TITLE:- **Cliff top habitats provide important alternative feeding resources for wading birds of conservation importance wintering on non-estuarine coasts.**

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Abstract

Rocky shores and beaches are important over-wintering areas for non-estuarine waders but have rarely been studied. We examined cliff top habitat use by 6 species of wader over 75km of coast to assess their potential value as alternative feeding sites to rocky and sandy shores. Both the regional and local survey showed that waders occurred on golf courses and recreational grasslands in higher frequencies than expected but arable and pasture use was lower than expected. We also compared local wader densities on rocky and sandy shores, pastures, golf courses, caravan parks and recreational grasslands over two winters. Sanderling predominantly fed on the beach whereas Oystercatcher, Dunlin, Turnstone and Redshank numbers significantly increased on golf courses and recreational grasslands over the winter period, with pasture being rarely used. General linear models were used to relate environmental factors to the presence and absence of each species on the cliff top habitats. Redshank was the only species that showed a higher probability of occurrence on cliff top habitats at high tide whereas the probability of Turnstone, Oystercatcher and Redshank occurring increased as temperatures declined. Using core sampling, we determined that invertebrate richness and abundance was significantly higher on the recreational grasslands and golf courses than on the pasture or the beach. Our data demonstrated that cliff top habitats are important alternative feeding areas for over-wintering waders in areas where the intertidal is bounded by cliffs. Current management creates short sward, open field habitats with a diverse and abundant invertebrate food supply exploited by waders. Any alterations to the land use of these areas should be carefully considered by planning authorities in light of the fact that they support species that are of conservation concern.

1. Introduction

Waders are primarily dependent on wetland habitats and estuarine areas (Granadeiro et al. 2006) outside the breeding season, but will also use other intertidal areas (e.g. Summers et al. 2002). Situated along the East Atlantic Flyway, the British Isles are important stop-over and over-wintering sites with an estimated 1.3 million birds overwintering in 1984/1985 (Moser 1987; Moser and Summers 1987). Further evidence as to the importance of the British Isles comes from the 1997/1998 Non-estuarine Coastal Waterfowl Survey (NEWS)) which estimated that 30.9% of the European population of Oystercatchers (*Haematopus* *ostralegus*), 41.7% of Dunlin (*Calidris alpina*), 60.0% of Redshanks (*Tringa totanus*) and 52.7% of Turnstones (*Arenaria interpes*) over-wintered in Britain (Rehfisch et al. 2003). The status and population trends of 44 out of the 47 wader populations (93%) along the East Atlantic Flyway have been established and 37% of these are thought to be in decline (Stroud et al. 2006). For example, *Calidris alpina* accounted for approximately a third of the waders counted during the1984/1985 survey (Moser 1987) however a 50% population decline over the last 25 years has resulted in this species recently being red-listed in Britain (Eaton et al. 2009). The degradation and loss of coastal habitats has been suggested to be one of the main factors causing the decline in wader numbers (Clemens et al. 2010).

There are many studies examining the use of estuarine tidal flats by waders (e.g. Granadeiro et al. 2006; Spruzen et al. 2008; Clemens et al. 2010). Access to intertidal feeding areas is regulated by the tidal cycle and waders may use adjacent marshes and grasslands to roost or supplement food intake at high tide (Velasquez and Hockey 1992). Man-made environments can also act as alternative habitats for waders (Colwell 2010). Waders are known to roost and forage in salt pans/works and lagoons (Shuford et al. 1998; Masero and Perez-Hurtado 2001; Sripanomyom et al. 2011) as well as in rice fields (Elphick and Oring 1998; Maeda 2001; Taylor and Schultz 2008; Lourenço and Piersma 2009) both of which can be further managed for waterbird conservation (e.g. Fasola and Ruiz 1996; Elphick and Oring 2003; Lourenço and Piersma 2008)).

In the USA., agricultural coastal grasslands are used as foraging areas for non-breeding waders (Colwell and Dodd 1995, 1997). Long-billed Curlews (*Numenius americanus*) and Marbled Godwits (*Limosa fedoa*) fed on coastal agricultural fields at high tide (Long and Ralph 2001). However, in Virginia U.S.A., whilst Dunlin and Turnstones used fields at high tide, other species (e.g. Killdeer (*Charadrius vociferus*), American Golden

Plover (*Pluvialis dominica*) and Buff-breasted Sandpiper (*Tryngites subruficollis*)) fed on such grasslands irrespective of tidal stage (Rottenborn 1996).

Sward length is particularly important in determining grassland use by foraging waders. Short sward vegetation provides easier access to prey and a clearer view of approaching predators (Colwell and Dodd 1995; Milsom et al. 1998; Evans Ogden et al. 2008) and appropriate management of agricultural fields can improve their suitability. Evans Ogden et al. (2008) suggested that autumn mowing, planting a mosaic of crops and applying manure to fields were all positive correlates of wader abundance on agricultural fields. Low levels of disturbance and low field boundaries may also enhance site use (Milsom et al. 1998) and ideally fields managed for waders should be within 0.5 km of the sea.

