# How Different Landscape Elements Limit the Breeding Habitatof Meadow Bird Species

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Source: Ardea, 98(2) : 203-209

Published By: Netherlands Ornithologists' Union

URL: https://doi.org/10.5253/078.098.0210

# How different landscape elements limit the breeding habitat of meadow bird species

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Van der Vliet R.E., van Dijk J. & Wassen M.J. 2010. How different landscape elements limit the breeding habitat of meadow bird species. Ardea 98: 203–209.

Meadow bird species in the Netherlands have shown a long-term decline in numbers. This has been generally attributed to agricultural intensification, but in addition an increase of disturbing elements may have played a role in the decline. In this review we compiled data from literature to explore to what extent breeding by meadow birds (Eurasian Oystercatcher *Haematopus ostralegus*, Northern Lapwing *Vanellus vanellus*, Black-tailed Godwit *Limosa limosa*) is limited by disturbing landscape elements. We considered elements that can be considered 'view-obstructing' (like trees or houses), and those that can be considered 'flat' (canal, road or railway). Our review shows that breeding birds keep a distance to both types of landscape elements, with distances ranging over 1 km for highways and village edges. Roads with high traffic intensity caused the largest disturbance. Eurasian Oystercatcher was most tolerant to the presence of landscape elements, and Black-tailed Godwit least tolerant.

Key words: Black-tailed Godwit, Eurasian Oystercatcher, grassland ecosystem, habitat loss, Northern Lapwing, meadow bird, Netherlands, openness of landscape, view obstruction

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In recent decades, populations of almost all meadow bird species in The Netherlands have declined, resulting in most of them being placed on the Dutch red list of threatened bird species, including Black-tailed Godwit *Limosa limosa* and Common Redshank *Tringa totanus* (van Beusekom *et al.* 2005). This decline has been attributed to several factors, including collecting eggs, hunting and alterations of habitat (Klomp 1951, Wymenga & Engelmoer 2001). However, it is now generally accepted that the decline has been mostly caused by a continuing intensification of agriculture in the breeding areas impairing reproductive success, for instance by an increased intensity of farmers' activities, increasing livestock densities, earlier and more frequent mowing, and lowering of groundwater levels (Beintema & Müskens 1987, Kruk 1993, Vickery *et al.* 2001, Newton 2004).

Another reason for the decline that has gained much less attention is that opportunities for safe breeding by meadow birds are hampered by an increase of elements that obstruct visibility in the otherwise open habitat (Dyrcz *et al.* 1981, van der Vliet *et al.* 2008). Klomp (1954) showed that Northern Lapwings were most effective in deterring potential predators in a treeless landscape, and calculated that Lapwings needed a field of at least 5 ha in size if lined by trees with a height of 6–10 m.

In this paper, we review effects of landscape elements on the breeding distribution of meadow birds, focusing on the species for which sufficient data have been published, Eurasian Oystercatcher *Haematopus ostralegus*, Northern Lapwing *Vanellus vanellus*, and Black-tailed Godwit *Limosa limosa*. Meadow birds keep a distance to elements in the landscape, thus resulting locally in lowered meadow bird densities. The distance where the population density is depressed due to the presence of a disturbing source is called the disturbance distance (cf. Veen 1973, van der Zande *et al.* 1980, Gill *et al.* 1996, Reijnen *et al.* 1996). The maximum disturbance distance is defined as the largest distance where a negative effect is still measurable. We use this maximum disturbance distance as an indicator of the effect that a landscape element may have on suitable habitat and on the distribution of meadow birds.

We aim to distinguish between two sources of disturbance, (1) elements that hamper visibility (view-obstructing elements), and (2) flat elements that cause disturbance by the presence of potential predators without impairing visibility (canals, roads and railways). By using data on traffic intensity we separate effects of the flat elements proper and the presence of 'predators'. Thus, based on a literature review, this paper gives an indication to what extent different sources of disturbance limit the distribution of breeding meadow birds. Forman & Alexander (1998) reviewed the disturbance caused by roads on wildlife. We use their framework to discuss our findings.

