Estuarine, Coastal and Shelf Science 131 (2013) 1–5

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

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

Short communication

The value of wader foraging behaviour study to assess the success of restored intertidal areas

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ARTICLE INFO

Article history:
Received 5 March 2013
Accepted 16 July 2013
Available online 24 July 2013

Keywords:
Redshank
foraging behaviour
intertidal mudflat
habitat creation

ABSTRACT

The loss of intertidal habitat in estuaries has resulted in the need to create new habitats in order to protect waterbird populations. In order to examine the waterbird colonisation of restored intertidal areas created in 2003 through the realignment of the flood defence in the Humber Estuary (UK), the feeding behaviour of Redshank (*Tringa totanus*) was observed in April 2008. Numbers of pecks, probes and paces (numbers of steps) and the prey intake events were compared between Redshank foraging on the restored mudflat and on the adjacent established mudflat. Redshank prey intake and success rate (prey intake divided by the total numbers of pecks and probes) were significantly lower on the restored mudflat compared to the adjacent established mudflat. Conversely, the number of steps taken while foraging and the number of paces per successful feeding event were significantly greater on the restored mudflat. This shows that focal behaviour in restored intertidal areas can be directly compared with that in natural established mudflat in order to examine differences in foraging behaviour. The findings emphasise that a study of foraging behaviour should be incorporated into the assessment of restoration success of intertidal areas as an indication of habitat quality.

1. Introduction

Throughout Western Europe and elsewhere, managed realignment schemes (also referred to as depolderisation) are in place to enable the creation and restoration of habitats lost as the result of land claim, erosion and coastal squeeze (Elliott et al., 2007). Intertidal areas can be created by moving the flood defence inland, allowing estuaries to flood the previous terrestrial land (French, 2006). Long term ecological monitoring at several managed realignment sites has compared the colonisation by the benthic invertebrate communities of restored or created estuarine mudflats with the adjacent, established mudflats (Evans et al., 1998; Garbutt et al., 2006; Mazik et al., 2007, 2010; Marquiegui and Aguirrezabalaga, 2009). Similarly, several studies have assessed the success of new intertidal habitats for waterbirds (Simenstadt and Thom, 1996; Evans et al., 1998, 2001; Atkinson et al., 2001, 2004; Armitage et al., 2007; Mander et al., 2007), focussing on species richness and abundance. However, these parameters provide only limited structural ecological information when assessing the responses of birds to habitat restoration and creation in the intertidal zone; here we consider that functioning information is more valuable as a measure of successful restoration (Elliott et al., 2007). Lindell (2008) also argues that behavioural sampling in both restoration and reference sites will provide valuable information with which to assess the success of restoration efforts. Although the position realignment sites occupy in the tidal range means that areas of mud remain exposed for longer period and thus can provide supplemental feeding time to waders, if the realignment sites do not succeed in providing similar feeding conditions to the area lost, then bird fitness, demographic rates and population size will be affected. If the success of new intertidal habitats created through realignment sites is to be assessed effectively, an understanding of foraging behaviour of birds which prey upon benthic invertebrates is therefore essential. Despite this, the behaviour of waterbird species in restored or created wetland habitats has been little studied (Brusati et al., 2001; Armitage et al., 2007).

At Paull Holme Strays, one of four realignment sites in the Humber Estuary, UK, Redshank *Tringa totanus* has significantly increased in foraging numbers within the first three years of site development (Mander et al., 2007). Redshank are polytypic, with six sub-species described by Cramp and Simmons (1983) of which two occur in Europe. The nominate race, *T. totanus totanus*, occurs throughout north western Europe, with the UK population representing the north-western edge of this range. *T. totanus robusta*