The UK has an estimated 17,381 km of coastline of which 42% is classified as hard rock substrate (Jackson and McIlvenny 2011). However, studies on wader use of non-estuarine habitats are few (Lourenço et al. 2013; Summers et al. 2002) despite important numbers over-wintering on the coast (Burton et al. 2008). In addition, they are major predators on rocky shores (Lourenço et al. 2013). Waders foraging on intertidal areas of the Orkney Islands tended to avoid steep shores and cliffs (Summers et al. 2002) and the different species showed a preference for foraging on particular substrates (e.g. Sanderling *Calidris alba* preferred sand, Turnstones rock and gravel and Purple Sandpipers *Calidris maritima* rocky substrates). From a longer term perspective, there is also concern about the loss of intertidal habitats due to ‘coastal squeeze’ (Jackson and McIlvenny 2011) and changes in intertidal invertebrate abundance due to climate change (Kendall et al. 2004). Whilst waders do use coastal fields to supplement intertidal feeding in estuarine areas (Moser and Summers 1987), little data exists for non-estuarine areas or where the intertidal is backed by cliffs.

Managed grasslands in the form of caravan parks, golf courses, and general recreational grasslands are created to support coastal tourism. These man-made habitats may provide cliff top feeding sites for waders when intertidal areas are inaccessible. As some wader species show high over-wintering site fidelity (Catry et al. 2004) we need to determine if these habitats are important in order to manage them effectively for both wildlife and recreation.

The current study aimed to assess the potential value of cliff top habitats as feeding sites for waders in non-estuarine areas. We studied the 6 commonest coastal over-wintering waders present in the region including Eurasian Oystercatcher (*Haematopus ostralegus),* Redshank (*Tringa totanus*), Dunlin (*Calidris alpina*), Red Knot (*Calidris canutus*), Turnstone (*Arenaria interpres*) and Sanderling (*Calidris alba*). Other species, such as Grey Plover *Pluvialis squatarola*, Ringed Plover (*Charadrius morinellus*), Bar-tailed Godwit (*Limosa lapponica*) and Eurasian Curlew (*Numenius arquata*) occurred infrequently, whereas Purple Sandpipers (*Calidris maritima*) exclusively foraged on the rocky shore and are not considered further.

We specifically aimed to address the following questions 1) Do foraging waders in the region use different cliff top habitats with equal frequency and is this independent of tidal stage? 2) Does the number of foraging waders vary significantly between cliff top and intertidal habitats, and is there any evidence of shifts in habitat use over time? 3) Are there any environmental factors that significantly influence the probability of occurrence of waders on cliff top habitats? 4) Do cliff top habitats have a higher invertebrate abundance and diversity than sandy shore areas?

2. **Materials and methods**

2.1 Site Description

The regional between Bridlington (latitude 54.07721°, longitude -0.18386°) and Sandsend (latitude 54.4909°, longitude -0.641937°; Fig 1) is typified by rocky platforms and sandy beaches backed by cliffs >30m in height. Arable land use predominates on the cliff tops punctuated by holiday parks, recreational grasslands, coastal towns and occasional grazing pasture. We selected 5 cliff top habitats for the regional study of wader habitat use including golf courses, caravan parks, recreational grasslands, arable fields and grazing pastures. Only 5 cliff top golf courses occur across the region, so we selected representative areas of the other 4 habitats as close as possible to these that had an open aspect adjacent to the cliff edge and were between 5-6ha^{-1} in area (25 sites in total).

To determine if the waders showed significant differences in habitat use over the winter period, Filey Bay, U.K. (latitude 54.21349°, longitude -0.29169°; Fig 1) was selected as a site for detailed observations. The site is a 1km^{2} area containing the 5 cliff top habitats used in the regional survey, and sandy/rocky intertidal areas. Our sampling design contained a 6.7ha^{-1} arable stubble field (AF) plot but this was excluded from further analysis waders never used that site. The remaining 6 plots included SS, a dynamic sandy shore plot of medium grained sand (area = 9 ha^{-1}at low tide) adjacent to a moderately sheltered complex barnacle–fucoid–mussel mosaic rocky shore (RS) (area = 9ha^{-1} at low tide). Both intertidal plots were bounded by cliffs and at high tide there was very little supra-littoral habitat remaining at sea level, merely small rocky outcrops used as roosting sites. The PA plot was a 7ha^{-1} cliff top pasture grazed by cattle during the summer months (mean sward length = 9.6 cm (SE ±1.2)). The local authority (Scarborough Borough Council (SBC)) manage a cliff top 6ha^{-1} pitch and put golf course (GC) and a 5ha^{-1} open access recreational grassland (RG) both regularly mown throughout the year to maintain a short sward length (mean = 4.3cm, SE

±0.4). The final plot was a 4ha^{-1} touring caravan site (CP) constantly managed to maintain a very short sward (mean = 3.1cm, SE ±0.1) throughout the year.

2.2 Wader use of regional cliff top habitats

To determine which cliff top habitats were used most frequently by waders across the region, and whether this was dependent on tidal stage, the 25 designated regional sites were visited four times each month (twice at high and twice at low tide) between November-March (500 site visits). On each visit, observers scanned the site from designated observation points and recorded the presence/absence of each species.

2.3 Local surveys of cliff top habitat use over time

A sampling method derived from the standard 'Low Tide Counts' method used by the British Trust for Ornithology (BTO) for the national Wetland Bird Survey scheme (WeBS) (Austin et al. 2007) was used to study local habitat use. Wader scan counts were conducted over two winters between October and March 2007-2008 and 2008-2009. The number of feeding waders on each plot was recorded during daylight hours using 10x40 binoculars and a tripod mounted 20x scope; preliminary nocturnal surveys failed to locate any waders feeding or roosting on the cliff tops. Four scan counts were made at high (1hr either side of high tide), low (1hr either side of low), rising (flooding tide within 2hrs of high) and falling (ebbing tide within 2hrs of low) each month to examine the effect of tidal stage on habitat use (Leeman and Colwell 2005). All plots were surveyed within an hour and the rainfall (mm. day^{-1}), air temperature (°C) and wind speed (km hr^{-1}) were recorded 30 minutes prior to each count. A total of 968 scan counts were made over the two year period.

