



HARBASINS Report:

Managed Realignment in the Humber Estuary, UK **[FINAL]**

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1. MANAGED REALIGNMENT IN THE HUMBER ESTUARY

1.1 Introduction to Managed Realignment on the Humber Estuary

In the UK, managed realignment schemes addressing coastal squeeze are largely initiated by the Environment Agency (EA) as part of their flood defence remit, with compensation sites for direct habitat loss usually identified through the Environmental Impact Assessment (EIA) process and/or as part of an Appropriated Assessment (AA). For the latter, schemes are usually initiated by the prospective developer.

On the Humber, the Environment Agency has developed a series of managed realignment schemes as part of its Flood Defence Strategy. These schemes primarily address intertidal habitat loss due to coastal squeeze, whereby the existence of flood defences in an environment of relative sea level rise entail a gradual loss (squeeze) of the intertidal zone. However, a component of the strategy addresses flood management capacity needs in the Upper Humber, whilst some schemes, at least in part, address the direct loss of intertidal habitat resulting from ongoing flood defence works on the estuary (whereby engineering constraints necessitate the encroachment of the seaward toe of the defences further into the intertidal zone from the existing alignment).

On the Humber Estuary, the Environment Agency employs a policy of a 1:1 ratio of habitat loss to creation for coastal squeeze, and a 1:3 ratio for habitat loss to creation for direct construction related losses from defence improvement works.

In addition to the Environment Agency's managed realignment projects, a series of sites have been identified by Associated British Ports (ABP). ABP is the main ports operator on the Humber, as well as being the Competent Harbour Authority. The strategy for these sites has been developed through the EIA and AA process, whereby port development needs (including the development of current intertidal and subtidal Habitat) ensure that compensatory intertidal habitat is created elsewhere in the estuary. To date, this strategy has seen the development of several managed realignment sites in the Humber to address current and planned port expansion.

Table 1.1 and Figure 1.1 detail both existing and proposed managed realignment schemes for the Humber Estuary initiated by the Environment Agency (Paull Holme Strays, Alkborough, Donna Nook, Skeffling, Welwick, Keyingham and Goxhill), together with existing schemes initiated by Associated British Ports (i.e. Chowder Ness and Welwick). These latter schemes at Chowder Ness and Welwick were both undertaken for the same purpose and designed and implemented to very similar timescales and principles by the ABP subsidiary consultancy company Associated British Ports Marine Environmental Research Ltd. (ABPmer).

It is estimated that over 700ha of intertidal habitat will be lost due to coastal squeeze and rising sea levels over the next 50 years in the Humber Estuary (Mander *et al.*, 2007).

Table 1.1: Existing and proposed managed realignment schemes in the Humber Estuary, UK (adapted from Environment Agency, 2008a).

Site for creating new intertidal habitat	Likely completion date*
ENVIRONMENT AGENCY(EA) SCHEMES	
Paull Holme Strays (North bank)	Completed in 2003
Alkborough (South bank)	Completed in 2006
Donna Nook (South bank)	2010
Skeffling (North bank)	Between 2010 and 2020
Welwick (North bank)	After 2020
Keyingham (North bank)	After 2030
Goxhill (South bank)	Medium to long term
ASSOCIATED BRITISH PORTS (ABP) SCHEMES	
Welwick (North bank)	Completed June 2006
Chowder Ness (South bank)	Completed July 2006

* Actual completion dates will depend on actual habitat losses

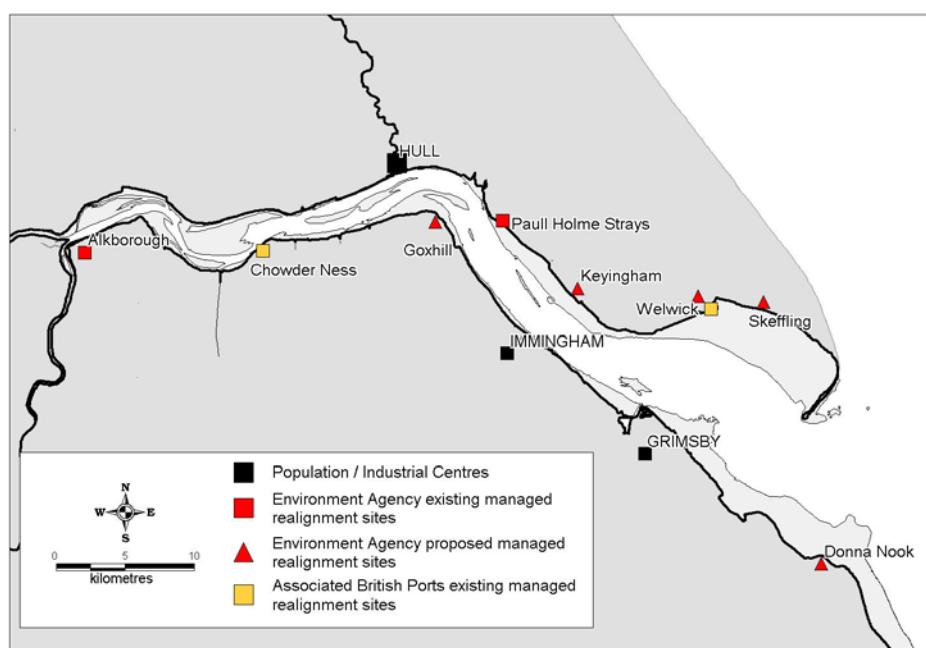


Figure 1.1: Existing and proposed managed realignment schemes in the Humber Estuary, UK.

The following sections describe a series of managed realignment sites in the Humber developed and created by both the Environment Agency and Associated British Ports, which are designed to address the issues of coastal squeeze, flood alleviation and direct habitat loss from development. The text describes the sites and their objectives, together with findings to date on how the habitats and associated assemblages within each project have developed once operational. Text is based on operational reporting by the site developer, together with findings from specific studies undertaken by IECS on some of the sites as part of the HARBASINS project.

1.2 Paull Holme Strays

The following text (Sections 1.2.1 - 1.2.4) is largely based on the Environment Agency (2008b) Paull Holme Strays environmental monitoring report.

1.2.1 SITE DESCRIPTION & OBJECTIVES

Paull Holme Strays (PHS) was the first major managed realignment scheme established by the Environment Agency in the Humber Estuary. It provides approximately 80ha of new intertidal habitat and it was originally anticipated that the site would ultimately create approximately 45ha of mudflat and 35ha of saltmarsh. The site is fronted by the extensive Paull Holme Sands mudflat, and is located adjacent to the Humber Estuary Special Protection Area (SPA), Ramsar site and candidate Special Area of Conservation (cSAC) which form part of the Natura 2000 network of European Sites.

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

- Provide cost effective flood risk management for the area;
- Create intertidal habitat to compensate for that lost through implementation of this and other flood defence schemes in the middle estuary (e.g. encroachment through works at Pyewipe - UW 15-17) which is compensated on a 1:3 ratio of habitat loss to creation for direct construction related losses from defence improvement works;
- Address additional habitat losses arising from coastal squeeze as identified in the Coastal Habitat Management Plan (CHaMP) which is compensated on a 1:1 ratio of habitat loss to creation for coastal squeeze.

Although the site was created prior to the Environment Agency's Humber Flood Risk Management Strategy, the habitat figures are included in the Environment Agency 50 year CHaMP balance sheet (Faith Spencer, EA, pers. comm., 2008).

Paull Holme Strays managed realignment scheme (costing a total of £7,400,000) was breached on 7th September 2003 and is illustrated in Figures 1.2 and 1.3. A five year monitoring programme began late 2003 to monitor accretion and erosion at the site, and to assess the development of intertidal habitat and associated assemblages, particularly benthic invertebrates, birds and vegetation. Specific targets were set for the site detailing species and numbers of avifauna required to utilise the site in order to ensure that the site is providing a functioning intertidal habitat (Faith Spencer, EA, pers. comm., 2008).



Figure 1.2: Aerial view of Paul Holme Strays managed realignment site post breach looking south east (Humber Estuary, UK).



Figure 1.3: Aerial view of Paul Holme Strays managed realignment site post breach looking west (Humber Estuary, UK).

1.2.2 ACCRETION & EROSION

Since its breach in 2003, sediment has accreted within the managed realignment site and during the monitoring period 2006-2007, this accretion was found to be ongoing. Although the rate of annual increase has slowed since the site was initially breached, accretion inside the realignment was still found to be much higher than in less sheltered areas outside the site. Between May 2004 and September 2007, the lower elevation areas of the site were found to have accumulated an average of 28.5cm of material (approximated to an average of 40.5cm of sediment in 4 years when back-calculated to the time of the breach in September 2003), compared with 3.3 to 12.6cm at similar elevations on mudflats outside the

site. Increased areas of elevation in the southern part of the site provide suitable areas for saltmarsh to develop, and this zone has accumulated an average of 5.5cm of sediment since the breach (back-calculated value). Outside the realignment, accretion totals ranged from 1.3 to 7.8cm.

The rapid rate of accretion within the realignment site is not unexpected, given the high suspended solid load within the waters of the middle Humber. For instance, topographic monitoring by IECS of a newly created semi-enclosed embayment created as part of a port development c. 1km upstream from Paull Holme Strays has identified over 100cm accretion of in an approximately 8 year period from the initiation of the development (Boyes & Allen, 2007).