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http://dx.doi.org/10.1016/j.ecss.2013.07.010

breeds in Iceland and the Faroe Islands and moves in winter to the UK as well as around the coasts of north-west Europe. As one of the most common wintering waders in north western European estuaries, Redshank detects its prey by sight, feeding on various prey by pecking or probing the mud and so their behaviour is easy to monitor as they search for food while walking over the intertidal area. There is an extensive literature on feeding behaviour of Redshank and its diet on intertidal areas (Goss-Custard, 1969, 1970, 1977a,b; Moreira, 1996), but little is known about the foraging behaviour of this species on a restored mudflat created as part of the realignment of the flood defence. This short note investigates the value of wader behaviour sampling at realignment sites to evaluate the success of restored intertidal areas. It tests the hypothesis that differences occur in the foraging behaviour of Redshank between a restored and an established mudflat up to five years after the restoration of the intertidal area.

2. Methods

2.1. Study area

The field work was carried at the Paull Holme Strays realignment site on the north bank of the Humber Estuary, UK, in April 2008 (Fig. 1). The Humber Estuary is an important wintering and stop-over site for several East Atlantic Flyway waders, supporting over 150,000 waterbirds in winter (Mander and Cutts, 2005; Calbrade et al., 2010). The Paull Holme Strays site (53°44′N, 0°16′W) is located within the middle section of the Humber Estuary about 10 km east of the city of Kingston-upon-Hull. Historically, the area within the realignment site was tidal marsh and mud, but over the past three centuries it was dyked, drained and converted into arable land. In 2003, a new earthen bank (dyke) was constructed at a distance of up to 500 m behind the existing defences. The existing defences were then breached in two places (north–west and south–east part of the site), in order to allow tidal inundation, accretion and subsequent development of new intertidal habitat. Since the site was breached, the topography, sediment characteristics, floral community and invertebrate assemblage have been rapidly changing in response to twice daily tidal inundation. Waders have rapidly colonised the realignment site, with foraging Redshank increasing from a monthly average of one individual in winter 2003/04 to 33 individuals in winter 2005/06 (Mander et al., 2007). Since the winter 2005/06 usage by foraging Redshank has continued to increase. In winter 2007/08, the monthly average peaked at 174 foraging Redshank (unpubl.data). Macro-infaunal sampling carried in September 2008 in the realignment site and outside on the established mudflat found the total invertebrate abundance to be highly variable but was higher in the established mudflat than inside the realignment whilst biomass did not differ significantly between the established mudflat and the realignment site (Mazik et al., 2010).

2.2. Observation methods

The foraging behaviour of Redshank was examined during daylight hours between 16th and 27th April 2008. At this time of the year, the return passage of Redshank to their breeding grounds leads to a peak count on the Humber, with numbers often greater than during the winter months (Allen et al., 2003; Mander and Cutts, 2005). A peak count of over 5000 birds was recorded on the Humber estuary in April 2004 during the 2003/04 Wetland Bird Survey (WeBS) low tide count (Mander and Cutts, 2005). A focal sampling approach, the systematic observation of just one individual, was followed by sampling individual Redshank. A total of 290 bird observations of randomly selected Redshank were carried out on the restored mudflat located in the realignment site and on an adjacent established mudflat (Fig. 1). The telescopic observations were carried out in daylight over a period of 6 h, starting either on a falling or a rising tide. Every hour up to four focal observations were carried out on individuals present in the restored mudflats and on the adjacent established mudflat. Each focal observation lasted for 1 min during which the numbers of pecks, probes in the substratum and successful intake of prey were recorded. Surface touch of more than half the bill length into the mud were categorised as probes, whist a touch on the mud surface was defined as a peck. The intake of prey was assumed to be successful when we observed either a