2.4 Invertebrate abundance and diversity in sedimentary habitats

To quantify prey availability in sedimentary habitats, sediment cores were taken in early December (late autumn) and at the beginning of March (late winter) from SS, RG, GC and PA during the second year of study (permission from the landowners was not granted to sample AF and CP). We systematically sampled 20 cores across each cliff top habitat plot and across the low shore of SS at low tide. A core of 11.5cm diameter was pushed 10 cm into the substrate (Sherfy et al. 2000) then covered to retain invertebrates present on the surface. The depressions left by core removal were immediately in-filled and the extracted cores frozen at -20°C within 1hr of collection. After thawing, the sediment was sieved through a 500μm sieve and the invertebrates preserved in 70% ethanol before identification to class/order (Tilling 1987). The abundance was converted to number m^{-2} prior to analysis (as in Taft and Haig 2006).

2.5 Data analysis

We collated the number of times each wader occurred in each cliff top habitat for both the regional and local survey. This was done separately for both high and low tide. We then tested the null hypothesis that waders occurred in each habitat with equal frequency using a Chi-squared test for homogeneity and compared regional and local frequency of occurrence in each habitat using Chi-squared tests for association (Fowler et al., 1998).

The over-wintering local wader counts were converted to number ha^{-1} prior to analysis and two-way ANOVA was used to determine if there were significant differences in wader abundance between the fixed factors plot and month. ANOVA is considered to be robust to non-normality and small violations of the assumption of equal variances in the case of a large number of replicates (Underwood 1997), however the significance level was set at $\alpha=0.01$ to lower the Type I error rate. The Tukey HSD test was used as a *post-hoc* test to determine the sources of the significant difference between groups (Underwood, 1997).

The local wader count data was converted into presence/absence data. Binary logistic regression models were then used to determine the effect of environmental predictor variables (tidal stage, rainfall, wind speed, temperature) on the probability of occurrence of each wader species on the cliff top habitats (PA, RG, CP and GC). Using presence/absence data avoided the problems associated with non-independence of plot use by individuals as waders are social foragers (Whittingham and Devereux 2008). The data was screened for outliers using Cleveland dotplots and examined for collinearity using a multi-panel scatterplot (Zuur et al. 2010). All environmental variables were retained for analysis as variance inflation factor (VIF) values were all < 3 and there was no evidence of excessive collinearity (Zuur et al. 2009). There was no evidence of lack of fit to the binary regression model as determined by Pearson Chi-squared goodness of fit tests ($p > 0.05$ for all models). The significance of each predictor variable was determined by analysis of deviance, in which a nested model is created by removing a single predictor and the significance of the predictor estimated from the difference in deviance (ΔD) between the nested and full models using a χ^2 distribution to determine the significance (Zuur et al. 2009).

Total invertebrate abundance (N), taxon richness (S) and Shannon Wiener diversity (H') were calculated. The data did not meet the assumptions of normality (Kolmogorov-Smirnov test, $P < 0.05$ in all cases), however all variances could be considered homogeneous (Levene's test, $P > 0.05$ in all cases). For the reasons justified above, ANOVA models were used to determine if there were significant differences in invertebrate H', S and N between selected plots (SS, RG, GC and PA) and season (autumn and winter) with *post-hoc* Tukey HSD tests to determine the sources of the significant difference between means. All data analysis was conducted using the R software package version 2.15.0 (R Development Core Team 2012).

3. Results

3.1 Regional wader presence/absence on cliff top habitats.

The results of the high tide regional survey indicated that Oystercatcher, Redshank, Dunlin, Knot and Turnstone occurred more frequently on recreational grasslands and golf courses and less frequently on arable and grazing pasture than expected (Chi-Squared, $p < 0.001$ in all cases; Fig.2a). Dunlin, Turnstone and Knot were never observed feeding on the arable or pasture fields even at high tide. Oystercatchers and Redshanks also fed on feeding on cliff top habitats at low tide (Fig. 2b) and both species occurred more frequently on the recreational grasslands and less frequently on arable and grazing pasture than expected (Chi-Squared $p < 0.001$ in both cases; Fig.2b). Sanderling were never observed on the cliff top habitats during the regional survey.

3.2 Local scale plot use over time and factors affecting cliff top habitat use

The percentage occurrence of each wader on each plot is presented in Fig. 3. The local presence/absence data for each species on each plot was compared to that obtained from the regional surveys. For all species, there was no significant association between habitat and scale of survey indicating that the waders occurred in similar frequencies on each habitat at both local and regional scales (Chi-squared, $p > 0.05$). Locally, waders rarely occurred on the pasture (PA) and Oystercatcher, Dunlin, Turnstone and Redshank had a similar percentage occurrence on the GC plot to that on the intertidal sites (RS and SS). Knot had the highest occurrence on RS and Sanderling on SS (Fig. 3).

