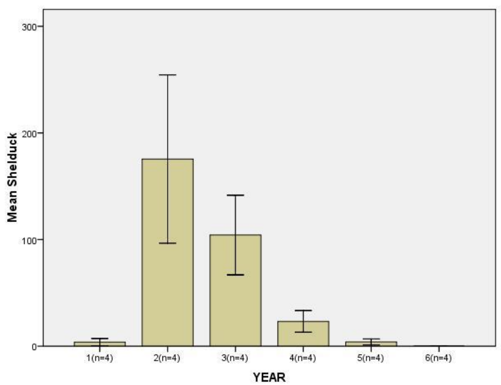
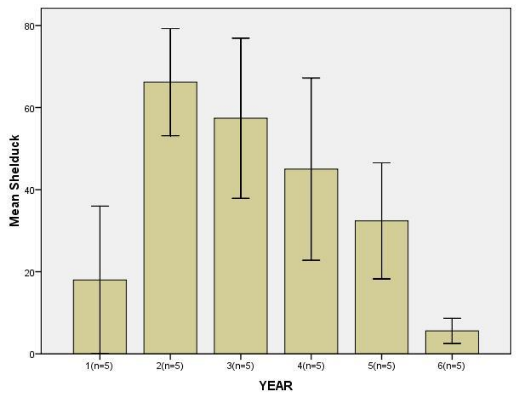
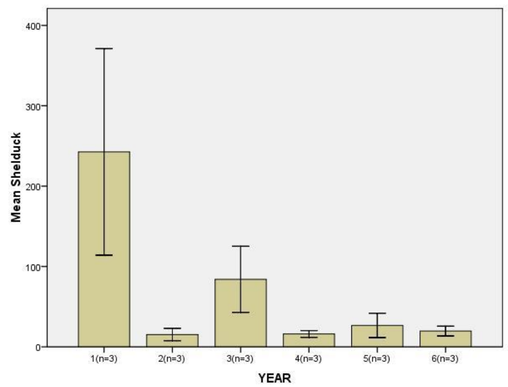
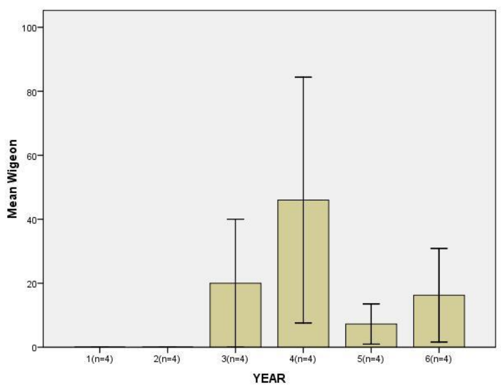
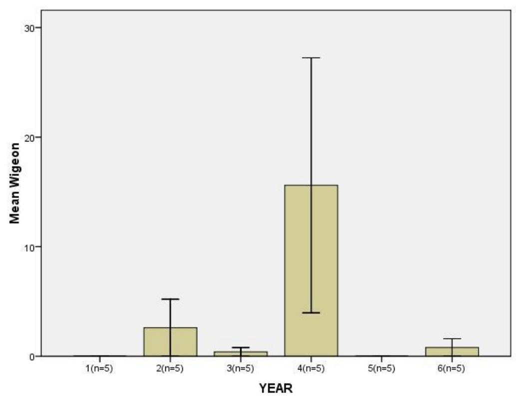
Species	1st winter (2003/04)	2nd winter (2004/05)	3rd winter (2005/06)	4th winter (2006/07)	5th winter (2007/08)	6th Winter (2008/09)	P
Wildfowl							
Shelduck	18	66	57	45	33	**6**	**NS**
Wigeon	0	3	0	16	0	**1**	**NS**
Teal	65	34	44	33	51	**17**	**NS**
Mallard	9	11	23	0	3	**1**	*****
Waders							
Oystercatcher	0	1	0	0	1	**1**	**NS**
Avocet	0	0	0	0	0	**0**	**NS**
Ringed Plover	0	0	0	0	0	**13**	**NS**
Golden Plover	1128	0	100	0	0	**0**	**NS**
Grey Plover	0	0	12	2	63	**4**	******
Lapwing	47	1	12	0	12	**4**	**NS**
Knot	22	0	0	0	0	**0**	**NS**
Dunlin	0	42	117	107	365	**92**	*****
Black-tailed Godwit	0	99	13	23	29	**12**	**NS**
Bar-tailed Godwit	0	0	29	13	53	**94**	*****
Curlew	0	11	18	10	13	**14**	*****
Redshank	2	34	33	109	174	**169**	******

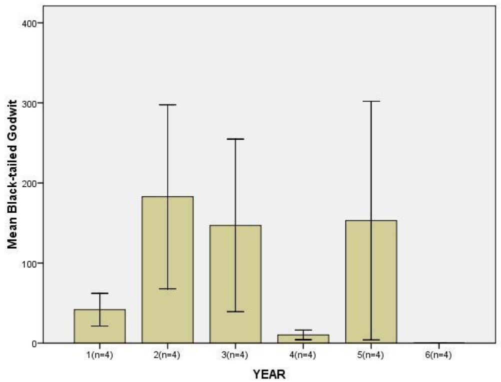
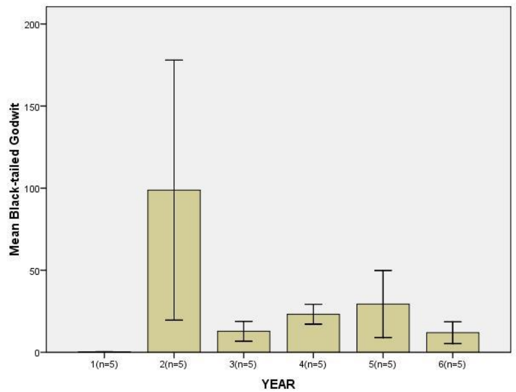
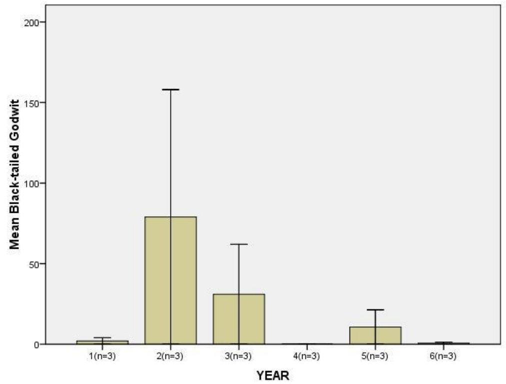
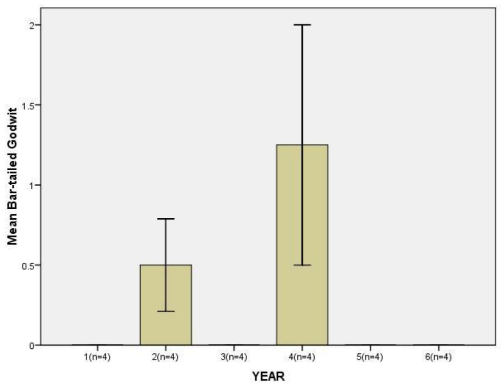
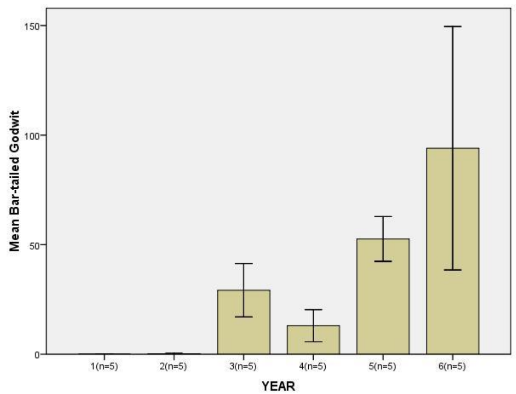
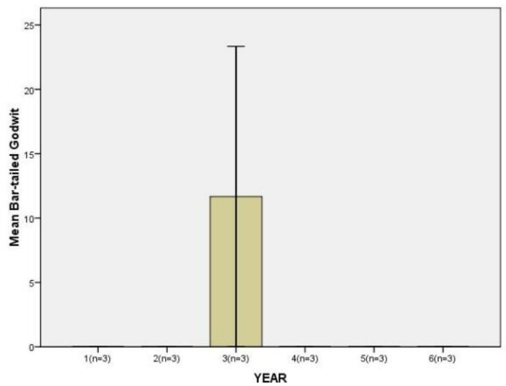
As with the autumn, there is a rapid turnover of waterbirds in the estuary in spring, with birds staying on a single site for only a few days or weeks before moving on to the next wetland (Davidson *et al*., 1991). As such, the lack of significant results is likely to be an artefact of the survey programme frequency (Table 22), rather than a population trend, as a single monthly count frequency may be insufficient to accurately assess waterbird usage in spring.

Table 6: Inter-annual comparison of foraging abundance during spring. Values relate to mean of foraging birds at low water for each year and level of significance between years in P column *** P<0.001, ** P<0.01, * P<0.05, NS P>0.05.

Species	1st spring (2004)	2nd spring (2005)	3rd spring (2006)	4th spring (2007)	5th spring (2008)	6th Spring (2009)	P
Wildfowl							
Shelduck	243	15	84	16	**27**	**19**	**NS**
Wigeon	0	0	0	0	**0**	**0**	**NS**
Teal	0	0	7	0	**2**	**0**	**NS**
Mallard	7	1	6	0	**4**	**7**	**NS**
Waders							
Oystercatcher	0	1	13	1	**0**	**2**	**NS**
Avocet	14	6	26	15	**3**	**3**	**NS**
Ringed Plover	0	8	0	2	**0**	**10**	**NS**
Golden Plover	0	0	0	0	**0**	**0**	**NS**
Grey Plover	0	0	1	1	**21**	**4**	**NS**
Lapwing	0	0	0	0	**0**	**0**	**NS**
Knot	0	0	0	0	**0**	**0**	**NS**
Dunlin	0	9	10	1	**65**	**2**	**NS**
Black-tailed Godwit	2	79	31	0	**11**	**1**	**NS**
Bar-tailed Godwit	0	0	12	0	**0**	**0**	**NS**
Curlew	0	27	15	1	**0**	**1**	**NS**
Redshank	5	24	57	0	**84**	**10**	**NS**

Figure 18: Seasonal mean numbers of key foraging species between years at low water ($\bar{x} \pm$ SE)

	Autumn	Winter	Spring
Shelduck			
Wigeon			No Birds

	Autumn	Winter	Spring
Black-tailed Godwit			
Bar-tailed Godwit			

Diet, prey-size selection and intake rates of Black-tailed Godwits *Limosa limosa* feeding on mudflats

FRANCISCO MOREIRA
Departamento de Zoologia e Antropologia, Faculdade de Ciências, Bloco C2, Universidade de Lisboa, P-1700 Lisboa, Portugal

This paper describes aspects of the winter feeding ecology of Black-tailed Godwits *Limosa limosa* on an intertidal mudflat in the Tagus estuary, Portugal. Their diet consisted mainly of the bivalve mollusc *Scrobicularia plana*, which represented 88% of the ingested biomass. The remaining 12% was the worm *Nereis diversicolor* and, occasionally, the snail *Hydrobia ulvae*. Ingested *Scrobicularia* varied between 10 and 20 mm in length, and all size classes of *Nereis* present in the sediment, except those smaller than 20 mm, were preyed upon. A change in dietary composition occurred over the winter, probably in response to changes in the availability of *Nereis* and small *Scrobicularia*. Intake rates averaged 74.9 mg dry weight per minute, which corresponded to a net energy intake of 1.21 kJ per min.