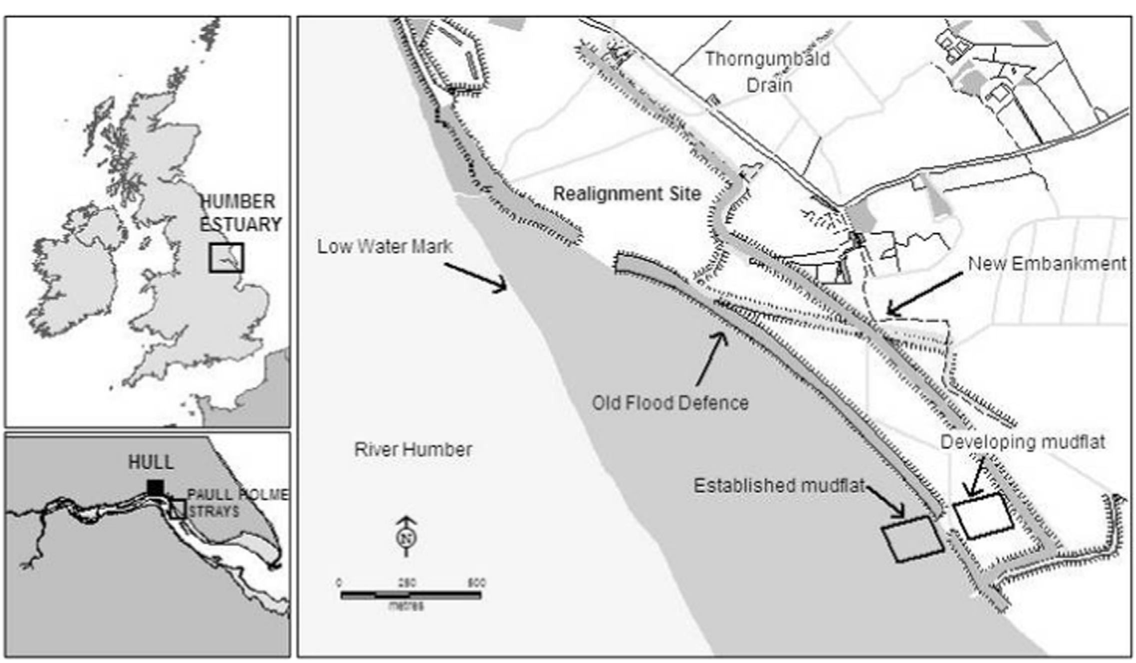

Fig. 1. Location of the Paull Holme Strays on the Humber Estuary and areas surveyed.

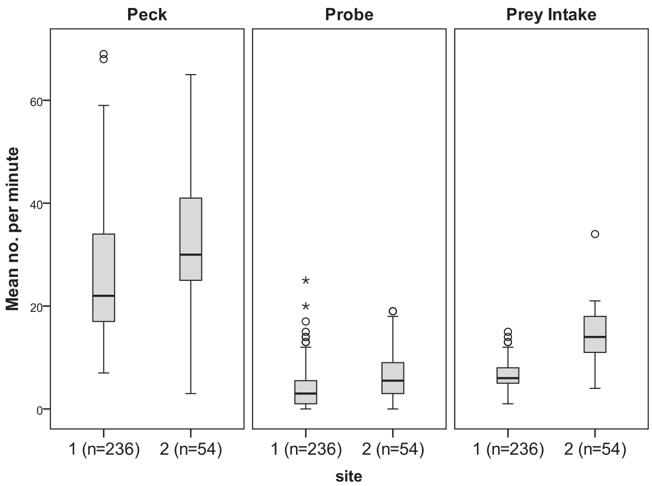

Fig. 2. Boxplot of number of peck, probe and prey intake observed on the restored mudflat (1) and on the adjacent established mudflat (2). Box plots represent the median values (horizontal line), interquartile distances (boxes), non-outlier range (whiskers), outliers (circles) and extreme values (asterisks).

prey being ingested or swallowing movements (Lourenço et al., 2005). In parallel, the movement of foraging Redshank was also examined by recording the number of paces taken by individuals during a one minute period. The observations were carried from a bird hide by a single observer positioned at a maximum distance of 50 m from the birds, by using a telescope (Kowa TSN 30x60) and a digital Dictaphone to record the behavioural data.