For all 6 wader species, there was a significant difference in numbers ha^{-1} between the plots (ANOVA, $p < 0.0001$ in all cases; Table 1; Fig.4). Mean Oystercatcher, Redshank and Knot ha^{-1} were all significantly lower on PA than other plots; Sanderling, Dunlin and Turnstone were absent (Table 1). Both numbers of Sanderling ha^{-1} and Knot ha^{-1} were significantly greater on the intertidal plots (Sanderling on the SS and Knot on the RS plot; Table 1; TukeyHSD, $p < 0.05$; Fig.4) however the other species had significantly greater numbers ha^{-1} on the GC plot (Table 1; TukeyHSD, $p < 0.05$; Fig. 4). Knot numbers ha^{-1} were significantly higher in February (mean = 0.54, SE ± 0.11) than in November (mean = 0.08, SE ± 0.03; Table 1; Fig. 4), but all other species showed no significant difference between months (ANOVA, $p > 0.05$; Table 1). Whilst there was no significant interaction between month and plot for both Sanderling and Knot (ANOVA $p > 0.05$; Table 1), the interaction was significant for all other species (ANOVA, $p < 0.001$; Table 1; Fig.4). The numbers ha^{-1} of Dunlin, Oystercatchers and Turnstones were all significantly higher on the RS plot during October but between December – February were significantly higher on GC (ANOVA, $p < 0.001$ in all cases; Fig.4). Redshank ha^{-1} was significantly higher on GC than all other plots between December - February (Tukey HSD, $p < 0.05$; Fig.4).

Binary logistic regression models of wader presence/absence indicated that high tide had a significant positive effect on the probability of Redshank feeding on the cliff top habitats (estimate = 0.615) but not for any other species. For Oystercatcher (estimate = -0.075), Redshank (estimate = -0.078) and Turnstone (estimate= -0.073) decreasing temperature increased the probability of occurrence on cliff top habitats (Table 2).

3.3 Invertebrate abundance, richness and diversity

Overall, 11 invertebrate taxa were identified from sediment cores (Table 3). Three of the taxa (Dermaptera and Neuroptera larvae, Thysanoptera) were only found on GC, Pulmonata only occurred at PA and Nephtyidae was the only taxon found in the SS samples (Table 3). The other taxa were more widely distributed across the cliff top habitats, albeit in varying abundance (Table 3). There were no significant differences in mean taxon richness (S) and Shannon Wiener H' between season nor any significant interaction between season and plot (ANOVA, $p > 0.05$ in all cases). However, mean N, S and H' were all significantly different between plots (Table 3, ANOVA, $p < 0.0001$ in all cases). Pairwise comparisons showed that all plots were significantly different in terms of average richness (S) (in order of magnitude GC > RG > PA > SS; Table 3) and GC had significantly higher mean N and H' than the other plots (remaining plots in order of magnitude RG > PA = SS; Table 3; Tukey HSD, $p < 0.05$). Average total abundance m^{-2} (N) was significantly higher in late autumn than in late winter (Table 3; Tukey HSD, $p < 0.05$).

4. Discussion

Our results show that waders used cliff top habitats for feeding over 75km of coastline. Five out of the 6 species studied occurred on golf courses, caravan parks and recreational grasslands in higher frequencies than expected at high tide (Fig.2a). Oystercatchers (Goss-Custard et al. 1996), Dunlin (Rottenborn 1996; Evans Ogden et al. 2005) and Turnstone (Smart & Gill 2003) have been shown to use fields adjacent to estuaries to supplement feeding at high tide, and alongside these species Knot and Redshank fed on cliff top habitats in the current study (Fig.2, 3). Sanderling and Purple sandpiper were absent from the cliff top habitats during the regional survey, with Sanderling occurred in the highest numbers in the SS plot during the local study (Fig. 4). Both species are regarded as intertidal specialists, with Sanderling foraging predominantly on sand and Purple sandpipers on rocky substrates (Summers et al. 2002).

Studies in the USA have demonstrated that pasture and arable fields are important alternative feeding areas at high tide (e.g. Evans Ogden et al. 2008), in contrast to this Dunlin and Turnstone did not use these habitats (Fig. 2, 3) and Oystercatchers, Redshanks and Knot used them infrequently (Fig. 2, 3). Waders have been shown to avoid fields with long vegetation that may hinder predator detection (Evans Ogden et al. 2008) or create difficulties in locating prey (Mouritsen 1994). Despite the cliff top location, the pasture and arable habitats were rarely used by waders on both the local and regional scale, however short sward grasslands were used frequently.

Local Dunlin, Redshank, Oystercatcher and Turnstone numbers ha^{-1} were all significantly higher on the golf course during December – February inclusive than on other plots (Table 1) and this may be a consequence of reduced access to intertidal resources. When short day-lengths and/or neap tides reduce access to visible intertidal prey, estuarine Oystercatchers used fields at high tide (Goss-Custard et al. 1996). However, apart from for Redshank, tidal stage was not a significant predictor of wader occurrence on cliff top habitats (Table 2). Estuarine waders also moved onto fields when intertidal resources became depleted or over-exploited (Smart and Gill, 2003) or because of anthropogenic disturbance (Dias et al. 2008). Disturbance has also been highlighted as a key factor in influencing the abundance of waders on rocky shores in Portugal (Lourenço et al. 2013) however this was not measured in the current study. In addition, individual Oystercatchers may escape the high levels of intraspecific competition often seen on intertidal mussel patches (Caldow et al. 1999) by foraging on cliff top habitats. Feeding on smaller buried prey reduces the opportunities for kleptoparasitism and may lead to higher intake rates (Stillman et al. 2002).

