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Spatial diversity in canopy height at Redshank and Oystercatcher nest-sites in relation to livestock grazing

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In this study we examined the effect of different livestock grazing treatments on breeding bird densities in a salt marsh habitat. To avoid an experiment on the large scale needed to directly measure grazing effects on bird densities, we followed a two-step approach. First, we measured vegetation micro-patterns (mosaic of lower vegetation and taller patches at 4×4 m) around Common Redshank *Tringa totanus* and Eurasian Oystercatcher *Haematopus ostralegus* nests and at random sites paired with these nests sites to judge suitability of micro-patterns for nest building. Secondly, we measured micro-patterns at 120 permanent plots in five different experimental grazing treatments to determine how grazing affects micro-patterns. We compared low stocking density of both cattle and of horses, high stocking density of cattle and of horses, and intermittent grazing with a high stocking density of cattle (i.e. yearly intervals of grazing and no grazing). Redshank and Oystercatcher nests occurred in sites with taller vegetation and more pronounced micro-patterns than found at random sites. Paddocks grazed with low densities of livestock or with a high density intermittent grazing treatment had micro-patterns preferred by the birds. We conclude that Redshanks and Oystercatchers may benefit in terms of potential nest sites from grazing at low livestock densities or at intermittent stocking densities through effects of grazing on micro-patterns in the vegetation.

Key words: biodiversity, cattle grazing, horse grazing, patchiness, salt marsh, spatial heterogeneity, vegetation structure, waders

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Salt marshes along the Wadden Sea have a long history of livestock grazing (Bakker *et al.* 1993). However, in recent decades the grazing of salt marshes in NW-Europe was no longer economically feasible (Bakker *et al.* 1993). Therefore, many marshes were abandoned leading to tall homogeneous vegetation (Bakker *et al.* 1993, Esselink 2000, Esselink *et al.* 2002, Sammul *et al.* 2012). Yet, during the same period, grazing has become a common management tool in nature conservation (Ebrahimi *et al.* 2010) and is used as a management tool on salt marshes along the Wadden Sea coast. Grazing with high stocking densities generally leads to a homogenous short vegetation (Bakker 1989), while a moderate grazing regime leads to a higher plant diversity (Bakker 1993).

The importance of spatial variation in canopy height for ground-breeding birds is well established. Norris *et al.* (1997, 1998) showed that the abundance of breeding Redshank on a marsh was determined by the floral composition and the diversity in canopy height. They also demonstrated how vegetation parameters were related to grazing management, and that lightly grazed marshes had the highest densities of Redshanks. Milsom *et al.* (2000) found a positive relationship between the numbers of ground-breeding birds and both canopy height and the frequency and size of

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tussocks on coastal grazing marshes. Verhulst *et al.* (2011) provided evidence that the abundance of waders dropped with the intensification of grazing management and that abundance was positively related to spatial variation in canopy height.

In this study we manipulated grazing intensity in order to causally relate breeding bird numbers to grazing regime. To avoid the large-scale experiment needed to measure effects on bird densities directly, we chose a two-step approach. First, we related nest site selection of Redshanks and Oystercatchers to canopy height and spatial variation in canopy height. Secondly, we compared bird nest vegetation parameters with the vegetation parameters of different experimentally induced grazing regimes. In this way we aimed to assess what grazing regime would provide the most suitable nesting opportunities for Oystercatchers and Redshank.

METHODS

Study area

The study area (Noard Fryslân Bûtendyks) was located on the mainland coast in the north of the Netherlands (53°20'N 5°43'E). It is part of a large salt-marsh area (>4000 ha), managed as a nature reserve. From the sea side towards a summerdike, the vegetation shows a gradient from a low salt marsh towards a higher salt marsh (Figure 1). The area is important for a great number of breeding birds, mostly waders, and thousands of geese overwinter there. In autumn, the geese in the study area prefer high density livestock grazed sites (Mandema *et al.* 2014). Therefore, in addition to livestock grazing, grazing by geese may affect spatial variation in canopy height.