2.3. Data analysis

We analysed the difference in foraging behaviour between the restored mudflat within the realignment site and the established mudflat, adjacent to the realignment site. Due to non-normality in the data, non-parametric Mann–Whitney Tests were used to determine differences in numbers of pecks, probes and successful intake of prey between the two areas. Additionally, the success rate of Redshank was calculated (successful prey intake per total number of pecks and probes) and compared between the two areas using a Mann–Whitney Test. Finally, the numbers of paces taken during a one minute period and the number of paces per successful feeding event were compared and statistically tested for significance difference between the two areas.

3. Results

Redshank were observed to feed in loose flocks, walking rapidly over the feeding grounds, pecking on the sediment surface or, more rarely, probing into the mud. There were fewer focal observations made on the established mudflat ($n = 54$) compared to the realignment site ($n = 236$), as the birds often dispersed out of range on the large intertidal habitat. When foraging on the intertidal areas, Redshank showed a lower number of pecks and probes and fewer prey intakes on the restored mudflat located in the realignment site compared to the established mudflat (Fig. 2). The mean number of pecks was 26 min^{-1} (SE ± 0.84) on the restored mudflat ($n = 236$) and 32 min^{-1} (SE ± 1.68) on the adjacent established mudflat ($n = 54$) (Mann–Whitney U-test, $U = 4390$; $P = 0.0001$). In both areas, Redshank were observed to probe into the mud fewer times than they were pecking the surface, with means of 4 (SE ± 0.28) probes min^{-1} and 6 (SE ± 0.67) probes min^{-1} on the restored mudflat and on the adjacent mudflat respectively (Mann–Whitney U-test, $U = 4169$; $P = 0.0001$). Successful prey intake rate was significantly higher on the established mudflat, with a mean of 14 (SE ± 0.69) prey items ingested min^{-1} on the adjacent established mudflat compared to 7 min^{-1} (SE ± 0.17) on the restored mudflat (Mann–Whitney U-test, $U = 1178.50$; $P = 0.0001$). The success rate (total number of successful prey intakes divided by the total number of pecks and probes) was also lower in the realignment site (Table 1). Mean success rates of 25% (SE ± 0.74) and 38% (SE ± 1.58) were observed respectively on the restored mudflat within the realignment site and on the adjacent established mudflat (Table 1). Mean success rates varied over the tidal cycle and followed a similar trend in both the restored and adjacent established mudflats, peaking after high water as the sediments become exposed (Fig. 3). Foraging Redshank were observed to walk for longer periods in the realignment site when compared to the adjacent established mudflat, and this was reflected by the higher number of paces taken on the restored mudflat (Table 1). When analysed in relation to the successful prey intake, the number of paces per successful prey intake was greater on the restored mudflat (Table 1).

4. Discussion

Wader foraging rates (i.e. pecking and feeding success) respond to prey availability and activity, and both of these are influenced by a series of environmental variables. Kuwae (2007) found foraging attempts of Kentish Plover (*Charadrius alexandrinus*) (attempts/unit time) to be higher in areas of high prey abundance and at a higher temperature whilst feeding success was higher in areas of high prey abundance, at low temperature and with increasing time after emersion (Kuwae, 2007). Emersion and subsequent change in the sediment hardness can also affect foraging modes e.g. pecking and probing (Kuwae et al., 2010). Field studies of the foraging behaviour of Redshank report large variations in feeding success and pecking rates in intertidal areas. Moreira (1996) found a mean of 23.3 pecks min^{-1}on the Tagus Estuary, Portugal, between January and March whilst feeding rates on the Ythan estuary (north-east Scotland) ranged from ca.30 pecks min^{-1} to ca.100 pecks min^{-1} between October and May (Goss-Custard, 1969).

Feeding rate is also variable in Redshank and ranged considerably depending on the prey items. Goss-Custard (1969) working on the Ythan Estuary, found feeding rates of less than 20 prey min^{-1}

Table 1
Parameters of the Redshank feeding behaviour measured and calculated.