The probability of Turnstone, Oystercatchers and Redshanks foraging on the cliff top habitats increased as temperature declined suggesting that birds were attempting to maximise intake rates during cold weather (Table 2). Small waders have higher rates of heat loss and may need to feed for longer periods of time, especially during periods of cold or wind chill (Evans 1976; Kelly et al. 2002). Stable isotope analysis revealed that Dunlin increased their intake from grasslands during periods of high rainfall or cold (Evans Ogden et al. 2005) and the authors suggested this reduced starvation mortality in severe weather. Even large waders such as Oystercatchers and Redshanks can suffer increased mortality rates from starvation during severe weather (Davidson and Evans 1982) and feeding on adjacent cliff tops may create a buffer against starvation (Evans Ogden et al. 2005). In the current study, 4 out of 6 waders fed on the grasslands irrespective of tidal state and this may reflect a switch between the intertidal and supra-tidal cliff top areas to maximise feeding rates.

Whilst the invertebrate prey densities in the short sward cliff top habitats were similar to those observed in wet agricultural areas in the USA (Taft & Haig 2006), those on SS were markedly lower than observed in local estuaries (e.g. Mander et al. 2013) or in previous studies on exposed sandy beaches (e.g. Hubbard & Duggan 2003). Many of the infaunal invertebrates usually preyed upon by waders (e.g. *Arenicola, Nereis, Macoma, Cerastoderma* (Colwell 2011; Mander et al. 2013) were absent. Large burrowing annelids such as *Arenicola* and *Nereis* require relatively stable sediments to form deep burrows (Evans 1987), however the beach at SS shows marked periods of erosion and accretion, and during the last 4 years 0.75m of sediment loss has occurred in the low shore (North Sea Coastal Observatory 2013). Feeding on the SS site was periodically enhanced by macrophyte wrack deposition which contained additional prey items for waders (Dugan et al. 2003). The RS plot contained a variety of biotopes including algal turf, mussel and barnacle patches, cobble fields, boulders and fucoid algal beds and, whilst not quantified here, intertidal invertebrates are abundant in various biotopes on the site (S.L. Hull unpublished data). Turnstones are regarded as specialist rocky shore feeders predating upon invertebrates on algae (Kendall et al. 2004) whereas limpets (Kendall et al. 2004) and mussels (Caldow et al. 1999) are favoured by Oystercatchers. Dunlin and Sanderling are ‘tidal followers ’and will prey upon invertebrates disturbed by wave action at the edge of the tide (Granadeiro et al. 2006) on both the rocky and sandy shore. However, despite the abundant prey and accessibility of this plot at low tide waders were still observed feeding on the cliff top habitats.

Annelids are an important dietary constituent for many wader species (Colwell 2010) and the RG and GC habitats had the highest oligochaete abundance; a factor of ten greater than that seen on PA (Table 3). Total invertebrate richness and diversity was also higher on GC and RG than at other sites (Table 3) and many prey items were just below the grass surface accessible to waders with short bills such as Turnstone and Dunlin (Mouritsen 1994; Barbosa 1995). Waders with a longer bills such as Oystercatchers (mean bill length 7.5 cm (Goss-Custard et al. 1987)) could access the annelids deeper in burrows. By selecting prey from different sediment depths (Lifjeld 1984; Davies and Smith 2001) or of different sizes, inter-specific competition is reduced by partitioning the resources available. Invertebrate total abundance was significantly lower in late winter and this may be the result of invertebrates burrowing deeper during periods of cold (Taft and Haig 2006) or could indicate a depletion of resources by foraging birds.

5. Conclusions

The current study has shown that small populations of non-estuarine over-wintering waders will use cliff top habitats on regional scale to supplement their food intake. Golf course and recreational grassland had a significantly higher invertebrate diversity and abundance than pasture, and provided a range of prey items that could be exploited by a variety of species. Our data suggest that the current management practice of regionally maintaining short sward grasslands on cliff edges adjacent to the intertidal is beneficial to small populations of waders. Such habitats may become more important especially if climate change results in 'coastal squeeze' (Jackson and McIlvenny 2011) or intertidal invertebrate abundance declines (Kendall et al. 2004). Planning authorities need to be made aware of the importance of these areas and regional land use changes should be carefully considered, as the current study has shown that they provide additional resources for small populations of waders many of which are in decline and are of conservation concern.

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Table 1. Summary of results of two-way ANOVA conducted on number of waders ha^{-1} for each species with Month and Plot as factors, the F values from the models and the mean counts (SE) on each plot (ns=not significant, *p <=0.01, **p <=0.001, ***p <0.0001).

	Plot	Month	Plot*Month	SS	RS	GC	PA	RG	CP
Oystercatcher	18.4***	1.4ns	3.2***	1.75 (0.18)	1.37 (0.15)	4.67 (0.47)	0.26 (0.07)	2.21 (0.32)	2.89 (0.43)
Redshank	16.7***	1.8ns	2.5***	0.28 (0.04)	0.07 (0.03)	0.99 (0.14)	0.01 (0.01)	0.22 (0.06)	0.29 (0.08)
Dunlin	13.2***	1.8ns	1.9**	0.57 (0.13)	0.13 (0.04)	1.91 (0.38)	0	0.58 (0.14)	0.15 (0.09)
Turnstone	12.8***	1.2ns	3.7***	0.29 (0.05)	0.02 (0.01)	0.04 (0.02)	0	0.02 (0.02)	0.05 (0.03)
Knot	11.7***	4.6***	1.4ns	0.25 (0.08)	0.91 (0.13)	0.41 (0.11)	0.01 (0.0)	0.18 (0.06)	0.01 (0.01)
Sanderling	10.2***	1.9ns	1.8ns	0.29 (0.05)	0.01 (0.01)	0.04 (0.03)	0	0.02 (0.02)	0.05 (0.03)

Table 2. Binary logistic regression analysis for the presence/absence of each wader species on cliff top habitats surveyed over two winters. Results of the Likelihood Ratio Chi-square tests from the analysis of deviance for each predictor variable in the model are presented (significant tests shown in bold; ns=not significant, *p <=0.05, **p <=0.01, ***p <0.001 in the text).