1.2.3 VEGETATION

Vegetation has now colonised the new mudflat areas inside the site, with this development continuing during 2006-2007. By 2007, 23 plant species typical of saltmarsh present in this part of the realignment were noted, with all species found outside the realignment also being recorded inside it. These include Sea Aster (*Aster tripolium*), Common Saltmarsh-grass (*Puccinellia maritima*), Common Cord-grass (*Spartina anglica*), and Common Glasswort (*Salicornia europaea*). Except at the highest elevations, very little of the pre-breach vegetation now remains, and the saltmarsh development appears to have been successful to date, with 29 of the 36 monitoring sites in the new saltmarsh supporting vegetation by 2007. Sea Arrow-grass (*Triglochin maritima*) was recorded for the first time during 2007, with Sea Aster and Common Saltmarsh-grass considerably more abundant than previous years.

Of particular interest is the continued high level of accretion on the low mudflat areas as it appears to be building material up to elevations which may eventually be suitable for saltmarsh. This has been particularly evident in the colonisation of the edges of the new mudflat by saltmarsh plants.

1.2.4 BENTHOS

Although benthic invertebrate communities on the established mudflats outside the site have remained relatively stable over time, they have undergone substantial changes inside the realignment and are still considered to be in an early stage of development. In 2004, the oligochaetes, *Paranais litoralis*, dominated the benthic fauna. However, in 2005, there was a distinct shift in dominance of terrestrial species and early colonising species to those more typical of an estuarine environment (Mazik *et al.*, 2007), with increased dominance of *Hediste diversicolor*, Collembola and *Hydrobia ulvae* in 2006 and 2007. Collembola are likely to be present inside the realignment due to the site's history and its proximity to terrestrial environments. Additionally, there has been a general shift from many small invertebrates to an increasing number of larger invertebrates, with the overall invertebrate biomass inside the site now similar to those of sampling locations outside.

Colonisation appears to be taking place predominantly around the western breach where the communities now closely resemble those on the upper shore mudflats outside the site in terms of their composition but not their abundance (Mazik *et al.*, 2007). However, general

diversity does still appear to be greater outside the site than inside, with 18 of the 25 species recorded also found to be present inside the realignment. Similarly, mean abundance outside the realignment has been estimated at 9,102 individuals per m², in comparison to 3,868 individuals per m² within the site itself.

Factors such as tidal inundation, particle size and organic content are important influences on colonisation and community development, with sites inside the realignment being higher in organic matter and siltier than those outside it. As such, this is reflected by species such as *H. diversicolor* characterising sites within the realignment, with a greater number of nematode worms outside the realignment. Colonisation is additionally restricted in areas of low or excessively high accretion (Mazik *et al.*, 2007).

Freshwater invertebrate diversity has additionally been monitored in four sites behind the new realignment (three soke dykes and a pond), all of which were created as part of the realignment scheme in compensation for the loss of a borrow pit which had supported a rich invertebrate fauna. There has been a general increase in brackish water indicator species (indicating changes in salinity over time), although during 2007, the pond appeared to be recovering and now supports seven species, three of them freshwater. Freshwater invertebrate diversity continued to be greatest in one of the soke dykes monitored with a well-developed vegetation/open water complex.

1.2.5 FISH

The monitoring package initiated at Paull Holme Strays by the Environment Agency has to date not included any aspects of fish usage, either in terms of the assemblage or site function. This is most likely due to the absence of any habitat or species targets being set for fish during the initial development of the management plan for the site. However, mudflats and saltmarsh provide important habitat for various fish life stages and therefore, as part of the European Interreg IIIB HARBASINS project, a detailed monitoring programme has been put in place for Paull Holme Strays over the last couple of years, the results of which are detailed below.

1.2.5.1 Survey Design & Methodology

Eight separate stations were located inside the realignment site (RLG), with five selected outside the site on established intertidal mudflats (two sites) and saltmarsh areas (three sites) which acted as controls (CTRL). These control sites were located adjacent to the main estuary channel in the lower estuary. Stations were placed across creek systems and natural drains, and sampled during Summer and Autumn of 2006 and 2007. Care was taken to sample the exact location/creek system on each occasion.

Fyke nets were used to sample four of the eight RLG stations and all of the CTRL stations, with two to four bottle traps additionally deployed at each station to complement the fyke net methodology. The bottle traps targeted the small/juvenile fish and invertebrate community, whilst the fyke nets were better suited to larger fish and crabs. Within the RLG and saltmarsh CTRL stations, the fyke nets were positioned to catch fish leaving the realignment and marsh sites. However, directional fishing was not possible on the mudflats. Additional

details on the gear used and general methodology employed at the site is provided in Pérez-Dominguez, 2008).

Along with the default static gear employed, a 1m push net (PSN) and large seine net (SEN) were also tested (see Pérez-Dominguez, 2008). The combined static and mobile gear assessments were conducted on two separate dates with the aim of comparing fyke net and bottle trap qualitative data (i.e. Catch Per Unit Effort (CPUE), No. fyke day⁻¹), with precise quantification of abundance per unit habitat (trawl, No. m⁻²).

All static gear was deployed for 24 hours (two full tide cycles) along with a water quality automated recording device (see Pérez-Dominguez, 2008 for details). Mobile gear was used during high tide at three separate stations within the realignment site the day before the fyke nets were deployed, with tow lengths of 10m and 25m respectively for the SEN and PSN. All catch was subsequently sorted with fish taken to the laboratory to be processed fresh for length and weight, and to conduct the stomach dissections. If the laboratory analysis could not be undertaken the same day, then the whole fish catch was immediately frozen until such analysis could take place.

1.2.5.2 Results & Discussion

Dominant species composition and density estimates were not found to differ significantly between the control and realignment stations (Figure 1.4), the only exception being the European eel (*Anguilla anguilla*) which was only found within the realignment. The three most abundant species, flounder (*Platichthys flesus*), sand goby (*Pomatoschistus minutus*) and seabass (*Dicentrarchus labrax*), contributed almost identical proportions of the total catch.

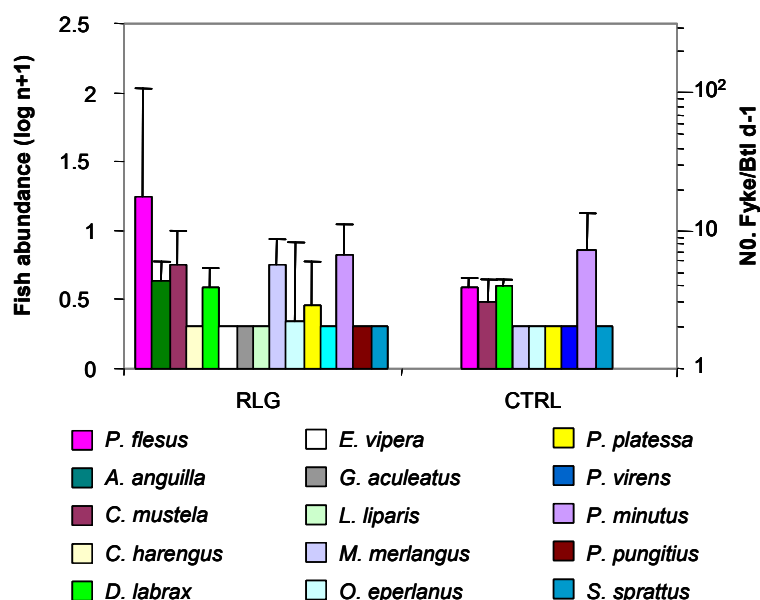


Figure 1.4: Fish abundance inside Paull Holme realignment site (RLG) and at the control stations (CTRL) outside the site. Abundances are transformed (Log n+1). Untransformed density equivalent are given in the secondary axis scale.

With respect to fish size, flounder and whiting (*Merlangius merlangus*) caught inside the realignment site were significantly smaller than those found at the control stations (Figure 1.5). A similar overall tendency (although not statistically meaningful), was found for an additional three species, with the reverse (larger fish in the realignment) occurring for only two of the total seven recorded species (Figure 1.5). The food and refuge concept of shallow estuarine habitats is widely used to explain fish usage of these areas (Walters & Korman, 1999; Paterson & Whitfield, 2000). Smaller fish may benefit from better nursery-defining quality elements (see Beck *et al.*, 2003) inside the realignment site, or have easier/longer time of access through the breach, although this does appear to be species dependent and hence, suggests active fish behaviour (Gillanders *et al.*, 2003, Colclough *et al.*, 2005).

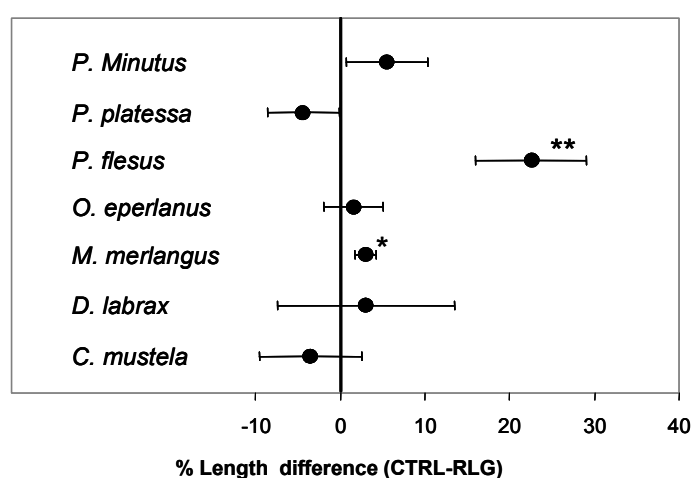


Figure 1.5: Length difference (%) between fish caught at the Paull Holme Strays managed realignment and control stations. Positive values indicate larger sizes at the control stations. Error bars represent standard error. * $p < 0.05$, and ** $p < 0.01$ (site and species independent t -tests).