Experimental set up

The experiment consisted of three replicates (55 ha/replicate) with five grazing treatments (11 ha paddocks for each treatment) per replicate in a full factorial design. Before the experiment, two of the replicates had been grazed for more than 10 years with approximately 1 cattle/ha and one replicate had been ungrazed during this period. The year before initiation of the experiment, the entire ungrazed replicate was grazed to homogenise the treatments. The grazing treatments implemented in 2010 were: (1) every year low stocking densities with 0.5 cattle/ha, (2) every year low stocking densities with 0.5 horses/ha, (3) every year high stocking densities with 1 cattle/ha, (4) every year high stocking densities with 1 horse/ha, and (5) intermittent grazing with a high stocking density of 1 cattle/ha at yearly intervals. An ungrazed treatment was not added to the experiment, because previous studies established that an ungrazed salt marsh is reduced in biodiversity (Bakker *et al.* 2003, Norris 1997, Norris 1998). Moreover, including a control area would reduce the number of grazing treatments that could be tested.

The grazing treatments were allocated randomly to each replicate; however, two horse grazed treatments were never placed next to each other, because horses were expected to influence one another if placed in adjacent paddocks. Fresh water was available for the grazing animals in each paddock (Figure 1). The livestock was let into the grazing experiment in 2010; the paddocks with intermittent grazing were not grazed in 2010 and were grazed in 2011. Grazing treatments were restricted to June through September.

Study species

We focused on the two most common breeding waders in the study area, the Common Redshank *Tringa totanus* and the Eurasian Oystercatcher *Haematopus ostralegus*. In the Wadden Sea area, both Redshank and Oystercatcher show a decline in breeding numbers since 1991 (Koffijberg *et al.* 2009). The two species represent two extremes in a range of nest concealment. Redshanks generally build concealed nests in tufts of vegetation and rely on camouflage. They only leave the nest at the very last minute upon approach of a predator (Niethammer & von Blotzheim 1966, Beintema et al 1995, Norris *et al.* 1998). Diversity in canopy heights was found to be an important factor in the nest-site choice of Redshanks (Norris *et al.* 1997, Verhulst *et al.* 2011). Tall tufts of vegetation offer nest concealment opportunities, while surrounding, more open and short vegetation provides an escape route and better views of approaching threats (Dallinga 1993, Whittingham & Evans 2004). Oystercatchers build their nests in relatively open vegetation, and rely on distraction displays and attack to deter predators (Niethammer & von Blotzheim 1966, Green *et al.* 1990).

We searched for nests of Oystercatchers and Redshanks in 2010 and 2011 by visually following birds to their nest after disturbance. Nests were also found by flushing incubating birds from their nests. We searched through every treatment thoroughly and throughout the breeding season.

Edge value and canopy height

Vegetation characteristics of Redshank and Oystercatcher nest-sites were determined following Berg *et al.*

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Figure 1. One of the replicates shows the five grazing treatments in the study area. The solid black line indicates the position of the summer dike. Within each replicate, grazing treatments were allocated randomly to the paddocks. The most western replicate is subdivided in six paddocks. One of the paddocks was not grazed because it was intersected by a ditch.

(1997). This method places a grid over the vegetation. The canopy height is measured in each grid cell. For each cell, the edge value can then be calculated as the average difference between the value of a cell and the values of its eight surrounding cells, weighted for the reciprocal distance to the middle cell with the formula

$$\text{Edge value (cm)} = \left(\sum_{i=1}^{4}|X - Y_i| + \sum_{j=1}^{4}|X - Z_j| / \sqrt{2}\right) / (4 + 4\sqrt{2})$$

(Berg *et al.* 1997) (Figure 2). X is the central cell in a square of 9 cells. Y_i represent the four adjacent neighbouring cells and Z_j the four diagonal neighbouring cells. The smaller the differences between a cell and its surrounding cells, the lower the edge value for that cell.

We placed a 4×4 m meter grid, consisting of 64 cells (50×50 cm) around each nest-site. Within each cell the canopy height was measured to the nearest cm using a Styrofoam drop disk (25 cm diameter, 75 g) (Holmes 1974, Stewart *et al.* 2001). From the canopy heights, edge values were calculated for the 36 inner cells of the grid (Berg *et al.* 1997). Subsequently, we averaged these 36 edge values to arrive at the average edge value. Additionally, the canopy heights measured at each of the 64 cells were averaged to calculate the average canopy height at each site.