Although Black-tailed Godwits *Limosa limosa* are common in some European estuaries during winter, with a few exceptions (e.g. Hale 1980, Amat & Aguilera 1989, Goss-Custard *et al.* 1991), data on the biology of this species in wintering areas are scarce. The Tagus estuary holds an average of 15,000 wintering Black-tailed Godwits, with a maximum of 35,000 (Rufino 1984, 1991), although some of these birds only roost in the estuary and feed in rice fields around it. In the estuary, this species feeds mainly during low tide, selecting mudflats as preferred feeding grounds (Moreira 1993). This paper describes the diet and some aspects of the feeding ecology of Black-tailed Godwits exploiting an intertidal mudflat.

METHODS

Study area and observation period

The study area is located along the southern margin of the Tagus estuary, Portugal (38°40'N, 9°W). It is a 7.15-ha bay, surrounded by saltpans and saltmarsh (Fig. 1). The main sediment is mud (with less than 15% of the particles >0.062 mm in diameter). The intertidal invertebrate community of muddy areas across the whole estuary is dominated by the worm *Nereis diversicolor*, the bivalve mollusc *Scrobicularia plana* and the snail *Hydrobia ulvae* (Calvário 1982, 1984). The area was visited frequently from 7 January to 15 March 1992. Feeding observations were made during daylight and when the whole mudflat was exposed, i.e. within 2 h of low tide.

Bird distribution

The intertidal flat had 11 sectors of approximately the same size (50 m × 50 m) marked out with bamboo canes at the corners (Fig. 1). Feeding and non-feeding (roosting or preening) birds in each of these sectors were counted at 30-min intervals during each visit. The number of feeding birds in each sector was then averaged for the winter and used to test whether birds preferred to feed in specific areas of the flat. Counts when humans were present in the bay were excluded from the analysis (n = 10).

Diet and feeding behaviour

Observations were made through a ×15–60 telescope. Individual birds were selected at random and watched for 1–2 min, with a modal length of 1 min. Previous observations showed that this time period was sufficient to obtain a true measure of the mean feeding rates and their variability from a sample of birds. Based on Goss-Custard (1969), the following aspects of feeding behaviour were quantified.

(1) *Number of probes.* Black-tailed Godwits generally fed by probing. Occasionally birds fed by "stitching" (Cramp & Simmons 1983): a rapid series of probes was made with the bill whilst it was in permanent contact with the sediment. This was considered as a single peck, and a new period of probing began when the bill was extracted from the mud.

(2) *The number of prey taken (feeding rate).* Prey could be recognized as they were being taken by the bird. Bivalves were easily distinguished from worms while they were held at the tip of the bill. Birds swallowing prey with the bill inserted in the sediment were rarely observed (<3% of the observations). Prey identification was confirmed by examination of the prey remains in droppings collected where the birds had been feeding.

(3) *Sizes of prey taken.* Sizes of prey were estimated visually by comparing with the bill length, which is approximately 90 mm (Cramp & Simmons 1983). Bivalves taken were classified into six size categories (antero–posterior length): 9 mm

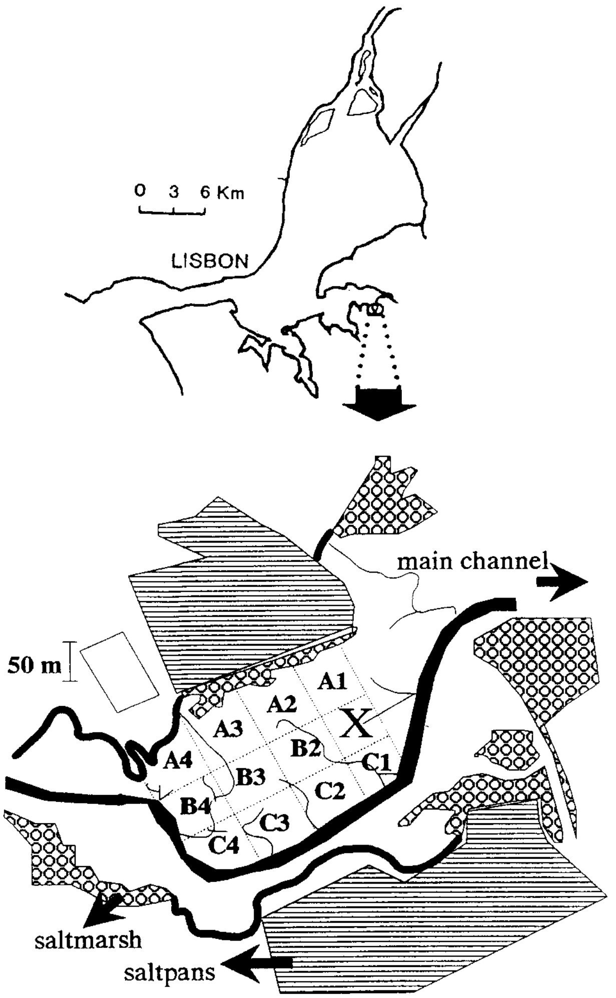


Figure 1. The Tagus estuary and diagram of the Black-tailed Godwit study area at low tide, with sectors defined in the intertidal flat. X indicates non-counted sector.

(one-tenth of bill length), 11 mm (one-eighth), 13 mm (one-seventh), 15 mm (one-sixth), 18 mm (one-fifth) and 22 mm (one-fourth). The size of worms was also estimated in bill length units: one, three-fourths, two-thirds, one-half, one-third, one-fourth, one-fifth or one-sixth of bill length. Worm length was estimated when the prey was hanging from the bill.

(4) *Sample of prey.* Random samples of *Scrobicularia plana* and *Nereis diversicolor* were collected by digging in the study area in February. The shell antero-posterior length was measured to the nearest millimetre, and the length of the cardinal tooth was measured under a binocular microscope with an eye-piece micrometer. Intact worms were killed by immersion in 70% ethanol, and their total length was measured to the nearest millimetre. The mandibles were extracted, and their length was measured using a binocular microscope. Regression analyses were performed in order to predict prey length from mandibles and cardinal teeth collected from droppings (Fig. 2). Cumulative frequency distributions of prey sizes in droppings (reconstructed from polychaete mandibles and mollusc shell fragments) were then used to correct the field estimates to actual sizes (Zwarts & Dirksen 1990, Zwarts & Blomert 1992). For example, the smallest 25% of the observed ingested *Scrobicularia plana* were estimated to be an average of 9 mm long. Based on the cumulative size distribution in droppings, the average size of the smallest 25% of bivalves was actually 10.9 mm. The same procedure was applied to the other size categories.

(5) *Dry weight of prey.* Dry weights were calculated from samples collected from the mudflat, measured (see above) and dried at 60°C to constant weight. Relationships between length and dry weight were then calculated (Fig. 3). In *Scrobicularia*, the shell was removed prior to weighing.

(6) *Intake rates.* Total ingested biomass was obtained by summing the dry weight of each of the ingested prey.

In addition, the following were recorded at the beginning of each observation: (1) the area where the bird was feeding (upper [A sectors] or lower [B and C sectors] of the shore); (2) time relative to low tide; (3) time relative to mudflat exposure; (4) the number of encounters over food (aggression); (5) date; (6) the number of birds of all species within ten bird-lengths of the observed bird.

All birds observed were feeding on exposed intertidal areas within 50 m of the observer, and 80% of observations were made within 2 h of low tide.

Sizes of prey in the substrate

On 10 February, three quadrats of 0.25 m^2 each were dug to 30 cm depth in A2, B2 and C2 (totalling nine quadrats); this is the maximum depth reached by prey (Esselink & Zwarts 1989, Zwarts & Wanink 1989). The samples were hand-sorted for bivalves, and the antero–posterior length was measured to the nearest millimetre. To sample *Scrobicularia* spat, seven cores of 0.006 m^2 surface area and 2 cm depth were taken in each of these areas and washed through a 0.25-mm-mesh sieve. *Scrobicularia* were counted and measured. On 20 February, a random sample of worms taken by digging in C2 was measured to the nearest millimetre (see above).

RESULTS

Occupation of the bay

Average feeding densities (birds/ha) of Black-tailed Godwits were bigger in the upper shore (A sectors) (median = 19.2, range = 12.0–29.6, $n = 4$) in relation to the lower shore (B and C sectors) (median = 10.4, range = 1.6–14.0, $n = 7$; Wilcoxon test, $z = -2.46$, $P < 0.05$). The proportion of birds in non-feeding activities (roosting or preening) was generally low (mean ± s.e. = 10.4 ± 2.08%, range = 0–42%, $n = 31$).

Diet and feeding behaviour

Analysis of droppings ($n = 51$) revealed the existence of three invertebrate species in the diet of Black-tailed Godwits:

The Wetland Bird Survey 2000–01
Wildfowl and Wader Counts

Mark Pollitt, Colette Hall, Steve Holloway, Richard Hearn, Paul Marshall, Andy Musgrove, James Robinson and Peter Cranswick

WeBS

Published by

British Trust for Ornithology, The Wildfowl & Wetlands Trust, Royal Society for the Protection of Birds and Joint Nature Conservation Committee

June 2003

BTO

WWT

RSPB

JOINT NATURE CONSERVATION COMMITTEE

CONTENTS

PRINCIPAL SITES

Table 4 below lists the principal sites for non-breeding waterfowl in the UK as monitored by WeBS. All sites supporting more than 10,000 waterbirds are listed, as are all sites supporting internationally important numbers of one or more waterbird species. Naturalised species (e.g. Canada Goose and Ruddy Duck) or non-native species presumed to have escaped from captive collections have been excluded from the calculations, as have gulls and terns since recording of these species is optional (see *Analysis* for further details).

A total of 178 sites are listed. Of these 156 supported one or more species in internationally important numbers and 83 held five-year peak mean waterbird totals of 10,000 or more birds. There are relatively few changes in the top 20 sites in the list, although there several sites have changed position. Whilst the Wash remains the top site in terms of waterbird numbers, Morecambe Bay is now second on the list following lower than average counts on the Ribble Estuary. Sustained high counts on the North Norfolk Coast are reflected in the sites leap to fifth position. Low counts at Hamford Water and on the Medway Estuary saw both sites fall out of the top 20, being replaced by the Alt Estuary and Montrose Basin.

Amongst sites supporting 10,000 waterbirds or more, numbers in 2000-01 were stable (within ±10% of previous five-year peak mean waterbird total) at 57% of sites, up (rise of 10% or more) at 17%, and down (a fall of 10% or more) at 27%. This was the fourth successive year in which more sites have shown a drop in numbers than have increased.

Fourteen sites showed major changes in numbers (a rise or fall of more than 30% in the present year compared with the five-year peak mean). High counts of Dunlin, Golden Plover, Lapwing and Wigeon accounted for the increased numbers on the Blackwater Estuary (+34%), the last two species also being the major influence on counts at the Somerset Levels (+31%). High numbers of Wigeon and Pink-footed Geese were chiefly responsible for the increase on Lindisfarne (+31%), the latter also accounting for significant changes at Dupplin Lochs (-49%), Slains Lochs (+41%), Loch of Skene (+62%) and at Wigtown Bay (-37%). Low counts were recorded for a wide number of species on the Medway Estuary (-52%). At the Ouse Washes (-35%) counts of Wigeon and Pintail were well down on previous years, whilst at Traeth Lafan (+42) counts for a number of wader species (notably Curlew, Oystercatcher and Redshank) continued the encouraging increases of recent years. At Loch of Harray (+37%), high Wigeon numbers were the major influence on the totals, whilst at Pitsford Reservoir (-33%) low numbers of the same species, coupled with below average counts of Lapwing and Golden Plover, saw the peak species total continue to fall.