Different elevation in k -dominance curves indicates a wider and more diverse fish assemblage using the realignment site (Figure 1.6). Interestingly, there is no obvious plateau in the k -dominance curves as the species rank increases. This could be interpreted as a reflection of an even species distribution, or may be the result of inadequate sampling effort. The latter could be related to differential station-related catch efficiency, or to strong gear selectivity resulting in the complete exclusion of a substantial component of the fish assemblage (Olin & Malinen, 2003; Pratt & Fox, 2001). If fishing effort is low, only the more abundant species (or those caught due to high efficiency of the gear) will be recorded and relatively few large steps will dominate the cumulative distribution.

Gear differences and selectivity, or level of fishing effort can introduce consistent bias on fish monitoring programmes (Pratt & Fox, 2001; Jennings & Polunin, 1996). A decision was therefore taken to conduct limited tests with alternate active sampling gear in order to increase confidence in the fyke net and bottle trap based analysis (Rozas & Minello, 1997; Colclough *et al.*, 2005). The push nets were fitted with fine mesh bags able to retain small individuals such as gobies, whilst the seine net was designed to provide estimates of larger,

more mobile targets. The comparison was undertaken inside the realignment site over two sampling events (10th July 2006 and 1st August 2006).

As predicted, a strong gear effect was observed in species recorded (Figure 1.7) and size of fish captured (Appendix 1.1). Push nets only captured sand goby as all larger fish were able to avoid this particular gear (Figure 1.7, Appendix 1.1). The seine net recorded the greatest number of species during the test, one of which was the snake pipefish (*Entelurus aequoreus*) which had not been recorded in the fyke nets. As this species can easily pass through the mesh used in the fyke nets, this probably accounts for it not being recorded in the fyke catches. Consequently, it is likely that the fyke net and bottle trap based assessment is excluding part of the fish assemblage which is influencing the shape of the *k*-dominance curves discussed above.

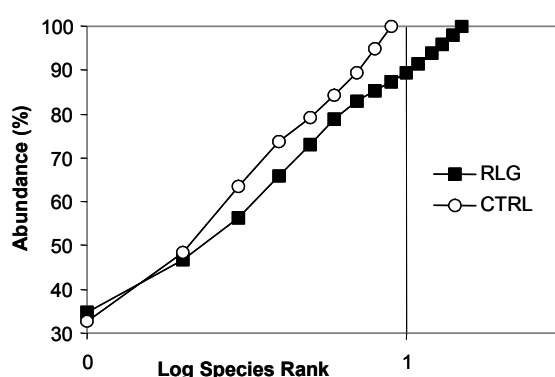


Figure 1.6: Paull Holme Strays managed realignment site, showing *k*-dominance curves by sampling station. All curves are derived from fyke net and bottle trap catches. RLG (realignment) and CTRL (control) stations.

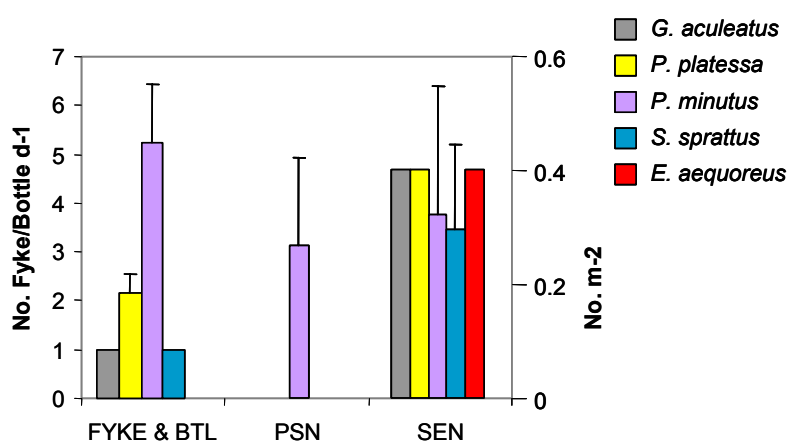


Figure 1.7: Parallel estimates of fish abundance and assemblage composition by gear type at Paull Holme realignment site. FYKE & BTL (fyke net and bottle traps, 19 and 29 total samples), PSN (push net, 80m² total area) and SEN (seine net, 1500m² total area). Error bars represent standard error. Missing error bars resulted from species recorded only once.

No differences in feeding incidence between the stations was apparent, with fish feeding equally both within and outside the managed realignment site (Figure 1.8). Prey items, whilst generally consistent between the control and realignments stations, did show some differences with respect to relative importance (Figure 1.9), probably reflecting local availability and fish assemblage composition (see Appendix 1.2 for the overall summary of prey items). However, it is of note that the high proportion of small bivalves (i.e. *Abra* sp.) in the diet of fish captured, predominantly flounder, at the control stations. Mysids and mud shrimps (*Corophium volutator*) were more abundant in fish caught inside the realignment.

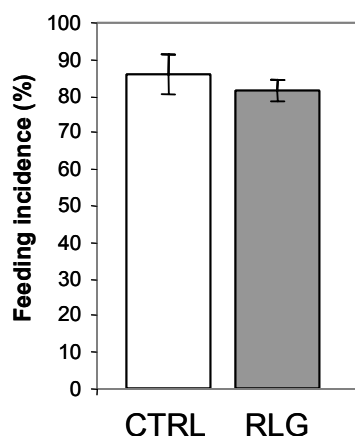


Figure 1.8: Feeding incidence at Paull Holme Strays managed realignment site calculated as the percentage of stomach with food (averaged across individual fish). RLG (realignment) and CTRL (control) stations. Bars indicate mean $\pm$ SE.

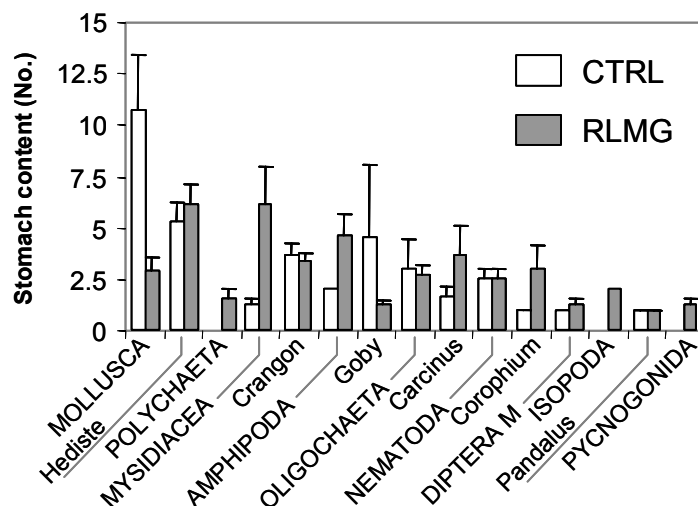


Figure 1.9: Feeding rates on prey items identified within fish stomachs at Paull Holme realignment site. Bars indicate average number of prey items with standard errors (SE). Prey items are listed in descending order of % contribution to total stomach content. RLG (realignment) and CTRL (control) stations. Prey taxonomical classification and names are provided in Appendix 1.2.

Based on comparisons of species assemblage, fish density, and prey consumption between realignment and control stations, Paull Holme Strays managed realignment site appears to function in a similar fashion to that of the control sites, and appears to have attained foraging equivalence in the 4 years since its creation (indicating mature ecological status). The methods used throughout the study could be improved as gear bias may be masking differences in fish species captured through partial exclusion of the fish assemblage. However, this does not invalidate the conclusions as the same gear and sampling methodology was employed throughout all stations (control and realignment) and as such, results should be comparable.

1.2.6 AVIFAUNA

The development of the avifaunal assemblage within the Paull Holme Strays realignment site, as well as on adjacent existing intertidal habitats has been monitored by IECS since the breach in 2003. The following text is largely based on Mander *et al.* (2007), which describes the development of the assemblage on the site up to 2006, as well as providing comparison with usage on adjacent existing intertidal areas.

A total of 34 species of waterfowl were recorded on the site during the first 3 years of its operation, with 19 species of wader and 11 species of wildfowl.

Up to 14,000 Golden Plover (*Pluvialis apricaria*) were recorded roosting on the site, as well as 4,500 Lapwing (*Vanellus vanellus*) and 1,300 Black-tailed Godwit (*Limosa limosa*), with peak roosting numbers usually occurring around high water when flocks moved onto the site from adjacent areas in response to tidal inundation. Low water usage by waders was at a reduced level, although Golden Plover and Lapwing remained on roosting on the site, these species primarily feeding on inland areas around the estuary during the night-time. Some foraging was also recorded around this low water period, with peak wader maxima generally recorded during the autumn passage, with approximately 300 waders foraging on the site at this time, numbers falling to around 200 during the winter, the overall size of the foraging wader assemblage thus substantially less than that of the roosting wader assemblage. This is characteristic of middle estuary sites on the Humber, where Golden Plover and Lapwing can be the dominant species but using the estuary primarily as a roost rather than foraging site (Cutts, N., IECS, pers. obs., 2008).

In general, wildfowl usage was at a lower level than the wader assemblage, with Shelduck (*Tadorna tadorna*), Teal (*Anas crecca*) and Mallard (*Anas platyrhynchos*) most commonly recorded, numbers peaking during the winter. Flocks of up to c. 300 Shelduck, 600 Teal and 100 Mallard have been recorded, but with the majority using the site for loafing rather than foraging. Notably, initial colonisation of the site by wildfowl was more rapid than by the wader assemblage, and in particular, relatively large numbers of foraging Teal were recorded during the initial period following the breach. However, Teal numbers declined thereafter, and it may have been the case that the species was feeding on vegetative matter from the inundated areas of rank grassland which formerly terrestrial in nature and kept *in situ* following the breach, as well as utilising the shallow borrow pit habitat which may also have trapped vegetative material.