Parameter	Oystercatcher	Redshank	Dunlin	Turnstone	Knot
AIC full model	660.9	518.6	409.4	508.6	222.6
TIDE STAGE	5.02ns	**9.82****	6.2ns	4.2ns	1.90ns
WIND SPEED (range 0.1 – 30 km hr^{-1})	0.87ns	0.06ns	1.81ns	0.03ns	0.07ns
TEMPERATURE (range -3 - 12°C)	**6.89****	**5.62***	3.27ns	**4.62***	0.24ns
RAINFALL (range 0-15 mm day^{-1})	0.87ns	0.14ns	0.15ns	0.53ns	2.04ns

Table 3. Mean (SE) invertebrate taxon abundance and H’, S and N for both plot and season during the second year of the study (plot abbreviations as in text).

	Late Autumn	Late Winter	GC	RG	PA	SS
Nematoda	53.8 (18.8)	95.0 (18.2)	85.0 (49.1)	157.5 (44.0)	55.0 (13.8)	0
Gastropoda	0	1.25 (1.25)	0	0	2.50 (2.50)	0
Dipteran larvae	0	2.50 (1.76)	2.50 (2.50)	0	2.50 (2.50)	0
Oligochaeta	291.3 (51.6)	120.0 (27.9)	430.0 (65.8)	365.0 (79.6)	27.5 (12.9)	0
Coleoptera larvae	38.8 (10.7)	61.3 (17.00)	125.0 (31.0)	67.5 (20.4)	7.50 (4.22)	0
Coleoptera pupae	12.5 (4.49)	28.8 (9.10)	57.5 (13.8)	25.0 (13.3)	0	0
Columbella	2.50 (1.76)	5.0 (3.94)	10.0 (7.84)	5.0 (3.49)	0	0
Nephtyidae	1.25 (1.25)	0	0	0	0	2.50 (2.50)
Neuroptera larvae	1.25 (1.25)	1.25 (1.25)	5.0 (3.49)	0	0	0
Dermaptera nymph	0	1.25 (1.25)	2.50 (2.50)	0	0	0
Thysanoptera	1.25 (1.25)	1.25 (1.25)	2.50 (2.5)	0	0	0
Total Abundance (N) m^{-2}	698 (115)	445.0 (79.2)	1160 (149)	995 (175)	125.0 (27.4)	5.00 (5.00)
Taxon Richness (S)	1.613 (0.18)	1.638 (0.18)	3.350 (0.22)	2.325 (0.20)	0.775 (0.14)	0.05 (0.05)
Shannon Wiener (H’)	0.487 (0.056)	0.455 (0.064)	1.028(0.071)	0.678 (0.071)	0.162 (0.049)	0.017 (0.017)

Figure legends.