Table 4. Total number of waterbirds at principal sites in the UK, 1996-97 to 2000-01 (includes only Core Count data and roost counts of Pink-footed and Greylag Geese), and species occurring in internationally important numbers at each (based on all survey data). Species codes are listed at the end of the table.

Site	96-97	97-98	98-99	99-00	00-01	Average	Int. imp. species
The Wash	279,907	345,431	289,879	374,095	286,586	315,180	PG SU OC GP GV L. KN DN BW BA CU RK
Morecambe Bay	251,813	312,950	265,610	232,806	246,807	261,997	PG SU PT OC KN DN BA CU RK TT BH LB HG
Ribble Estuary	299,134	281,427	259,593	236,382	222,068	259,721	BS WS PG SU WN T. PT OC GV KN SS DN BW BA RK
Thames Estuary	171,098	185,175	158,088	125,737	158,792	159,778	DB GA OC RP GV KN DN BA RK
North Norfolk Coast	119,201	170,687	143,217	178,106	168,919	156,026	PG DB WN PT GV KN BA RK TE
Humber Estuary	81,633	159,866	192,589	172,515	163,066	153,934	SU GP GV L. KN DN BW BA RK
Solway Estuary	157,399	146,086	152,251	141,460	128,292	145,098	WS PG YS SU PT OC KN DN BA CU RK
Dee Estuary (Eng/Wal)	151,210	128,426	108,017	92,284	135,113	123,010	SU T. PT OC KN DN BW CU RK TT
Mersey Estuary	116,030	117,312	93,910	106,045	109,878	108,635	SU T. PT DN BW RK
Loughs Neagh & Beg	101,708	82,232	103,350	97,308	101,668	97,253	CA WS PO TU SP GN

Species codes

AV Avocet
BA Bar-tailed Godwit
BS Bewick's Swan
BW Black-tailed Godwit
CA Cormorant
CO Coot
CU Curlew
DB Dark-bellied Brent Goose
DN Dunlin
E. Eider
EW European White-fronted Goose
GA Gadwall
GD Goosander
GN Goldeneye
GP Golden Plover
GV Grey Plover
HG Herring Gull
JI Greylag Goose (Icelandic population)
JH Greylag Goose (Northwest Scotland population)
KN Knot
L. Lapwing
LB Lesser Black-backed Gull
LN Long-tailed Duck
MA Mallard
MS Mute Swan
ND Great Northern Diver
NW Greenland White-fronted Goose
OC Oystercatcher
PG Pink-footed Goose
PO Pochard
PT Pintail
QS Light-bellied Brent Goose (Svalbard population)
QN Light-bellied Brent Goose (Greenland poplulation)
RK Redshank
RM Red-breasted Merganser
RP Ringed Plover
SP Scaup
SS Sanderling
SU Shelduck
SV Shoveler
SZ Slavonian Grebe
T. Teal
TE Sandwich Tern
TT Turnstone
TU Tufted Duck
WM Whimbrel
WN Wigeon
WS Whooper Swan
YN Barnacle Goose (Greenland population)
YS Barnacle Goose (Svalbard population)

Ian Shepherd ♦ Ornithologist ♦ 38 Lindsey Road ♦ Cleethorpes ♦ Lincolnshire ♦ DN35 8TN
Tel: 01472 697142 ♦ Mobile: 07815533742 ♦ E-mail: IShphrd@aol.com

HABITAT CREATION MEASURES AT CHOWDER NESS/BARTON CLIFF

Monthly Bird Monitoring, September 2006 to March 2007

1.0 Fieldwork Methodology

The survey area included the sea banks around the coast realignment site, the new intertidal area within, intertidal ground fronting that realignment site, and two areas of intertidal ground upstream of the proposed realignment area, both of equivalent length.

Fieldwork involved monthly visits between September 2006 and March 2007, with the aim of identifying the abundance, distribution and species composition of waterbirds feeding, roosting and/or loafing in the area.

The survey period covered falling tide, low water and rising tide (+/- 4 hours either side of low water), and visit dates with low water occurring between late morning and early afternoon were chosen in order to maximise surveying time in available daylight.

During each visit hourly point counts were made of all waterbird species using the new intertidal ground within the realignment site and the original intertidal area, fronting that site. These counts were undertaken from the adjacent public footpath along the seabank. The distribution of each waterbird species was recorded during each hourly count, and their activity (feeding, roosting etc.) also noted, along with the position of the tideline. That count/mapping procedure was then repeated on the two intertidal areas on South Ferriby shore, from the public footpath at South Ferriby Cliff (SE997224).

Any significant events of disturbance to waterfowl using the survey area, and any subsequent effects on their numbers, distribution and/or activity, were noted.

Casual records of terrestrial bird species seen or heard within the survey area were also made from the seabank through each monthly visit

2.0 Results

2.1 Intertidal Survey Areas

Numbers of waterbirds were generally low in all four intertidal areas monitored, throughout the September to March survey period. *Table 2.1a* gives, for each intertidal survey area, the number of survey visits on which each waterbird species occurred. *Table 2.1b* summarises September – March range and mean numbers of each waterbird species for each of the four count areas.

Black-headed gulls also used the area during five survey visits. None used the site during the November or December surveys. A flock of 31 fed during the early morning of the September survey, with single figure numbers then remaining through that day. There were then just single figure numbers occasionally present during ebb tides.

Up to 3 common gulls fed during the early mornings of the September and October surveys, but despite its regular presence on the nearby eastern Read's Island flats, the species was not seen to use this site again until March, when 2 birds loafed on the tideline.

2.1.2 Bird Usage of the New Chowder Ness Foreshore Area, Within the Coast Realignment Site

A total of 13 waterbird species used the newly created Chowder Ness Foreshore area. Numbers per visit of each waterbird species using the new intertidal area are given in *Table 2.1.2a*.

Table 2.1.2a Waterbird Usage of the New Chowder Ness Foreshore, September 2006 to March 2007

	Visit date and Waterbird Numbers Using the New Intertidal Area (min-max per visit)						
Species	**05/09/06**	**05/10/06**	**06/11/06**	**04/12/06**	**03/01/07**	**01/02/7**	**02/03/07**
Grey heron	0 – 1	0 – 1	0	0	0 – 1	0	0
Shelduck	0	7 – 12	5 – 9	0 – 7	0 – 6	11 – 14	10 – 18
Teal	0	0 – 12	0	0	0	0	0
Avocet	0 – 4	0	0	0	0	0	0
Ringed plover	0 – 7	1 – 2	0 – 5	0 – 17	0	1 – 21	0
Golden plover	0 – 314	0 – 22	0	0	0	0	0
Lapwing	61 – 142	0 – 115	6 – 51	0 – 101	0 – 2	0 – 32	0 – 1
Dunlin	0 – 3	0 – 8	0 – 22	8 – 39	0 – 3	0 – 41	0 – 2
Curlew	0 – 2	0 – 8	1 – 9	0 – 1	0	0 – 26	2 – 55
Redshank	1 – 5	5 – 8	3 – 6	2 – 7	0 – 1	0 – 1	0 – 1
Greenshank	1	0	0	0	0	0	0
Black-headed gull	5 – 54	0 – 5	0 – 32	0 – 1	0	0 – 71	0 – 57
Common gull	0 – 4	0	0	0	0	0 – 3	0 – 1

Throughout the survey period, most waterbird usage was concentrated on the disturbed ground along the line of the removed seawall and the adjacent area of new mudflats within 10m of that area.

Three waterbird species - lapwing, dunlin and redshank - were present on the new mudflats during all seven of the monthly surveys.

Two lapwings fed on the flats during the October survey. All other records of the species were of birds roost/loafing along the line of the removed seawall or on adjacent flats towards the eastern end. Numbers of lapwing roost/loafing were highest from September to December, when visit peaks ranged from 51 to 142 birds. Only 1-2 were present in January and March and a visit peak 32 in February only stayed to mid ebb (mid morning) with none in the area through the remainder of that survey.

Numbers of dunlin feeding on the new foreshore were generally low, rarely reaching double-figures. Usage was concentrated on the disturbed ground along the line of the removed seawall and adjacent areas of new flats within 10m. Only single-figure numbers fed during the September and October surveys. There was an arrival of 22 dunlin just after low tide during the November survey. Some of that flock roosted on the rubble along the line of the removed seawall whilst others fed nearby. During the December survey that area was again used as both a roosting and feeding area by up to 36 dunlin. No more than 3 dunlin fed on the site during the January to March surveys and none did so at low tide or during flood tides. At the start of the February survey 41 dunlin were roosting on rubble along the line of the removed seawall, and had probably roosted there over the pre-dawn high tide. All but 1 bird of that flock flew off towards Read's Island prior to the next hourly count.

Only single-figure numbers of redshank used the area through the survey period. Visit peaks ranged from 5 to 8 birds from September to December then only single redshank were occasionally present through the January to March surveys. Some feeding redshank used the mudflats close to the new seawall during the autumn 2006 surveys but all subsequent records were of birds feeding on, or close to, the line of the removed seawall.

No shelduck were present during the September survey. From October to March the species was present through most hourly count periods. Visit peaks, October to March, ranged between 5-18 shelduck, and mainly involved feeding birds which were widespread over the eastern half of the new mudflats. The seaward edge of the new foreshore, along the line of the removed seawall, was used as a refuge area by shelduck when birds feeding on the landward and central areas of the new flats were disturbed by the arrival of walkers on to the top of the new seawall. Up to 5 shelduck also roost/loafed on that area occasionally during five of the seven survey visits.

Only single-figure numbers of curlew used the new foreshore during September to December surveys. All usage was concentrated along the line of the removed seawall. No curlew were present during the January survey. Numbers were higher during the February and March surveys as curlew flocks feeding on adjacent fields moved to and from a roost/loafing area on the disturbed ground along the line of the removed seawall. Some birds from those flocks also fed briefly on new mudflats along and beside their roosting area.

Ringed plover were present during five of the seven monthly surveys. None were seen during the January or March surveys. All records involved birds using the disturbed ground along the line of the removed seawall. Single-figure numbers fed there during the September, October and November surveys, with up to 3 also roosting there in November. During the December survey none were present until an arrival around mid ebb which peaked briefly at 17 birds before all but 1 flew off towards Read's Island/Ferriby. The survey peak involved 21 ringed plover which were roosting along the line of the removed seawall at the start of the February survey, along with a dunlin flock. All but 2 of that flock had left the site by mid ebb.

Golden plover usage was restricted to autumn 2006, when all records were of birds roost/loafing along the line of the removed seawall or on adjacent flats towards the eastern end, often in association with lapwings.

Three species – teal, avocet and greenshank – only occurred during single autumn 2006 surveys.

Ian Shepherd ♦ Ornithologist ♦ 38 Lindsey Road ♦ Cleethorpes ♦ Lincolnshire ♦ DN35 8TN
Tel: 01472 697142 ♦ Mobile: 07815533742 ♦ E-mail: IShphrd@aol.com

HABITAT CREATION MEASURES AT CHOWDER NESS/BARTON CLIFF

Monthly Bird Monitoring, September 2007 to March 2008

1.0 Fieldwork Methodology

The survey area included the sea banks around the coast realignment site, the new intertidal area within, intertidal ground fronting that realignment site, and two areas of intertidal ground upstream of the proposed realignment area, both of equivalent length.