Analysis of the waterfowl assemblage data has suggested that there has been a shift towards an assemblage more characteristic of a middle estuary site over time. Whilst there was a relatively rapid colonisation by wildfowl, the wader assemblage has taken some time to develop. In the first winter the foraging assemblage was extremely species poor, as might be expected, given the limited prey availability. However, the assemblage has developed, with flocks of Dunlin (*Calidris alpina*), Bar-tailed Godwit (*Limosa lapponica*) and Grey Plover (*Pluvialis squatarola*) recorded foraging on the site during the third winter, these species having been absent during the initial winter following breaching. This would accord with the development of the invertebrate community of the site outlined in Section 1.2.4 as described by Mazik *et al.* (2007), and is consistent with waterfowl assemblage development findings from other UK realignment sites e.g. Orplands and Tollesbury. In particular, predators of small polychaetes tend to colonise an area before those feeding mostly on bivalve species (Atkinson *et al.*, 2001, 2004).

Whilst the movement of the macro and meiofaunal benthic community towards one resembling that of adjacent 'existing' mudflats might be expected over time, the wildfowl and wader community using the site as a feeding resource have not exhibited such a clear trend (presumably as a range of external factors aside from food availability may influence movement). Despite an initial relatively swift development towards a characteristic avifaunal community for the site by three years post breaching, as reported in Mander *et al.* (2007), whilst there have been substantial increases in the numbers of Redshank (*Tringa totanus*) using the managed realignment site as a feeding resource, Dunlin numbers have remained stable, and the abundance of other actively feeding benthivores such as Black-tailed Godwit and Curlew (*Numenius arquata*), have, if anything, fallen from the levels of 2006.

The reasons for this possible reduction (or at least non-concomitant increase) in some actively feeding benthivore bird species at the site are currently unclear, but may reflect a variety of external factors, including relative population levels using the Paull Holme Strays area in the context of regional, or even national population trends, as well as other factors such as weather conditions and disturbance.

One unexpected gain from the creation of the site has been the development of an Avocet (*Recurvirostra avosetta*) colony within the realignment area. However, 2007 and 2008 have seen high spring tides during the main breeding period substantially affect breeding success, with nest sites being flooded out. As such, it is expected that a degree of habitat modification will be required as part of the site's management strategy in order to increase the potential success rate for the species as a breeding bird at the site in the future.

The Paull Holme Strays site has met its initial targets for supporting a wader population equal to or greater than that lost through direct landclaim and coastal squeeze arising from flood defence works in the middle estuary. Analysis of the assemblage developing on the realignment site compared to that of the existing intertidal frontage shows a gradual development towards an assemblage characteristic of the area. However, the foraging assemblage remains dissimilar from that of adjacent existing mudflats in the middle Humber, and whilst targets have been met in terms of species using the site, this is for an area of mudflat far greater than that lost to coastal squeeze and direct landclaim. Waterfowl foraging densities on the realignment site remain substantially below those from adjacent

areas on the Humber and the site's waterfowl carrying capacity is considered to be well below that for a mid estuary intertidal area.

Most importantly, initial analysis of data from adjacent intertidal sites on the estuary suggest that currently the majority of species colonising Paull Holme Strays have simply undertaken adventitious emigration movements from previously habitually used areas into the realignment site (Cutts & Hemingway, 2008). Monitoring of the development of the avifaunal assemblage at Paull Holme Strays will continue for several more years, with analysis addressing some of the issues discussed above.

1.2.7 CONCLUSIONS

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

1.3 Chowder Ness

The following text (Sections 1.3.1 - 1.3.3) is based on the ABPmer (2008) map-based online database of managed realignment and tidal exchange projects in NW Europe.

1.3.1 SITE DESCRIPTION & OBJECTIVES

A new Roll-on Roll-off terminal which opened in July 2006 was constructed by Associated British Ports (ABP) at Immingham harbour on the south bank of the estuary, resulting in the direct loss of 22ha of intertidal mudflat and potentially up to 5ha of indirect losses in the Humber Estuary proposed Special Protection Area¹ (pSPA) and possible Special Area of Conservation² (pSAC). As a direct result of the development, and in consultation with regulatory bodies and local nature conservation interest groups, two managed realignments schemes at Chowder Ness and Welwick (Section 1.4) were identified as contributing to a compensation package for the impacts of constructing the new harbour. Initial objectives at Chowder Ness were to create 10.5ha of mudflat and 0.8ha of saltmarsh which could support a variety of invertebrate and bird species.

In order to create the site, new flood defences were constructed to the rear of the site with a minimum height of 6.7m above ODN (Ordnance Datum Newlyn³). Although 200m remain, 570m of the existing seawall was removed in a series of stages to a level of approximately 1.6 - 2.0m ODN, with the removal rather than the creation of solitary breaches chosen for a number of reasons:

- Improved connectivity with the wider estuary;
- More accurate re-creation of the type of environments which existed prior to reclamation;
- It allows the whole cross sectional area of the estuary including the realignment site to respond to estuary wide changes;
- Increased energy levels within the site, thereby improving the probability that mudflat habitat will be maintained (with mudflat creation being the primary objective of the site).

Although not taken into account when determining the height of the new defence due to uncertainties involved in judging its long term sustainability, a strip of saltmarsh is expected to develop in front of the new (landward) sea defences.

With a total area of 15ha and representing only 0.02% of the estuary's intertidal area and 0.01% of its spring tidal prism, Chowder Ness managed realignment site was considered to be relatively small scale in relation to the estuary as whole. As large lengths of sea wall

¹ The Humber Estuary pSPA has now been granted full SPA status by the Secretary of State for the Environment.

² The Humber Estuary pSAC has now been formally submitted by Defra to the European Commission for full SAC status. As such, the estuary is now a candidate SAC (cSAC) and afforded full protection as though already adopted by the Commission.

³ Ordnance Datum Newlyn (ODN) corresponds to the average sea level measured by the tide gauge at Newlyn, Cornwall (UK) between 1915 and 1921.

were removed, the effects on estuarine tidal velocities, sedimentation and accretion, and water levels, were anticipated to be extremely localised and of a relatively small magnitude (ABPmer, 2004).

Chowder Ness managed realignment scheme (costing a total of £1,500,000) was breached in July 2006 and is illustrated in Figures 1.10 and 1.11. As with Welwick (Section 1.4), an initial 10 year monitoring programme is currently being undertaken to describe both changes to sites fronting the realignment (bathymetry, invertebrates and waterfowl), and to the realignments site itself (topography, saltmarsh composition, changes to intertidal invertebrates and wildfowl usage).



Figure 1.10: Site preparation works for Chowder Ness managed realignment site in July 2006 immediately prior to the breach (Humber Estuary, UK).



Figure 1.11: Chowder Ness managed realignment site post breach during 2007 (Humber Estuary, UK).

1.3.2 ACCRETION & EROSION

Although the first monitoring report has yet to be published, basic results of the topographical monitoring (using a combination of LiDAR⁴ and/or laser methods) show that there has been an overall accretionary trend, with an average increase of 9cm across the site being approximated (with a caveat that the relatively high rates of accretion observed in some areas could be a function of errors associated with the survey methodology). In relation to the pre-existing fronting intertidal areas at Chowder Ness, the greatest changes in elevation were associated with the pre-existing area of saltmarsh at the eastern entrance to the realignment site. As predicted, the extent of this area of saltmarsh has been reduced, with this change being attributed to increased tidal flow.

1.3.3 AVIFAUNA

During the 2006/2007 count season, a total of 13 waterbird species were found to be using the newly created intertidal area at Chowder Ness, with the majority of usage being concentrated on the disturbed ground along the line of the removed seawall and the adjacent area of new mudflat within 10m of that area. Lapwing, Dunlin and Redshank were present during all seven monthly surveys, and the most abundant species observed included Golden Plover, Lapwing, Dunlin, Black-headed Gull and Curlew. All target species established for the site were observed with the exception of black-tailed godwit which was not seen in any of the monitored intertidal areas either on or off-site.

An additional requirement of the Chowder Ness scheme was to create terrestrial habitats to support a range of farmland bird species at the top and landward side of the new flood embankment, and along a grassland berm between the base of the embankment and the soke dyke (with associated planted hawthorn). Although the grassland and hedgerow are relatively newly habitats and as such, monitoring will continue to determine areas against pre-defined targets, six bird species were observed using the grassland of the newly created embankment during 2007, four of which held breeding territories. Again, all target species were observed with the exception of Linnet and Reed Warbler.

1.3.4 FISH

It is understood that no requirement for the monitoring of fish usage at Chowder Ness managed realignment site was identified in the consenting process. This may possibly have been because the loss of such function from the original development (landclaim) site was not identified during the EIA process, and/or that the potential for new habitat function was not identified or prioritised in the site during the same process. As such, monitoring of fish usage in these areas has been undertaken as part of the HARBASINS project, with the results of the programme summarised below.

⁴ Light Detection and Ranging - airborne mapping technique.

1.3.4.1 Survey Design & Methodology

The survey design for Chowder Ness comprised three stations within the realignment site, and two control stations located along the edge of the saltmarsh outside the site. Fyke nets were used exclusively for this site, and samples were taken between June and September 2007. A brief outline of gear operation and catch processing is provided in Section 1.2.5 and described in greater detail in Pérez-Dominguez (2008).

1.3.4.2 Results & Discussion

Although both the realignment and control stations showed the same two dominant species (flounder and eel), they had quite different compositions in relation to the less abundant components of the assemblage (Figure 1.12). Inside the realignment, these minor species were typically freshwater or anadromous (i.e. European smelt, *Osmerus eperlanus*), whilst at the control sites, they were primarily brackish but of marine origin.