A total of 29 Oystercatcher and 22 Redshank nests were paired with a random site and both were measured. For proper comparison, the paired sites were located in the same grazing treatment (coordinates randomly generated in ArcGIS (ESRI Inc. 2009) and with similar surface elevation as the nests.

To understand how livestock affects spatial variation in canopy height we compared average edge values in different grazing treatments. We placed

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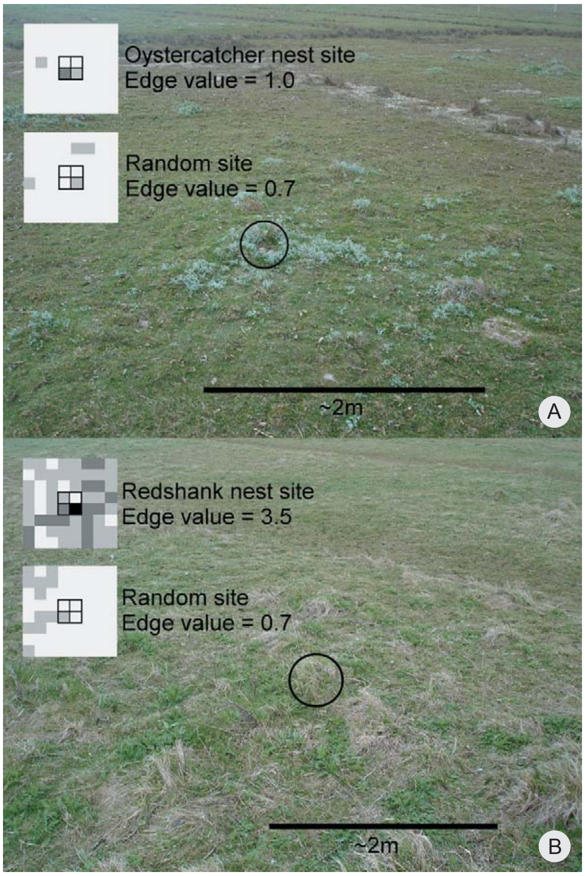

Figure 2. An Oystercatcher (A) and Redshank (B) nest site. The circle in each photograph indicates the position of the nest. The square grids in both photographs show the differences in canopy height between the 64 cells of the grid around a nest site and around a paired random site. The cross in the middle of the grid indicates the position of the nest or random coordinate. For illustration purposes, the canopy height is subdivided in four classes. White is 0–5 cm, light grey is 6–10 cm, dark grey is 11–20 cm and black is >20 cm.

permanent plots (four on the high marsh and four on the low marsh) within all paddocks and at similar elevation between grazing treatments within a replicate. Average edge values and average canopy height in the permanent plots were measured in 2011 (the second year of grazing) with the same method as for the nest sites.

A visit to a measuring site, including setting up the grid and measuring canopy height in 64 cells lasted a maximum of 20 minutes. Measurements were not taken during rain, fog or in extreme temperatures to avoid cooling or overheating of the eggs.

Analysis

Edge values and average canopy heights at nest sites and at random sites were compared using a Wilcoxon signed-rank test (package 'stats' in R 2.15.0, R Development Core Team 2012). Multiple comparisons were corrected with a Bonferroni adjustment.

To study the experimental effects of the different grazing treatments on average edge values, we created a Linear Mixed Model with the average edge values of the permanent plots as the response variable and grazing treatment as an explanatory variable. The random structure of the model was defined as a random intercept for each replicate ($n = 3$). To compare average edge values between different grazing treatments, we used the multcomp package (Hothorn *et al.* 2008) in R (R Development Core Team 2012) for simultaneous comparisons of all five factor levels. A similar model with the average canopy height was created. In all statistical models, the response variables were transformed by taking the natural log to normalise the residuals and correct for heteroscedasticity of the model. The models were fitted using the lme4 package (Bates *et al.* 2011) in R 2.15.1 (R Development Core Team).

Table 1. Total number of Redshank and Oystercatcher nests found in each replicate in 2010 and 2011.