Fieldwork involved monthly visits between September 2007 and March 2008, with the aim of identifying the abundance, distribution and species composition of waterbirds feeding, roosting and/or loafing in the area.

The survey period covered falling tide, low water and rising tide (+/- 4 hours either side of low water), and visit dates with low water occurring between late morning and early afternoon were chosen in order to maximise surveying time in available daylight.

During each visit hourly point counts were made of all waterbird species using the new intertidal ground within the realignment site and the original intertidal area, fronting that site. These counts were undertaken from the adjacent public footpath along the seabank. The distribution of each waterbird species was recorded during each hourly count, and their activity (feeding, roosting etc.) also noted, along with the position of the tideline. That count/mapping procedure was then repeated on the two intertidal areas on South Ferriby shore, from the public footpath at South Ferriby Cliff (SE997224).

Any significant events of disturbance to waterfowl using the survey area, and any subsequent effects on their numbers, distribution and/or activity, were noted.

Casual records of terrestrial bird species seen or heard within the survey area were also made from the seabank through each monthly visit

2.0 Results

2.1 Intertidal Survey Areas

Table 2.1a gives, for each intertidal survey area, the number of survey visits on which each waterbird species occurred. *Table 2.1b* summarises September – March range and mean numbers of each waterbird species for each of the four count areas.

end flats, but all had gone by mid-flood. This flock was first seen on South Ferriby flats from dawn and had probably become disorientated in dense overnight fog.

Curlew used the area during six of the seven monthly surveys. None were seen here in January. Usage was concentrated on the eastern end flats, during the early morning ebb tide. The highest count was of just 4 curlew feeding there in October. Only single curlew in September was seen to use the site at low tide and there was no flood tide usage.

Turnstones were present on the stony areas of beach, just seaward of the line of the old seawall, during three monthly surveys. Three were there in September, and then just single birds in December and February.

Black-headed gulls also used the area during just three survey visits, despite its regular presence on the adjacent new mudflat area. A flock of 10, including 9 roosting birds, were present during the September survey. Otherwise there was just occasional usage by single-figure numbers, with none seen here during the October, November, December or March surveys.

Up to 3 common gulls roosted during the early morning of the February survey. This was the only occasion on which this species was seen to use the old mudflats area, despite the regular presence of small numbers on the adjacent new mudflat area and of flocks on the nearby eastern Read’s Island flats.

2.1.2 Bird Usage of the New Chowder Ness Foreshore Area, Within the Coast Realignment Site

A total of nineteen waterbird species used the newly created Chowder Ness Foreshore area. Numbers per visit of each waterbird species using the new intertidal area are given in *Table 2.1.1a.*

Table 2.1.1a Waterbird Usage of the New Chowder Ness Foreshore, September 2007 to March 2008

	Visit date and Waterbird Numbers Using the New Intertidal Area (min-max per visit)						
Species	**29/09/07**	**25/10/07**	**09/11/07**	**07/12/07**	**21/01/08**	**19/02/08**	**20/03/08**
Grey heron	0	0 – 1	0	0	0	0	0
Shelduck	68 – 105	41 – 96	67 – 89	60 – 66	15 – 33	17 – 24	62 – 69
Wigeon	0	0 – 12	0	0	0	0	0
Teal	8 – 12	0 – 44	0 – 4	0	0	0	0 – 9
Oystercatcher	0	0	0	0	0	0	0 – 2
Ringed plover	0 – 7	1 – 2	0 – 1	0 – 16	0	0 – 1	0 – 7
Golden plover	0 – 31	0 – 31	0	0	0	0	0
Grey plover	0	0	0 – 1	0	0	0	0
Lapwing	11 – 55	9 – 47	0 – 46	0 – 408	0 – 51	0	0
Knot	0 – 2	0	0 – 3	0	0	0	0
Dunlin	5 – 17	3 – 5	0 – 4	0 – 22	0	0 – 4	0 – 7
Little stint	0	0 – 2	0	0	0	0	0
Curlew	4 – 17	3 – 5	4 – 11	2 – 5	0 – 6	1 – 22	0 – 4
Black-tailed godwit	0	0	0	0 – 4	0	0	0
Redshank	6 – 16	8 – 20	2 – 5	0 – 5	2 – 9	0 – 1	0 – 2
Black-headed gull	0 – 81	0 – 13	0 – 21	8 – 21	0 – 8	0 – 19	0 – 30
Common gull	0 – 25	0	0 – 12	0 – 19	0 – 2	0 – 8	0 – 13
Herring gull	0 – 1	0	0 – 1	0	0 – 6	0 – 2	0 – 5
Gt Black-backed gull	0	0	0	0	0 – 9	0	0

Four waterbird species – shelduck, curlew, redshank and black-headed gull, were present on the new mudflats during all seven of the monthly surveys.

Shelduck flocks were present on the new mudflats area throughout the day during all seven of this season's monthly surveys, September 2007 to March 2008. Visit peaks through that period ranged between 24 (February) and 105 (September) shelduck. This distribution of feeding flocks was often concentrated on the eastern half of the site, though small numbers of feeding shelduck were seen to use all areas except the narrow western end. The seaward edge of the new foreshore, along the line of the removed seawall, was sometimes used as a refuge area by shelduck when birds feeding on the landward and central areas of the new flats were disturbed by the arrival of walkers on to the top of the new seawall, by the farmyard. Shelduck roosted on that area occasionally during all seven monthly surveys, with peak counts per survey of roosting birds ranging from 3 (September) to 49 (October).

Curlews were present on the new mudflats area during almost all hourly count periods through this season's surveys, September 2007 to March 2008. Only single-figure numbers were present regularly, though there were survey visit peaks of 17 in September and 22 in February. Those higher counts during the September and January surveys were a result of curlew flocks feeding on adjacent fields and moving to and from a roost/loafing area on the disturbed ground along the line of the old seawall.

Only single-figure numbers of redshank were present on the new mudflats area regularly through the September to March survey period, though there were visit peak counts of 16 birds in September and 22 in October. Visit peaks then ranged from 5 to 9 birds from November 2007 to January 2008 and only 1-2 redshank were present through the February and March 2008 counts. Feeding activity was concentrated on areas of mudflats just inside the line of the old seawall, close to the new seawall and at the narrow western end of the site. Very few redshank were seen to feed in the central area of mudflats. Only single redshank were seen to roost within the site, during the September and October surveys.

Black-headed gulls were present throughout the morning ebb tides of all seven monthly surveys, September 2007 to March 2008, with highest numbers invariably on the site at the start of surveying. Peak counts per survey visit ranged from 8 (January) to 77 (September). Smaller, usually single-figure, numbers occurred from low tide onwards. Almost all black-headed gulls seen on the site were roost/loafing on or just inland of the line of the old seawall. Up to 4 birds fed whilst on the site during five of the seven monthly surveys.

Ringed plover were present during six of the seven monthly surveys. None were seen during the January survey. Usage was concentrated on the disturbed ground along the line of the removed seawall, another area close to the new seawall by the farmyard and the western end flats. Single-figure numbers fed during the September, October and November and March surveys, with up to 4 also roosting during the September survey. The survey peak involved 16 ringed plover which were feeding on flats just inside the line of the removed seawall during the afternoon flood tide of the December survey, amongst a dunlin flock.

Numbers of dunlin feeding on the new foreshore were generally low, rarely reaching double-figures. Usage was concentrated on the disturbed ground along the line of the removed seawall and adjacent areas of new flats within 10m. Only single-figure numbers fed during the October, November, February and March surveys. Up to 17 dunlin fed through the ebb tide of the September survey and the season peak count was of 22 feeding during the afternoon flood tide of the December survey. Dunlin were only seen to roost on the site during the September survey, when just 5 roosted at low tide.

Flocks of roosting lapwings were present along the line of the removed seawall or on adjacent flats during all monthly surveys between September 2007 and J ranged from 46 to 55 lapwing. Single-figure numbers fed on the same area during the October, November and January surveys. None were seen on the site during the February or March surveys.

Just single figure numbers of herring gulls were seen during five monthly surveys, always roost/loafing with other gull species, on or adjacent to the disturbed ground along the line of the old seawall. The peak count was of 6 birds in January.

Teal were seen on the new mudflats during four of the seven monthly surveys, feeding at the eastern end, often in vegetation by the seawall base. Flocks were present through the day during the September and October 2007 surveys, numbers peaking at 44 in October. Four teal were feeding during the morning of the November survey. No more were seen here during surveys until 9 birds fed through much of the day in March.

Knot were seen on the new mudflats during two monthly surveys. Two fed briefly at the western end during the September survey and up to 3 birds fed there up to low tide during the November survey.

Golden plover usage was restricted to autumn 2007, when all records were of birds roost/loafing along the line of the removed seawall or on adjacent flats towards the eastern end, often in association with lapwings. Up to 31 birds were seen there during both the September and October 2007 surveys.

Seven species only occurred during a single survey visit during the 2007-08 season. A single grey heron fed at the eastern end for a few minutes during the September survey. Up to 12 wigeon wandered from their usual roosting area on the ‘old’ mudflats on to disturbed ground along the line of the old seawall during the October survey. Also on that day 2 little stints fed at the western end throughout the survey. A single grey plover, which had been feeding on the South Ferriby flats, stopped on the new mudflats for just a few minutes before continuing its eastwards movement during the November survey. Four black-tailed godwits roosted on the disturbed ground along the line of the old seawall for two hours during the December survey. Nine great black-backed gulls roost/loafed on the new mudflats at dawn during the January survey. Two oystercatchers fed on the new mudflats, close to the seawall fronting the farmyard, during the March survey.

2.1.2 Bird usage of the Eastern South Ferriby Intertidal Area

The eastern stretch of the South Ferriby shore (South Ferriby Cliff SE999226 to Leggott’s Quarry SE994219) comprises an eroding clay cliff –the coastal path here has been lost to erosion – with a narrow shingle beach at its base and a narrow area of rock-strewn mud to seaward. At low tide the shore is approximately 120m wide from cliff base to tideline.

A total of nine waterbird species used the eastern South Ferriby flats. Numbers per visit of each waterbird species using the are given in *Table 2.1.2a.*

Ian Shepherd ♦ Ornithologist ♦ 38 Lindsey Road ♦ Cleethorpes ♦ Lincolnshire ♦ DN35 8TN
Tel: 01472 697142 ♦ Mobile: 07815533742 ♦ E-mail: IShphrd@aol.com

HABITAT CREATION MEASURES AT CHOWDER NESS/BARTON CLIFF

Monthly Bird Monitoring, September 2008 to March 2009

1.0 Fieldwork Methodology

The survey area included the sea banks around the coast realignment site, the new intertidal area within, intertidal ground fronting that realignment site, and two areas of intertidal ground upstream of the proposed realignment area, both of equivalent length.

Fieldwork involved monthly visits between September 2008 and March 2009, with the aim of identifying the abundance, distribution and species composition of waterbirds feeding, roosting and/or loafing in the area.

The survey period covered falling tide, low water and rising tide (+/- 4 hours either side of low water), and visit dates with low water occurring between late morning and early afternoon were chosen in order to maximise surveying time in available daylight.

During each visit hourly point counts were made of all waterbird species using the new intertidal ground within the realignment site and the original intertidal area, fronting that site. These counts were undertaken from the adjacent public footpath along the seabank. The distribution of each waterbird species was recorded during each hourly count, and their activity (feeding, roosting etc.) also noted, along with the position of the tideline. That count/mapping procedure was then repeated on the two intertidal areas on South Ferriby shore, from the public footpath at South Ferriby Cliff (SE997224).

Any significant events of disturbance to waterfowl using the survey area, and any subsequent effects on their numbers, distribution and/or activity, were noted.

