Road illumination and nature
III Local influence of road lights on a black-tailed godwit (Limosa l. limosa) population

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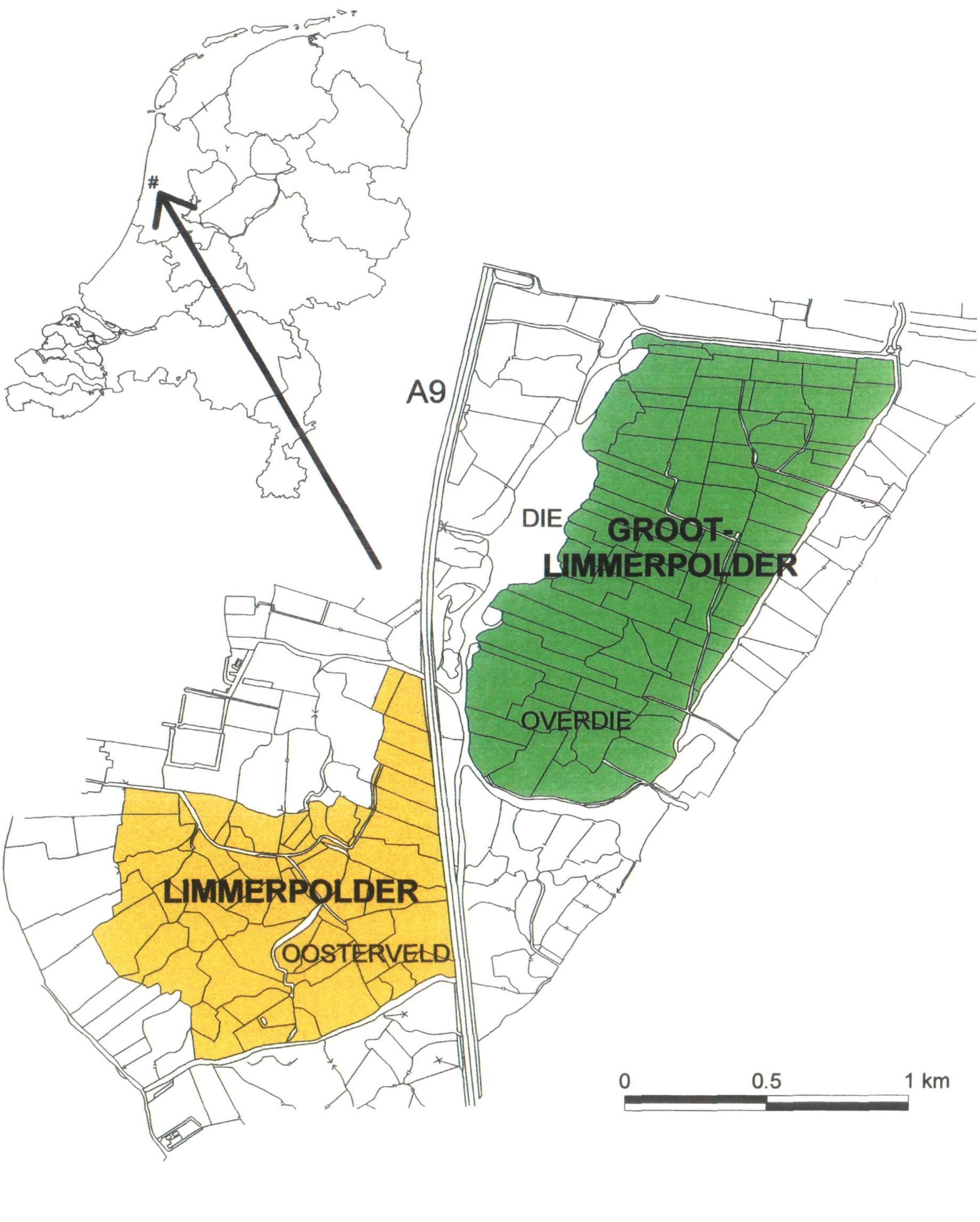
Review

This report is the result of a research project concerning the effects of road illumination on a local breeding population of black-tailed godwit (*Limosa l. limosa*). This species was chosen because of its relevance for nature policy and as a guide species for meadow birds in general.
The previously conducted literature study revealed that the influence of artificial illumination on, for instance, birds is far-reaching. Illumination has an effect on annual processes such as reproduction, migration and moulting, it influences the distribution of daily activities, and it causes attraction and repulsion. As a consequence, illumination may deregulate processes and behaviour, and therefore possibly endanger the adjustment to environmental conditions. The conclusions concerning the risks that this may cause to the annual activities are, for the most part, based on laboratory experiments. The significance for the practice of outdoor illumination in the natural environment is not clear. The results of field experiments concerning daily activities and spatial behaviour are more concrete. Both aspects have been investigated using a local breeding population of black-tailed godwit in the repreduction period.
This research indicates that the influence of road illumination on the black-tailed godwit and, speaking in more general terms, on meadow birds, can be reduced by avoiding the exposure of breeding areas to illumination.

Content

MAPS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Preface

Public outdoor illumination holds an important place in the functioning of our modern society. It fulfills an important function not only for security reasons, but for the purpose of comfort as well. This illumination penetrates from towns and villages ever deeper into the countryside. Darkness thus becomes a rare phenomenon. This expansion of illumination does not go unnoticed by society, neither in the Netherlands nor in other countries. A growing awareness is developing. On the one hand, people are beginning to experience it as a nuisance psychologically. And on the other hand, it is a reason for nature conservationalists to sound the alarm because the natural rhytm of light and dark is of great importance for numerous biological processes. The presence of light at unnatural moments, or in places that are dark by nature, can result in a disturbance of these processes.

The interest for the subject on the part of society caused it to be placed on the political agenda. The Dutch Lower Chamber declared itself in favour of a restraint on plans for illumination in the countryside. Moreover, the Chamber repeatedly insisted on further research on the possible effects of illumination on nature. As a result, the Dienst Weg- en Waterbouwkunde of Rijkswaterstaat, i.e. the Office for Road and Water Engineering of the Department of Public Works in the Netherlands, has commissioned the DLO-Institute of Forestry and Nature Research, now Alterra, to conduct a research study into the effects of road illumination on nature.
The first results of that research appeared in July 1997, namely the report "*Wegverlichting en natuur, deel I: Een literatuurstudie naar de werking en effecten van licht en verlichting op de natuur*" (Road illumination and nature, part I: A literature study on the action and effects of light and illumination on nature). The next report was published late 1997, entitled "*Wegverlichting en natuur, deel II: Haalbaarheidsstudie aanvullend onderzoek*" (Road illumination and nature, part II: Feassibility study additional research).

The findings of these studies resulted in the start of a research project on the possible influence of road illumination on ground breeding birds of open landscapes, i.e. so-called meadow birds. Black-tailed godwit *Limosa l. limosa* has been selected as a guide species. For various reasons, the scope of the project was limited. The results can therefore be seen as indications only. In this project, the conditions during a reproduction season along a motorway without road illumination (1998) are compared with those during the next reproduction season with road illumination (1999). A second comparison involved a situation out of reach of any road influence and the same situation under the influence of experimental road illumination.
Regarding the continuation of the project, it is expected that research will be conducted into the possible influence of road illumination on the spatial behaviour of ground dwelling mammals, and into the relation between bats and road illumination. The results of the projects can be used to support the meanwhile adjusted policy for public illumination or, if need be, to adjust the present policy again.

On behalf of the Dienst Weg- en Waterbouwkunde
The project leader,

Hans de Vries

Acknowledgement

This research could be carried out thanks to the interest in the subject, the confidence in the researchers and the personal and benevolent dedication of the commissioner, the Dienst Weg- en Waterbouwkunde of Rijkswaterstaat, specifically Mr. J.G. de Vries. We are very obliged to him for this. The concern and involvement of the supervising committee also deserves our gratitude. Members of this committee were ing. J.G. de Vries (chairman) and drs. G. Veenbaas, representing the Dienst Weg- en Waterbouwkunde, prof. dr. F.J. Verheyen, ing T.D.J. van de Brink, ing. T. van den Broek, ir. I. 't Hart and ir. E.F.M. van Langen. The temporary experimental illumination could not have been realized without the asistance and co-operation of the gentlemen H. Witte and J. Stam, steward and area manager of Het Noordhollands Landschap, Mr. J.J. Sander, in his capacity of landuser, and the gentlemen E. van Langen, B. Culic, R. van den Ende and G. Jordens of Rijkswaterstaat, Noord-Holland.

The fieldwork was made possible thanks to the decision of Het Noordhollands Landschap and the local landowners to grant permission to enter their grounds and conduct observations. Without their willingness, this research could not have been carried out.
Leo van den Bergh, Gerard Müskens and René Henkens, all three employees of IBN-DLO, now Alterra, assisted during the fieldwork. Moreover, assistance was also provided by the gentlemen Nico Groen, Bob van Poelgeest, Jan Terlouw, Herman Tweehuizen, Adri Vermeule and Ed Zijp. We thank our helpers for their willingness and dedication. The meadow bird protectors, namely the gentlemen C. Beers, C.H. Hogenterp, J.A.M. Mannes, W. Vaandrager and J. van Wonderen, gave permission to use their nest markings. By doing so, they took a lot of work off our hands. We owe them very much indeed.

Aart van den Berg played an important role as advisor at the start of working out the field data. Georgios Martakis did part of the statistics. Ruut Wegman took charge of the technical aspects of working out the data. Their very dedicated contribution can not be easily overrated.

Abstract

The influence of road illumination on the black-tailed godwit is studied in the open grassland area on both sides of the A9 motorway between Limmen and Akersloot, in the northwest part of the country. The black-tailed godwit has been selected as a guide species for meadow birds in general.
The research area covers 230 hectares. With over 50 pairs/100 hectares, the population of black-tailed godwit in this research area is one of the best in the country.

The research set-up involved a comparison of an area adjacent to the A9, which was not illuminated in 1998 and illuminated in 1999. To that aim, the illumination of the A9 was switched off during the first year and switched on again in the second one. In addition, an area out of reach of the influence of the traffic on the A9 was similarly taken into account. Road illumination identical to that of the A9 (24 light poles) was installed early 1999. This road illumination was then switched on and off in the reproduction season, simultaneously with the A9 illumination.
The existing influence of the motorway and traffic on the population of black-tailed godwit is considered to be a fact. The following was established during the research: the exact position of the nests found in 1998 and 1999, their distance to the motorway and to the temporary illumination, the number of eggs of each clutch, the measures and – as a control – the weights of the eggs, the date of laying of the first egg and possible losses of clutches.
In addition to a general description of the research area, all of the plots have been individually characterised in detail to be able to account for the nest choice of the birds. This concerned sward height and structure, drainage conditions and management.

The scope of the research is limited and the results are therefore only indications of the possible effects of road illumination on the development of the black-tailed godwit population in the area. Even more so since the nest fidelity of the birds and the annual variation in weather conditions, along with related field conditions at the beginning of the reproduction season, appear to play an important complicating role.

The characterisation of the individual plots is used to calculate the relative chance of occupation by black-tailed godwit for nesting. Next, the possible influence of illumination is determined. The results indicate that road illumination affects the habitat quality for black-tailed godwit. Road illumination has a significant negative influence on the suitability as a breeding area, one that may reach over several hundreds of metres. It is also indicated that birds that breed early choose their nest further away from the light source compared to birds that start later. A possible influence of illumination on the average egg volume per nest, as an indication for breeding success and condition of the parent birds, does not appear to be demonstrable. Any influence of illumination on nest predation also appears to be not demonstrable.
An influence of the motorway appears to be absent in the area. It can apparantly be compensated by other factors (site conditions) that also determine habitat quality. The observation that the negative influence of illumination is compensated to a much lesser degree by the suitability of the site might suggest that the influence of illumination is stronger than the influence of the road (road traffic) as such.

It is recommended to repeat the research over a longer series of years and in more areas, and to include a common meadow bird species that exhibits a less strong nest fidelity.

1 Introduction

1.1 General

This report is the third one in a series that presents the results of investigations into the influence and effects of light and road illumination on nature. The first project was a literature study. This showed that light and illumination basically have a complex and, in part, fundamental influence on animals, but also that hardly anything is known about the effects in the field. The second project reviewed the feasability of experimental research in the field. This resulted in a project focussing on the possible influence of road illumination on the black-tailed godwit, which serves as a guide species for 'meadow birds'[1] and ground breeders in open landscapes in general.
The set-up and length of the investigation had to be restricted. Thus, the results provide but indications for the possible effects of road illumination on the local population of the black-tailed godwit.

1.2 Research questions

The principal question is:

- Does road illumination have any influence on the quality of the breeding biotope of the black-tailed godwit along motorways?

In more detail, the questions are:

- Does road illumination have any influence on:
  - the establishment and population density of breeding birds, in addition to the effect of road traffic;
  - the breeding period, which may increase the risk of loss of clutches and, as a consequence, affect the breeding success;
  - the reproduction through the influence on the condition of breeding birds, and thus on the breeding success;
- the reproduction through facilitation of nest predation by crows, foxes, etc.?

Apart from this, the question may be raised whether or not illumination as such influences black-tailed godwit populations. Illumination might also contribute to the influence of other external factors.

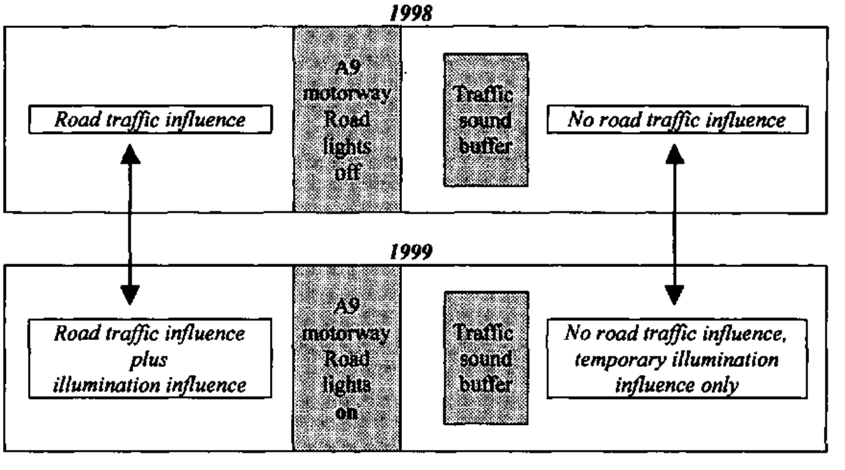
1.3 Research set-up

The experiment covered only two years. In order to obtain sufficient data to produce reliable conclusions, the experiment was confined to one large area with a high population of breeding birds. The selected area is an open grassland area in the province of Noord-Holland, between the old coastal ridges of Limmen-Heiloo and Akersloot-Boekel, south of Alkmaar, cut in half by the A9 motorway.
Basically, the set-up involved a comparison of a grassland area along a major

[1] *The term 'meadow birds' refers to a group of a grassland birds that are characteristic of traditionally managed, low productive moist to wet meadows in The Netherlands. The core of this group consists of black-tailed godwit, lapwing *Vanellus vanellus*, redshank *Tringa totanus*, snipe *Gallinago gallinago* and ruff *Philomachus pugnax*; others are e.g. oystercatcher *Haematopus ostralegus*, yellow wagtail *Motacilla flava*, shoveler *Anas clypeata* and garganey *Anas querquedula*.

motorway that was not illuminated in the first year (1998) and illuminated in the second year (1999). To distinguish possible influences of illumination from the influence of road traffic, a situation out of reach of the influence of road traffic was simultaneously studied without road lights in 1998 and with temporary road lights in 1999.
A highly schematized illustration of the situation and set-up is given in figure 1.1.

Figure 1.1 Scheme of the set-up of the experiment



The experiment focussed on the nest choice of the birds and the fate of their clutches. Only the first clutches of the season were taken into account; possible second clutches were neglected. Second breeding attempts are usually undertaken due to failure of the first one. It may be assumed that possible influences of illumination decrease as the length of the daylight period increases, that the choice of the nest site and the breeding success become increasingly exposed to disturbance by farming activities (mowing, grazing, etc.), and that the condition of the birds involved might be less than at the beginning of the first breeding attempt. Therefore, no more new nests were taken into account from the second week of May onwards.

The nests of the black-tailed godwit are searched for and localized to determine the distance from the light sources as a measure for the possible spatial influence of illumination on the population density. The clutches are then monitored to determine the possible influence of illumination on the breeding success in relation to the proximity of the nests to the illumination. The start of breeding of each clutch (date of laying of the first egg), the number of eggs and the condition of the eggs (measures and weights) in each clutch, and possible loss by predation are considered indicators of this influence.