## METHODS

To quantify the effects of elements in the landscape on meadow bird populations, we searched literature sources for quoted disturbance distances, using both widely available and grey literature. We assumed that distances to field borders were negligible compared to the distance to landscape elements. We aimed to find figures for the disturbance distance for the three species separately but unfortunately not all sources made this distinction. Many studies were carried out in western Netherlands, where most Dutch meadow birds breed (Bijlsma *et al.* 2001). In most study sites, habitat was homogeneous, although some were heterogeneous with respect to meadow vegetation type. We only included studies that had considered this heterogeneity in their conclusions. Also, most studies distinguished between roads with or without a supporting view-obstructing element. If they did, we also made this distinction in our categories of elements. Studies calculated distances by either interpreting numbers of breeding meadow birds along a transect perpendicular to the disturbing source, or by interpreting field data afterwards.

Effects by landscape elements on disturbance distances were statistically tested for each species separately and for the species pooled. View obstruction and traffic intensity were the independent variables. Based on the original publications, traffic intensity was scored as 'low' (values 0 and 1), 'intermediate' (value 2), and 'high' (value 3). Note that both view-obstructing and flat elements can have a high intensity of traffic. Unfortunately, inclusion of species as an independent variable led to strong deviations from normality, even after log-transformation of the data.

The effect of view obstruction and traffic intensity on the average disturbance distance was tested by ANOVAs. A Bonferroni post-hoc test was used to identify significant differences between levels of traffic intensity. Data were log-transformed as data assumptions were not met, but for Eurasian Oystercatcher log-transformation did not lead to improvement. Non-parametric tests were therefore used for this species to test main effects. Because these tests yielded similar results as the ANOVA, we only present the results of the latter. To test whether the presence of disturbing elements caused lower densities within 500 m from the element, we used a series of $\chi^2$-tests. As a preliminary log-linear analysis showed no significant interactions between variables, separate $\chi^2$-tests were made. This could only be performed for all species pooled due to the small amount of data for each species separately. To test for species-specific avoidance distances, we included species as a third independent variable.

## RESULTS

Visual inspection of Table 1 shows a large variation in the distance that meadow birds keep from view-obstructing and flat elements. The largest disturbance distance (>1 km) was reported for the high-intensively used highways. However, flat elements with low traffic intensity like cycle paths also resulted in disturbance distances of 100 m or more. Among view-obstructing elements, 'edge of a village or city' caused the largest disturbance distance. Forest edges, hedges or reed beds, – elements without traffic – showed disturbance distances of up to 350 m (Table 1). Traffic intensity was the only parameter that influenced breeding distance significantly ($\chi^2 = 8.85$, $P = 0.012$). At the lowest traffic intensity, disturbance distance was less than 500 m in 71% of the cases, whereas at intermediate and high traffic intensities this value was as low as 30% and 18%, respectively.

Eurasian Oystercatcher showed the smallest disturbance distance in nine between-species comparisons, Northern Lapwing in three comparisons, and Black-tailed Godwit in none of the comparisons (Table 1).

ANOVA-tests confirmed that Northern Lapwing and Black-tailed Godwit were significantly affected by traffic intensity, but Eurasian Oystercatcher was not (Table 2). In Northern Lapwing, post-hoc tests showed

**Table 1.** Maximum disturbance distance (m) from landscape elements for three species of meadow bird in The Netherlands during the breeding season. ( A) References do not distinguish between species; (B) References distinguish between species. Figures between parentheses indicate approximate car traffic density, in numbers per day. Species abbreviations: Oys = Eurasian Oystercatcher, Lap = Northern Lapwing, God = Black-tailed Godwit. View obstructing: 0 = no, 1 = yes. Traffic intensity: 0 and 1 = low, 2 = intermediate, 3 = high.  - = no data available.

| Landscape element **A** | View obstructing | Traffic intensity | Distance for three species combined | Reference |
|---|---|---|---|---|
| Forest edge | 1 | 0 | 100 | Altenburg & Wymenga 1987 |
| Tree line, hedge | 1 | 0 | 50 | Altenburg & Wymenga 1987 |
| Reed bed/reedy edge | 1 | 0 | 50 | Brandsma 1991 |
| 'group of trees' | 1 | 0 | 250–350 | van 't Veer & Scharringa 2008 |
| High dam without tree line | 1 | 0 | 50 | Altenburg & Wymenga 1987 |
| 'building' | 1 | 1 | 175 | van 't Veer & Scharringa 2008 |
| Edge village/city | 1 | 1 | 100 | Altenburg & Wymenga 1987 |
| | 1 | 1 | > 500 | Wind 1977 |
| | 1 | 1 | 1200 | Veen 1973 |
| Canal without tree line | 0 | 0 | 50 | Altenburg & Wymenga 1987 |
| Cycle path without tree line | 0 | 1 | 100 | Altenburg & Wymenga 1987 |
| Minor/municipal road | 0 | 1 | 800–900 | Veen 1973 |
| Minor road with tree line | 1 | 1 | 100 | Altenburg & Wymenga 1987 |
| Highway (5000–10,000) | 0 | 2 | 150 | Altenburg & Wymenga 1987 |
| | 0 | 2 | 1200 | Veen 1973 |
| Railway | 0 | 2 | 650 | Veen 1973 |