Casual records of terrestrial bird species seen or heard within the survey area were also made from the seabank through each monthly visit

2.0 Results

2.1 Intertidal Survey Areas

Numbers of waterbirds were generally low in all four intertidal areas monitored, throughout the September to March survey period. *Table 2.1a* gives, for each intertidal survey area, the number of survey visits on which each waterbird species occurred. *Table 2.1b* summarises September – March range and mean numbers of each waterbird species for each of the four count areas.

including 126 roost/loafing, were on the shore during the early morning of the September survey. None were seen to use this area during the November, December or March surveys, with just occasional single-figure numbers present during the October, January and February surveys.

A single ringed plover fed just seaward of the remains of the old seawall during the March survey, but again this species preferred to use the area along the line of the old seawall on disturbed ground herein regarded as within the new mudflat area.

Shelduck were seen to roost/loaf in the tide during two survey visits: 8 birds during the October survey and a single bird in January all retreated to the tide briefly after being disturbed from the new Chowder Ness mudflats.

Small numbers of teal were present on the shore during the September and October surveys, with peak count just 7 birds in September.

Four turnstones were present on the stony areas of beach, just seaward of the line of the old seawall, at low tide during the November survey.

Up to 15 common gulls roosted during the early morning of the September survey, amongst the black-headed gull flock. This was the only occasion on which this species was seen to use the old mudflats area, despite the regular presence of small numbers on the adjacent new mudflat area and of flocks on the nearby eastern Read's Island flats.

Three herring gulls roost/loafed on the tideline during the early morning of the December survey.

2.1.2 Bird Usage of the New Chowder Ness Foreshore Area, Within the Coast Realignment Site

A total of sixteen waterbird species used the newly created Chowder Ness Foreshore area. Numbers per visit of each waterbird species using the new intertidal area are given in *Table 2.1.1a.*

Table 2.1.1a Waterbird Usage of the New Chowder Ness Foreshore, September 2008 to March 2009

	Visit date and Waterbird Numbers Using the New Intertidal Area (min-max per visit)						
Species	**26/09/08**	**27/10/08**	**27/11/08**	**11/12/08**	**22/01/09**	**23/02/09**	**24/03/09**
Shelduck	13 – 14	12 – 40	0 – 42	38 – 48	22 – 56	44 – 59	24 – 27
Wigeon	0	0 – 21	0 – 6	0	0	0	0 – 9
Teal	0 – 9	0 – 19	0	0	0	0	0
Oystercatcher	0	0	0	0	0	0	0 – 2
Ringed plover	0 – 20	0	0 – 17	0	0 – 2	0	1 – 3
Golden plover	0	0 – 22	0 – 97	0 – 46	0 – 20	0	0
Grey plover	0	0	0	0 – 1	0	0	0
Lapwing	0 – 81	2 – 78	79 – 176	0 – 166	43 – 183	0 – 7	0 – 4
Dunlin	0 – 203	0 – 56	0 – 150	0 – 1	0 – 34	0	0
Curlew	1 – 7	1 – 10	0 – 7	0 – 28	0 – 7	1 – 21	7 – 44
Black-tailed godwit	0	0	0	0	0 – 31	0	0
Redshank	0 – 2	1 – 9	0 – 7	3 – 10	2 – 10	0 – 2	1 – 8
Black-headed gull	0 – 8	0 – 34	0 – 7	0 – 14	0 – 29	3 – 22	5 – 13
Common gull	0	0 – 10	0 – 2	0 – 16	0 – 8	4 – 36	1 – 23
Herring gull	0 – 7	0	0 – 1	0 – 10	0 – 2	0	0
Gt Black-backed gull	0	0 – 1	0	0 – 1	0	0	0

Five waterbird species – shelduck, lapwing, curlew, redshank and black-headed gull, were present on the new mudflats during all seven of the monthly surveys.

Shelduck were present on the new mudflats area throughout the day during all seven of this season's monthly surveys, September 2008 to March 2009. Visit peaks ranged between 14 birds (September) and 59 birds (February). The distribution of feeding flocks was often concentrated on the eastern half of the site, though small numbers of feeding shelduck made occasional use of the entire area. The seaward edge of the new foreshore, along the line of the removed seawall, was sometimes used as a refuge area by shelduck when birds feeding on the landward and central areas of the new flats were disturbed by the sudden appearance of walkers and/or dogs on the top of the new seawall, by the farmyard. Shelduck roosted on that area during all seven monthly surveys, with peak counts per survey of roosting birds ranging from 4 (September and November) to 42 (February).

Roost/loafing lapwings were present along the line of the removed seawall or on adjacent flats during all monthly surveys. Flocks were present from September to January, with visit peaks then ranging between 78 and 183 birds. Only single-figure numbers roost/loafed on the area during the February and March surveys. Lapwings were seen to feed on the new mudflat area during five of the seven surveys. All feeding occurred on mudflats along the edge of the roosting area. The peak count of feeding lapwing was of 27 around low tide during the October survey. Otherwise just single-figure numbers fed briefly during the November, December, January and March surveys.

Curlews were present on the new mudflats area during almost all hourly count periods through this season's surveys, September 2008 to March 2009. Only single-figure numbers of feeding curlews were regular, with visit peak counts of feeding birds for September to February ranging between 3 and 10 birds. More were present during the March survey when a survey peak of 44 curlew included 26 feeding birds. Although there was some concentration of feeding birds along the outer edge and across the eastern half of the site, feeding curlew were seen to use all but the extremely narrow western end. Single-figure numbers of curlew also roost/loafed on the new mudflats regularly, with occasional usage by higher numbers – 28 in December, 16 in February, 24 in March - caused by movements of curlew flocks from adjacent fields on to the area to bathe/roost/loaf along the outer edge.

Only single-figure numbers of redshank were present on the new mudflats area regularly through the September to March survey period, with visit peak counts of 10 birds in December and January. Feeding activity was concentrated on areas of mudflats just inside the line of the old seawall, close to the new seawall and at the narrow western end of the site. Very few redshank were seen to feed in the central area of mudflats. Only single redshanks were seen to roost within the site, during the September and October surveys.

Black-headed gulls were present during the morning ebb tides of all seven monthly surveys, September 2008 to March 2009, with highest numbers on the site at the start of each survey visit. Peak counts per survey visit ranged from 7 (November) to 34 (October). Smaller, usually single-figure, numbers usually occurred from low tide onwards, though 22 were roosting at mid flood during the February survey. Almost all black-headed gulls seen on the site were roost/loafing on or just inland of the line of the old seawall. There was a survey peak of 26 birds feeding during the early morning of the January survey, but otherwise just 1-2 black-headed gulls fed on the new mudflats area during all but the October survey, when none were seen to feed.

Small numbers of common gulls used the new mudflats area during six of the seven monthly surveys, with none seen during the September visit. Almost all common gulls seen on the site were roost/loafing on or just inland of the line of the old seawall, amongst black-headed gulls. There was a survey peak of 23 birds roosting during the early morning of the March survey, but numbers present rarely exceeded 10 birds though the survey season. Up to 2 common gulls fed on the new mudflat area during the December survey and up to 4 birds did so during the January survey.

Despite the peak count of 203 dunlin this season, numbers using the new foreshore were generally low, rarely reaching double-figures, and the species was absent during 36 of the 56 hourly count periods this season, including all of the February and March survey visits. Usage was again concentrated on the disturbed ground along the line of the removed seawall and adjacent areas of new flats within 15m. The flock of 203 birds arrived from the west to feed on the flats just landward of the old seawall remains, at mid ebb during the September survey, but only stayed for 30 minutes before returning westward towards Read's Island. A flock of 56 also arrived on that area of mud about two hours after low tide during the October survey, but again they stayed to feed for less than an hour. In November a flock of 100 arrived at mid ebb to join 47 dunlin already present. Once again this flock had left the area westwards before the start of the next hourly count, leaving just a single feeding dunlin on site for the remainder of the day. Only a single dunlin fed, from low tide onwards, during the December survey and there were also only singe –figure numbers present through the January survey until a flock of 34 arrived two hours after low tide. No dunlin were seen to use the new mudflat area during the February or March surveys.

Ringed plover were present during four of the seven monthly surveys. None were seen during the October, December or February surveys. All usage was concentrated on the disturbed ground along the line of the removed seawall. A flock of 20 roosted along that area during the early morning of the September survey, and 17 did so during the November survey. Ringed plover were then not seen to use the new mudflats area again until January when 2 were present during the ebb tide period. Up to 3 were present during the March survey.

Golden plover usage was restricted to birds roost/loafing along the line of the removed seawall or on adjacent flats towards the eastern end, often in association with lapwings. None were present during the September, February or March surveys. Visit peak counts from October to January ranged between 20 and 97 birds.

Small numbers of herring gulls were seen during four monthly surveys. All records were of birds roost/loafing with other gull species, during early mornings, on or adjacent to the disturbed ground along the line of the old seawall. The peak count was of 10 birds in December. None were seen to use this area during the October, February or March surveys.

Up to 21 wigeon wandered from their usual roost/loafing area on the 'old' mudflats on to disturbed ground along the line of the old seawall during the October survey, as did 6 birds around low tide during the November survey and up to 9 birds during the ebb tide of the March survey.

Teal were seen on the new mudflats during two of the seven monthly surveys, feeding at the eastern end, often in vegetation by the seawall base. Teal were present through the day during the September and October 2007 surveys, numbers peaking at 19 in October. None were seen to use the area between November and March.

Single great black-backed gulls roost/loafed on the new mudflats during the early mornings of the October and January surveys.

Three species occurred during a single survey visit only during the 2008-09 season. A single grey plover was present around the low tide period of the December survey, first roosting on the disturbed ground along the line of the old seawall, then feeding on adjacent mudflats. A flock of 31 black-tailed godwits arrived from the west with a lapwing flock and roosted on the disturbed ground along the line of the old seawall during the flood tide of the January survey. Two oystercatchers fed on the eastern end of the new mudflats during the March survey.

2.1.2 Bird usage of the Eastern South Ferriby Intertidal Area

The eastern stretch of the South Ferriby shore (South Ferriby Cliff SE999226 to Leggott's Quarry SE994219) comprises an eroding clay cliff –the coastal path here has been lost to erosion – with a narrow shingle beach at its base and a narrow area of rock-strewn mud to seaward. At low tide the shore is approximately 120m wide from cliff base to tideline.

A total of six waterbird species used the eastern South Ferriby flats. Numbers per visit of each waterbird species using the are given in *Table 2.1.2a.*

Wigeon was the only waterbird species present during all seven monthly survey visits. Parties roost/loafed and fed along the tideline and on the stone beach through the ebb tide, and then often moved off upstream with the flood tide. Visit peak numbers roost/loafing, September to February ranged between 61 and 155 birds, with just 8 remaining in March. Between September and November visit peak counts of feeding wigeon ranged from 43 to 119 birds. None were seen to feed during the December, February or March surveys and just 11 fed along the tideline in January.

Only a single redshank fed on this area regularly during this season's surveys, with none present here during the November or December surveys. Two redshank were feeding along the tideline during the ebb tide of the January survey. None were seen to roost in this area.

Mallard were present along the tideline during four of the seven monthly surveys. None were seen during the September, October or February surveys. Only single-figure numbers used the area, with peaks of just 4 mallard roost/loafing in October and February.