Parameters	Restored mudflat				Established mudflat				Mann–Whitney test (U)
	$N = 236$				$N = 54$				
	Mean	SE	Median	Interquartile range	Mean	SE	Median	Interquartile range	
Success rate (%)	25.32	±0.74	23.30	17.18	37.98	±1.58	36.54	12.70	2587.50*
Number of paces	75.33	±0.94	73.00	18	55.59	±1.72	55.50	16.00	1874.00*
Number of paces per successful feeding event	14.28	±0.77	11.18	7	4.56	±0.30	4.04	3.00	571.50*

* Comparison significant at $P = 0.0001$.

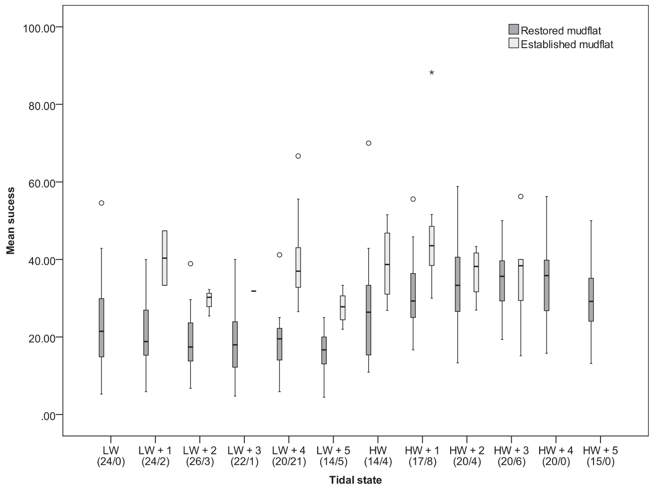

Fig. 3. Tidal variation of success rate observed on the restored mudflat and on the adjacent established mudflat. Box plots represent the median values (horizontal line), interquartile distances (boxes), non-outlier range (whiskers), outliers (circles) and extreme values (asterisks). Parenthesis on the *x*-axis contain the number of observations in each site (restored mudflat and established mudflat) at each tide.

when feeding on the mud snail *Hydrobia*, the bivalve *Macoma* and the polychaete *Nereis (now Hediste)* and up to 60 prey min^{-1} when feeding on *Corophium*. In our study, the feeding rate or prey intake was at the lower end of the range found by Goss-Custard (1969) and there was a significance difference between feeding rates on the established mudflat (14 prey min^{-1}) and the restored mudflat (7 prey min^{-1}). The pecking rates measured on the restored mudflat and on the established mudflat also showed significant difference. Hence, it is of note that Redshank feeding behaviour differed between the established mudflat and the restored mudflat in the realignment site.

The significantly higher number of steps taken by Redshank on the restored mudflat combined with a lower feeding success was also of note. The number of paces per successful feeding event also corroborated this result, showing that individual Redshank required a greater feeding effort (i.e. number of paces) per prey item ingested on the restored mudflat when compared to the neighbouring established mudflat. Typically, birds feeding in comparable conditions feed in similar ways.