	Replicate 1		Replicate 2		Replicate 3		Total
	Oystercatcher	Redshank	Oystercatcher	Redshank	Oystercatcher	Redshank	
1 horse/ha	1	1	2	5	5	0	14
1 cattle/ha	2	5	6	6	3	1	23
0.5 horses/ha	1	0	4	3	9	1	18
0.5 cattle/ha	2	1	7	7	4	2	23
Intermittent 1 cattle/ha	2	2	4	5	3	3	19
Total	8	9	23	26	24	7	97

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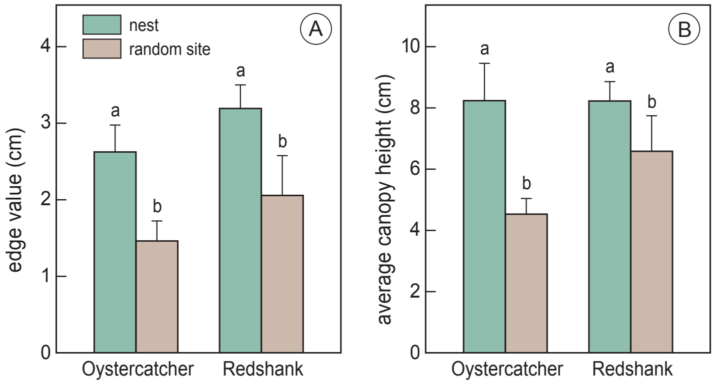

Figure 3. Both Oystercatchers and Redshanks choose nest sites with significantly higher average edge values (A) and a taller canopy height (B) than found at random sites as indicated by the average edge values and the average canopy height respectively. Letters denote significant differences.

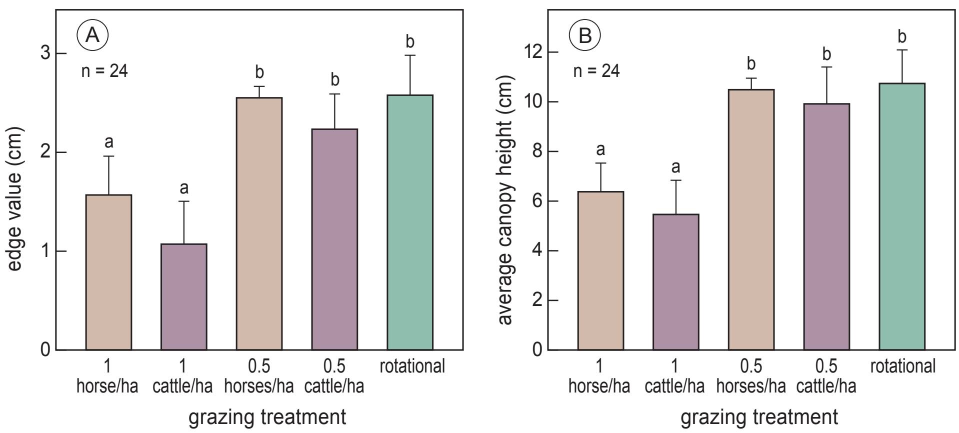

Figure 4. Measurements taken at permanent plots (n = 120) show that the low density grazed treatment and the intermittent treatment have significantly higher average edge values (A) and a taller average canopy height (B) than high density grazed sites as indicated by the average edge values and the average canopy height respectively. Letters denote significant differences between treatments (fixed effect) as found with a Linear Mixed Effects Model. For readability of the figures, the non-transformed edge values and canopy heights are shown.

RESULTS

Nest sites of Redshanks and Oystercatchers exhibited significantly higher edge values and taller canopy than found at random sites (Figure 3). Surprisingly, we did not find differences in the edge values between Redshank and Oystercatcher nests, although there was a trend towards higher values at Redshank nest-sites.

From the grazing experiment, we found that the average edge values and average canopy height of lightly grazed treatments (0.5 horse/ha, 0.5 cattle/ha and intermittent grazing) were significantly higher than the average edge values and average canopy height at heavily grazed treatments (1 horse/ha and 1 cattle/ha) (Figure 4). The average edge values in low density grazed or intermittently grazed treatments were similar to the edge values around the nest sites (compare Figure 3 and Figure 4), suggesting that they should be preferred for nesting by waders. However, the number of nests found in 2010 and 2011 (after establishing the grazing treatments) did not differ between grazing treatments (Table 1). In low density and intermittently grazed paddocks we found 6.7 ± 3.9 (average ± SD) nests per paddock in the two years of study, while in high density grazed paddocks we found 6.2 ± 3.4 nests per paddock.