The assemblage within the realignment appears to be more diverse in comparison with the control sites (Figure 1.13), with the shape of the *k*-dominance curves possibly suggesting (as with the fish sampling undertaken at Paull Holme Strays) an incomplete fish assemblage sample representation, or a reduced number of species present in the area. Based on catch per unit effort, flounder was found to be less abundant inside the realignment site, where average fish size was significantly reduced (Figure 1.14). A similar trend was noted for the eel, although no significant density or size effect was found.

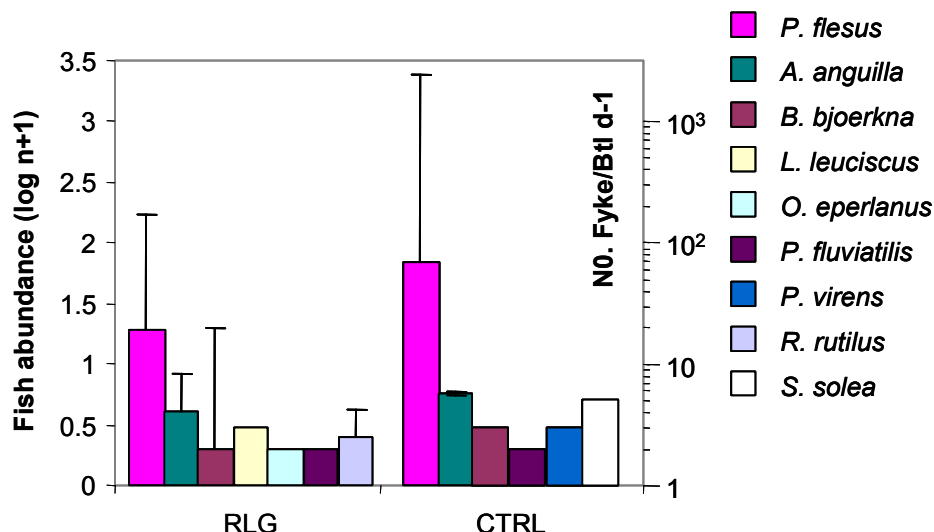


Figure 1.12: Fish abundance inside Chowder Ness managed realignment site (RLG) and at the control (CTRL) stations outside the site. Abundances are transformed (Log n+1). Untransformed density equivalent are given in the secondary axis scale.

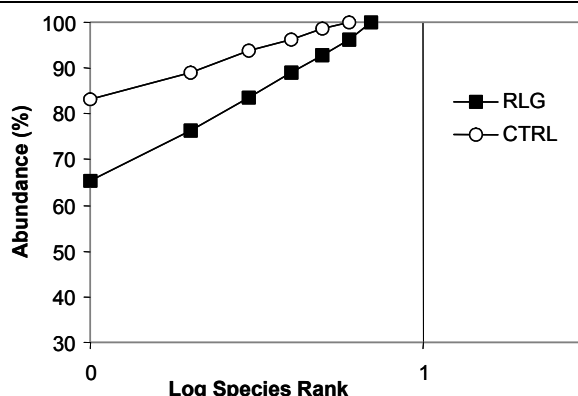


Figure 1.13: Chowder Ness managed realignment site, showing k -dominance curves by sampling station. All curves are derived from fyke net and bottle trap catches. RLG (realignment) and CTRL (control) stations.

Significantly fewer fish were found to be feeding inside the realignment site when compared with the control stations (Figure 1.15), highlighted by the two most abundant species (eel and flounder). Impaired feeding was also still detectable from the stomach content analysis of those fish which were found to be feeding within the realignment site, e.g. fewer mud shrimp (*Corophium volutator*) recorded from stomach content analysis of species feeding within the realignment when compared to those outside (Figure 1.16 and Appendix 1.2).

Feeding incidence can be a useful functional indicator of habitat quality and benthos-fish coupling in intertidal areas (Dale & Beyeler, 2001). Reduced feeding rates may be directly related to the short timescale since the site was breached in July 2006. Benthic invertebrates, primarily *C. volutator*, and the ragworm (*Hediste diversicolor*), may not yet have had time to fully colonise the site. It is anticipated that carrying capacity in the restored system will improve with time as prey populations increase. This hypothesis, and the adequacy of feeding incidence as a proxy for habitat quality, will require further assessments at the realignment site and a continued monitoring programme across diverse habitats and fish species.

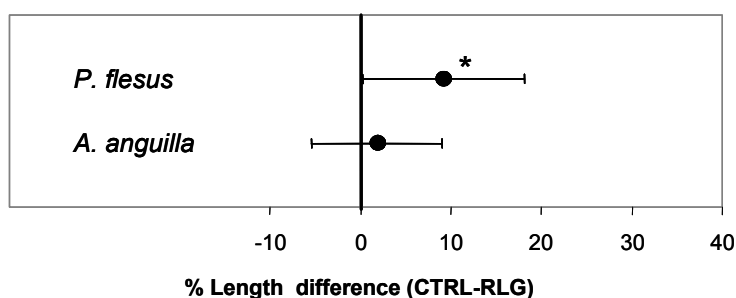


Figure 1.14: Length difference (%) between fish caught at the Chowder Ness managed realignment and control stations. Positive values indicate larger sizes at the control stations. Error bars represent standard error. * $p < 0.05$ (site and species independent t -tests).

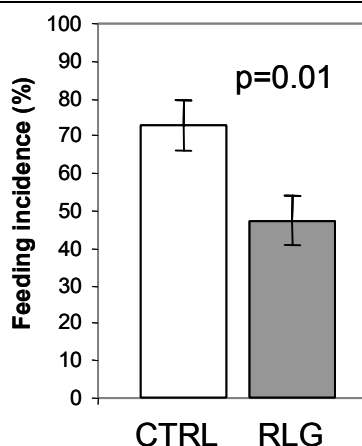


Figure 1.15: Feeding incidence at Chowder Ness managed realignment site calculated as the percentage of stomach with food (averaged across individual fish). The p value indicates significant differences across realignment and control sites (Kruskal-Wallis One-Way Analysis of Variance). RLG (realignment) and CTRL (control) stations. Bars indicate mean $\pm$ SE.

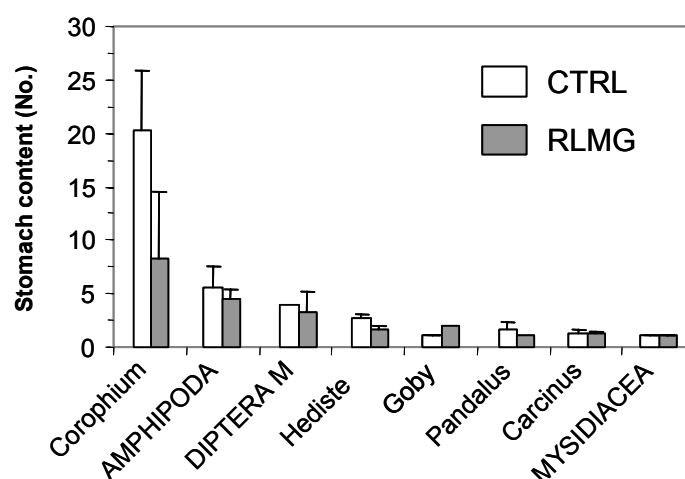


Figure 1.16: Feeding rates on prey items identified within fish stomachs at Chowder Ness managed realignment site. Bars indicate average number of prey items with standard errors (SE). Prey items are listed in descending order of % contribution to total stomach content. RLG (realignment) and CTRL (control) stations. Prey taxonomical classification and names are provided in Appendix 1.2.

1.4 Welwick

The following text (Sections 1.4.1 - 1.4.3) is based on the ABPmer (2008) map-based online database of managed realignment and tidal exchange projects in NW Europe.

1.4.1 SITE DESCRIPTION & OBJECTIVES

As with Chowder Ness (Section 1.3), the new Roll-on Roll-off terminal constructed by Associated British Ports (ABP) at Immingham harbour on the south bank of the estuary, resulted in the direct loss of 22ha of intertidal mudflat and potentially up to 5ha of indirect losses in the recently designated Humber Estuary SPA and cSAC (although these designations were pSPA and pSAC at the time of construction). As a result of the development, and in consultation with regulatory bodies and local nature conservation interest groups, two managed realignments schemes at Chowder Ness and Welwick were identified as contributing to a compensation package for the impacts of constructing the new harbour. The primary objectives at Welwick were to create between 15-38ha of intertidal mudflat, together with 12-28ha of saltmarsh and 4-10ha of grassland.

To avoid disturbance of overwintering and breeding birds at Welwick, works were restricted to the months between April and August, with the site being constructed over a 2 year period. For its creation, new flood defences were constructed to the rear of the site with a minimum height of 6.1m above ODN. As with Chowder Ness, a strip of saltmarsh was anticipated to develop in front of the new defences, although this saltmarsh strip was not taken into account when determining the embankment height due to uncertainties with its long term sustainability. The 70,000m³ of material required for the defences was obtained from within the site (combination of reprofiling and creation of temporary borrow pits), with the new embankment seeded and left to stabilise for a year.

The existing seawall was removed in stages over a length of 1,400m and as with Chowder Ness, the wholesale removal rather than creation of solitary breaches was chosen for a number of reasons:

- Improved connectivity with the wider estuary;
- More accurate re-creation of the type of environments which existed prior to reclamation;
- It allows the whole cross sectional area of the estuary including the realignment site to respond to estuary wide changes;
- Increased energy levels within the site, thereby improving the probability that mudflat habitat will be maintained (with mudflat creation being the primary objective of the site).