| Landscape element **B** | View obstructing | Traffic intensity | Distance for species separately Oys | Lap | God | Reference |
|---|---|---|---|---|---|---|
| Plantation | 1 | 0 | - | 300 | 250 | van der Zande *et al.* 1980 |
| Single farm house | 1 | 1 | 150–250 | 250–350 | 350–450 | Wind 1978 |
| | | | 630 | 470–630 | 470–875 | van der Zande *et al.* 1980 |
| Minor/municipal road | 0 | 1 | 0 | 480 | 720 | van der Zande *et al.* 1980 |
| | | | 200–300 | 350–450 | 250–350 | Wind 1978 |
| Provincial road (5000) | 0 | 2 | 0 | 750 | 750 | van der Zande 1975 |
| Provincial road (10,000) | 0 | 2 | 550–650 | 600–700 | >1000 | Wind 1978 |
| Provincial road (5000; with ribbon-development) | 1 | 2 | 550–650 | 600–700 | >1000 | Wind 1978 |
| Provincial road (5000; with scattered farms) | 1 | 2 | 100–200 | 450–550 | 750–850 | Wind 1978 |
| Highway (5000–10,000) | 0 | 2 | 0 | 625 | 625 | van der Zande *et al.* 1980 |
| | | | > 625 | 625 | 625 | Verstrael *et al.* 1983 |
| | | | 1700 | 120 | 230 | Reijnen *et al.* 1996 |
| Highway (50,000) | 0 | 3 | 0 | 2000 | 1000 | van der Zande 1975, van der Zande *et al.* 1980 |
| | | | 3530 | 560 | 930 | Reijnen *et al.* 1996 |
| | | | - | 1800–2100 | 1800–2100 | Verstrael *et al.* 1983 |
| Railway | 0 | 2 | - | 250 | 375 | Grontmij 1981 |

significant differences in disturbance distance between the three categories, with shorter distances at low intensities and larger distances at high intensities. In Black-tailed Godwit, distances were longer at high traffic intensities in comparison to intermediate and low traffic intensity. Disturbance distances were not affected by view-obstructing elements (Table 2). When all species were pooled, no significant effect of any of the landscape element characteristics were found (Table 2).

## DISCUSSION

### Possible ecological explanations

Our review supports the notion that Northern Lapwing and Black-tailed Godwit keep distances from elements with elevated traffic intensity. Forman & Alexander (1998) list several factors that can cause disturbance by roads for breeding birds: pollutants, noise, direct human presence, and loss of visibility. Below we discuss the relevance of these four factors for the disturbance distances that we found. (1) Pollutants like lead have an effect over distances that are much smaller than the disturbance distances than we compiled from literature (cf. Reijnen *et al.* 1996 and Table 1). Furthermore, an effect of pollutants does not explain distances as observed for natural elements like forests. This factor does not seem to have much weight in explaining the distribution of meadow birds. (2) Reijnen *et al.* (1996) postulated that noise, rather than visual stimuli, explained disturbance distances by roads. Indeed, we found the largest disturbance distance for highways, which can be considered the noisiest landscape element (Table 1). Despite this, noise may not be the only explanation for meadow bird species as they use visual cues as well as sounds in e.g. their display behaviour. (3) Similarly, disturbance by man is an important cause of disturbance given that the largest disturbance distances were associated with highest traffic intensity (Table 1). Also, objects with the lowest traffic intensity, like minor roads and cycle paths, have smaller disturbance distances than for instance highways (Table 1). However, as human disturbance is often a combination of noise and traffic it is difficult to distinguish between the most important underlying reason. (4) Because meadow birds give priority to detect predators (van der Vliet *et al.* 2008), lack of visibility to scan for predators, must also partially explain disturbance distances for meadow birds – in line with the fourth explanation given by Forman & Alexander (1998). Indeed, elements not used by man equally had large disturbance distances.