DISCUSSION

Redshanks and Oystercatchers built their nests in areas with relatively tall vegetation and high variation in canopy height. Such vegetation was more prominent in low livestock densities or at intermittent grazing treat-

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ments than in the higher stocking density treatments, suggesting that breeding opportunities were more abundant in the low livestock treatments. Grazing by geese may fortify this effect, because geese prefer the high density grazed treatments in autumn, leading to an even greater homogenisation of the vegetation in the high density grazed treatments (Mandema *et al.* 2014).

Spatial variation in canopy height and average canopy height are known to be important in the nest-site choice of waders. We found that both Redshanks and Oystercatchers chose nest sites with higher average edge values than at random sites, implying a preference for spatial variation in canopy height around nest sites. Spatial variation in canopy height may provide better camouflage for the nest, while retaining an open view and escape route from the nest (Dallinga 1993, Whittingham *et al.* 2004). Additionally, increasing spatial diversity in canopy height may result in an increased invertebrate diversity (Olff & Ritchie 1998, Balmer & Erhardt 2000, Dennis *et al.* 2001, Woodcock *et al.* 2005, Rickert *et al.* 2012), providing food for chicks, once hatched.

Although we found a trend towards higher edge values and canopy heights at Redshank nests, the differences between the two species were not significant. Both species selected nest sites with higher edge values and canopy heights than at paired random sites. Considering the different nest-defence strategies of the two species (Niethammer & von Blotzheim 1966, Beintema et al 1995, Norris *et al.* 1998), this result is surprising. Perhaps differences between the species are more prominent on a smaller scale, e.g. the canopy height directly at the nest.

There was no indication that breeding bird numbers differed by experimental grazing treatment. We suggest that breeding opportunities were not limited by grazing regime through vegetation structure. Possibly, the densities of breeding Redshanks and Oystercatchers in each grazing treatment were lower than potential nest-sites allowed. However, since both Redshank and Oystercatcher are long-lived, site-faithful bird species (Thompson & Hale 1989, Jackson 1994, Heg *et al.* 2003, Bruinzeel 200), it may take years for individual birds to adapt to changes in the vegetation structure. We suspect that the duration of the experiment has been too short to find effects on bird densities and recommend a continuation of our experiment in order to study long term effects of livestock grazing on bird densities.

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SAMENVATTING

In het hier gepresenteerde onderzoek hebben we een beweidingsexperiment uitgevoerd om te begrijpen hoe beweiding invloed heeft op de aantallen broedvogels. Om de invloed van beweiding op aantallen broedvogels direct te meten, zou een onwerkbaar groot onderzoeksgebied nodig zijn. We hebben het probleem daarom op een andere manier benaderd. Rond de nesten van Tureluurs *Tringa totanus* en Scholeksters *Haematopus ostralegus* en rond willekeurige plekken hebben we micropatronen (mozaïek van korte en hoge vegetatie op een schaal van 4×4 m) in de vegetatie gemeten om te bepalen hoe geschikt micropatronen zijn voor nestbouw. We hebben ook micropatro-

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nen gemeten in 120 permanente kwadraten bij vijf verschillende beweidingsregimes om te bepalen hoe beweiding micropatronen beïnvloedt. De regimes betroffen respectievelijk lage dichtheden van koeien of paarden, hoge dichtheden van koeien of paarden, en een beheer met een jaarlijks afwisselend beheer met een hoge dichtheid van koeien en geen beweiding. Tureluur- en Scholeksternesten kwamen voor op plekken met een hogere vegetatie en een grotere variatie in vegetatiehoogte dan op willekeurige plekken in het gebied. We vonden ook dat eenheden met een lage veedichtheid of met het rotatiebeheer micropatronen hadden zoals deze werden geprefereerd door Tureluurs en Scholeksters. We concluderen dat Tureluurs en Scholeksters voordeel kunnen hebben, in termen van potentiële nestplekken, van beweiding met een lage dichtheid aan vee of met een rotatiebeheer via effecten van beweiding op micropatronen in de vegetatie.

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