Following this, breaches were created in the existing saltmarsh in front of the site. These were required as the fronting marsh could not be removed completely (due to conservation designations) in order to increase wave energy even further. With the typical elevation of the marsh being 3.2m ODN (coinciding with Mean High Water Spring level), the breaches would allow the site to flood and drain sufficiently. The location of the breaches were chosen to minimise marsh losses (approximately 0.4ha), their width having been assessed

by calculating the discharge and considering the critical threshold for erosion of sediment. As such, the suggested breach size was considered large enough for the velocities to be below the critical threshold for erosion.

With a total area of 54ha and representing only 0.4% of the estuary's intertidal area and 0.02% of its spring tidal prism, Welwick managed realignment site was additionally considered to be relatively small scale in relation to the estuary as whole. As with Chowder Ness, due to large lengths of sea wall having been removed, the effects on estuarine tidal velocities, sedimentation and accretion, and water levels, were anticipated to be extremely localised and of a relatively small magnitude (ABPmer, 2003).

Welwick managed realignment scheme (costing a total of £1,500,000) was breached in June 2006 and is illustrated in Figures 1.17 and 1.18. As with Chowder Ness, an initial 10 year monitoring programme is currently being undertaken to describe both changes to sites fronting the realignment (bathymetry, saltmarsh evolution, invertebrates and waterfowl), and to the realignments site itself (topography, saltmarsh composition, changes to intertidal invertebrates and bird usage).



Figure 1.17: Aerial view of the Welwick managed realignment site prior to preparation of the site (Humber Estuary, UK).



Figure 1.18: Welwick managed realignment site post-construction showing avifaunal usage (Humber Estuary, UK).

1.4.2 ACCRETION & EROSION

Although the first monitoring report has yet to be published, basic results of the topographical monitoring (using a combination of LiDAR and/or laser methods) show that there has been an overall accretionary trend, with an average increase of 15cm across the site being approximated (with a caveat that the relatively high rates of accretion observed in some areas could be a function of errors associated with survey methodology). Within the pre-existing fronting intertidal areas, relatively large areas of deposition were apparent to seaward of the fronting saltmarsh. In addition, evidence suggested small scale erosion along the seaward boundary sites, consistent with predictions resulting from modelling of the site.

1.4.3 AVIFAUNA

During surveys conducted between September 2006 and March 2007, a total of 29 waterbird species were recorded, with the realignment site having developed as a major roosting site for a number of wading birds at high water. Following high water, the majority of wading birds were subsequently observed moving onto the fronting or adjacent intertidal areas as the tide receded. As the site developed over winter, increasing numbers of Grey Plover, Redshank, Dunlin and Curlew were observed foraging from high to low water, with wildfowl species also being well represented in the realignment site, particularly Shelduck. With the exception of Black-tailed Godwit which was not observed in any of the intertidal areas monitored either on or off-site, all target species established for the site were observed.

As with Chowder Ness, an additional requirement of the Welwick scheme was to create terrestrial habitats to support a range of farmland bird species. During May 2007, a breeding bird survey concentrating on saltmarsh, hedgerows and floodbanks was undertaken, with the area surveyed found to support a range of breeding bird communities, most of which related to habitat variations, specifically wetland and terrestrial. A total of 27 different bird

species were observed, including all three target species within the survey area adjacent to the newly created realignment site.

1.5 Alkborough

1.5.1 SITE DESCRIPTION & OBJECTIVES

At 440ha, Alkborough Flats situated on the south bank of the Humber Estuary at the confluence of the Rivers Trent and Ouse is the largest coastal realignment site to be completed as part of the Humber Management Plan to date. It is the second Environment Agency managed realignment site to be established on the estuary, and was created as replacement habitat to compensate for both coastal squeeze (on a 1:1 ratio of habitat loss to creation for coastal squeeze), and for direct construction related losses from defence improvement works in the upper estuary (on a 1:3 ratio for habitat loss to creation for direct construction related losses).

The scheme was additionally created to reduce water levels in the upper estuary during extreme events, with the capacity of the site being so extensive that a 150mm reduction in high tide levels over a large part of the upper estuary is being predicted by the Environment Agency (Humber Management Scheme, 2007). Although the site was created prior to the Environment Agency's Humber Flood Risk Management Strategy, the habitat figures are included in the Environment Agency 50 year CHaMP balance sheet (Faith Spencer, EA, pers. comm., 2008) (see Burdon and Cutts (2008) for further information on management strategies within the Humber Estuary).

Alkborough is an area of low lying arable land jointly owned by the Environment Agency, Natural England and Associated British Ports although the project is being undertaken and delivered through a partnership between the Environment Agency, Natural England and North Lincolnshire Council (Humber Management Scheme, 2007).

Engineering works began on site in 2005 and in August 2006 the final stage of construction was completed. On 6th September 2006, the old flood defence bank was breached and on the next high tide, inundation occurred. Following the breach, the newly created open water areas, covering approximately 170ha on each high tide, have developed quickly and are attracting a large number of birds (Humber Management Scheme, 2007). The scheme cost a total of £10,200,000 and is illustrated in Figures 1.19 and 1.20.

A detailed five year monitoring programme has been established to assess the general development of the site and ensure it has provided functioning intertidal habitat (Faith Spencer, Environment Agency, pers. comm.). Mudflat development and accretion, invertebrates (including estuarine and those inhabiting freshwater/brackish features), saltmarsh communities, aquatic plants (inhabiting freshwater/brackish features), fish and epibenthos, and birds are being monitored at the site and this information will be used to advise future Environment Agency managed realignment sites at a regional and national level.



Figure 1.19: Alkborough managed realignment site prior to construction works (Humber Estuary, UK).



Figure 1.20: Alkborough managed realignment site post breach (Humber Estuary, UK).

1.5.2 GENERAL

Although the first monitoring report (2007-2008) for the site has yet to be published, early indications show that the site is rapidly accreting, and that initial sediment depth measurements can broadly be related to predictions of tidal inundation. In areas of low predicted inundation (100 inundations per year), sediment accretion was found to be less than 5cm compared to more than 20cm (with a maximum of 58cm) in areas with more than 500 inundations per year (Mazik *et al.*, in prep.).

The site also shows the presence of early colonising invertebrates and is being utilised by waterfowl for feeding and roosting. During the winter of 2007/8, the Alkborough site regularly supported several hundred Shelduck, together with over 100 Wigeon (*Anas penelope*) and over 1,000 Teal. An interesting wader assemblage has also developed, with over 100 Avocet and Black-tailed Godwit feeding on the site during autumn passage. In addition, over the winter, the site has been used as a roost by flocks of Golden Plover in excess of the national importance qualifying threshold, as well as by over 2,000 Lapwing. Dunlin and Redshank have also been recorded within the feeding assemblage on the site.

The technical feasibility study for the scheme has predicted that the site will initially develop a mosaic of habitats, the majority of which will become wet grassland and reedbed. In addition, there will be areas of mud and open water within the site, although with time parts of these will develop into saltmarsh and reedbed. Parts of the site will only flood on extreme tide events, and it is expected that these areas will be managed as grazing marsh (English Nature, 2006).

1.5.3 FISH

It is understood that no requirement for the monitoring of fish usage at Alkborough managed realignment site was identified in the consenting process. This may possibly have been because the loss of such function from the original development (landclaim) site was not identified during the EIA process, and/or that the potential for new habitat function was not identified or prioritised in the site during the same process. As such, monitoring of fish usage in these areas has been undertaken as part of the HARBASINS project, with the results of the programme summarised below.

1.5.3.1 Survey Design & Methodology

Alkborough managed realignment site was a late addition to the survey programme and was therefore only sampled once during March 2008. As with Chowder Ness (Section 1.3.4), the survey design comprised three stations within the realignment site, and two control stations located along the edge of the saltmarsh outside the site. Stations were sampled using fyke nets and a small beam trawl inside the realignment, with only fyke nets used for the control stations. A brief outline of gear operation and catch processing is provided in Section 1.2.5, and described in greater detail in Pérez-Dominguez (2008).

1.5.3.2 Results & Discussion

As one sampling event is not adequate to capture general ecological trends, the following description simply provides a single 'snapshot' of the condition of the site during March 2008, approximately 18 months after the site was initially breached.

Three fish of the fish species collected in the fyke nets (Figure 1.21) were freshwater or euryhaline species typically from freshwater habitats. Species richness and diversity was found to be very similar both within and outside the realignment site (Figure 1.22), which may indicate initial colonisation by locally occurring species. Sampling using the beam trawl did not catch any additional species, but did capture smaller fish (e.g. flounder and three-spined stickleback, *Gasterosteus aculeatus*), highlighting the critical importance of multi-gear

assessments to capture a more accurate representation of the fish assemblage (Figure 1.23 & Appendix 1.1).

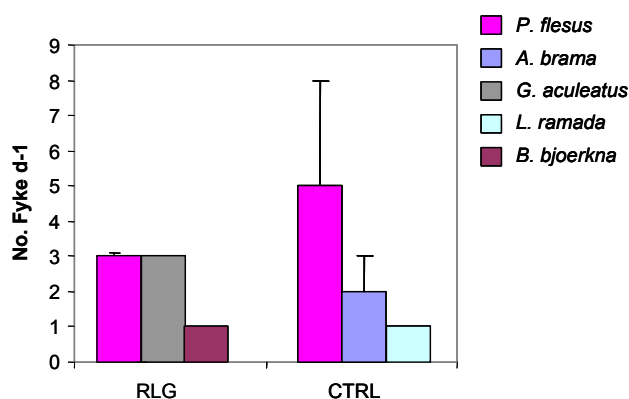


Figure 1.21: Fish density inside Alkborough managed realignment site (RLG) and at the control (CTRL) stations outside the site.