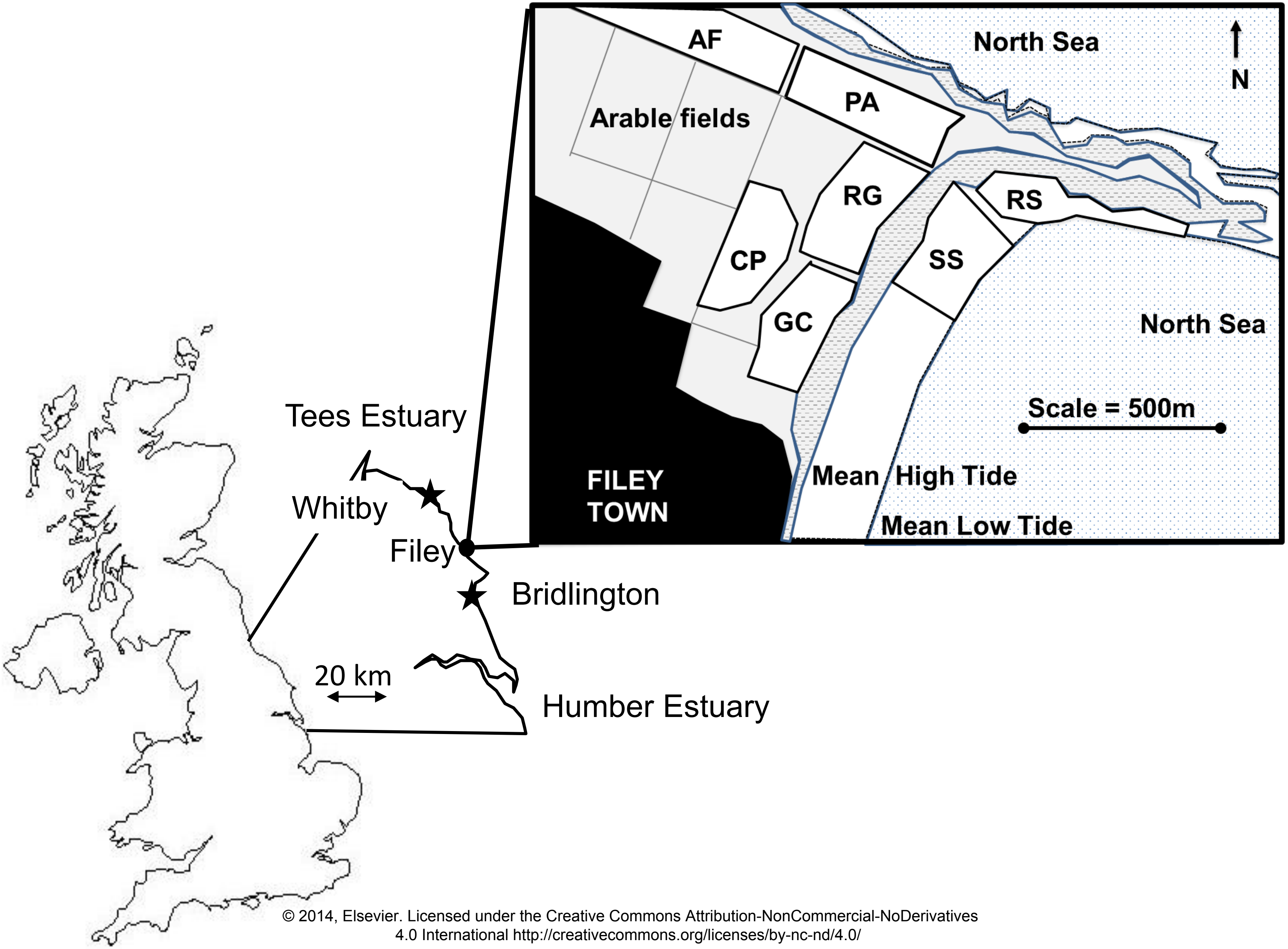
Fig. 1. Map showing the regional study area on the north east coast of England. The Filey study sites are indicated as, beach (SS), rocky shore (RS), pasture (PA), golf course (GC), caravan park (CP) and recreational grassland (RG).

Fig.2 Percentage occurrence of each wader species on the different cliff top habitats at a regional scale at different tidal stages a) high tide and b) low tide.

Fig.3. Percentage occurrence of the presence of each wader species on the different cliff top habitat types at the main study site.

Fig.4. Mean (± SE) wader's ha^{-1} for each species showing changes in plot use over months.

Figure(s)


AF
PA
Arable fields
RG
RS
CP
SS
GC
North Sea
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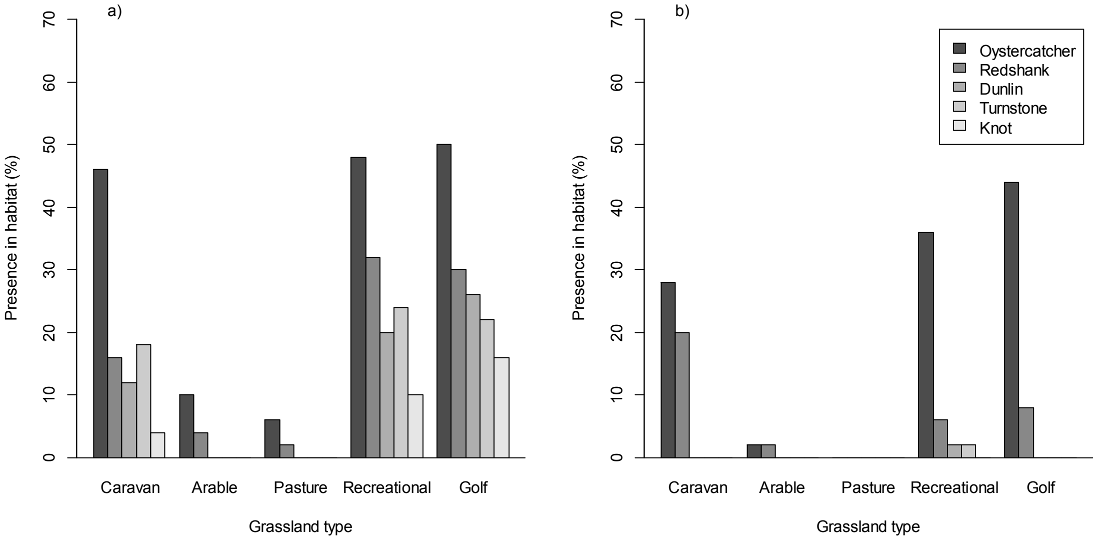
North Sea
Scale = 500m
FILEY TOWN
Mean High Tide
Mean Low Tide
Tees Estuary
Whitby
Filey
Bridlington
20 km
Humber Estuary

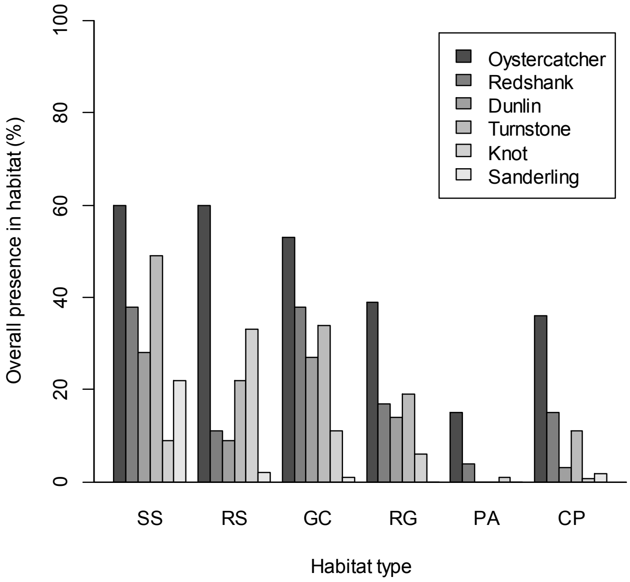
Figure(s)