The questions concern the final effect of road illumination. As a consequence, no distinction has been made between the influence of the lumination[2], the illumination[3] and the presence of the light poles.

[2] Luminance is the intensity of the source(s) in a specific direction, divided by the source area projected onto a plane perendicular to that direction (unit: $cd.m^{-2} = lm.m^{-2}.sr.^{-1}$).
[3] Illuminance is the quotient of the luminous flux incident per unit area (unit: $lx = lm.m^{-2}$).

1.4 Research area selection

The choice of the area is based on the previous reconnaissance of 'good' black-tailed godwit areas in the Netherlands as formulated by Reijnen (1995) for his study on the influence of road traffic on breeding birds.

These areas are tested by the following criteria:

- *recent inventories show that the area clearly represents a good to very good black-tailed godwit area with a reasonably stable population in recent years;*
- *the area borders on or is cut through by a motorway where temporary illumination can be realised and where noise barriers that may also form a barrier for light are lacking;*
- *the area is large enough for two separate experiment sites (see figure 1.1: experiment site along motorway, and a control site of equal size), which*
- *cover the effect distance of intensive road traffic for black-tailed godwit; this distance ranges from several hundreds of metres up to a kilometre, depending on traffic density and driving speed (see* Reijnen 1995*);*
- *can be covered by one group of field workers in one week (five working days); this amounts to 100 to 125 ha for each site;*
- *the habitat quality of the area is sufficiently homogeneous to allow for two comparable experiment areas of ≥ 200 ha in all;*
- *the habitat conditions in the area for black-tailed godwit are as as constant as possible, the area should preferably for the most part be owned and/or managed by a nature conservation organisation;*
- *the area is not too remote (traveling distance and time) and reasonably accessible by foot; the walking time and distances in the field should not be excessively extended by detours necessary to avoid wide ditches;*
- *the distance of the selected sites to the nearest other roads must be in accordance with Reijnen et al.* (1992: table 1)*, and should therefore not exceed 1 kilometre; shorter distances may be considered if traffic noise buffers are present; this should be confirmed by earlier inventories of the black-tailed godwit population distribution* (Reijnen 1995: 48)[4].

* *Note: The shape of the sites is less important and may be adapted to the conditionsin the field, though their width should vary as little as possible with the distance from the motorway.*

These criteria limit the choice to but one single area, namely the grassland area between Limmen and Akersloot that was previously mentioned. Regarding the fourth criterium, it should be noted that the area is part of a nearly finished reallotment scheme. In the area, the influence of this scheme is almost entirely restricted to an enlargement of the meadow bird reserve; see also chapter 2.

1.5 This report

This report can be divided into a section consisting of documentation (chapters

[4] These concern countryside roads where a speed limit of 80 km/hr applies. The effect distance of car traffic on such roads is 96 m at a traffic density of e.g. 5000 to 10,000 cars/day, 224 m at 20,000 to 30,000 cars/day, and 335 m at a traffic density of 40,000 to 50,000 cars/day.

By switching off the road illumination of the A9 in 1998 and installing temporary light poles in the open grassland area in 1999, the project ran the risk of being misunderstood by the users of the motorway and the local people. Therefore, those concerned were informed of the project as much as possible, for instance by means of billboards along the A9.
Photo D.A. Jonkers

A view of the research area Groot-Limmerpolder in May 1998. The picture was taken from the eastern border of the area, towards Lake Die and the A9 behind that water in the west. In the foreground, one sees tussocky grassland. In the background, the swampy groves and wide reed fringes along Lake Die, muffling the sound of the traffic on the A9.
Photo J.G. de Molenaar

A view of the research area Limmerpolder in April 1998. Due to the wet spring, the grassland was soggy and locally filled with puddles. The picture was taken towards the northwest.
Photo D.A. Jonkers

The temporary road light poles installed in the reasearch area Groot-Limmerpolder, in an early evening in May 1999. The picture was taken towards the southwest.
Photo Alterra

2, 3 and 4) and a section consisting of results and the discussion (chapter 5 to 10).

The area and the two research sites to the west and east of the A9 motorway are described in chapter 2. Chapter 3 then provides background information on the ecology of the black-tailed godwit. This general section is concluded by chapter 4, which deals with the methods.

Chapter 5 presents the general results of the field work. The selection by the birds of their exact nesting site is analyzed in chapter 6. This provides the basis for answering the questions put forward in § 1.2 in the chapters 7 to 10. The last chapter reviews the results.

Additional background information is presented in the annexes.

2 Description of the area

2.1 General

The research area lies between Limmen and Akersloot. It is a former beach plain that forms a flat lowness between the old coastal ridges of Akersloot-Boekel and Limmen-Heiloo. The A9 runs along and cuts through the middle of the area. It is a very open, rather poorly drained grassland area. Trees and shrubs are absent, buildings of any kind are virtually absent and the disclosure by farm roads is minimal.

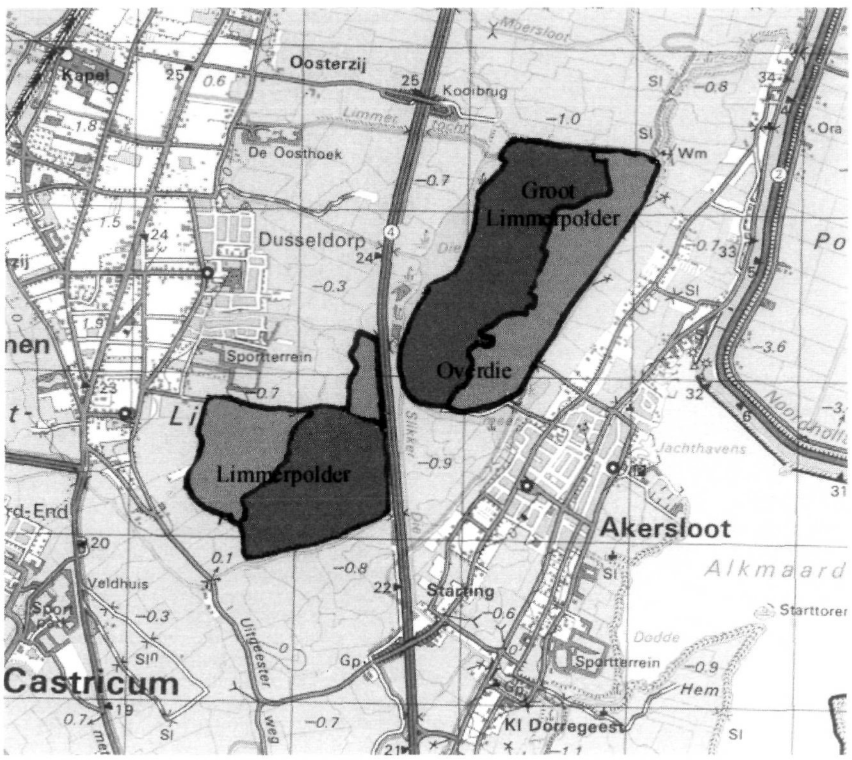
In the course of the reallotment scheme, some minor works were carried out. One very minor road has been extended, a few ditches have been filled in, some others have been newly dug, and locally, along a very few wide ditches, the verge has been dug off to permit new nature development. In 1998, there were heaps of soil or bare ground in a few places.

The research area consists of two parts:

- the area open to the influence of the motorway and the traffic on it: Limmerpolder, to the west of the A9 between that road and the villages Limmen/ Dusseldorp;
- the area largely out of reach of the influence of the motorway and the traffic on it: Groot-Limmerpolder, to the east of the A9, between Lake Die, the watercourses Kromme Sloot and the Mientsloot on the side of the village of Akersloot.

Both areas are good black-tailed godwit habitats. The population density is several dozen per 100 hectares. A large part of both sites is owned by the nature conservation organisation Het Noordhollands Landschap. Groot-Limmerpolder, which is used as the control or reference, is discussed in more detail in § 2.4.

Figure 2.1 Situation and limits of the research sites. Dark grey: owned by Het Noordhollands Landschap; light grey: privately owned.



2.2 Limmerpolder

The grassland area on the west side of the A9 is bordered by the Dusseldorpervaart, the A9, the Schulpvaart and the Uitgeesterweg/Dusseldorp. It lies fully open to the influence of the motorway.

The selected research area Limmerploder covers nearly 100 hectares. The distance from its western border to the road Uitgeesterweg en the village of Dusseldorp is about 200 to 300 m[5]. The site is immediately adjacent to the A9. *The course of its northern, western and southern borders have been adapted to* the form of the plots. Trees and shrubs are absent, apart from a small willow standing along the Schulpvaart, which was cut in 1999. A very small blind farmers road runs from Dusseldorp into the southern part, with a branch into the northern part. There are no buildings of any kind. The central and southern part of the site is owned by Het Noordhollands Landschap and is called 'Oosterveld' (see *figure* 2.1). *The entire area is grassland that is leased under restrictive* conditions for the benefit of the avifauna. The remaining, privately owned part of the site is principally grassland where agricultural use is locally adjusted to benefit the avifauna as well.

The land use in the area ranging from the old coastal ridges of Limmen-Heiloo towards the A9 consists of a small zone of permanent bulb fields just outside the research site - a narrow transitional zone of grassland where, from time to time, plots are used as bulb fields either a single or several years and then turned into grassland again - permanent grassland.
The soil is rather complex. It consists of clay soils and peat soils over a vlayey subsoil.[6] The drainage conditions are not optimal. The recent soil map indicates, almost exclusively, a class II ground water level. This means a GHG (average highest ground water level) between 5 to 10 and 15 to 25 cm below soil level, and a GLG (average lowest ground water level) ranging from 60 to 80 cm below soil level.

2.3 Groot-Limmerpolder

This part of the area east of the A9 is bordered by the ditches Limmertocht, Mientsloot and Kromme Sloot, and the marsh zone along Lake Die close to the motorway. The entire area is grassland. In the course of the reallotment scheme Limmen-Heiloo, a large part has been alloted to Het Noordhollands Landschap, which already owned the lake and other grounds and calls its property 'Het Die'. On the topographic map, the southern part of Groot-Limmerpolder is called polder Over Die.

[5] This correspondends with a traffic density of roughly 25,000 cars/day.
[6] From the coastal ridge towards the A9, and thus from high to low, the sequence is: irregular 'strandwalovergangsgronden' (transitional coastal ridge sand soils) – 'delgronden' – 'pikkleigronden', clay on old seasand or light clay ('zavel') on peat – peaty 'pikkleigronden' on peat (*De Roo 1953*) The *recent soil map 1 : 50.000 (SC-DLO 1995) shows mainly: clay soils formed by 'drechtvaaggrond'* ('Drecht' vague soils: claylike hydrovague soils poor in calcium, with peat in the subsoil starting between 40 and 80 cm. depth [code Mv41C]), raw peat soils represented by 'waardveengronden' ('Waard' peat soils: peat soils with a grey clay cover thinner than 40 cm, with clay less deep than 120 cm. [code kVk] or sand less deep than 120 cm. [code kVz]), and 'eerdveengronden' represented by 'koopveengronden' ('Koop' peat soils: a claylike earthy peat layer over sand less deep than 120 cm. [code hVz]).

The selected research area covers approx. 140 hectares (see figure 2.1). Towards the A9, the area is largely protected by the reed and shrub vegetation along Lake Die. Otherwise, trees en shrubs are absent. From Akersloot in the east, three blind and partly unpaved roads lead into the area. Two of these are only accessible by means of farmyards. One, halfway, was extended as an unpaved road in 1999. Two buildings are present in this area: a barn and a shed for a pony.

The soil shows little variation. Between the coastal ridge of Akersloot and the A9, it consists entirely of peaty clay soil on peat[7]. The narrow band of raw peat soil along Lake Die is outside the selected site.
Drainage is limited. The recent soil map indicates a class II ground water level for (almost) the entire area (see previous paragraph). Drainage conditions in the reserve of Het Noordhollands Landschap are even more limited. In april, the ditch water level rose to approx. 3 decimetres below soil level. Elsewhere, the ditch water level is approx. 2 to 3 decimetres lower and drainage is better.

2.4 Groot-Limmerpolder as a reference

The effect distance of roads on meadow birds is considerable. In open areas and at a speed limit of 120 km/hr, a traffic density of 5,000 vehicles/day corresponds on average to an effect distance of 125 m; a traffic density of 15,000 vehicles/day thus corresponds to an effect distance of 250 m, 50,000 vehicles/day corresponds to 600 m and 150,000 vehicles/day corresponds to 1000 m. *(Reijnen et al. 1992)*. However, the effect distance varies from species to species. For the black-tailed godwit, it is generally larger than the average for meadow birds. A traffic density of 5,000 vehicles/day corresponds to an effect distance of about 230 m under the same conditions, while 50,000 vehicles/day corresponds to 900 m (*Reijnen 1995*).

The principal factor that determines the effect distance is the noise that is produced by road traffic (*Reijnen 1995*). The effect distance thus depends on the absence or presence of sound muffling conditions along the road.
It is well known that a high vegetation muffles sound better than a low plant cover (*Reijnen et al. 1992*). However, the travel of sound is at least as dependent on soil properties. In particular a thick, porous topsoil, i.e. a thick humus layer below a well developed plant cover, appears to muffle sound very effectively (*Martens s.a.*). Finer textured plant biomass increases the extent of muffling as well.

The distance from the western border of the research area Groot-Limmerpolder to the A9 varies from 100 to 500 m and is largely sheltered by a medium high vegetation zone along Lake Die. This zone is formed by swampy groves and wide reed fringes with an especially porous toplayer consisting of peat, grading into peatmoss covered by litter that gradually merges into 1 - >1,5 m high 'standing litter' formed by dead reed. In view of this and in reference to Reijnen et al. (1992), Reijnen (1995; based on *Moerkerken & Middendorp 1981* and

[7] 'Venige pikkleigronden op veen' (*De Roo 1953*). According to the recent soil map 1 : 50.000 (*SC-DLO 1995*) the soil consists only of 'rauwveengronden', i.e. both types of 'waardveengronden' (code kVz and kVk) mentioned in note 4.

Huisman 1990), and our own auditory observations during varying weather conditions, we assume that any disturbance due to traffic sounds will not, or will hardly reach past the marshy eastern shore of Lake Die.
The effect distance of the influence of road traffic is calculated with the effect prediction method of Reijnen et al. (1992). The starting points are:

- the traffic density on the A9 near Limmen-Akersloot was approx. 90.000 vehicles/day in the period March through May 1998 and amounted to over 90.000 vehicles/ day in 1999 (according to *RWS Noord-Holland, dienstkring Alkmaar*);
- the speed limit on the A9 is 120 km/hr[8].
- the mentioned vegetation zone along Lake Die is considered a sound buffering forest, in spite of the likelihood that this vegetation zone muffles sound at least as much as forest does.