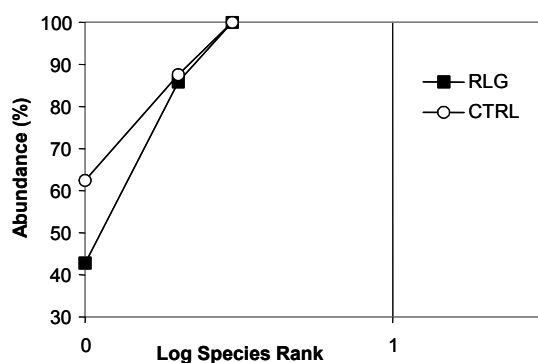


Figure 1.22: Alkborough managed realignment site, showing *k*-dominance curves by sampling station. All curves are derived from fyke net and bottle trap catches. RLG (realignment) and CTRL (control) stations.

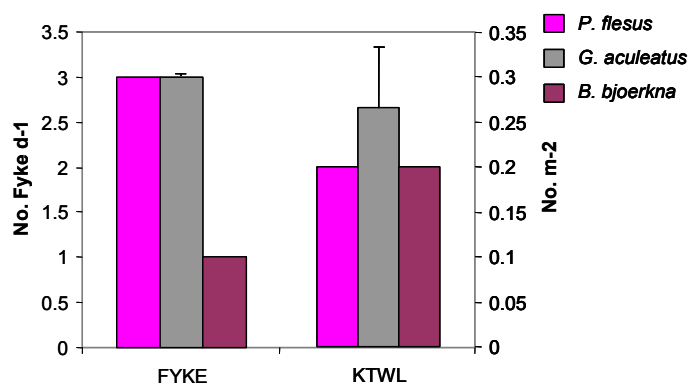


Figure 1.23: Parallel estimates of fish abundance and assemblage composition by gear type at Alkborough managed realignment site. FYKE (fyke net, 3 total samples) and KTWL (mini bean trawl, 60m² total area). Error bars represent standard error. Missing error bars resulted from species recorded only once.

1.6 Donna Nook

Donna Nook located on the south bank of the Humber Estuary is the third Environment Agency planned managed realignment site on the estuary, with a potential completion date of 2010. As with Paull Holme Strays and Alkborough, it is intended as replacement habitat to compensate for both coastal squeeze (on a 1:1 ratio of habitat loss to creation for coastal squeeze), and for direct construction related losses from defence improvement works in the upper estuary (on a 1:3 ratio for habitat loss to creation for direct construction related losses). It is not intended as a flood storage site (Faith Spencer, EA, pers. comm., 2008).

1.7 Discussion and Comparison of Fish Sampling in the Humber Estuary

The following section discusses the fish sampling and analysis undertaken at Paull Holme Strays, Chowder Ness and Alkborough managed realignment sites. This sampling was specifically undertaken as part of the European Interreg IIB HARBASINS project, and is described above in Section 1.2.5, Section 1.3.4 and Section 1.5.3 for the three realignment sites. Further detail in relation to fishing gear used and subsequent analysis of catch is provided in Pérez-Dominguez (2008).

The ecological assessment of newly created intertidal habitat should aim to identify and describe quality aspects defining the natural development of the system towards a climax state. Such an assessment is normally based on time series analysis or alternatively, on the use of control climax sites as reference (Goldsmith, 1992). The presence and abundance of certain species or species performance estimates (reproductive output, growth rate, feeding incidence, physiology, life history, etc.) provides direct evidence for the realisation of a determined set of essential quality elements (such as prey items, salinity, thermal range, dissolved oxygen and spawning substratum) in the environment. Fishes have diverse lifestyles and specific adaptations to a wide set of conditions and food sources (Bone *et al.*, 1999; Nelson, 2006), a quality that makes them good high level integrators in ecological studies and therefore an excellent end point reference for whole ecosystem functioning.

In comparison to the control intertidal stations, the Paull Holme Strays managed realignment site appears to have achieved a mature stage of development, supporting similar fish species and providing comparable food sources (Figure 1.24). However, in contrast, Chowder Ness (breached in July 2006 just less than a year prior to the initial IECS fish sampling survey) has not yet developed to its full potential. Foraging equivalence could be a useful metric to gauge quality of aquatic habitats, or in restored sites, evaluate the pace of recovery.

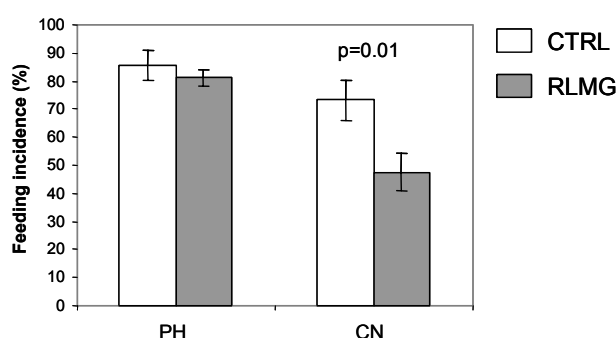


Figure 1.24: Feeding incidence calculated as the percentage of stomach with food (averaged across individual fish) for RLG (realignment) and CTRL (control) stations at PH (Paull Holme Strays) and CN (Chowder Ness). The p value indicates significant differences across realignment and control sites (Kruskal-Wallis one-way analysis of variance). Bars indicate mean $\pm$ SE.

Hierarchical cluster analysis across realignment sites and stations (Figure 1.25) further

suggests the advanced successional status of Paull Holme Strays which has attained a very similar profile to those of the control intertidal areas. However, a different scenario is apparent at the newly created realignment sites at Chowder Ness and Alkborough, although this may be due to the reduced salinity regime of these areas.

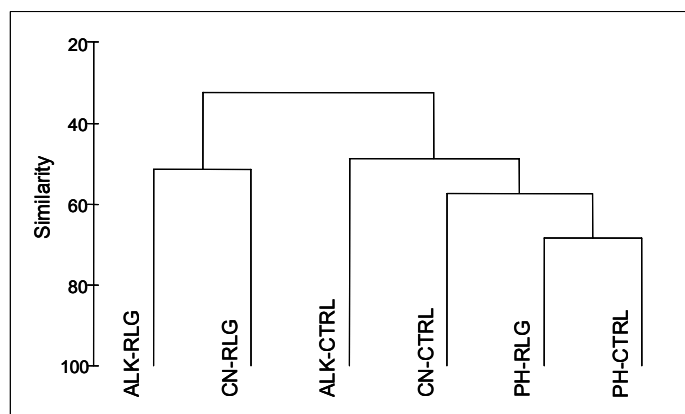


Figure 1.25: Taxonomic similarities between samples from realignment and control sites. The assessment is based on intertidal fyke netting and bottle trapping. RLG (realignment) and CTRL (control) stations at ALK (Alkborough), CN (Chowder Ness) and PH (Paull Holme Strays) managed realignment sites.

The realignment sites appear to be favoured by smaller fish, although this effect seems to be species dependent (Figure 1.26). Smaller fish, probably new recruits in the case of flounder tend to rely more (and consequently benefit more), from the creation of new intertidal habitat which can act as a nursery area for estuarine and marine fish species (Figure 1.27). These assessments however, are limited by the methodology and gear selection, and this is often decided upon operational constraints. In many cases sampling difficulties in intertidal habitats narrows gear choice to just one or two viable methods and typically have to choose the less bad of several bad gear choices. Gear bias is a constant problem and multigear assessments seems to be the best way to increase our chances to obtain a more complete picture of intertidal fish assemblages.

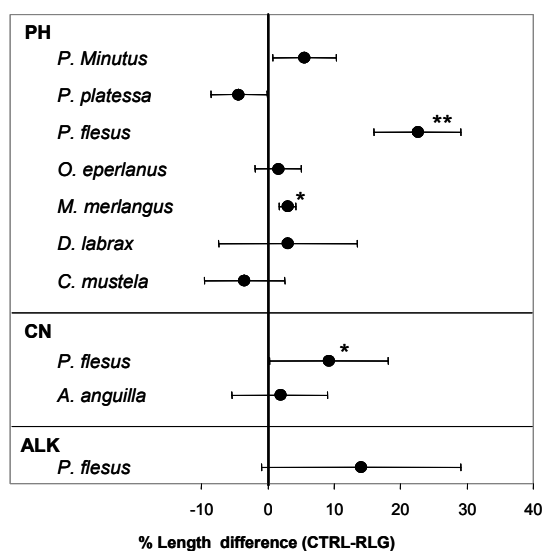


Figure 1.26: Percentage length difference between control and realignment caught fish. Positive values indicate larger sizes at the control stations. Error bars represent standard error. * $p < 0.05$, and ** $p < 0.01$ (site and species independent t -tests)

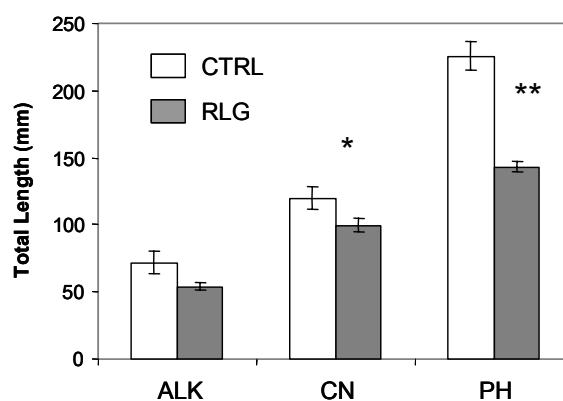


Figure 1.27: Total length of flounder collected from control (CTRL) and realignment sites (RLG). Error bars represent standard error. Significant differences were found across sites by ANOVA ($p < 0.05$). * $p < 0.05$, and ** $p < 0.01$ (site independent t -tests)

1.8 References

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Appendix 1.1: Gear Comparison Length Data

Paull Holme Strays: Mean total length with standard error of fish collected during the gear comparison trials. FYKE (fyke net); BTP (bottle trap); PSN (push net); SEN (seine net). n indicates the number of fish measured.