The difference in feeding behaviour could be related to prey species composition and abundance in the intertidal areas where the focal observations took place. Redshank has a varied diet which is dominated mainly by the amphipod *Corophuim volutator*, the polychaete *Hediste diversicolor*, the bivalves *Macoma balthica and Scrobicularia plana* and the gastropod *Hydrobia ulvae* (Goss-Custard, 1969; Goss-Custard and Jones, 1976; Moreira, 1996). Samples taken in September 2008 at a single station in each area found the restored mudflat to be dominated by oligochaete worms (Enchytraeidae) whilst oligochaete worms (Enchytraeidae), nematodes, *H. diversicolor and H. ulvae* were predominantly found on the established mudflat (Mazik et al., 2009). It is of note that invertebrate sampling indicated a lower mean abundance (3057 individuals m^{-2}) and biomass (1.2 g m^{-2}) at the station located on the restored mudflat when compared to the station on the established mudflat (9427 individuals m^{-2} and 48.7 g m^{-2}) (Mazik et al., 2009). Environmental variables such as time from emersion, sediment penetrability and weather conditions (i.e. temperature and wind speed) will also affect the availability of prey to waders (Kuwae, 2007; Kuwae et al., 2010). Of these variables, time from emersion may explain the discrepancy in foraging behaviour between the two areas, as the restored mudflat position on the upper shore means that inundation of the intertidal areas is less frequent than on the adjacent established mudflat. Despite this, the fact that Redshank choose to feed in the restored mudflat over other established mudflats is an indication of the value of the site. It could be inferred that despite a lower reward in the restored mudflat probably due to lower prey availability and higher foraging constraints e.g. sediment penetrability, Redshank's choice to feed in the restored mudflat could be the result of reduced interference with other Redshank, as well the greater availability of larger prey in the restored mudflat (albeit in lower abundance). Biomass/abundance ratio, which indicates average biomass per individual, is higher in the restored mudflat when compared to established mudflat, suggesting that larger but few animals are found in the restored mudflat.

5. Limits and perspectives

The emphasis, when creating new mudflat as part of compensatory measures (Edwards and Winn, 2006), is to achieve set targets e.g. an increase in the ecological carrying capacity (Elliott et al., 2007) or the maximum number of birds an area can support over the winter which can be easily measured and compared to an area of mudflat lost. This study shows the value of a comparison of foraging behaviour between a restored and its adjacent established mudflat given that few studies have incorporated behavioural data into assessments of restoration success for waterbirds (Brusati et al., 2001; Armitage et al., 2007); this is despite the value of these studies to compare habitat quality (Lindell, 2008). Mudflats created as mitigation and compensation measures, for example for the loss of area by port developments in estuaries (Elliott et al., 2007), should be designed to provide the same quality and quantity of food supplies as the areas they are designated to replace, hence a measure of carrying capacity. Although this study was restricted to a small mudflat within the realignment site and over a limited period during daylight hours (April), and therefore might conceivably not be representative of the overall use of the realignment site, it highlights the value of focal foraging observations to examine differences between restored and established mudflats. Hence incorporating studies of foraging behaviour into assessments of restoration success should be considered as components of the evaluation of success and such a study could be applied to intertidal areas created or restored as part of mitigation measures. Indeed, foraging habitat quality is better indicated or assessed by focussing on foraging behaviour rather than conventional assessment indicators such as count data (e.g. bird density). It is, however, recommended to include a greater spatial and temporal coverage of the restored intertidal areas to fully assess the quality of the intertidal areas created, e.g. focal observations in other parts of the site, over the winter period and at night time. Additionally, dedicated macro-infaunal sampling could be conducted in combination with focal observations in order to investigate the bird–prey relationship and its influence on the feeding behaviour. Although of limited spatial and temporal coverage, the study suggests that the restored mudflat five years after its creation was yet to provide similar feeding conditions to that of the neighbouring established mudflat.

6. Conclusions

This study showed that foraging behaviour parameters such as prey intake rate and number of paces are valuable to determine the foraging behaviour of Redshank on intertidal areas and compare the species feeding effort on established and restored mudflats. A feeding behaviour study is thus of high importance to gain further knowledge on the ecological functioning of realignment sites when these schemes are created to offset for the loss of estuarine areas elsewhere. Our study demonstrates that even after five years the feeding conditions on a mudflat created as part of a managed realignment scheme differ from the adjacent established mudflat. Feeding behaviour data can be a valuable tool to assess the development of realignment site for waders, and thus complement the monitoring in place which investigates the rate of colonisation of restored mudflat created as part of managed realignment sites (Atkinson et al., 2004; Mander et al., 2007).

Acknowledgements

We would like to thank Dr Anita Franco, Dr Krysia Mazik and four anonymous referees for useful comments on an earlier version of this manuscript and Nick Cutts for useful discussion of the topics within this paper. Environment Agency are acknowledged for their support.

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