In landscapes with view-obstructing elements, meadow birds prefer breeding further away from perches used by avian predators, resulting in decreased predation rates (Berg *et al.* 1992, Johansson 2001, contra Ottvall *et al.* 2005, Wallander *et al.* 2006). For predators, a landscape with elements is attractive due to availability of suitable nesting sites and, for avian predators, perching opportunities (Preston 1957, Galbraith 1989, Andrén 1992, Brandsma 1992). Furthermore, predators may use landscape elements as a hiding place when attacked by meadow birds (Elliot 1985). Finally, an open landscape may make avian predators more susceptible to stronger wind blows, which reduces the success rate of their attacks on potential prey (Quinn & Cresswell 2004). It is therefore not surprising that predation rates for meadow birds have been found to be especially high in a landscape with scattered trees, tree lines or other elements (Wymenga & Engelmoer 2001). More research is needed to elucidate the ecological understanding of disturbance distances caused by landscape elements to meadow birds, e.g. the differences between element types, and also the influence of elements for each species separately.

### Data variability and uncertainty

There are several weaknesses in the data sets we used (Table 1; also van der Zande *et al.* 1980, Altenburg &

**Table 2.** Effects of view obstruction and traffic intensity of landscape elements on breeding distances of Eurasian Oystercatcher, Northern Lapwing, Black-tailed Godwit and all species pooled (tested by ANOVAs). Significant effects are highlighted in bold.

| | Eurasian Oystercatcher* ($n$ = 13) | | Northern Lapwing** ($n$ = 16) | | Black-tailed Godwit ($n$ = 16) | | All species pooled** ($n$ = 45) | |
|---|---|---|---|---|---|---|---|---|
| | $F$ | $P$ | $F$ | $P$ | $F$ | $P$ | $F$ | $P$ |
| Obstruction | 0.003 | 0.956 | 0.058 | 0.813 | 0.329 | 0.577 | 1.172 | 0.285 |
| Traffic intensity | 0.579 | 0.580 | **5.067** | **0.025** | **5.212** | **0.023** | 0.432 | 0.652 |
| Obstruction × Traffic intensity | 0.127 | 0.730 | 0.326 | 0.579 | 0.845 | 0.376 | 0.018 | 0.894 |

*Data assumptions violated; ** log-transformed.

Wymenga 1987). Most importantly, in most studies meadow birds were studied as one group for which the response by an element was considered the same for all species (e.g. Veen 1973, Altenburg & Wymenga 1987, Brandsma 1991). However, in reality the impact of the element is likely to be species specific (e.g. van der Zande *et al.* 1980, Reijnen *et al.* 1996). Another point of concern is a very high variability in disturbance distances. This effect is most obvious for the disturbance caused by roads. For instance for Eurasian Oystercatcher, estimates for disturbance distance from highways with 5000 to 10,000 cars a day vary from 0 to 1700 meters (Table 1). Furthermore, it should be noted that several studies did not take into account effects by direct human disturbance. Finally, in some studies, data have been collected in relatively small areas, where other factors, not quantified or perhaps overlooked, may have played a role.

**Implications for conservation of the landscape**

Our review shows that still little is known how elements in the landscape influence the breeding distribution of meadow birds. Highways resulted in the highest reported disturbance distances (Table 1). For the western part of The Netherlands, 16% less pairs of Black-tailed Godwit were present because of the disturbance distance along highways (Reijnen *et al.* 1997). We presume that with the ongoing alteration of the landscape even fewer pairs are breeding as other elements add to unsuitable habitat. Larsen & Madsen (2000) similarly demonstrated the influence of view-obstructing elements in open grassland habitats for wintering Pink-footed Goose *Anser brachyrhynchus*. They calculated an effective loss of 68% of the total field area due to the presence of view-obstructing elements.

In this respect, the extreme site fidelity shown by meadow birds to the previous year's breeding site, especially when a breeding attempt has been successful (Klomp 1954, Thompson & Hale 1989, Groen 1993, Johansson 2001), may be a disadvantageous trait in a changing landscape. It may lead to a higher extinction risk of local meadow bird populations (Kruk *et al.* 1998). In contrast, in an unchanged landscape, extreme site fidelity may be beneficiary from an evolutionary point-of-view, as the birds are familiar with local environmental factors and, possibly, conspecifics (Johansson 2001). Because of site fidelity, not only continuity of the management of agricultural fields (Beintema & Rijk 1988, Beintema *et al.* 1995) but also the conservation of an open landscape appears to be essential for the conservation of meadow birds (van der Vliet *et al.* 2008). We consider that the adverse effect of development on openness, leading to a reduced predator visibility, may become a more important factor for meadow birds in the near future.