TAXA	FYKE		BTP		PSN		SEN	
	mean (SE)	n	mean (SE)	n	mean (SE)	n	mean (SE)	n
<i>Anguilla anguilla</i>	430	1	.	.	.	.	.	.
<i>Clupea harengus</i>	57.0	1	.	.	.	.	.	.
<i>Entelurus aequoreus</i>	.	.	.	.	.	.	338	1
<i>Gasterosteus aculeatus</i>	.	.	.	.	.	.	32.0	1
<i>Osmerus eperlanus</i>	195 (n/a)	2	.	.	.	.	.	.
<i>Platichthys flesus</i>	199 (7.9)	52	.	.	.	.	223 (7.4)	3
<i>Pleuronectes platessa</i>	57.0 (5.2)	5	45.0	1	.	.	25.0	1
<i>Pomatoschistus minutus</i>	16.8 (2.1)	4	24.5 (0.6)	133	21.3 (1.5)	8	38.9 (2.1)	16
<i>Sprattus sprattus</i>	.	.	.	.	.	.	52.4 (1.8)	34

Alkborough: Mean total length with standard error of fish collected during the gear comparison trials. FYKE (fyke net); KTWL (mini beam trawl). n indicates the number of fish measured.

TAXA	FYKE		KTWL	
	mean (SE)	n	mean (SE)	n
<i>Abramis brama</i>	97.5 (4.2)	4	.	.
<i>Blicca bjoerkna</i>	90.0	1	119	1
<i>Gasterosteus aculeatus</i>	54.0 (3.5)	3	39.8 (1.0)	4
<i>Liza ramada</i>	123	1	.	.
<i>Platichthys flesus</i>	67.5 (6.7)	13	55.5 (3.5)	2

Appendix 1.2: Stomach Analysis Summary Tables.

(A) Taxa and number of prey items with coefficient of variation (CV) found in fish caught at control stations outside Chowder Ness managed realignment site. n indicates the number of stomachs examined.

Prey Item	Chowder Ness CONTROL											
	<i>Anguilla anguilla</i> Eel		<i>Platichthys flesus</i> Flounder		<i>Perca fluviatilis</i> Perch		<i>Pollachius virens</i> Saithe		<i>Blicca bjoerkna</i> White bream		<i>Dover Sole</i> Sole	
	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n
CRUSTACEA												
- AMPHIPODA												
<i>Corophium volutator</i>	31.9 (0.7)	8	5.0 (0.9)	5	.	.	.	.	.	.	3	1
<i>Gammarus duebeni</i>	11.5 (1.0)	6	2.4 (0.7)	1	.	.	.	.	.	.	1	1
- DECAPODA												
Brachyura, <i>Carcinus maenas</i>	1	1	1.5 (0.5)	2	.	.	.	.	.	.	.	.
Caridea, <i>Pandalus montagui</i>	1	1	1	1	.	.	3	1	.	.	.	.
- MYSIDIACEA												
Mysidiacea sp	.	.	1	2	.	.	.	.	.	.	.	.
POLYCHAETA												
<i>Hediste diversicolor</i>	2.3 (0.7)	4	2 (0.5)	6	.	.	.	.	.	.	4.3 (0.4)	3
DIPTERA												
Diptera, maggot	.	.	4	1	.	.	.	.	.	.	.	.
TELEOSTEI												
<i>Platichthys flexus</i>	.	.	1	1	.	.	.	.	.	.	.	.
<i>Pomatoschistus minutus</i>	1.0	1	.	.	.	.	.	.	.	.	.	.
Empty stomachs		2		4		1		1		2		1
Total		23		23		1		2		2		6

(B) Taxa and number of prey items with coefficient of variation (CV) found in fish caught at stations inside Chowder Ness managed realignment site. n indicates the number of stomachs examined.

Prey Item	Chowder Ness REALINGMENT													
	<i>Leuciscus leuciscus</i> Dace		<i>Anguilla anguilla</i> Eel		<i>Platichthys flesus</i> Flounder		<i>Perca fluviatilis</i> Perch		<i>Rutilus rutilus</i> Roach		<i>Blicca bjoerkna</i> White bream		<i>Osmerus eperlanus</i> Smelt	
	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n
CRUSTACEA														
- AMPHIPODA														
<i>Corophium volutator</i>	.	.	27	1	2.0 (0.5)	3	.	.	.	.	.	.	.	.
<i>Gammarus duebeni</i>	.	.	3 (0.9)	2	4.7 (0.8)	1	.	.	.	.	.	.	.	.
- DECAPODA														
Brachyura, <i>Carcinus maenas</i>	.	.	1.3 (0.4)	3	1.3 (0.4)	4	.	.	.	.	.	.	.	.
Caridea, <i>Pandalus montagui</i>	.	.	.	.	.	.	1	1	.	.	.	.	.	.
- MYSIDIACEA														
Mysidiacea sp	.	.	1	1	1	1	.	.	.	.	1	1	.	.
POLYCHAETA														
<i>Hediste diversicolor</i>	.	.	1.7 (0.7)	3	1.7 (0.5)	6	.	.	.	.	.	.	.	.
DIPTERA														
Diptera, maggot	.	.	5.0 (1.1)	2	1.5 (0.5)	2	.	.	.	.	.	.	.	.
TELEOSTEI														
<i>Pomatoschistus minutus</i>	.	.	.	.	.	.	2	1	.	.	.	.	.	.
Empty stomachs		2		1		22		0		3		2		1
Total		2		13		39		2		3		3		1

C) Taxa and number of prey items with coefficient of variation (CV) found in fish caught at control stations outside Paull Holme Strays managed realignment site. n indicates the number of stomachs examined.

Prey Item	Paull Holmes CONTROL															
	<i>Platichthys flesus</i> Flounder		<i>Pleuronectes platessa</i> Plaice		<i>Ciliata mustela</i> Rockling		<i>Pollachius virens</i> Saithe		<i>Pomatoschistus minutus</i> Sand goby		<i>Dicentrarchus labrax</i> Seabass		<i>Osmerus eperlanus</i> Smelt		<i>Sprattus sprattus</i> Sprat	
	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n	mean (CV)	n
CRUSTACEA																
- AMPHIPODA																
Amphipoda sp	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Corophium volutator</i>	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
- DECAPODA																
Brachyura, <i>Carcinus maenas</i>	1.8 (1.0)	5	.	.	1	3	.	.	.	.	3	1	.	.	.	.
Caridea, Crangon sp.	3.3 (0.7)	6	.	.	5.8 (0.2)	4	3	1	2	1	.	.	1	1	.	.
Caridea, Crangon sp. >40mm	.	.	.	.	2	1	.	.	.	.	.	.	.	.	.	.
Caridea, <i>Pandalus montagui</i>	1	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
- MYSIDIACEA																
Mysidiacea sp	1	2	.	.	1	1	.	.	.	.	.	.	.	.	.	.
<i>Mysidopsis angusta</i>	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
MOLLUSCA																
Bivalvia, Abra sp.	11.2 (1.3)	18	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bivalvia, Cerastoderma sp.	22.7 (0.6)	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gastropoda, Hydrobia sp.	1.4 (0.6)	5	.	.	.	.	.	.	.	.	.	.	.	.	.	.
NEMATODA																
Nematoda sp	.	.	.	.	.	.	.	.	.	.	2.5 (0.3)	2	.	.	.	.
OLIGOCHAETA																
Oligochaeta sp	3.0 (0.9)	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.
POLYCHAETA																
<i>Hediste diversicolor</i>	4.5 (0.8)	18	.	.	.	.	.	.	.	.	10 (0.5)	3	.	.	.	.
DIPTERA																
Diptera, maggot	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.
TELEOSTEI																
<i>Pomatoschistus minutus</i>	4.5 (1.1)	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Empty stomachs		1		1		1		0		0		2		0		1

Total	71	1	10	1	1	8	1	1
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(D) Number of prey items with coefficient of variation (CV) found in fish caught inside Paull Holme Strays managed realignment site. n indicates the number of stomach examined.

[illegible]

Paul Holmes REALINGMENT															
	<i>Anguilla anguilla</i> Eel		<i>Platichthys flesus</i> Flounder		<i>Pleuronectes platessa</i> Plaice		<i>Ciliata mustela</i> Rockling		<i>Pollachius virens</i> Saithe		<i>Dicentrarchus labrax</i> Seabass		<i>Osmerus eperlanus</i> Smelt		<i>Merlangius merlangus</i> Whiting
POLYCHAETA															
Eteone sp.	.	.	2	1	1	1	.	.	.	.	.	.	.	.	.
<i>Hediste diversicolor</i>	11.0 (0.4)	3	6.7 (1.5)	79	2.8 (0.3)	6	2.0 (0.7)	5	.	.	.	.	.	.	1.8 (0.4) 6
DIPTERA															
Diptera, maggot	.	.	1.3 (0.4)	3	1	1	.	.	.	.	.	.	.	.	.
TELEOSTEI															
Un-id remains	.	.	1	3	.	.	.	.	.	.	.	.	.	.	.
<i>Pomatoschistus minutus</i>	.	.	1	3	.	.	2.0 (0.7)	2	.	.	.	.	.	.	1 2
Empty stomachs		3		19		2		0		0		8		1	4
Total		9		192		16		52		1		13		3	33