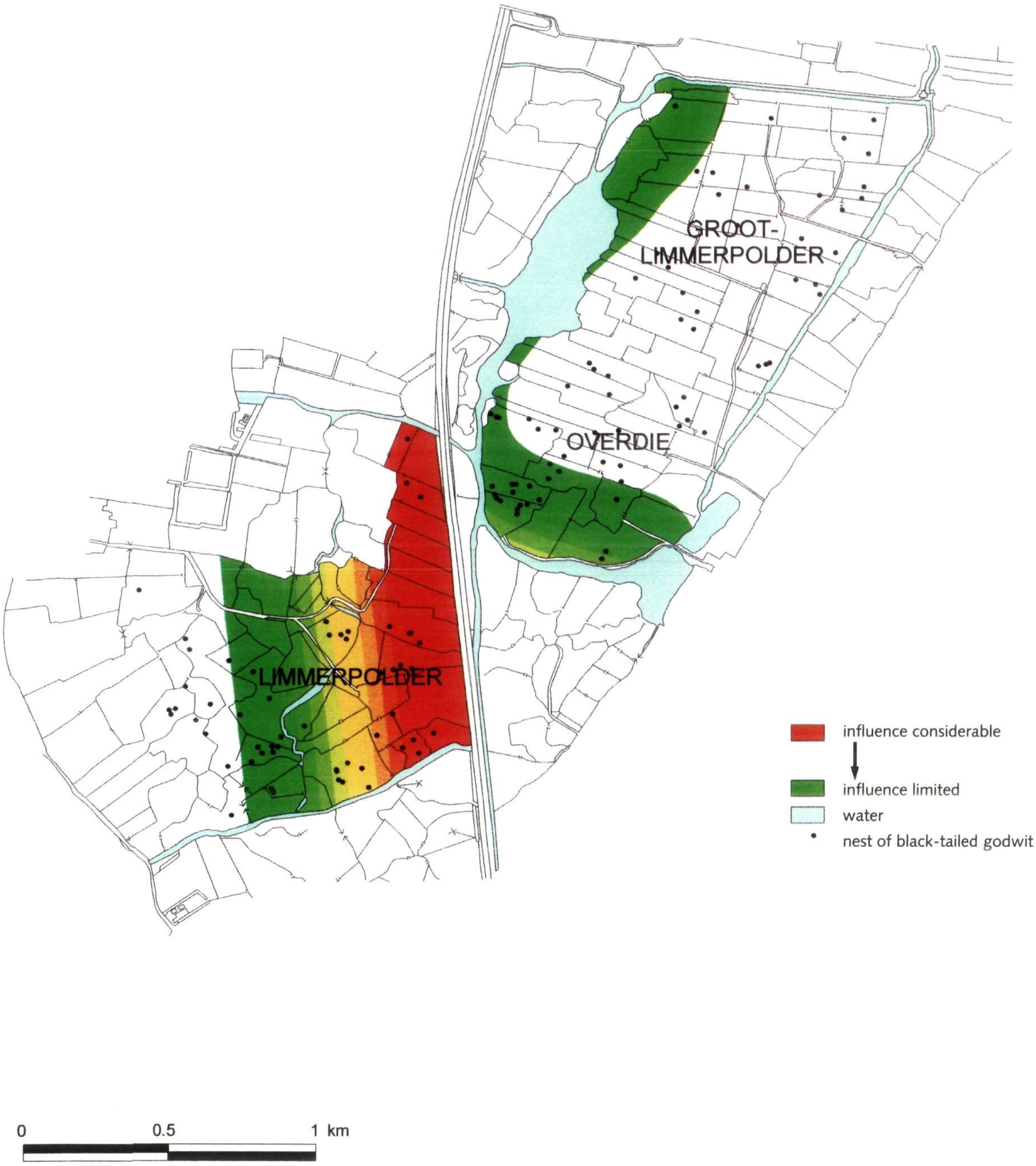
The results are shown on the two maps inserted at the end of this chapter. The differences between them are minimal. However, two aspects concerning these maps deserve mentioning. On the one hand, the proximity of the sea coast, the prevailing winds from that side and the open landscape towards the coast, suggest a possible underrating of the effect distance east of Lake Die. On the other hand, the preceeding leads to the assumption that the sound muffling influence of the plant cover is stronger than that of the average forest in the effect prediction method of Reijnen et al. (1992). Moreover, a detailled application of that effect prediction method of Reijnen et al. (1992) requires interpolation. In view of these remarks, the calculations and the resulting maps should be considered indicative.

2.5 Management

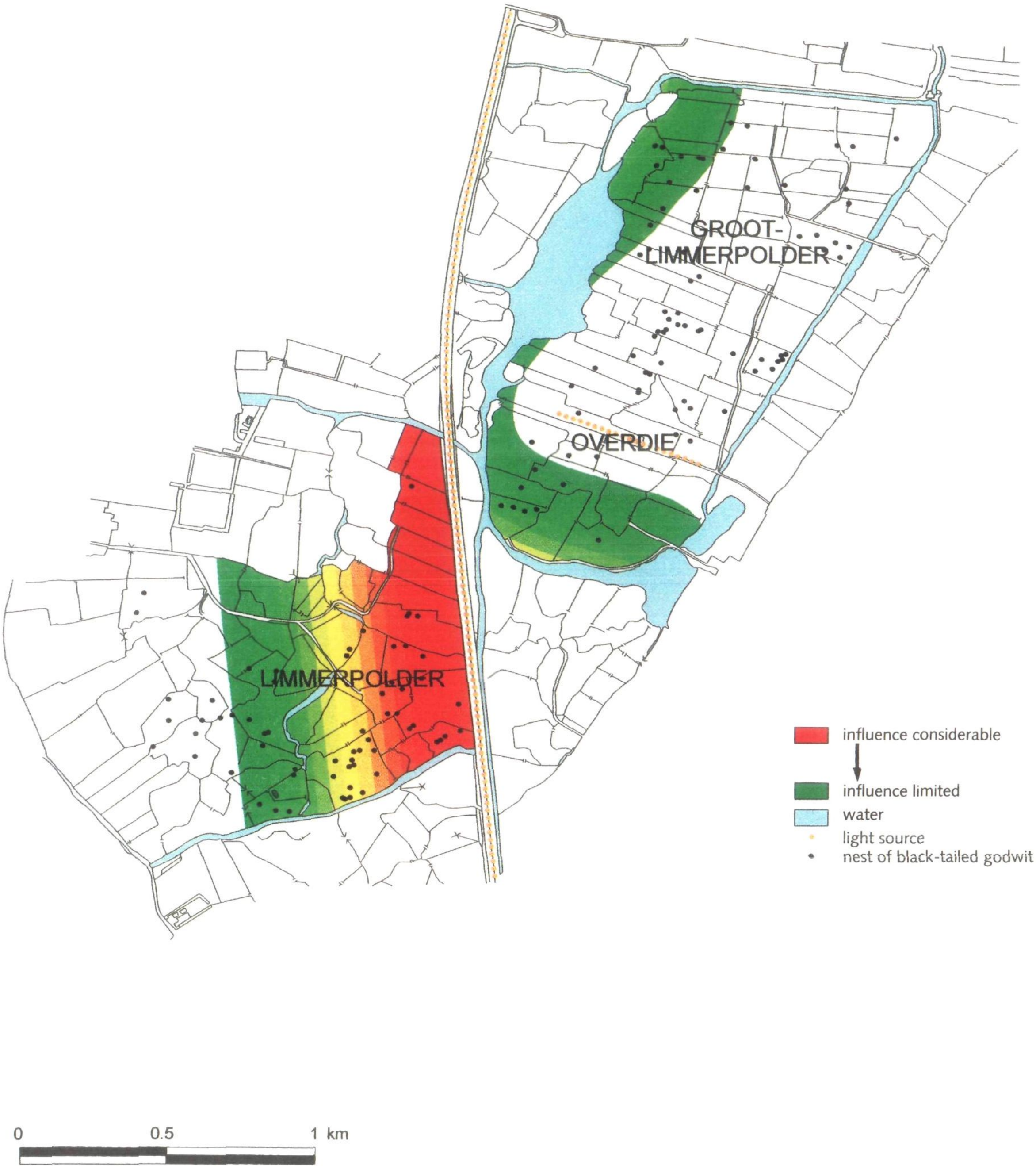
Het Noordhollands Landschap manages its grounds (Oosterveld and Het Die) as a 'meadow bird' reserve.This implies that manuring, tending the grass in whatever way by rolling etc., mowing, grazing, etc. are excluded during the entire reproductive period (March 15th to June 15th). Grazing, in terms of period, type of cattle, and stocking rate, is adjusted to obtain a grass cover structure that best suits the birds. Fertilizing is restricted to the local application of coarse stable dung. This was recently done on a few plots in the reserve Oosterveld. In both reserves, the aim is to realise a ditch water level of approx. 3 dm below ground surface.
The private grounds in Limmerpolder and Groot-Limmerpolder are drained deeper and are in regular agricultural use. Nonetheless, grazing in the breeding season is limited to a few plots. These are used for sheep, either all year round or seasonally, or cattle (mainly heifers), starting from late April. Grassland management activities such as rolling, manuring and mowing are commonly carried out from late April to early May onwards, usually on a rather limited scale, due to the conditions of the grounds. Along the western border of the research area Limmerpolder, a few plots are alternately exploited as grassland and bulbfields.

[8] According to Reijnen et al. (1992), the first two starting points hold in open, unsheltered grassland with an effect distance of traffic on the density of meadow bird populations amounting to 780 metres (1998) and 800 metres (1999), respectievely.

Map 1. Influence of motorway in 1998
(in intervals of 50 metres)



Map 2. Influence of motorway in 1999
(in intervals of 50 metres)



3 Intermezzo

3.1 Brief profile of the black-tailed godwit as a breeding bird

In The Netherlands, the first black-tailed godwits reappear in late February. For several weeks after their arrival, they tend to flock together. During the day, they feed on well-fertilized grassland; during the night, they rest on shallowly inundated land and wet places. In the research area Groot-Limmerploder, there was one such resting place in the northwestern corner, adjacent to Lake Die, which was sometimes also used during the day. Only early in the morning, and sometimes in the evening too, do they visit their future breeding places. The groups gradually fall apart in the course of the second half of March. Some of the birds are then already paired, others do not meet their partner until they are on the breeding place (*Moedt 1995a,b*).

On arriving from their spring migration, black-tailed godwits will have suffered a loss of weight, while the coming months require a considerable energy investment. A female, for instance, needs 50% of her normal body weight in material for the production of a complete clutch (*Moedt 1995b: 88*). During the breeding season, the birds mainly live on insects and their larvae (esp. larvae of the dragon fly), earthworms and some plant material. They search for food mainly during the day, in spite of the fact that they rely less on sight in doing so, but rather feel by probing their long bill into the soil. Because of this, they prefer areas with soft, wet to damp soils. On hard surfaces, they peck their prey and other food from the surface.

Black-tailed godwits breed on moist to wet grassland. In a suitable area, they often breed more or less clustered in loose colonies, in which the nests may be quite close together (see map 11 at the end of chapter 6). They prefer a more or less uneven sward and they usually breed in tussocks in which they hide their nest by pulling the grass blades together. They show a high degree of nest-fidelity. Research in Schaalsmeerpolder (Wormerland community, in the province Noord-Holland), brought to light that half of the black-tailed godwits bred within 50 m from their nest place in the preceeding year (*Groen 1993a*). This implies that a single inventory in a changeable area may result in a distorted image of their preference in relation to grassland characteristics.

The date of return and the subsequent weather conditions in the breeding area determine the date of laying the first egg, and coupled the starting date of breeding. The first clutches appear from late March onwards, in a nesting hollow selected by the female from the various ones made by the male. In normal years, most pairs start to lay eggs in the first week of April (*Glutz von Blotzheim et al. 1977*). In the course of the meadow bird research in Schaalsmeerpolder that was carried out in the period 1984-1992, it appeared that the average date of laying the first egg varied from 20 to 48 days after the date of arrival (*Groen 1993b*).

As a rule, the clutches count four eggs. Breeding starts about five days after the first egg has been laid, when the clutch is completed. Thus, the eggs are laid almost dayly. The median date of egg laying (i.e. the day when more than half of the total number of eggs is laid, say the peak of the start of breeding) falls approx. on April 16th (*Beintema 1995a*) in the Netherlands (excluding the province of Friesland). After 24 to 25 days of breeding, all of the young hatch

almost simultaneously (*Moedt 1995a, Beintema 1995a*). Outside Friesland, the peak in hatching falls around May 10th (*Beintema 1995a*), on average.
Early breeding increases the chance of staying ahead of the risk of losses owing to grassland management and exploitation practices (such as slurry injection, mowing) and/or trampling by cattle. On the other hand, early hatching increases the risk of the chickens being exposed to unfavourable weather and a limited food supply – and *vice versa*.

3.2 Grassland management and black-tailed godwit

Site preference, choice of nest and breeding success are strongly influenced by water management and grassland management; see figure 3.1

Fertilizing, grazing and water management largely determine the development of the structure of the grass cover. The application of mineral fertilizer - and of liquid manure and slurry, although to a somewhat lesser degree – provides an even distribution and results in a more rapid growth of the grass cover. This may suit black-tailed godwit (but not lapwing). The distribution of coarse stable dung is much more uneven. This, and the gradual process of mineralization of the material will, on the whole, cause a less rapid growth of the sward, which then attains a more tussocky structure. This is favourable for breeding for both black-tailed godwit and lapwing, and for the food availability, the latter holds especially for the chickens (insects). The straws in the stable dung are also a source of nest material, which is particularly appreciated by the black-tailed godwit. The structure of the sward also depends on the preceeding grazing regime, including the cattle species and the grazing density (see *De Molenaar 1996*).
Furthermore, water management and fertilizing are of great importance through

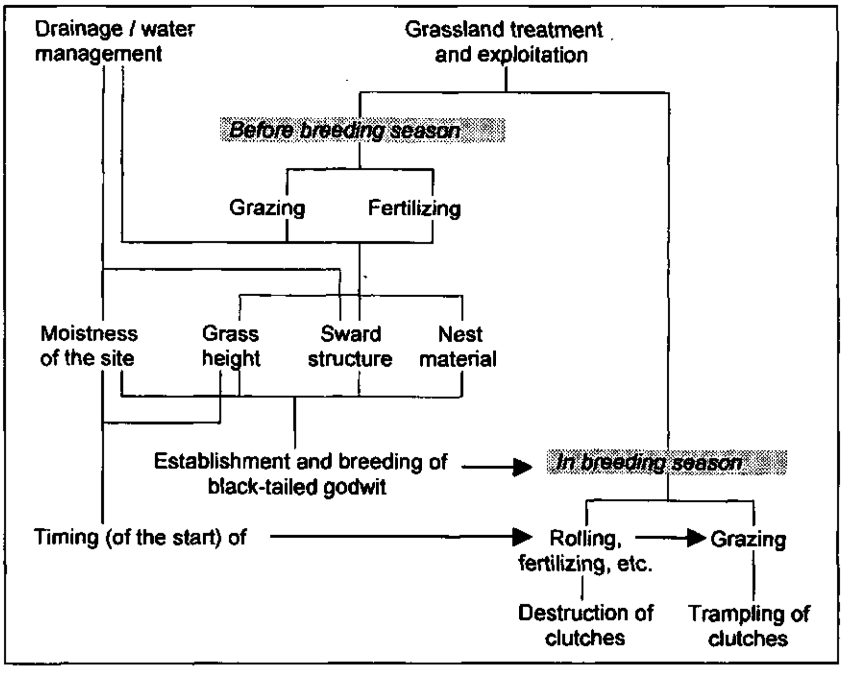


Figure 3.1 General scheme of the influence of water and grassland management on the black-tailed godwit

the timing of agricultural activities in the field, such as rolling, manuring, mowing, grazing.
These activities can be moved back to an earlier time in the breeding season, by deeper drainage (increasing the carrying capacity of the soil, c.q. decreasing the susceptability for trampling of the soil, fertilizing effect of intensified mineralization of organic soil material, earlier and quicker warming up of drier soil) and by fertilizing (accelerated grass growth). This adjustment increases the risk of loss of clutches and chickens by being driven over, trampled upon, mowed to pieces, etc.

Vice versa, the omission of fertilising peat grassland goes hand in hand with a marked decline in the numbers of meadow birds. The soil acidifies and, as a result, earthworms may disappear almost completely. Where annual manuring is continued, the soil does not acidify, or to a lesser degree (*Brandsma 1997*). When chalk is added to acidified soil, the soil becomes less acid and the number of earthworms strongly increases in the following years. Simultaneously, the density of black-tailed godwit (and lapwing) increases again (*op. cit.*).

The presence and the amount of food depend on the acidity of the soil and the content of organic matter. But, the actual availability or attainability determines if, and to what extent, the food source can be utilized. The availability is a matter of the depth at which the food is found in the soil (the depth of the groundwater level on the one side, and bill length on the other), plus the penetration resistance of the soil (wetness). In deeply drained plots (water level approx. 90 cm below ground surface), much fewer earthworms are found than in moderately drained ones (idem 50 cm below ground surface). In deeply drained plots, increasing the water level to approx. 20 cm below ground surface leads to an increase of earth worms after several years, but the same increase in moderately drained ones does not have this effect. However, in both cases the number of meadow birds increases immediately (*op.cit.*).

4 Field work

4.1 Field work programme

The breeding period is from late March to late May. The main period and therefore the best period in which to search for the nests is from the middle of *April until into the first half of May (see § 3.1). In combination with the* following, this has been translated in the phasing of the fieldwork in 1998, as presented in table 4.1. In 1999, the first two steps are combined in a short verifying field survey.