Table 2.1.2a Waterbird Usage of the Eastern South Ferriby Intertidal Area, September 2008 to March 2009

	Visit date and Waterbird Numbers Using the Eastern South Ferriby Intertidal Area (min-max per visit)						
Species	**26/09/08**	**27/10/08**	**27/11/08**	**11/12/08**	**22/01/09**	**23/02/09**	**24/03/09**
Greylag goose	0	0	0	0	0	0 – 2	0
Wigeon	34 – 90	80 – 151	0 – 111	0 – 61	0 – 91	0 – 155	0 – 8
Mallard	0 – 2	0 – 3	0 – 2	0 – 2	0	0	0
Curlew	0 – 1	0	0	0	0	0 – 1	0 – 1
Redshank	0 – 1	0 – 2	0	0	0 – 2	0 – 1	0 – 1
Black-headed gull	0 – 2	0	0	0 – 1	0	0	0

Curlew fed along the tideline during three of the seven monthly survey visits, though only single feeding birds were present, tending to stay only briefly before moving back upstream, or inland.

Ian Shepherd ♦ Ornithologist ♦ 38 Lindsey Road ♦ Cleethorpes ♦ Lincolnshire ♦ DN35 8TN
Tel: 01472 697142 ♦ Mobile: 07815533742 ♦ E-mail: IShphrd@aol.com

HABITAT CREATION MEASURES AT CHOWDER NESS/BARTON CLIFF

Monthly Bird Monitoring, September 2009 to March 2010

1.0 Fieldwork Methodology

The survey area included the sea banks around the coast realignment site, the new intertidal area within, intertidal ground fronting that realignment site, and two areas of intertidal ground upstream of the proposed realignment area, both of equivalent length.

Fieldwork involved monthly visits between September 2009 and March 2010, with the aim of identifying the abundance, distribution and species composition of waterbirds feeding, roosting and/or loafing in the area.

The survey period covered falling tide, low water and rising tide (+/- 4 hours either side of low water), and visit dates with low water occurring between late morning and early afternoon were chosen in order to maximise surveying time in available daylight.

During each visit hourly point counts were made of all waterbird species using the new intertidal ground within the realignment site and the original intertidal area, fronting that site. These counts were undertaken from the adjacent public footpath along the seabank. The distribution of each waterbird species was recorded during each hourly count, and their activity (feeding, roosting etc.) also noted, along with the position of the tideline. That count/mapping procedure was then repeated on the two intertidal areas on South Ferriby shore, from the public footpath at South Ferriby Cliff (SE997224).

Any significant events of disturbance to waterfowl using the survey area, and any subsequent effects on their numbers, distribution and/or activity, were noted.

Casual records of terrestrial bird species seen or heard within the survey area were also made from the seabank through each monthly visit

2.0 Results

2.1 Intertidal Survey Areas

Numbers of waterbirds were generally low in all four intertidal areas monitored, throughout the September to March survey period. *Table 2.1a* gives, for each intertidal survey area, the number of survey visits on which each waterbird species occurred. *Table 2.1b* summarises September – March range and mean numbers of each waterbird species for each of the four count areas.

Mallard were also seen to use this area during three surveys, in November, December and February, when 2 birds were present as the tide ebbed, usually roost/loafing though 2 were seen to pick-feed in the tide in November.

There was very little usage by common gulls of the original intertidal area, despite the regular presence of small numbers on the adjacent new mudflat area and of flocks on the nearby eastern Read's Island flats. Just 1-2 birds occasionally roost/loafed during the ebb tides of the October, December and January surveys and a single bird fed briefly on the tideline during the January survey.

There was very little usage by curlew of the original mudflats area through the survey season. Parties of curlew arriving on to the Chowder Ness intertidal area from adjacent fields again preferred to settle on the new mudflats area and largely ignored the original area. Curlews were only seen to use the original mudflats during the early mornings of the September and December surveys, when 1-2 birds fed and a single bird roosted.

Three turnstones were present on the stony areas of beach, just seaward of the line of the old seawall, through the ebb tide of the December survey.

Two herring gulls roost/loafed on the tideline during the early morning of the September survey.

2.1.2 Bird Usage of the New Chowder Ness Foreshore Area, Within the Coast Realignment Site

A total of sixteen waterbird species used the newly created Chowder Ness Foreshore area. Numbers per visit of each waterbird species using the new intertidal area are given in *Table 2.1.1a.*

Table 2.1.2a Waterbird Usage of the New Chowder Ness Foreshore, September 2009 to March 2010

	Visit date and Waterbird Numbers Using the New Intertidal Area (min-max per visit)						
Species	**16/09/09**	**16/10/09**	**17/11/09**	**15/12/09**	**13/01/10**	**11/02/10**	**12/03/10**
Shelduck	0	7 – 19	24 – 41	23 – 25	4 – 6	21 – 23	21 – 29
Wigeon	0 – 2	0 – 2	0 – 4	0	0	0	0
Teal	0	9 – 34	0	0	0 – 2	0	0
Oystercatcher	0	0	0	0	0	0	0 – 1
Ringed plover	0	0 – 12	0 – 8	0	0	0	0
Golden plover	0 - 73	87 – 334	0 – 210	0 – 155	0	0 – 16	0 – 2
Lapwing	6 – 77	9 – 80	48 – 679	53 – 438	0	0 – 18	0
Dunlin	0	188 – 288	0 – 122	80 – 177	0 – 5	0 – 13	0
Curlew	28 – 37	4 – 21	3 – 20	4 – 7	0 – 1	1 – 32	3 – 29
Black-tailed godwit	0	0	0 – 2	0	0	0	0
Bar-tailed godwit	0	0 – 2	0 – 1	0 – 2	0 – 3	0	0
Redshank	0 – 8	3 – 31	2 – 19	4 – 8	1 – 8	0 – 10	0 – 10
Red-necked phalarope	0	0	1	0	0	0	0
Black-headed gull	0 – 340	0 – 26	2 – 19	0 – 64	0 – 22	0 – 34	0 – 17
Common gull	0 – 8	0 – 17	0 – 34	0 – 8	0 – 17	0 – 17	0 – 12
Herring gull	0 – 2	0	0 – 1	0 – 2	0 – 3	0 – 1	0

Four waterbird species – curlew, redshank, black-headed gull and common gull, were present on the new mudflats during all seven of the monthly surveys.

The highest usage by curlew of the new intertidal area occurred through the September survey, when 28 – 37 birds were present through the day. Whilst curlew were present through much of the day during all but the January surveys, numbers using the new intertidal area only exceeded 10 birds for brief periods when flocks visited the area from adjacent fields. These flocks visiting from inland produced October to March peak counts of 19 feeding curlew and 30 roost/loafing curlew during the February survey. Although there was some concentration of feeding birds along the outer edge and across the eastern half of the site, feeding curlew were seen to use all but the extremely narrow western end.

Redshanks were present on the new intertidal area during all but three of the hourly counts made through the September to March survey period. Usage was highest through the October survey, when double-figure numbers fed through much of the day with a peak of 31 birds around mid ebb. Through all other surveys single-figure numbers of redshank were usually present and visit peaks ranged between 8 (September, January and March) and 19 (November) birds. Feeding activity was concentrated on areas of mudflats just inside the line of the old seawall, around the inlet creek, close to the new seawall and at the narrow western end of the site. Very few redshank were seen to feed in the central area of mudflats. Redshanks were occasionally seen to roost within the site during the November, December, February and March surveys, usually just 1-2 birds roosted, with a peak of 5 birds roosting on the disturbed ground along the line of the old seawall at low tide during the February survey.

Black-headed gulls were present during the morning ebb tides of all seven monthly surveys, with highest numbers usually present during the early mornings of each visit. Almost all black-headed gulls seen on the site were roost/loafing on or just inland of the line of the old seawall. Peak counts of roost/loafing birds per survey visit ranged from 17 (March) to 340 birds (September). Smaller, usually single-figure, numbers usually occurred through the day from mid ebb onwards, though numbers were slightly higher through afternoon flood tides during the October and November surveys. No black-headed gulls were seen to feed on the new intertidal area during the October, January or March surveys. There was a survey peak of 5 birds feeding during the early morning of the December survey, but otherwise just 1-2 black-headed gulls fed on the new mudflats area intermittently during the September, November and February surveys.

Small numbers of common gulls used the new mudflats area during all of the seven monthly surveys. All common gulls seen on the site roost/loafed on or just inland of the line of the old seawall, often with black-headed gulls. There was a survey peak of 34 birds roosting at low tide during the November survey. Other visit peak counts ranged between 8 and 17 birds, though numbers present averaged less than 10 birds through the survey season.

Shelduck were present on the new mudflats area throughout the day during six seven of this season’s monthly surveys. None used the Chowder Ness area during the September 2009 survey, when shelduck flocks were concentrated in the Read’s Island area. Visit peaks on the new Chowder Ness area ranged between 6 birds (January) and 41 birds (November). The distribution of feeding flocks was often concentrated on the eastern half of the site, though small numbers of feeding shelduck made occasional use of the entire area. The season’s peak count of feeding shelduck was of 36 in November, with visit peaks of 19 – 25 birds feeding during the October, December, February and March surveys. No more than 6 shelduck fed through the January count. Up to 5 shelduck were seen to roost during surveys between October and February, and then a peak of 13 birds roosted during the March survey.

Roost/loafing lapwings were present along the line of the removed seawall or on adjacent flats during all monthly surveys. Flocks were present from September to January, with visit peaks then ranging between 78 and 183 birds. The onset of very cold winter weather in late December then resulted in much less usage by lapwings from January onwards. No lapwings were seen during the January or March surveys, and only 16 birds roost/loafed through the morning of the February survey. All feeding occurred on mudflats along the edge of the roosting area. Just single-figure numbers of lapwings fed briefly during the September, November, December and February surveys.

No dunlin were seen on the new intertidal area during the September survey but visit peaks from October to December ranged between 177 and 288 birds. The survey peak of 288 dunlin were roosting on the disturbed ground along the old seawall remains, at the start of the October survey. Flocks of dunlin remained on the site throughout that survey, with a peak of 234 feeding during the ebb tide before around 100 birds flew off towards the Read's Island flats at low tide. Flocks of over 100 dunlin fed at the start of the November survey (until disturbed, see section 2.2) and through much of the December survey. Few used the area after the mid-winter onset of freezing weather. Only single-figure numbers were present through the flood tide of the January survey, then a peak of 13 at low tide during the February survey and none seen in March. Usage was again concentrated on the disturbed ground along the line of the removed seawall and adjacent areas of mudflats within 20m.

Golden plover usage was almost entirely restricted to birds roost/loafing along the line of the removed seawall or on adjacent flats towards the eastern end, often in association with lapwings. Visit peak counts of roost/loafing birds from September to December ranged between 73 birds (September) and 470 birds (October). The onset of very cold winter weather in late December then resulted in much less usage by golden plover from January onwards. None were seen during the January survey, then up to 14 roosted through the morning of the February survey and just 2 birds arrive at low tide and roosted for three hours during the March survey. Just 3 birds fed briefly on mudflats beside the roost area during the September survey, and 2 birds also fed in that area during the February survey.

Small numbers of herring gulls were seen during five monthly surveys. All records were of birds roost/loafing with other gull species, during early mornings, on or adjacent to the disturbed ground along the line of the old seawall. The peak count was of just 3 birds in January. None were seen to use this area during the October or March surveys.

Bar-tailed godwits fed on mudflats in and around the inlet creek during four of the seven monthly surveys, from October to January. A peak of 3 birds was present just after low tide during the January survey.

Two wigeon wandered from their usual roost/loafing area on the 'old' mudflats on to disturbed ground along the line of the old seawall during the September and October surveys, as did 4 birds during the November survey.