On the positive side, meadow birds are known to have adapted to changes in their breeding habitat. Mulder (1972) and Beintema *et al.* (1985) showed that meadow birds were able to respond to the intensification of agricultural management by breeding earlier in response to an earlier start of agricultural activities. Likewise, many pairs of Eurasian Oystercatcher and Northern Lapwing breed in arable fields nowadays (Klomp 1954, Imboden 1970, Kooiker 1984, Galbraith 1989, Berg *et al.* 1992), although these are still shunned by grassland specialists like Black-tailed Godwit (Mulder 1972). Incidentally, Eurasian Oystercatcher and Northern Lapwing are generally also the least affected by the presence of landscape elements, whereas Black-tailed Godwit seems to be most affected. It seems that meadow birds may also be able to cope with the loss of predator visibility. De Molenaar *et al.* (2000), for instance, found that birds that arrived later at their breeding area chose their breeding sites close to road illumination, because the earlier birds already bred at sites the farthest from this object. In this way, the later birds, having the choice between no breeding or breeding at a less favourable site, showed to have adapted to a certain extent to the presence of the disturbing object.

Many policy measures have been taken by the Dutch government to preserve meadow bird species, and their habitat, because they are internationally important. Such measures have often been directed to the improvement of nesting and recruitment success, and include for instance creation of reserves, facilitation of nest protection schemes by volunteers, payment to farmers for successfully protecting nests while carrying out agricultural activities, and payment for delay of agricultural activities during the breeding season. However, up to now such measures did not stop the decline of meadow bird species (e.g. Kleijn *et al.* 2001, Berendse *et al.* 2004, Schekkerman 2008). One of the reasons might be that the landscape context has so far not been taken into account, making an effort to improve the suitability of breeding sites less successful. For meadow bird conservation, priority should be given to the protection of open and quiet landscapes (without much human disturbance). If such landscapes are to be disclosed, sources of disturbance of the landscape, stemming from a loss of openness or from the presence of human beings, should perhaps be concentrated. It would make one edge of the meadow bird habitat disturbed but would leave the remainder open and undisturbed. We argue that, before taking measures directed to the benefit of breeding meadow birds, the already present human disturbance in and the openness of the landscape should be considered.

## ACKNOWLEDGEMENTS

We thank Margien Bootsma, Tom van der Have, Arie van Noordwijk, Max Rietkerk, Peter de Ruiter, Eddy Wymenga and two anonymous referees for their useful comments on earlier drafts of this text.

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## SAMENVATTING

Weidevogels hebben een voorkeur voor een open landschap met zo min mogelijk landschapselementen die hun blikveld in de weg staan. Op deze manier kunnen predatoren op tijd worden opgemerkt en weggejaagd. Ook platte landschapselementen, zoals wegen, zouden een verstoring van het blikveld kunnen opleveren door de bewegingen van de gebruikers van die elementen op de achtergrond. Het resultaat van deze verstoringen zou kunnen zijn dat weidevogels een afstand tot dergelijke landschapselementen aanhouden bij de selectie van een geschikte plek om te broeden, met als gevolg een verminderde dichtheid in vergelijking tot een situatie waarbij deze elementen er niet zouden zijn geweest. Wij hebben in de literatuur gezocht of hiervoor aanwijzingen zijn te vinden voor Scholekster *Haematopus ostralegus*, Kievit *Vanellus vanellus* en Grutto *Limosa limosa*. De resultaten van dit literatuuronderzoek laten zien dat deze soorten inderdaad een afstand aanhouden tot beide typen landschapselementen. Voor snelwegen en stads- en dorpsranden kan die afstand meer dan een kilometer bedragen. De grootste verstoringsafstand werd gevonden voor wegen met een hoge gebruikersdruk. Maar ook natuurlijke elementen, zoals bosranden en rietvelden, hebben een negatieve invloed op vestigingsmogelijkheden voor weidevogels. De soorten verschillen wel in hun tolerantie ten opzichte van de vestigingsmogelijkheid in zulke gebieden. De Scholekster is het meest tolerant, de Grutto het minst. Wij beargumenteren waarom de inrichting van het landschap aandacht verdient tijdens de planning van beleid.

*Corresponding editor: Julia Stahl*
*Received: 8 July 2008; provisionally accepted 5 May 2009; accepted 2 September 2010*