Table 4.1
Survey of the fieldwork programme

Period	Fieldwork	Aim
April 1st week	* general field survey	orientation, choice of research sites
2nd week	* preliminary inventory of territoria	closer reconnaissance
3rd week	* search for nests	localization and marking of nests
	* observations of clutches	condition of the clutches
4th week	* search for new nests	localization and marking of new nest
	* observations of clutches	condition of the clutches
	* revisit to previously found nests	control observation
	* determination of the position	exact position of nests
	* description of plots	background information
May 1st + 2nd week	* control of previously found nests	control observation
	* search for new nests and determination of their position	see above
	* observations of new clutches	condition of the clutches
3rd week	* control of previously found nests	control observations
	* collecting data on grassland management	background information
4th week	* control of collected data	copletion of field work

4.2 Search for and marking of nests and eggs

The search for and monitoring of meadow bird nests requires a great deal of expertise and consumes a lot of time. We, as researchers, were then placed for a dilemma: whether to invest time in the search for as much nests as possible, or to invest time in monitoring all of the nests found. The problem is that considerable numbers of nests are required for the statistic reliability of an investigation per area or situation that is to be compared to others. In reality, this requirement is rarely met (*Beintema 1995a*). It is therefore essential to find an optimum balance between enlarging the sample as much as possible by investing in the search for additional nests, and limiting the number of control visits to the nests by maximalizing the period between these visits (*op. cit.*).

It is not easy to find the hidden nests of the black-tailed godwit. There are several methods for searching for meadow bird nests. In our experience, the most efficient way is to localize the spots where birds fly away from possible nests, and to follow birds presumably returning to their nests. This procedure has been followed here.
To find a previously located nest again as easily as possible, the spot is marked by placing a stick nearby. This stick is placed obliquely, pointing in the direction of the nest. Each nest is identified by writing the number of the plot and the plot-wise number of the nest on the stick. Nest-wise, each egg is given a

number with a waterproof marker. After hatching, disturbance and abandonment or complete predation, the sticks are removed.

4.3 Monitoring the clutches

As mentioned before, it is desirable to minimise the number of visits to the nests and to maximise the duration of the control intervals. Another reason in favour of limiting the number of revisits is that traces of the searcher in the grass and the nest marking sticks may facilitate predation. Furthermore, it should be taken into account that searching for and visits to nests during unfavourable weather (strong wind, coldness, precipitation) increases the risk that temporarily abandonned clutches fail due to cooling down. To conclude, which employment of capacity is possible in view of the available means and organization, and what is acceptable in view of inevitable disturbance in the field, is a practical matter.
Taking this into consideration, the fieldwork was conducted by one team of two persons in each research area, which monitored each nest once a week. The latter implies that each nest, depending on the breeding stage in which it was found, was visited one to three times.

4.4 Condition of the clutches

The condition of the clutches is determined by calculating the average volume of the eggs in each nest. To this aim, the length and width of the eggs is measured once using a slide-rule with nonius (accurancy 0.1 mm). The volume is then calculated with the formula $V = 0{,}5035 \times L \times B^2$ (*Spaans & Spaans 1975*). The egg volume is a good indication for the quality of the parent birds and the breeding succes in terms of survival of the chickens (*Bolton 1991*).
Furthermore, the eggs are weighed with an electronic balance and using a steelyard on a few occasions. The weight was expressed in tenths of grammes. Most eggs were weighed once, others twice or three times. As such, the egg weight is not very relevant, as it decreases with the development of the embryo. They are weighed to obtain a means to monitor the field notes concerning the measurements of the eggs.

4.5 Breeding stage of the clutches

The breeding stage (in days) is derived from the behaviour of the egg in water. This is done using so-called incubometers, a refined variant of the common immersion test; see annex 1. With this device, it is possible to estimate the starting date of the breeding of the clutches. By deducting five days, it is possible to establish when the first egg of the clutch was laid.
This method provides a certain spread in data that may vary from one to a few days, dependent on the stage of breeding when it is applied. By averaging, repetition and combining this with the date on which hatching was observed, the spread has been narrowed to one day.

Breeding black-tailed godwit on the nest. As a rule, the birds are very shy and when approached, they take to the air at already a considerable distance. However, sometimes they are so attached to their nest that they may be carefully approached up to less than one metre. Both forms of behaviour do not facilitate the search for the nests.
Photo J.G. de Molenaar

Black-tailed godwit like to use straws to build their nests. That is why they prefer grassland that is mowed rather than grassland that is grazed (*Buker & Reyrink 1989, Groen 1993*), and especially grassland fertilised with coarse stable dung. As a rule, a clutch counts four eggs, sometimes they hold three eggs.
Foto J.G. de Molenaar

With the help of the inclination of the egg in the water-filled incubometer, the stage of breeding can be determined.
Photo D.A. Jonkers

On grazed plots, here with sheep, nest protectors are placed to prevent trampling of the clutches. The stick next to the nest protector is used to mark the nests. The stick states the number of the plot and the number of the nest.
Photo D.A. Jonkers

4.6 Loss of clutches

Predation and other causes of loss are established by the way in which the egg or eggs are damaged. Obviously, this does not apply when an egg or eggs have disappeared. Clutches are considered to be abandonned if the eggs are still present but cold when the average breeding time has expired.

4.7 Habitat conditions

The quality of the habitat is of course important for the black-tailed godwit's choice of their nest place. The conditions that influence this choice are dealt with in chapter 3.

They concern the moisture or drainage conditions of the plots, the structure of the sward, the grass height, fertilizing (i.e. with course srable dung) and grazing. Plot-wise, these conditions are noted in accordance with previoulsy drawn up scales. The classes of these scales and their definition are presented in annex 3. The scales for grass height and moisture or drainage conditions have been simplified in the course of working out the field data.

4.8 Road illumination and experimental illumination

The illumination of the A9 is placed in the middle of the road. The specifications of the illumination is as follows: the lamps are placed 25 m apart at a height of 12 m. Their type is SOX 135W. Each has a capacity of 159 Watt and a light current of 22500 lumen. The lamps are attached to armature type SDP 252/135 (data: *Werktuigbouwkundige Elektrotechnische Dienst van Rijkswaterstaat, Directie Noord-Holland*). The illuminance on the surface is presented in figure 4.1[9].

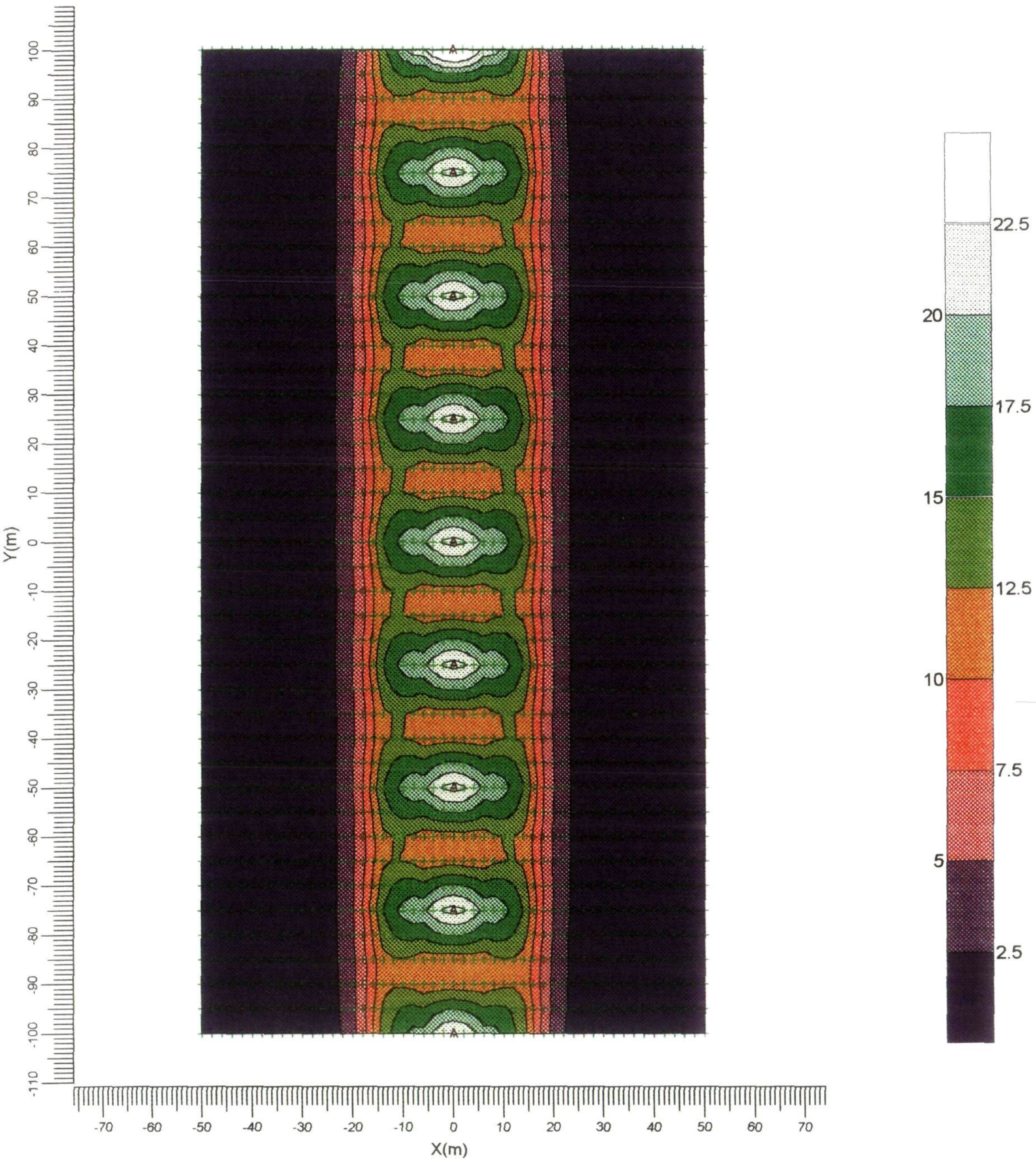
The same qualifications apply to the temporary experimental illumination in Groot-Limmerpolder. The selection of the location of this illumination was determined by two conditions:

- from a practical point of view: the supply of electricity in the near vicinity, combined with a road into the polder with a verge where a cable could be installed underground and where armatures could be placed;
- from a research-technical point of view: the presence of a high density of breeding pairs; concerning this aspect, we started from the situation in 1998 in a substantial part of Groot-Limmerpolder that qualifies as a reference area (see § 2.4).

For a start, there were four alternatives that answered to the first condition. On observing condition number 2, only one remained. And so 24 armatures were placed at the location of the remaining alternative, ample time before the arrival

[9] In figure 4.1, the illuminance is given in lux, measured on the horizontal surface. The unit lux is adjusted to the sensitivity of the human eye. The sensitivity of the eyes of birds may differ somewhat; thus, in contrast to man, birds can see near-ultraviolet light (*De Molenaar et al. 1997*). Therefore the illustration only serves as an indication of the extent of the illumination.

Figuur 4.1 Spatial distribution of the illuminance on the horizontal surface, in lux, by the road lights



of the black-tailed godwits to prevent unwanted disturbance during the stage of their establisment. The armatures were placed in the verge of the plots to minimise negatives effects to the adjacent habitat. The illumination of the A9 and the temporary illumination switched on simultaneously. The switching off did not occur synchronously. During the entire research period, the experimental illumination switched off a quarter of an hour earlier in the morning. This could not be helped, but it will not have had any consequences for the research as this happenend when dawn had nearly passed.

The presence of light poles as such might have consequences for the black-tailed godwits, as it may facilitate predation. The poles offer look-out posts for predators, such as gulls and crows. Whether or not this was the case was checked during the field work.

4.9 Statistic method

The site factors that may influence the nest choice of black-tailed godwit are drainage conditions, sward structure, grass height, fertilising (with coarse stable dung) and grazing (see § 3.2).
Grazing and fertilising with mineral fertiliser, liquid manure and slurry are not included in the statistic analysis. These activities indirectly influence the nest choice through their effect on grass height and sward structure. Thus, they are not independent factors. Besides that, if, when and how grazing and/or fertilising took place before the field work period is not exactly known for a large number of plots. On the other hand, the plots that were fertilised with stable dung are certainly known, as the straws remain visible in the field for a long time. Black-tailed godwits may prefer plots that are treated in this way, as they use the straws to make their nests.
As a consequence, the statistic analysis comprises drainage conditions, sward structure, grass height and fertilising with stable dung in comparison with the influence of road (traffic) and illumination.

The habitat conditions (e.g. sward structure) have to be compared with each other class-wise (e.g. smooth, somewhat tussocky, very tussocky) to determine their impact on the choice of the nest location.
The class-wise comparison of the numbers of nests based on habitat conditions results in a distortion owing to the significant differences in the area of the various condition classes. Consequently, the differences in area must be compensated for. An estimation of the area distribution is made using a very large number of points (*Sanders 1999*). In this case, 1000 points were used. Normally, a chi-quadrate test is applied. Because of the number of possible combination classes, it was thought more pratical to use a logit regression.

To establish which factors significantly determine the nest choice, the following statistic analysis is applied. A marginal test is a test for each factor separately; a conditional test is a test for each factor, given the other ones. Factors may influence each other. In turn, this may influence the significance.
The regression analysis is only applied to the factors that appear to be significant based on the conditional test. Regression analysis is a statistical method to investigate the occurrence of e.g. black-tailed godwit nests in relation to site

factors. Nominal (classes), ordinal (classes) and quantitative (distances) factors can be tested simultaneously (*Sanders 1999*).

Thus, the site factors drainage conditions, stable dung application, sward structure, grass height and distance to road (influence of road traffic) are tested in GENSTAT for 1998 and 1999 separately. Next, the distance to the illumination is added. The result of the regression analysis is processed with GIS to produce a 'relative chance of occupation' map, by substituting the site factor classes for estimations of the regression coefficients and adding these up (*Sanders 1999*). This 'chance of occupation' depends on the number of randomly chosen points, making the result a relative chance (from small to large). Of course, the tests do not demonstrate a causal relation, only a statistical relation between the choice of nest position and site factors.

It is assumed that the first birds to arrive can occupy the best positions (*Reijnen 1995*). Thus, there should be a positive relation between the 'chance of occupation' map and both of the dates on which the first eggs are laid, as well as the breeding (i.e. hatching) success. This was tested using a normal lineair regression. The breeding or hatching success is defined as the average egg volume of each clutch (see § 4.4). Next, the distance to the illumination is related to the dates on which the first eggs are laid and the breeding/hatching success by linear regression.

The possible relation between the 'chance of occupation' and both the dates on which the first eggs are laid, as well as the breeding (i.e. hatching) success, is tested using a normal lineair regression. The breeding or hatching success is defined as the average egg volume of each clutch (see § 4.4). Next, the distance to the illumination is related to the dates on which the first eggs are laid and the breeding/hatching success by linear regression.

5 Results of the inventory

5.1 Weather conditions and site conditions

The reference year 1998 and the experiment year 1999 were characterised by an exceptionally wet and cold early spring. Later on in the course of the breeding season of 1998, the weather brightened considerably and it was almost continuously dry. In 1999, the weather improved later on in the breeding season.
As a result, a considerable number of the plots in Limmerpolder remained more or less soggy far into the second half of April. The Oosterveld Reserve frequently saw long-lasting puddles and sheets of water, especially in 1999.
A similar situation could be found in Groot-Limmerpolder in 1998, where many plots were more or less soggy far into April, with the exception of some plots where trenches were replaced by drains. Due to the superfluous rainfall, this situation lasted even longer in 1999, but it became drier later on.
Later on in the breeding season of 1999, the water board raised the ditch water level in Over Die drastically. A number of plots was inundated, causing the loss of some black-tailed godwit clutches. This loss did not affect the investigations, as the locations of the nests and the parameters of the clutches had already been measured.
The site conditions are presented on maps 3 – 10 at the end of this chapter.

5.2 Breeding density, general

The area is one of the best in the Province of Noord-Holland and the Netherlands. The average breeding density in both years was well over 50 pairs/100 hectares. The density is even higher on the grounds of Het Noordhollands Landschap. In the Oosterveld Reserve, the density was over 70 pairs/100 hectares. The density was slightly less in the Het Die reserve. The highest density was found in Over Die, with approx. 80 pairs/100 hectares. The positions of the nests are shown on the maps concerning the site conditions at the end of this chapter.

The populations in the two research areas seem to be developing differently. In Limmerplder, the population appears to show an increase and stabilisation, apparently without any influence of the reallotment activities. The general appearance of this area appears to have hardly changed. In 1998, 32 territories[10] are reported from this area and 53 in 1999 (*Provincie Noord-Holland*, unpublished).
The Groot-Limmerpolder showed a decline. In 1994, 142 territories were established here (*Provincie Noord-Holland*, unpublished). The decline is concentrated in the northern and eastern parts of the area, which are privately owned.