Fig. 2

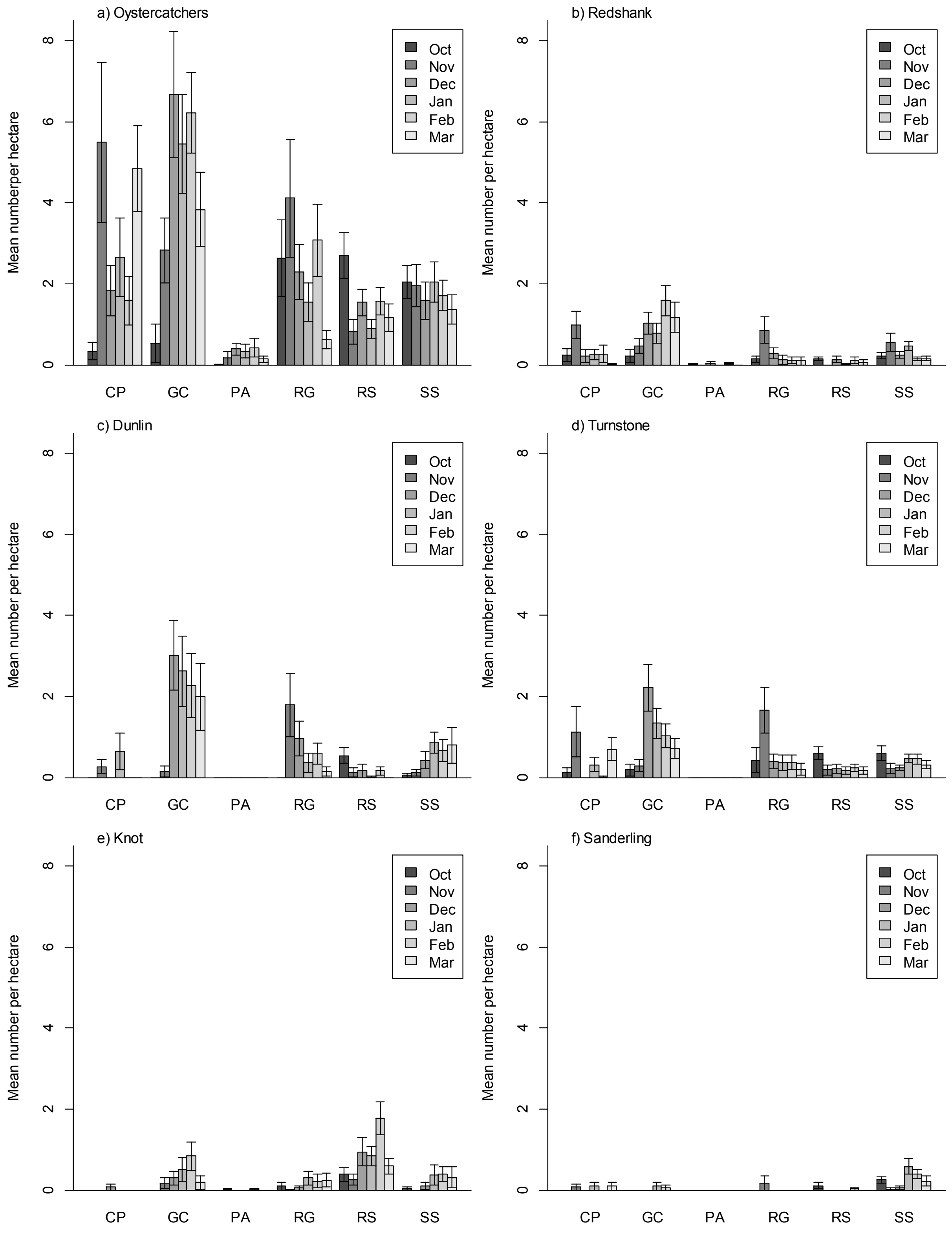


Figure(s)

Fig. 3



Figure(s)


a) Oystercatchers
b) Redshank
c) Dunlin
d) Turnstone
e) Knot
f) Sanderling
Mean numberper hectare
Mean number per hectare
0
2
4
6
8
Oct
Nov
Dec
Jan
Feb
Mar
CP
GC
PA
RG
RS
SS

HIGHLIGHTS

- Over 75 km of rocky coastline, Oystercatchers, Redshanks, Dunlin, Knot and Turnstones fed on cliff top golf courses or recreational fields rather than arable or grazing pasture.
- The abundance of foraging individuals of these species increased between December – February compared to that at other sites.
- The probability of Turnstone, Oystercatcher and Redshank feeding on cliff top habitats increased as temperatures declined.
- Sediment samples revealed that the richness and abundance of invertebrate taxa was significantly higher in the recreational grasslands and golf courses than pasture or the beach.
- Our data suggest that cliff top habitats are important alternative feeding areas for waders on rocky and sandy shores and any alterations to the land use of these areas should be carefully considered by planning authorities as they support species that are of conservation concern.