Teal were seen on the new mudflats during two of the seven monthly surveys, feeding at the eastern end or near the farm, often in vegetation by the seawall base. Teal were present, feeding, through the day during the October 2009 surveys, numbers peaking at 28 birds. Two moved from the original mudflats area to feed amongst vegetation along the seawall base to the west of the farm at low tide during the January survey.

Ringed plover were only seen to use the area during the October and November surveys. All usage was concentrated towards the outer edge of the new intertidal area, on disturbed ground along the line of the removed seawall and the flats within 25m of that area.. A flock of 12 roosted along that area during the early morning of the October survey, and 8 birds fed there during the early morning of the November survey. During both of those surveys a single ringed plover returned to feed on the new mudflats during the afternoon flood tide. No ringed plover were seen to use the area again during surveys through to March.

Three species occurred during a single survey visit only during the 2009-10 season. Two black-tailed godwits arrived from the west two hours before low water during the November survey and stayed to feed on mudflats beside the inlet creek for three hours. A single red-necked phalarope also fed around the inlet creek and adjacent mudflats throughout the November survey: a very unexpected record of a scarce passage migrant which occurs almost annually on the Humber during August or September but had only been recorded in Lincolnshire in November once before. A single oystercatcher roosted on the disturbed ground along the line of the removed seawall during the first hour of March survey.

2.1.3 Bird usage of the Eastern South Ferriby Intertidal Area

The eastern stretch of the South Ferriby shore (South Ferriby Cliff SE999226 to Leggott's Quarry SE994219) comprises an eroding clay cliff –the coastal path here has been lost to erosion – with a narrow shingle beach at its base and a narrow area of rock-strewn mud to seaward. At low tide the shore is approximately 120m wide from cliff base to tideline.

A total of nine waterbird species used the eastern South Ferriby flats. Numbers per visit of each waterbird species using the are given in *Table 2.1.2a.*

Wigeon was the only waterbird species present during all seven monthly survey visits. Parties roost/loafed and fed along the tideline and on the stone beach through the ebb tide, and then often moved off upstream with the flood tide. Visit peak numbers roost/loafing, September to March ranged between 21 and 278 birds. No wigeon were seen to feed during the November, January, February or March surveys and only a few wigeon did so, briefly, during the September, October and December surveys. A peak of just 27 fed, along the tideline, during the early morning of the October survey.

Only 1-2 redshank fed on this area regularly during this season's surveys, with none present here during the February or March surveys. A single redshank roosted on the stony beach during the ebb tide of the November survey.

Mallard were present along the tideline of the eastern south Ferriby flats during four of the seven monthly surveys. None were seen there during the November, February or March surveys. Up to 12 mallard roost/loafed around the tideline through the morning of the September survey but otherwise only single-figure numbers used the area, intermittently through the October, December and January surveys.

Ringed plover were only seen on the eastern South Ferriby flats during the first, September, survey when a flock of 15 ringed plover settled on the eastern South Ferriby flats for about an hour during the ebb tide, 10 roosting on the stony beach whilst 5 birds fed close-by. Only a single bird remained on the area by low water.

Vol. 305: 203–217, 2005 | MARINE ECOLOGY PROGRESS SERIES Mar Ecol Prog Ser | Published December 23

Predicting site quality for shorebird communities: a case study on the Humber estuary, UK

Richard A. Stillman[1,*], Andrew D. West[1], John D. Goss-Custard[1], Selwyn McGrorty[1], Natalie J. Frost[2], Donald J. Morrisey[2,3], Andrew J. Kenny[2,4], Allan L. Drewitt[5]

[1]Centre for Ecology and Hydrology Dorset, Winfrith Technology Centre, Winfrith Newburgh, Dorchester, Dorset DT2 8ZD, UK
[2]ABP Marine Environmental Research Ltd, Pathfinder House, Maritime Way, Southampton, Hampshire, SO14 3AE, UK
[3]National Institute for Water and Atmospheric Research Ltd, PO Box 893, Nelson, New Zealand
[4]Centre for Environment, Fisheries and Aquaculture Science, Burnham Laboratory, Remembrance Avenue, Burnham-on-Crouch, Essex CM0 8HA, UK
[5]English Nature, Northminster House, Peterborough, Cambridgeshire PE1 1UA, UK

ABSTRACT: The conservation importance of estuaries is often measured by bird numbers, but monitoring numbers is not necessarily a reliable way of assessing changes in site quality. We used an individual-based model, comprised of fitness-maximising individuals, to assess the quality of the Humber estuary, UK, for 9 shorebirds; dunlin *Calidris alpina*, common ringed plover *Charadrius hiaticula*, red knot *Calidris canutus*, common redshank *Tringa totanus*, grey plover *Pluvialis squatarola*, black-tailed godwit *Limosa limosa*, bar-tailed godwit *L. lapponica*, Eurasian oystercatcher *Haematopus ostralegus* and Eurasian curlew *Numenius arquata*. We measured site quality as predicted overwinter survival. The model accurately predicted the observed shorebird distribution (if non-starving birds were assumed to feed on any prey or patch on which intake rate equalled or exceeded their requirements), and the diets of most species. Predicted survival rates were highest in dunlin and common ringed plovers, the smallest species, and in Eurasian oystercatchers, which consumed larger prey than the other species. Shorebird survival was most strongly influenced by the biomass densities of annelid worms, and the bivalve molluscs *Cerastoderma edule* and *Macoma balthica*. A 2 to 8% reduction in intertidal area (the magnitude expected through sea level rise and industrial developments) decreased predicted survival rates of all species except the dunlin, common ringed plover, red knot and Eurasian oystercatcher. This paper shows how an individual-based model can assess present-day site quality and predict how site quality may change in the future. The model was developed using existing data from intertidal invertebrate and bird monitoring schemes plus new intertidal invertebrate data collected over 2 winters. We believe that individual-based models are useful tools for assessing estuarine site quality.

KEY WORDS: Climate change · Estuary management · Behaviour-based model · Site quality · Waders

INTRODUCTION

Estuary managers are often required to monitor the quality of a site for important bird species or to assess how potential changes to a site may influence site quality. For example, in European estuary 'Special Protection Areas' (SPAs), European Union Habitats Directive 92/43/EEC requires that member states take appropriate steps to avoid the deterioration of natural habitats and the habitats of species as well as disturbance of the species for which areas have been designated. The conservation importance of an estuary is often measured in terms of bird numbers using the estuary, but monitoring numbers is not necessarily a reliable way of assessing changes in site quality. In particular, this is because the numbers of birds using a

*Email: rast@ceh.ac.uk

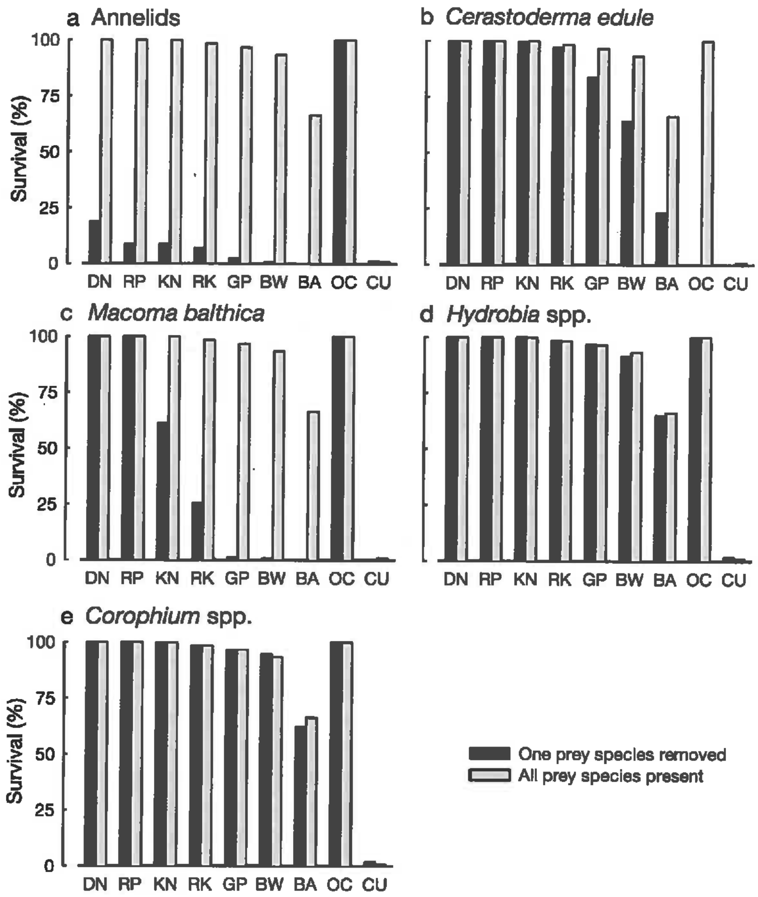


Fig. 9. Predicted effect of removing individual prey species on percentage overwinter survival of shorebirds in Humber estuary. Predictions are for 'worse-case' estimates of prey biomass (see 'Results'). DN: dunlin; RP: common ringed plover; KN: red knot; RK: common redshank; GP: grey plover; BW: black-tailed godwit; BA: bar-tailed godwit; OC: Eurasian oystercatcher; CU: Eurasian curlew. Specific names in Table 1

DISCUSSION

We have shown how both present-day and future site quality can be measured from the predicted survival rates of shorebirds. We used an individual-based model to make these predictions because the survival rates of shorebirds in the Humber estuary have not been measured directly, and direct measurements would be of little use in predicting how future changes to the estuary may affect its quality. Our measure of site quality does not suffer from the problem of measuring quality in terms of bird numbers (i.e. that bird numbers may change on a site due to factors outside the site itself).

Our model has previously been used to predict the effect of environmental change and management on Eurasian oystercatchers consuming shellfish (Stillman et al. 2000, 2001, 2003, West et al. 2003, Goss-Custard et al. 2004). The model was extended by being applied to a community of interacting shorebirds. To be of general value it is important that individual-based models can be applied to a wide range of species and that they can be developed within a relatively short time scale. We have shown how general relationships can be used to predict the behaviour of shorebirds, and that these can accurately predict the distribution of birds. This approach greatly increased the speed with which the model could be developed, as no foraging observations were required for the Humber estuary itself.

The model was also extended by using either rate-maximising or satisficing-decision rules, instead of just rate-maximising rules as previously. We have shown that satisficing decisions more accurately predicted the observed distribution of shorebirds. Rate-maximising decisions predicted too many birds in the best patches. Satisficing decisions may be more appropriate at large spatial scales over which it is unlikely that birds have the perfect knowledge of patch quality required to move to the patch(es) in which their intake rate is maximised. More studies are required to test the predictive power of models based on different decision rules at different spatial scales.

As with any model, the accuracy of our predictions will depend on the accuracy with which different parameters are measured. A number of parameters needed to be derived from estimates at other sites (e.g. the seasonal decline in the quality of prey and the body mass of birds) whereas, if possible, these should be measured from the site itself to obtain more precise parameter values. One of the key model parameters, which is also time-consuming to measure, is the abundance and distribution of the invertebrate food supply. However, we have shown how a range of simulations can be run to incorporate the full range of possible prey-biomass densities. Although this approach generated a wide range of predictions (e.g. habitat loss of the order anticipated decreased bird survival in the worse-case [low food] simulations but not in the better-case [average food] simulations), these predictions can still be used by estuary managers, who often use the precautionary principle (i.e. consider the worse case) when making decisions in the face of such uncertainty.