[10] This data does not originate from nest inventories, but is derived from observations of behaviour indicating breeding that result in the assumption of territories. This procedure goes hand in hand with some complications. First, searching for and localising the nests of black-tailed godwits show that observations of behaviour that are taken to indicate breeding do not inevitably result in nesting; at least not close to where such behaviour was observed, in many cases. Second, in suitable sites the density may be so high that observations of behaviour indicating breeding become confusing to the effect that any quantitative interpretation may be incorrect.
Otherwise, the territory concept is relative in the case of black-tailed godwit. In suitable sites, they may nest very close together; see the cluster map at the end of chapter 6. The reader is also referred to annex 2.

In the province of Noord-Holland, the characteristic breeding density of the black-tailed godwit is 27 pairs/100 hectares for watery peat grassland areas and 20 pairs/100 hectares in other grassland areas (*Beintema 1995a, based on unpublished data of Provincie Noord Holland*). In that province, the highest densities of 27 pairs/100 hectares are attained in the so-called 'snipe-rich meadow bird community' (*Ruitenbeek et al. 1990*). This is a community of wet peat grassland areas, to which our research area may be considered to belong. In a selection of grassland areas in the centre of the province of Noord-Holland (approx. 25% of which is designated as a reserve), the density of black-tailed godwit populations amounted to 20.1 and 26.5 pairs/100 hectares in the period 1983-1984 and 1990-1992, respectively (*Provincie Noord-Holland 1994*). In the meadow bird reserve Eilandspolder, the average density was approx. 25 (11-40) pairs/100 hectares (*op. cit.*) in the period 1982-1992. In the Eempolders in the province of Utrecht, the average density was 12 to 14 pairs/100 hectares in 1989 (*Terlouw & De Wijs 1990*). In the province of Friesland, a maximum density of 83 pairs/100 hectares was counted in nature reserves on clay soils in 1994. In reserves in peat grassland, the maximum equalled 55 pairs/100 hectares.
In the course of the selection of the research area, a considerable decline could be observed in various renowned meadow bird areas. In Polder Mijnden, the numbers dropped from 52 (1988) to 33 (1994) pairs/100 hectares; Polder Westbroek saw a decline from 26 (1986) to 14 (1994) and Polder Achttienhoven from 52 (1978) to 4 (1994; *Van Veen et al. 1994*). This data is largely based on territory inventories (see note 8 and annex 2). In the areas in the province of Friesland where members of the BFVW protect meadow birds, the density fluctuates around approx. 19 pairs/100 hectares, but this density recently dropped too (*Bond van Friese Vogelbeschermingswachten, various years*). During the past decade, the average decline is estimated at over 50% (*president of the Bond van Friese Vogelbeschermingswachten, personal communication*). However, in some reserves in Friesland, the densities may still amount to many dozens of pairs/100 hectares. This data is collected by volunteers who protect the nests meadow birds and thus refers to nests that were actually located, rather than to inventories of territories as is the case elsewhere.

5.3 Breeding population Limmerpolder

In 1998, fifty-three nests were found and monitored in the research area Limmerpolder, which covers nearly 100 hectares. In 1999, 63 nests were found and monitored.

It is evident that the black-tailed godwit prefers the 60 hectares of Het Noordhollands Landschap. In 1998, the density in this area was approx. 65 pairs/100 hectares, and 83 pairs/100 hectares in 1999. Compared to the densities elsewhere in the country, these densities are very high. Apart from the general conditions, the restrictions that apply to the land users are undoubtedly of influence. The four plots halfway along the ditch along the southern border of Oosterveld that were not occupied in 1998, were far too wet in that year and situated around a willow stand. In the winter of 1998-1999, this grove was felled; the remains were still present in the form of large heaps of branches. In 1999, five pairs of black-tailed godwit were found to breed on two of these plots. In 1999, dry parts were somewhat more common on a local scale.

The density on the privately owned area of nearly 40 hectares is almost 50% lower (in 1998 35 pairs/100 hectares, in 1999 32 pairs/100 hectares). This is attributed to sheep grazing in winter, which results in a very short and even sward that is less suitable for the breeding of black-tailed godwit. This effect was demonstrated by a plot that was not grazed in 1998 and had five nests in that year. The next year, following previous sheep grazing, it was occupied by only two pairs nesting in the plot's very verge.

In relation to the breeding season, the influence of the period of grazing differs essentially (see figure 3.1). Grazing before the breeding season, together with other management activities, determines the suitability of the plots for the establishment of black-tailed godwit. If plots are grazed in the breeding season, after breeding pairs have been established, this may cause considerable losses of clutches due to trampling (*Beintema 1995a*).
In both years, the number of plots grazed during the breeding season was very limited. In the north-eastern corner of the area, adjacent to the A9, four of the six plots were grazed by large numbers of sheep; numbers ranged from about 25 to over 100 animals/hectare. On two of the plots, the grazing started relatively late in 1998, and these were the only two occupied by black-tailed godwits. In 1999, one of these two plots was made unsuitable by early sheep grazing, whereas the situation in the other plot remained the same. Elsewhere in Limmerpolder, two plots were grazed by sheep with about 10 to 20 animals/hectare. In the breeding season of 1998, cattle (heifers) were found grazing for some time on six plots, and on 2 plots in 1999. The densities varied from 5 to 15 head/hectare. It is evident that there is no place for meadow birds on plots with a grazing and trampling pressure of that extent.

5.4 Breeding population Groot-Limmerpolder

The research area Groot-Limmerpolder covers approx. 130-140 hectares. In 1998, 70 nests were found. In 1977, this number equalled 77. The population density is thus a fraction lower than in the Limmerpolder area, i.e. over 50 pairs/100 hectares.

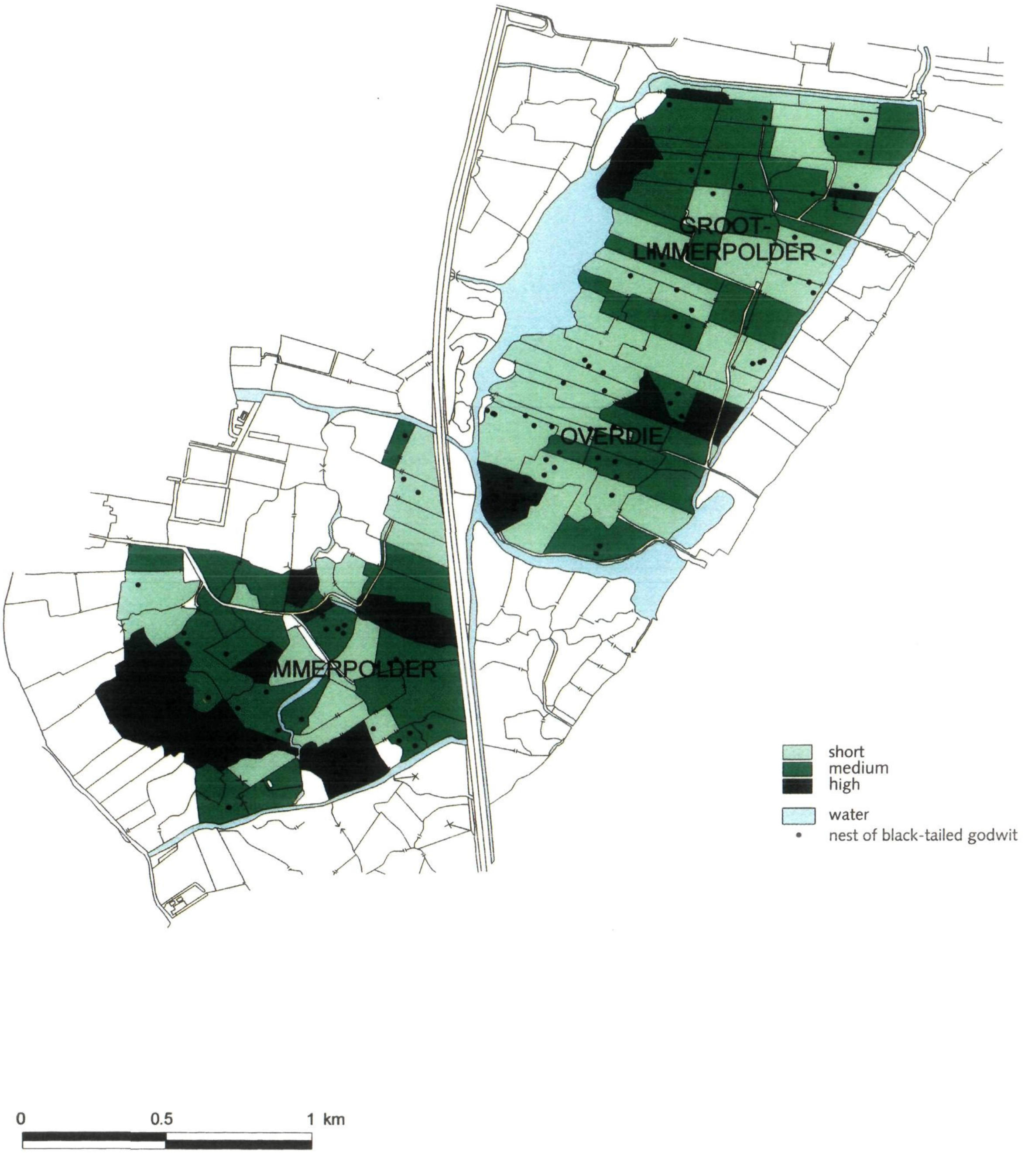
The distribution of the nests differs from the pattern observed in Limmerpolder. The density gradually decreases from south to north. In the southern 2/5th part (i.e. Over Die), this amounted to approx. 84 pairs/100 hectares in 1998; in the northern 3/5th part, a value of approx. 29 pairs/100 hectares applied. In 1999, the density in Over Die was 80 pairs/100 hectares and 38 pairs/100 hectares in the northern part.
There is a certain concentration of nests on the grounds of Het Noordhollands Landschap, but the difference between the occupation of the grounds of this organisation and the privately owned grounds is far less conspicuous in 1998 than the difference between the southern and the northern part of the area.
In 1998, one can observe a tendency towards clustering of nests, especially in

Over Die. In 1999, clustering was observed on two plots located more or less in the centre of the area.

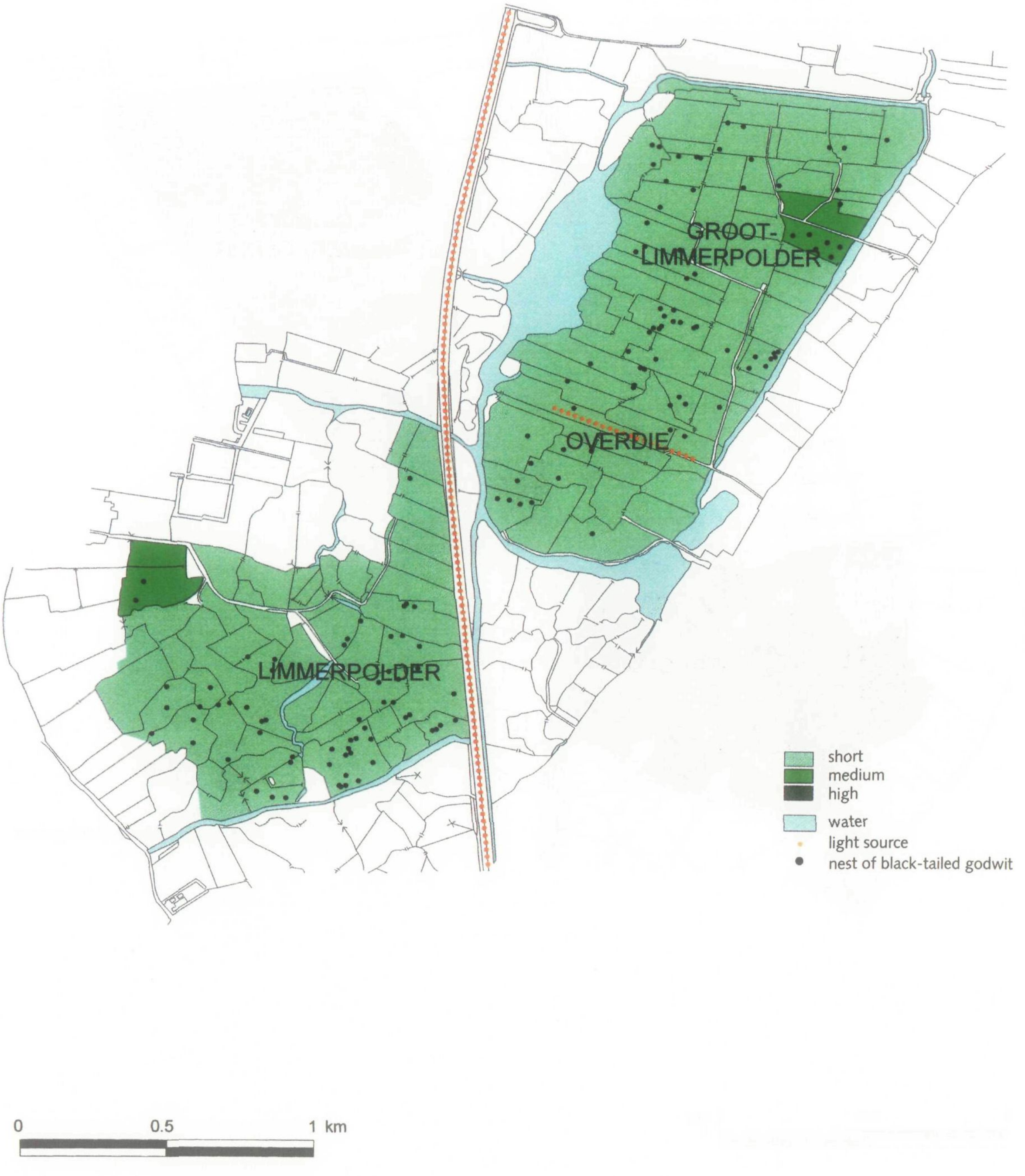
A small number of plots was grazed in the breeding season in Groot-Limmerpolder as well. In 1998, five of the 42 plots in the northern part were grazed. One by a pony, one by cattle (approx. 14 head/hectare) and three by sheep (approx. 5 to 35 animals/hectare).
In the southern part of the area, Over Die, only three of the 31 plots were grazed by 12 to 14 sheep/hectare. This was also the case in 1999. Breeding black-tailed godwit could not be found on any of the sheep grazed plots. In addition, four more plots were grazed in 1999 by cattle, starting early in May. Most of the black-tailed godwits had already established themselves before the cattle was brought in, so that the presence of the cattle should not have influenced the occupation pattern. Nests were already present on three of these plots.

Notable is the absence of nests in a 150 m wide zone bordering on Lake Die, in both years. This is presumably due to the influence of trees along the shore of Lake Die. Trees provide an excellent lookout for predators. The marshy character of this zone may also play a role.
The absence of nests on plots in the eastern part of Over Die may in part be attributed to the habitat conditions: mostly plots with a low, uniform sward and some plots with a recently re-sown sward. This does not hold for a stretch of plots in the north of Over Die, nor for the northern part of Groot-Limmerpolder

Map 3. Grass height in 1998



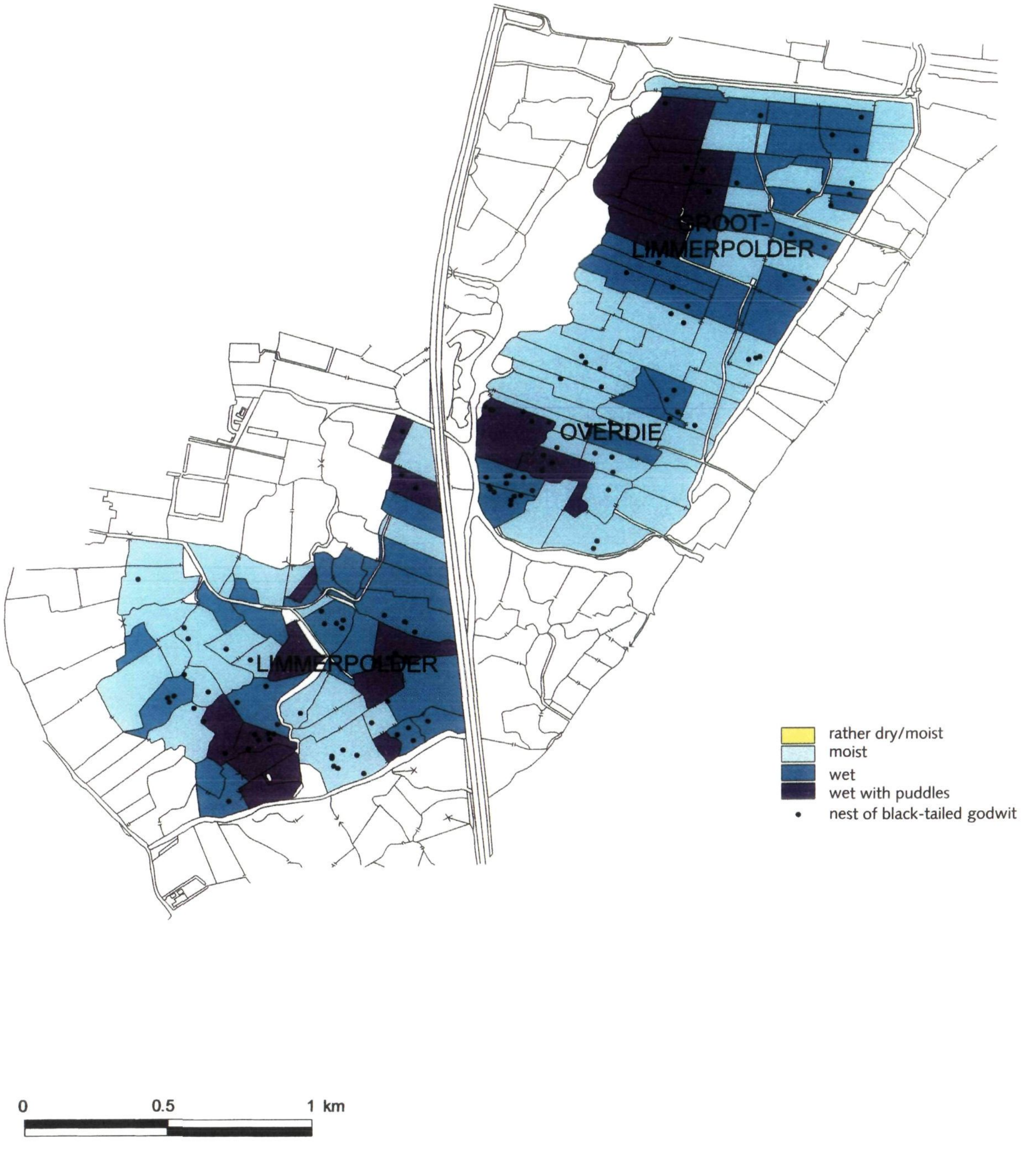
Map 4. Grass height in 1999



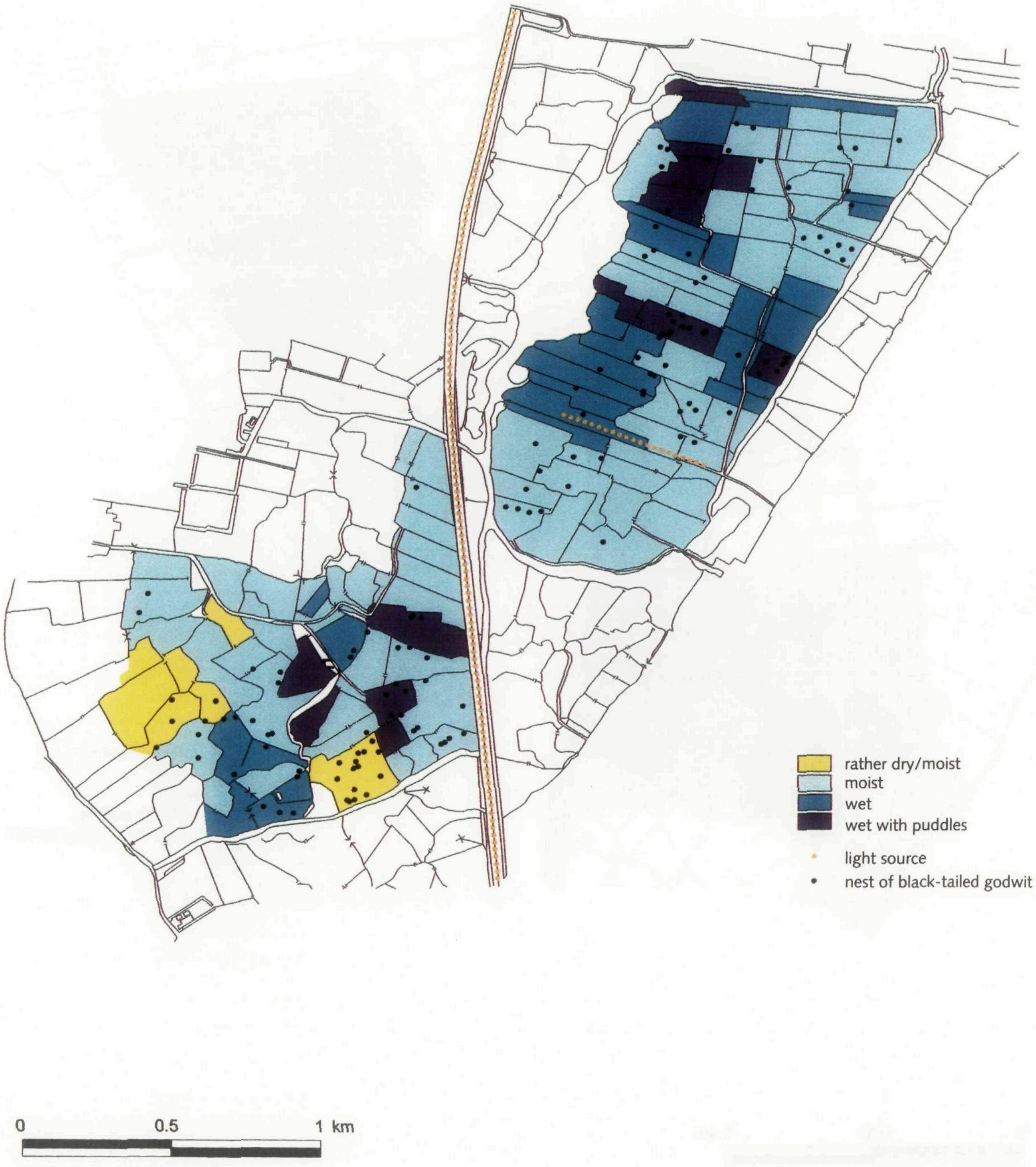
Map. 5. Sward structure in 1998

Map 6. Sward structure in 1999.

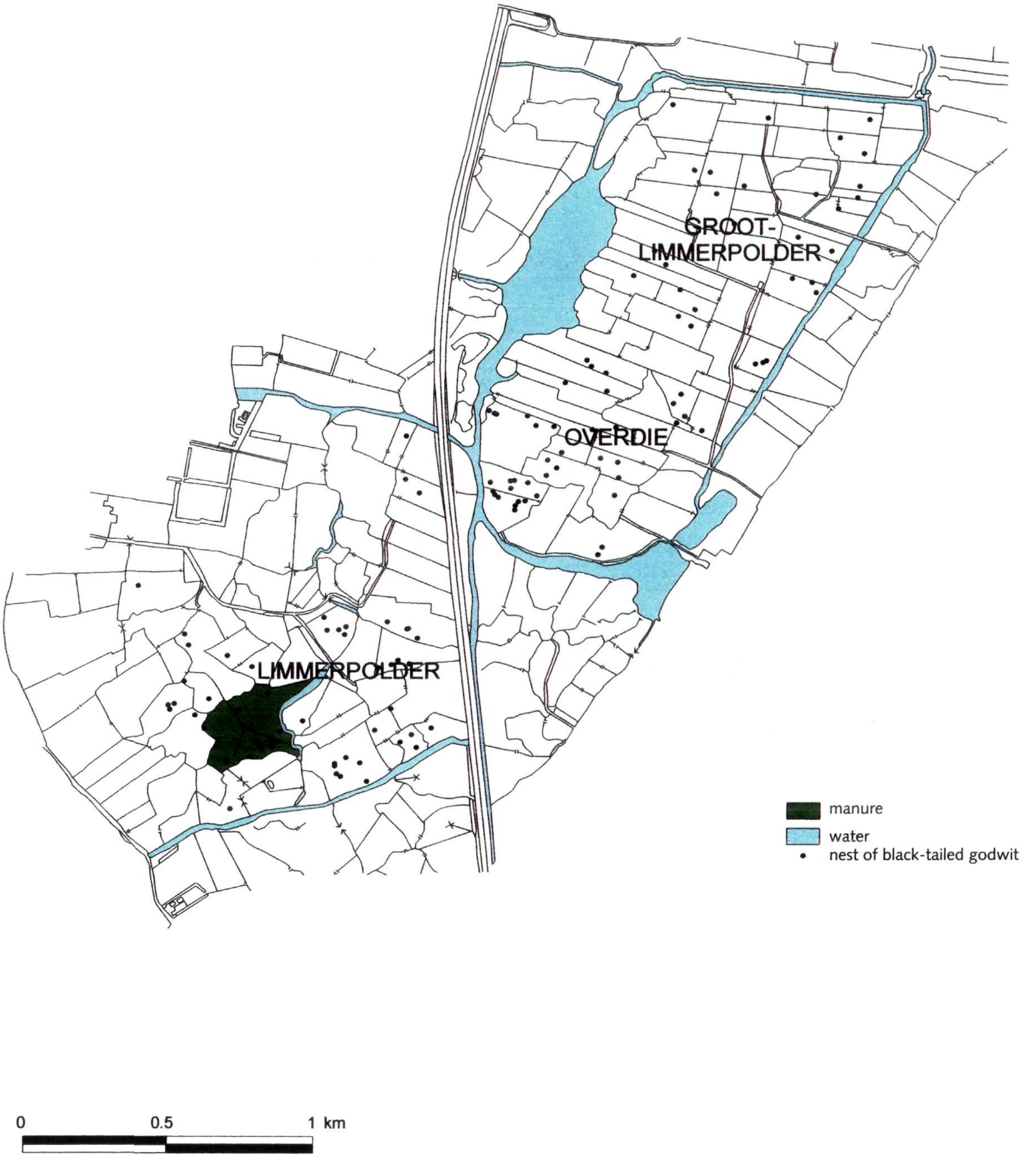
Map 7. Drainage conditions in 1998



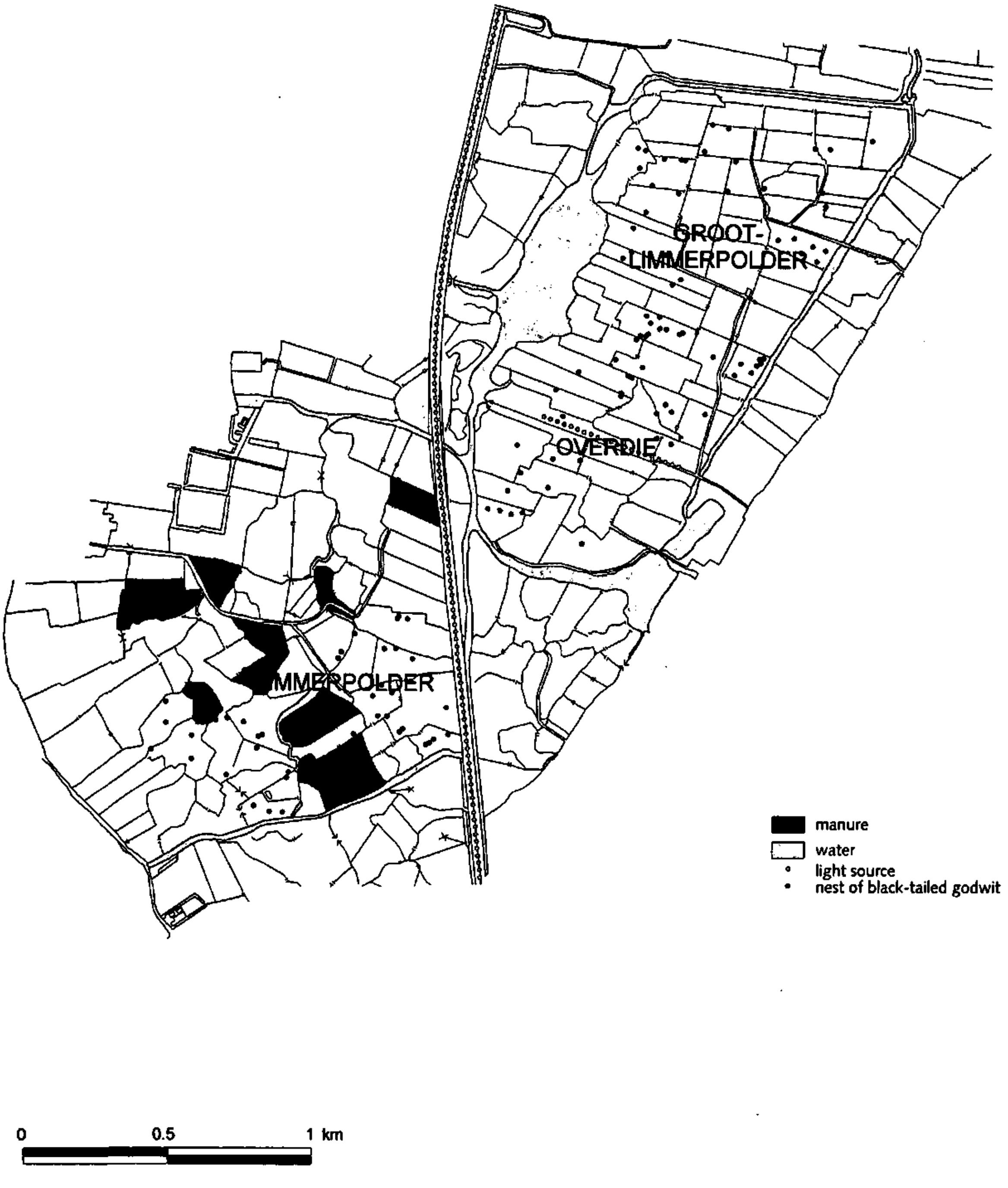
Map 8. Drainage conditions in 1999



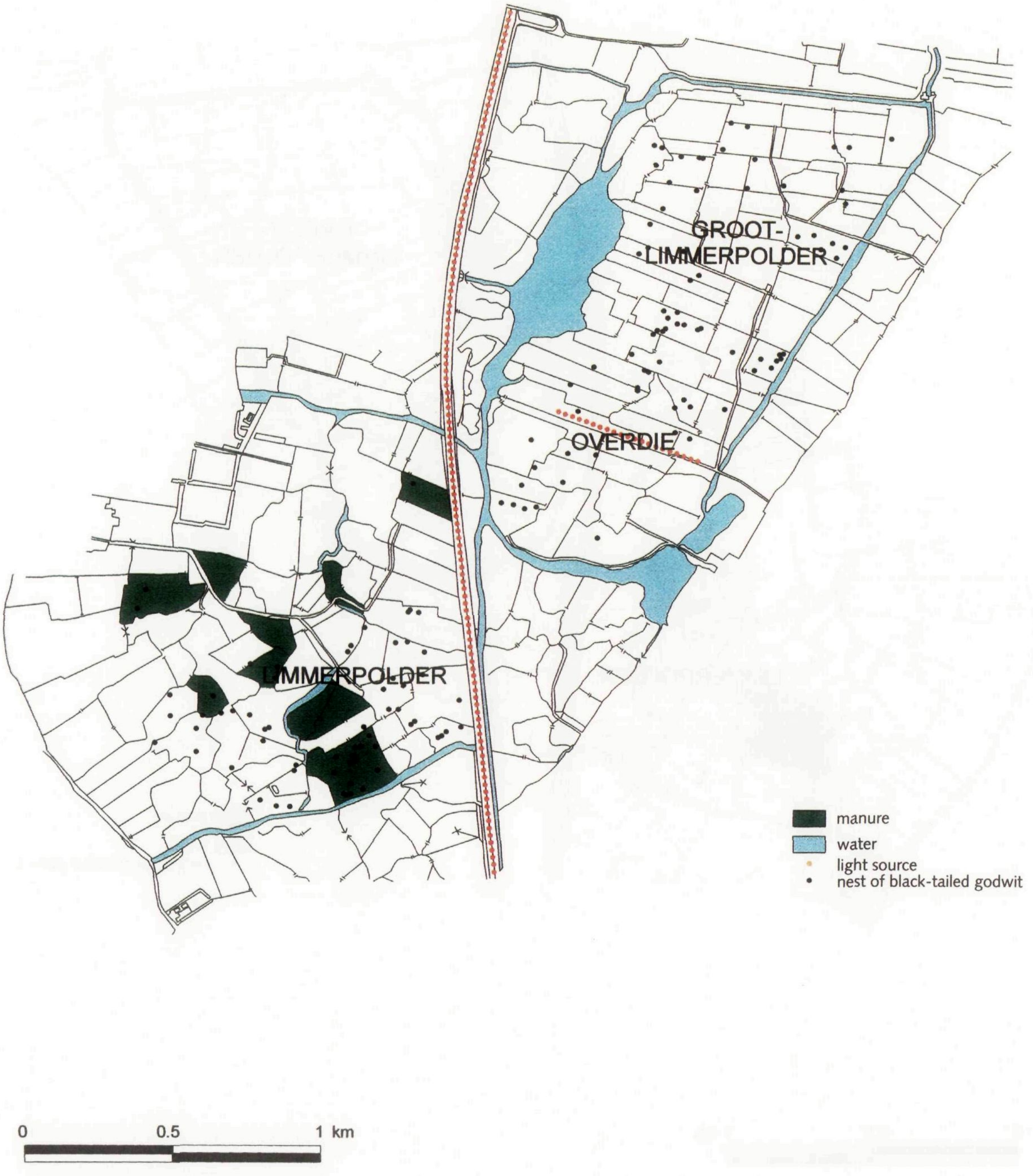
Map 9. Fertilization with manure in 1998



Map 10. Fertilization with manure in 1999



Map 10. Fertilization with manure in 1999



6 Nest choice

6.1 Nest choice and field conditions

The results of the statistic tests show which field factors significantly determine the location of the nest (table 6.1; for an explanation of marginal and conditional: see § 4.6). Of course, the tests do not demonstrate a causal relation, only a statistical relation between choice and field conditions.
Table 6.1 shows differences between 1998 and 1999. In 1998, the grass height, sward structure, drainage and fertilising with stable dung are significant. In 1999, only the sward structure and drainage are significant. Evidently, the grass height could not be significant in 1999, seeing that the grass height was low everywhere due to the weather conditions at the time the birds choose their nests. When interpreting the conditions in a given year, one should also consider the influence of nest fidelity (see § 3.1).