Our model predicted survival from food availability, but other factors such as human disturbance or raptor predation may also be important. Disturbance from

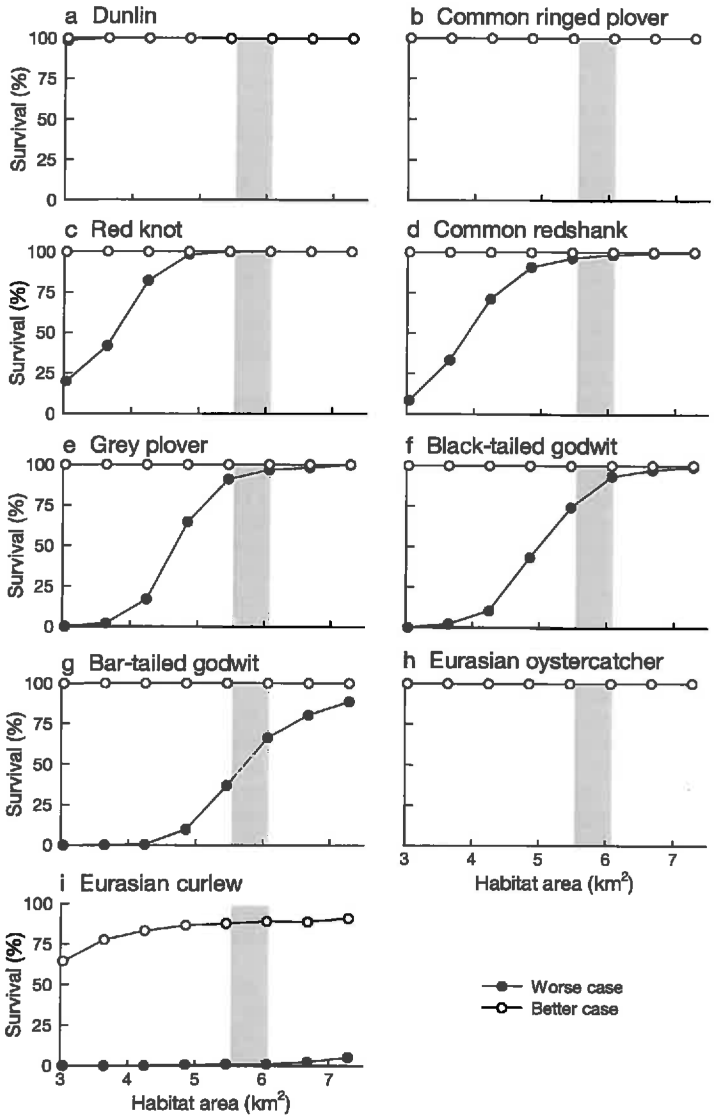


Fig. 10. Predicted effect of changes in intertidal habitat area on percentage overwinter survival of shorebirds in Humber estuary. Predictions are for either better- or worse-case estimates of prey biomass (see 'Results'). Grey bars show expected range of habitat loss, up to 8 % of present day habitat. Specific names in Table 1

humans is likely to be relatively low throughout much of the large, muddy and inaccessible tidal flats of the Humber, but can be included in the model (e.g. Stillman et al. 2001, West et al. 2003). Predation by raptors can be a key factor determining the distribution and survival of shorebirds (e.g. Whitfield 1985, 2003, Quinn & Cresswell 2004). We cannot rule out the possibility that survival rates for the Humber estuary will be lower than predicted due to raptor predation, or that starving birds will be forced to feed in areas with a higher predation risk, further decreasing survival rates (e.g. Whitfield 1985, 2003, Quinn & Cresswell 2004). We would expect disturbance from raptors to reduce shorebird densities in areas of high vulnerability, such as fields or mudflats close to cover from which raptors can launch attacks (e.g. Quinn & Cresswell 2004).

The model predicted that the presence of fields around the estuary provided supplementary feeding areas which increased the survival rates of Eurasian curlews. None of the other species were as reliant on fields in the standard set of simulations, as their mortality rates were generally within the expected range when only intertidal habitats were available. However, other species (e.g. black-tailed godwits, common redshanks and Eurasian oystercatchers) can feed in terrestrial fields. If fields had been present in all simulations, the model would have predicted increased high-tide use of fields in the more extreme simulations (e.g. low food density and intertidal habitat area) as shorebirds needed to compensate for low food intake rates during low tide. These simulations were not run, beause of uncertainty as to the intake rates that different species would achieve in the fields and because the food supply in the fields was not surveyed. Monitoring the number of birds using supplementary habitats such as fields is a convenient way of assessing the difficulty birds are having in meeting their energy requirements.

Even though our model was developed within a relatively short time period, what is ideally required is a simple measure of site quality that can be recorded even more quickly. Goss-Custard et al. (2004) have shown how the amount of bivalve food per Eurasian oystercatcher in autumn is related to the overwinter mortality rates of the birds. Importantly, the amount of food per bird needs to be between 4 and 8 times the amount the birds actually consume in order to maintain low (ca. 1 %) mortality rates. This happens because interference competition excludes sub-dominant birds from much of the food supply, and less efficient birds starve before the food supply is depleted to the point at which the average bird dies (Goss-Custard et al. 2004). Goss-Custard et al. (2004) used single-species models. Calculating the required food per bird is more complicated for the multi-species model used in this study because the different-sized species have different daily food requirements and consume different species and size ranges of prey. However, it is possible to draw some simple conclusions as to the amount of food required. Survival rates fell below 90 % when autumn, estuary-wide food biomass density was below about 4 g AFDM m^{-2} (Fig. 8). One possible conservation objective for the Humber estuary would be to monitor whether the lower 99% confidence limit of biomass density falls below this limit, to determine whether site quality is being maintained. Our simulations showed that site quality was unaffected by the biomass densities of *Hydrobia* spp. and *Corophium* spp. This implies that if survey resources are limited, it will be less important to estimate the biomass densities of these species, than to estimate the densities of annelids, *Macoma bathica* or *Cerastoderma edule*. Further studies on other estuaries are required to determine whether these conclusions are more widely applicable.

This paper has shown how an individual-based model can assess present-day site quality and how this may change in the future. The model predicted prey biomasses below which survival rate would decrease, which shorebird species would be most vulnerable, and that habitat loss of the order anticipated might decrease the survival rates of some species. Importantly, the model was developed relatively quickly, and assessed site quality in terms of shorebird survival rates, rather than simply numbers. We believe that individual-based models are a useful tool for assessing the quality of estuarine sites for shorebirds.

Acknowledgements. The Humber estuary model was developed jointly by the Centre for Ecology and Hydrology and ABP Marine Environmental Research. Model simulations were jointly funded by ABP Marine Environmental Research and English Nature. We thank the Environment Agency for supplying and giving permission for the use of benthic invertebrate data, and the British Trust for Ornithology and their volunteers for collecting and supplying bird-count data.

LITERATURE CITED

ABP Research & Consultancy (1998) Model configuration report, Humber Estuary tidal model. Rep. 507. ABP Research & Consultancy, Southampton

Atkinson PW, Clark NA, Bell MC, Dare PJ, Clark JA, Ireland PL (2003) Changes in commercially fished shellfish stocks and shorebird populations in the Wash, England. Biol Conserv 114:127–141

Barnett BE (1984) Observations on the intertidal fauna of the south bank of the Humber Estuary. Mar Environ Res 13:33–53.

Blomert AM, Ens BJ, Goss-Custard JD, Hulscher JB, Zwarts L (eds) (1996) Oystercatchers and their estuarine food supplies. Ardea 84A

Boyd H, Piersma T (2001) Changing balance between survival and recruitment explains population trends in red knots *Calidris canutus islandica* wintering in Britain, 1969–1995. Ardea 89:301–315

Buck AL (1997) An inventory of UK estuaries. Vol 5. Eastern England. Joint Nature Conservation Committee, Peterborough

Catley GP (2000) Humber Estuary wetland bird survey—twelve months of high and low tide counts, September 1998 to August 1999. Res Rep 339. English Nature, Peterborough

Clarke KR (1993) Non-parametric multivariate analyses of changes in community structure. Aust J Ecol 18:117–143

Gameson ALH (1982) Description of estuary and surveys. In: Gameson ALH (ed) The quality of the Humber Estuary, 1961–1981. Yorkshire Water Authority, Leeds, p 1–4

Gill JA, Watkinson AR, Sutherland WJ (1997) Causes of the redistribution of Pink-footed Geese *Anser brachyrhynchus* in Britain. Ibis 139:497–503

Gill JA, Norris K, Potts PM, Gunnarsson TG, Atkinson PW, Sutherland WJ (2001) The buffer effect and large-scale population regulation in migratory birds. Nature 412:436–438

Goss-Custard JD (1977) The energetics of prey selection by redshank, *Tringa totanus* (L.), in relation to prey density. J Anim Ecol 46:1–19

Goss-Custard JD (1993) The effect of migration and scale on the study of bird populations: 1991 Witherby lecture. Bird Study 40:81–96

Goss-Custard JD (ed) (1996) The oystercatcher: from individuals to populations. Oxford University Press, Oxford

Goss-Custard JD, Sutherland WJ (1997) Individual behaviour, populations and conservation. In: Krebs JR, Davies NB (eds) Behavioural ecology: an evolutionary approach. 4th edn. Blackwell Science, Oxford, p 373–395

Goss-Custard JD, Warwick RM, Kirby R, McGrorty S and 6 others (1991) Towards predicting wading bird densities from predicted prey densities in a post-barrage Severn estuary. J Appl Ecol 28:1004–1026

Goss-Custard JD, Caldow RWG, Clarke RT, Durell SEA le V dit, Sutherland WJ (1995a) Deriving population parameters from individual variations in foraging behaviour. I. Empirical game theory distribution model of oystercatchers *Haematopus ostralegus* feeding on mussels *Mytilus edulis*. J Anim Ecol 64:265–276

Goss-Custard JD, Caldow RWG, Clarke RT, Durell SEA le V dit, Urfi J, West AD (1995b) Consequences of habitat loss and change to populations of wintering migratory birds—predicting the local and global effects from studies of individuals. Ibis 137:56–66

Goss-Custard JD, Stillman RA, West AD, Caldow RWG, McGrorty S (2002) Carrying capacity in overwintering migratory birds. Biol Conserv 105:27–41

Goss-Custard JD, Stillman RA, West AD, Caldow RWG, Triplet P, Durell SEA le V dit, McGrorty S (2004) When enough is not enough: shorebirds and shellfishing. Proc R Soc Lond B 271:233–237

Kersten M, Piersma T (1987) High levels of energy expenditure in shorebirds; metabolic adaptations to an energetically expensive way of life. Ardea 75:175–187

Johnson C (1985) Patterns of seasonal weight variation in waders on the Wash. Ringing Migr 6:19–32

Musgrove AJ, Pollitt MS, Hall C, Hearn RD, Holloway SJ, Marshall PE, Robinson JA, Cranswick PA (2001) The Wetland Bird Survey 1999–2000: wildfowl and wader counts. British Trust for Ornithology (BTO), Thetford

Nagy KA, Girard IA, Brown TK (1999) Energetics of free-ranging mammals, reptiles and birds. Annu Rev Nutr 19:247–77

Quinn JL, Cresswell W (2004) Predator hunting and prey vulnerability. J Anim Ecol 73:143–154

Stillman RA, Goss-Custard JD, Clarke RT, Durell SEA le V dit (1996) Shape of the interference function in a foraging vertebrate. J Anim Ecol 65:813–824

Stillman RA, Goss-Custard JD, Caldow RWG (1997) Modelling interference from basic foraging behaviour. J Anim Ecol 66:692–703

Stillman RA, Goss-Custard JD, West AD, Durell SEA le V dit,