Table 6.1
Stastic significance of the habitat factors determining the 'chance of occupation', tested separately (normal) and in relation to each other (conditional); ns = p>0.05; * = 0.01<p≤0.05; ** = 0.001<p≤0.01; ***= 0.0001<p≤0.001

	1998	1999		
	Marginal	Conditional	Marginal	Conditional
Grass height	***	***	ns	ns
Sward structure	ns	*	***	*
Drainage	***	**	***	***
Stable dung	**	*	**	ns
Road influence	ns	ns	ns	ns

The regression analysis only considers the factors that appear to be significant based on the conditional test (with at least one * in table 6.1). The results are presented in annex 4. In GIS, the site factor classes are substituted by estimations of the regression coefficients (annex 4) and then added up. The outcome is a 'relative chance of occupation' map (§ 4.9).

The nest choice preference of the black-tailed godwits in 1998 is given in table 6.2. Table 6.3 shows that for 1999. The values (chance of occupation) have been corrected for differences in area of the site factors in question. The values are made proportional by adjusting the lowest chance to 1. Thus, for instance, the chance of finding nests in 'uniform, high and wet grassland' is 6.8 times higher than the chance that they will be found in 'uniform, low and moist grassland', and the chance of finding nests in 'predominantly tussocky, low and moist grassland' is 2 times higher than the chance that this will occur in 'uniform, intermediate and moist grassland'.

In 1998, the black-tailed godwits prefer to nest in predominantly tussocky, high and wet grassland (value 15.9 in table 6.2). The grass height (*** in table 6.1, value 6.8 in table 6.2) is more important than sward structure (* in table 6.1, value 5 in table 6.2). At the same time, wet plots are preferred to moist plots and plots with puddles.

In 1999, the black-tailed godwits do demonstrate a preference for predominantly tussocky grassland, which is comparatively dry (value 6.9 in table 6.3). At the same time, there is a preference for very wet grassland (plots with puddles; value 5.2 in table 6.3). The preference for predominantly tussocky is in accordance with the preference in the first year, but the preference for comparatively dry and for very wet grassland is not. Grass height is not relevant in 1999 (*ns* in table 6.1).

Table 6.2
Relative nest position preference of black-tailed godwit (relative values) as regards drainage conditions, sward structure and grass height in 1998

Sward structure	Grass height	Drainage conditions Moist	Wet	With puddles
	Low	1	2.1	1.3
Uniform	Intermediate	1.3	2.7	1.7
	High	3.3	6.8	4.3
	Low	1.4	2.9	1.8
Some tussocks	Intermediate	1.8	3.7	2.3
	High	4.6	9.3	5.9
	Low	2.4	5.0	3.1
Predominantly	Intermediate	3.2	6.5	4.1
tussocky	High	8.0	15.9	10.2

Table 6.3
Relative nest position preference of black-tailed godwit (relative values) as regards drainage conditions and sward structure in 1999. Grass height was not relevant in 1999

Drainage Conditions	Sward structure Uniform	Some tussocks	Predominantly tussocky
Somewhat moist	3.1	4.4	6.9
Moist	1.2	1.7	2.8
Wet	1	1.4	2.2
With puddles	2.3	3.3	5.2

The nesting preference in 1998 and in 1999, in terms of plot-wise chance of occupation, is presented on the maps 12 and 13 at the end of this chapter.

6.2 Differences between 1998 and 1999

In 1998, the grass height plays a major role in nesting preference, while it is generally assumed that black-tailed godwits prefer to nest in grass tussocks or on the somewhat drier and more rough verge of a trench (*Ruitenbeek et al. 1990, Beintema 1995c*). In 1999, the influence of the grass height is not significant.

The preference for high grass is most evident in the southwestern part of Over Die (in Groot-Limmerpolder), where a concentration of thirteen nests was found in 1998. The nests were located on two plots with a high and dense perennial rye-grass cover (*Lolium perenne*), without even a trace of variation in structure. Two years earlier, these plots had been re-cultivated by killing the old sward, ploughing, fertilising and re-sowing. As a result, the structure differed strongly from the rest of the mainly permanent grassland in both Groot-Limmerpolder and Limmerpolder. In 1999, there were only five nests on these two plots. The sward was considerably lower at that time and hardly any different from the average conditions elsewhere in Groot-Limmerpolder and Limmerpolder. Under these circumstances, the nests of the black-tailed godwits were concentrated everywhere on low and tussocky plots.

Territory maps that were made in the course of a meadow bird inventory by the research department of the province Noord-Holland show the presence of only one territory on these two plots in 1994. In combination with the number of nests found in 1998, this suggests that nest fidelity offers a less plausible explanation for the situation in 1998.
It seems more likely that it is a matter of the initial growing rate of such renewed

rye grass plots as compared with the growing rate of permanent, moderately to poorly drained and fertilised grassland prevailing elsewhere in the area. In areas where the grass growth starts late and slow, due to unfavourable conditions of drainage and management, it might for reasons of shelter be attractive to choose such early plots with high dense grass for nesting. If this supposition is true, it implies that the average date of laying of the first egg of the clutches that are present should be earlier than the average first date of egg-laying in the whole area. Indeed, an analysis of the thirteen clutches on both renewed rye grass plots reveals that they were laid about one week (i.e. five to nine days) earlier than average. Thus, a comparison calls for carefully taking into account the distribution of the height and the structure of the grass cover. The high dense grass seems to become attractive when the growth of tussocks is delayed by an overall late and slow grass re-growth – otherwise tussocky grassland is preferred. When tussocky grassland is present before late March, high grass is a second choice.

6.3 Nest choice and road influence

Previous research has shown that motorways influence the nest choice of black-tailed godwit: the population density is low near the road and increases with increasing distance to the road (*Reijnen et al. 1992, Reijnen 1995*; see also § 2.4). This finding is not supported by the result of our statistic analysis (table 6.1). This observation is in agreement with Reijnen (*1995*), who pointed out that the negative influence of road traffic on the quality of the breeding habitat may be compensated in concrete situations by other factors – in particular management, sward structure and grass height. The colony-forming concentration of nests close to the A9 in Over Die (§ 6.2) is a striking illustration of this.

6.4 Clustering and nest fidelity

There are three complications when searching for the possible influence of road illumination on the nest choice of black-tailed godwit, namely the following phenomena:

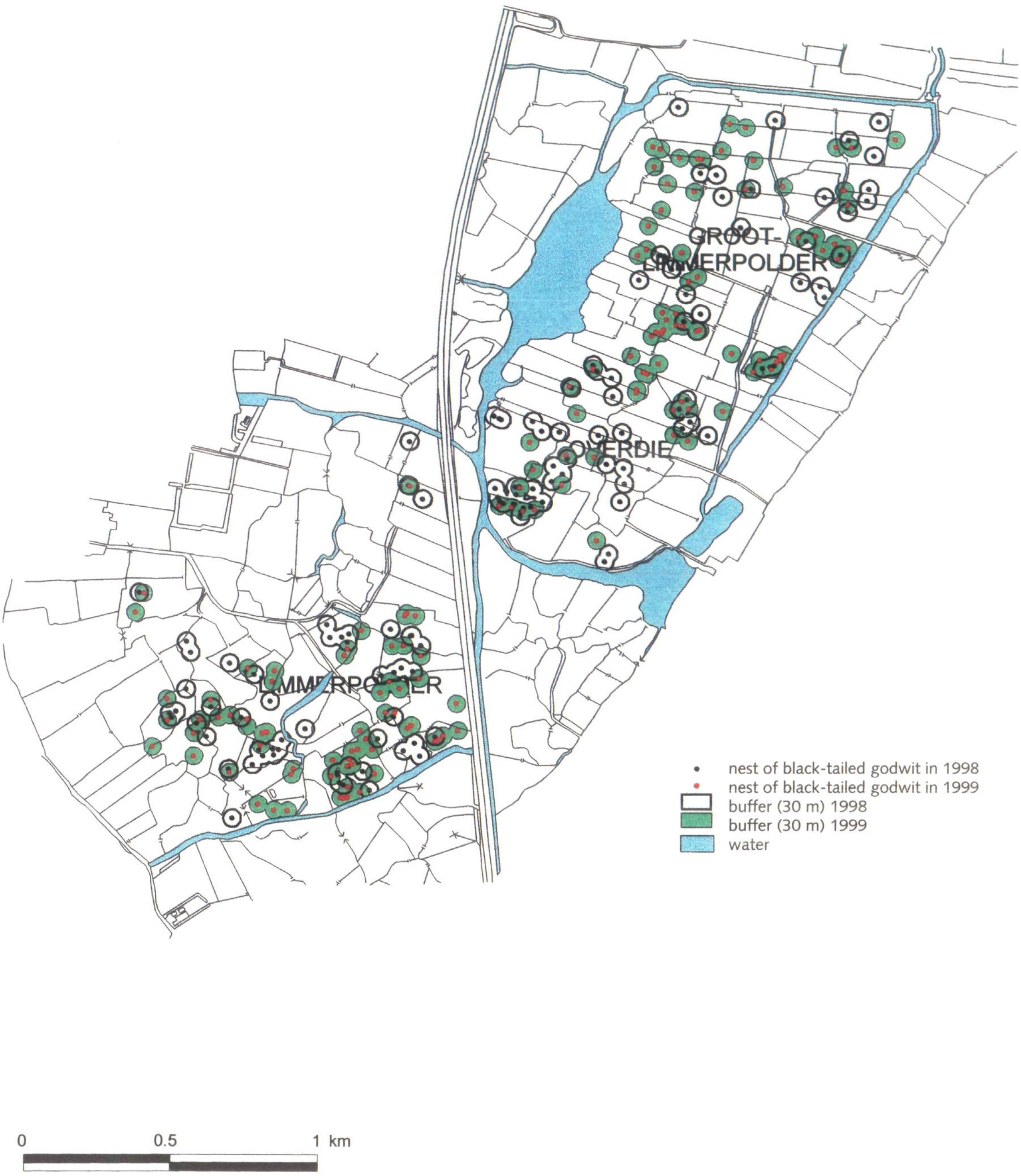
- nest clustering,
- nest fidelity, and
- annual variation in grassland habitat conditions.

Black-tailed godwits display a certain tendency to nest more or less close together. This clustering seems to be variously influenced by differences in suitability between grassland plots, protection against predators (the principle of 'safety in numbers') and, possibly, nest fidelity.
The degree of clustering is traced by laying a buffer around each nest in GIS, after which the nests with overlapping buffers are considered clustered. Taking into consideration the size of the plots and the variability between the two areas and between the two years, the optimal buffer size is estimated at 30 m. The map following this chapter illustrates the result. According to this procedure, about two-thirds of the nests appear to be clustered in 1998 and in 1999. This is illustrated in map 11.

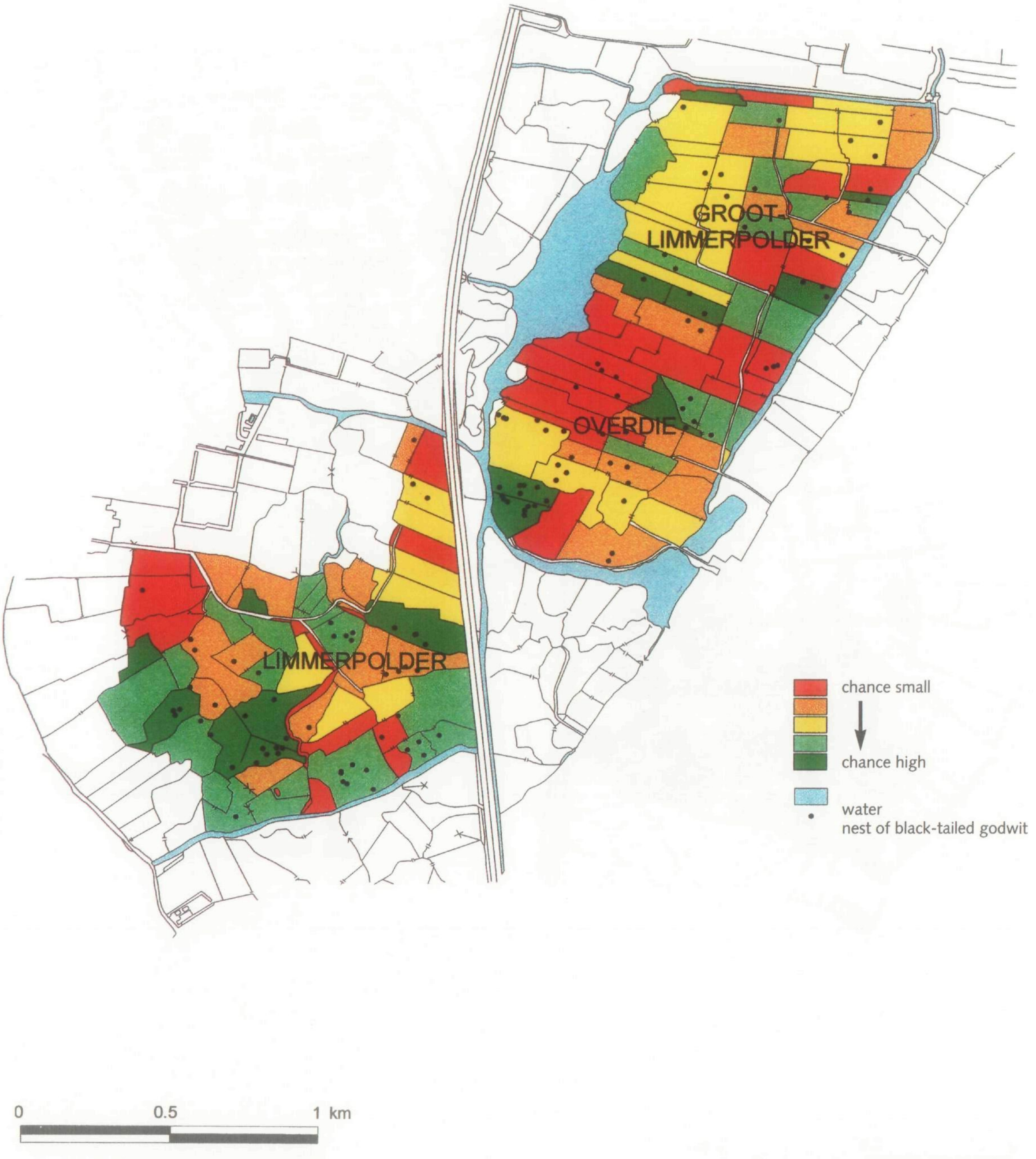
In addition, black-tailed godwits demonstrate the previously mentioned nest fidelity (see § 3.1). An analysis of this phenomenon is not part of this study, but map 11 provides a fair indication. The buffers around over two-fifths of the nests in 1998 are overlapped by buffers around nests in 1999. This nest fidelity, enforced by the tendency to cluster together, suppresses the possible effects of all sorts of changes in the field, including the effect of road illumination on nest choice and population density.

The finding that field conditions, in the sense of habitat quality, are not constant from year to year owing to in particular differences in weather conditions and grassland management, is clearly shown by the two maps presenting the chance of occupation. As regards management, and besides grazing, mowing and grassland treatment by fertilising in general, rolling, sward renewal etc., the nature of the applied fertliser also plays a role.
In both years, part of the plots owned by Het Noordhollands Landschap in Limmerpolder were supplied with stable dung during the winter. Traces were abundantly present in the nests of the black-tailed godwits, which eagerly use the straws from this dung to furnish their nests. This was particularly the case in 1999. On a relatively dry plot, where the grass sward was rough but still quite low, there was nevertheless a concentration of nests that were abundantly furnished with straws. As far as could be traced, stable dung had not been applied on the private grounds in both areas.

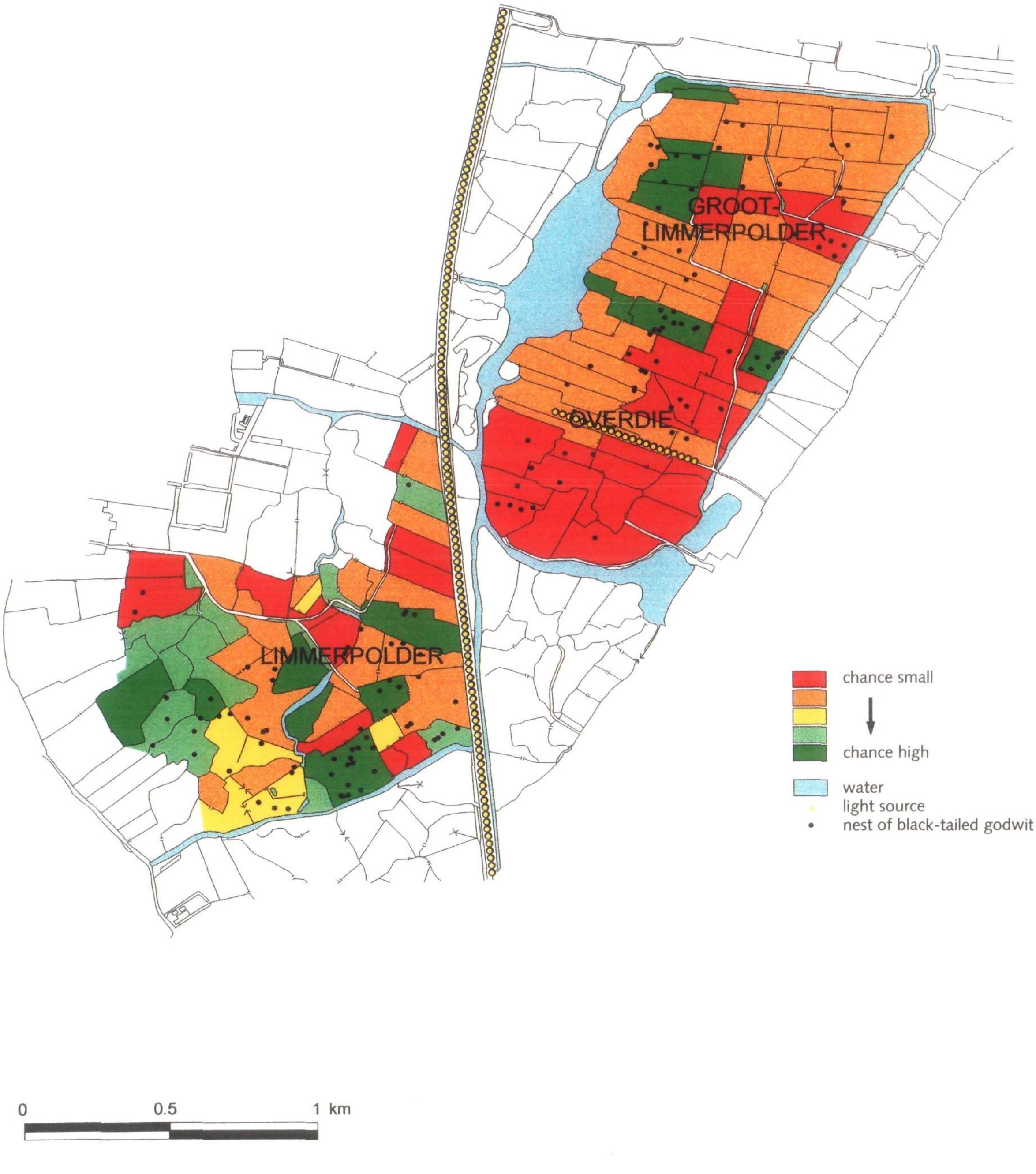
Map 11. Nests with buffer



Map 12. Chance of occupation per parcel by black-tailed godwits in 1998



Map 13. Chance of occupation per parcel by black-tailed godwits in 1999



7 Illumination and nest choice

7.1 Possible influence of illumination

The question is: does road illumination influence the nest choice and thus have an effect on the population density? It is a known fact that road traffic has a negative effect on the population density along roads (*Reijnen 1995*).

It is imaginable that the nest choice is influenced by illumination as a result of:
1 attraction to or repulsion by the illuminated space (luminance intensity; e.g. as regards prevention of predation, with the dilemma that a possible prey may notice a predator sooner, but also that the predator can see its prey better);
2 attraction to or repulsion by the visibility (luminance intensity) of light sources[11].

These possible influences cannot be distinguished on the basis of the localisation of the nests. Only the effect may be found. Therefore, no distinction is made between luminance, illuminance, etc. As regards possible attraction by luminance intensity, it should be noted that it is very likely that the lamps that were used had little influence, owing to the minor component of short-wave radiation in their emission (cf. *De Molenaar et al. 1997*).

The possible effect of illumination in the sense of the first point is spatially restricted. The measurable illuminated area (in lux, note 7 with § 4.8) covers a zone of about 50 m wide on both sides along the row of the light poles, see figure 4.1. Along the A9 motorway, where the illumination is placed in the middle, this zone hardly reaches over the ditches along the road verges to the borders of Limmerpolder and the south-west corner of Groot-Limmerpolder (i.e. Over Die). The possible effect in the sense of point 2 reaches much further, the burning lights can be seen at a distance of many kilometres away. However, the maximum distance at which attraction or repulsion may occur is not known.

7.2 Nest position

The search method is described in § 4.2. In practice, the nests with eggs were visited once a week a total of three times. The position of each nest is determined in the field by measuring the distance at right angles to the two nearest squared ditches or other fixed points of reference. This data is used to digitalise the nest position on a map in the office. Next, the following was calculated:
1 in Limmerpolder: the distance to the road illumination means of the A9;
2 in Groot-Limmerpolder/Over Die: the distance to the temporary experimental illumination; i.e. in 1998, the distance to the planned row of light poles and to the row of light poles present at that time.

The distribution of the nests is given in table 7.1 and on map 14, in zones with a width of 100 m, parallel to the light pole rows.

[11] It should be noted that the visibility of light poles may also play a role, but possible effects of illumination, the visibility of light sources and that of lamp poles cannot be separated in view of the set-up of this experiment.

Table 7.1
Distribution of black-tailed godwit nests in both experimental areas

	Number of nests located				
	Limmerpolder, with road traffic influence, plus Groot-Limmerpolder/ Over Die, the part out of reach of road traffic influencce				
Distance to the illumination (in metres)	Absolute: Without illumination 1998	Absolute: With illumination 1999	In Percentages: Without illumination 1998	In Percentages: With illumination 1999	Degree of change 1998-1999
< 100	9	7	9,8	6,3	- -
100-200	20	20	21,7	18,2	- -
200-300	6	11	6,5	10,0	+
300-400	8	16	8,7	14,5	++
400-500	11	22	12,0	20,0	++
500-600	4	3	4,3	2,7	-
600-700	7	10	7,6	9,0	+
700-800	8	5	8,7	4,5	-
800-900	8	11	8,7	10,0	+
900-1000	11	5	12,0	4,5	-

Table 7.2
Statistic significance of the habitat factors, in relation to each other (conditional), wich determine the chance of occupation; ns = p>0.05; * = 0.01<p≤0.05; 0.001<p≤0.0.01; *** = p<0.001

Term	mscar	cscar
Light	ns	*
Plot suitability	***	***

7.3 Analysis

The statistical test (table 7.2) reveals that the illumination has a significant influence (* in the table), although the habitat quality (plot suitability) in terms of e.g. drainage conditions and 'tussockyness' has a greater significant influence (*** in the table) on the nest choice.

The absolute numbers in table 7.1, on the left, do not seem to confirm the statistic finding. However, the number of nests in 1998 differs from that of 1999. When the absolute numbers in that table are expressed as percentages (table 7.1, on the right), this provides a different picture, one that corresponds with the outcome of the statistic test. The relative number of nests appears to decrease in a zone ranging from 250 up to 300 m from the illumination, and to increase in the next 200 to 250 m wide zone. The illumination apparently has a negative influence.

7.4 Conclusion

The influence of the illumination is statistically significant and negatieve. The observation suggests that the repulsive effect, which is more or less curbed and distorted by the phenomena of nest fidelity and habitat quality respectively, is what caused the nests to be driven back to a distance between approx. 250-300 to 500 m from the illumination. It is uncertain how this situation will develop in the course of time. Thus, the effect distance remains as yet unknown.

It is concluded in general that if illumination has an effect on the population density of the black-tailed godwit, c.q. the quality of grassland as a breeding habitat of black-tailed godwit, then the effect is negative and possibly covers hundreds of metres.

Table 7.3
Relative distribution of black-tailed godwit nests in each experimental area

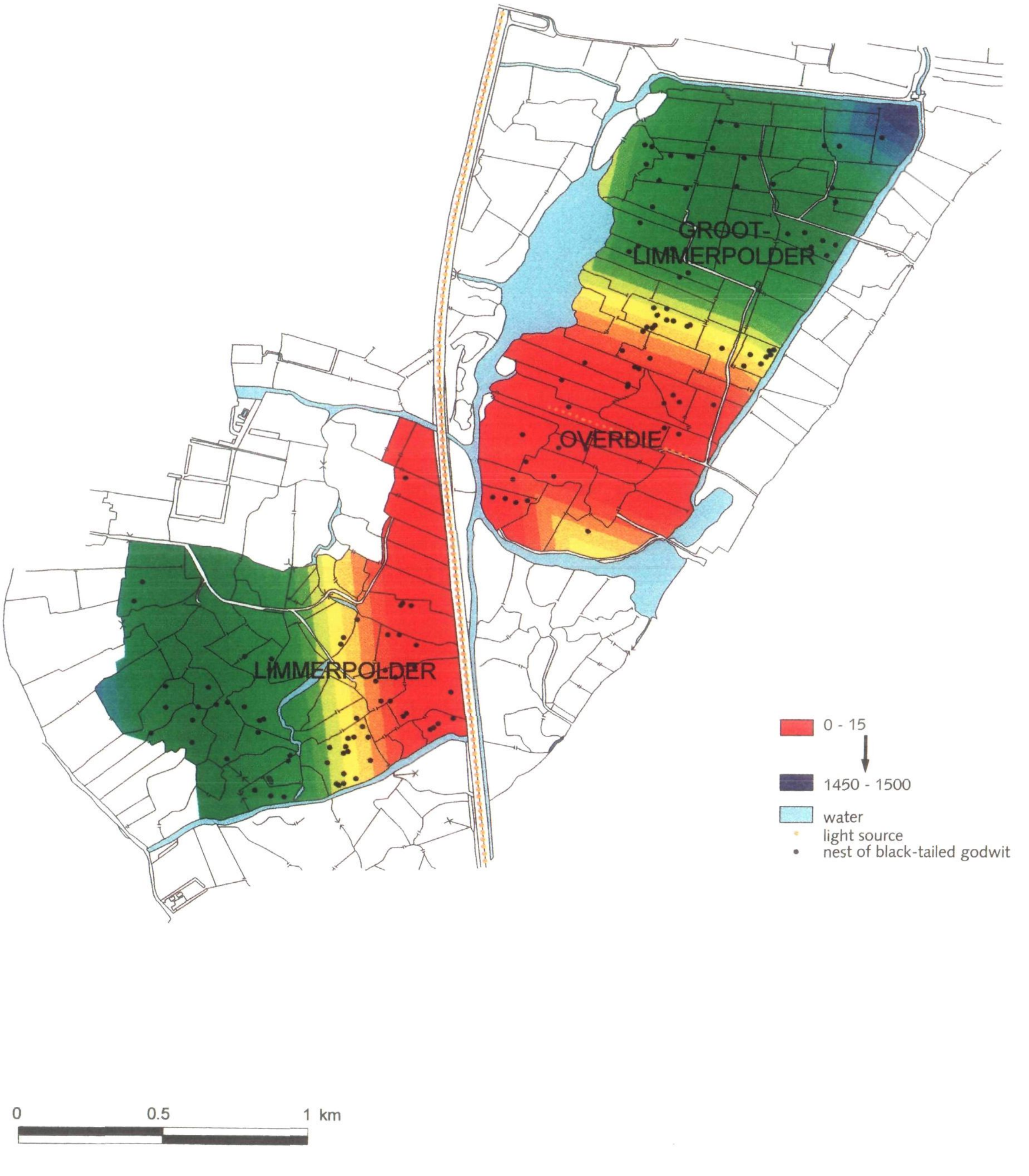
Distance to the illumination (in metres)	Relative number of nests located (in percentages)			
	Limmerpolder with reach of road influence		Proefgebied Over Die out of reach of road influence	
	Without illumination 1998	With illumination 1999	Without illumination 1998	With illumination 1999
< 100	2,0	5,2	19,5	7,8
100-200	17,6	17,2	26,8	19,6
200-300	11,8	12,1	0	7,8
300-400	11,8	15,5	4,9	13,7
400-500	13,7	17,2	9,8	23,5
500-600	2,0	0	7,3	5,9
600-700	9,8	13,8	4,9	3,9
700-800	11,8	8,6	4,9	0
800-900	7,8	5,2	9,8	13,7
900-1000	11,8	5,2	12,2	3,9

It should be repeated that the findings are purely indicative due to the set-up of the research. It is a comparison between only two years in one area, plus a reference area. The comparison is complicated by the differences between those two years in terms of weather and grassland conditions. Moreover, the value of the factors that are considered is limited, which can probably be attributed to the complicating phenomenon of nest fidelity. Furthermore, it cannot be ruled out that the fact that there were suddenly light poles and illumination in the field when the birds returned from their wintering quarters, may have caused some disturbance and thus some distortion of the effect. In conclusion, the situation 'road without illumination' (the A9 in 1998) is not completely true, since road traffic produces light in twilight and darkness.
Otherwise, it should be repeated that no distinction is made between luminance, illuminance, etc. as only the final effect has been studied.

A comparison between relevant parts of Limmerpolder and Groot-Limmerpolder (Over Die) indicates that the influence of illumination is far less conspicuous in the first (table 7.3).

The most plausible explanation for this difference is the evident shift in habitat quality that occurred in Limmerpolder between 1998 to 1999 towards the road (see maps 12 and 13, following chapter 6), and thus towards the road illumination. This indicates that the effect of illumination may also be more or less compensated for by the grassland quality, but less so than the effect of road traffic (see § 6.3). In other words: the almost equal number of nests in Limmerpolder in 1999 as compared with 1998 may be expected to be lower, had the shift in grassland quality not occurred.
This suggests that the influence of the illumination might be stronger than the influence of the road, even though it is less significant than the influence of the grassland quality. However, it is not justified to draw such a conclusion.

Map 14. Distance to light source in 1999
(in intervals of 50 metres)



8 Illumination and breeding period

8.1 Possible influence of illumination

The question is: does road illumination influence the start of the breeding period? On the one hand, earlier breeding may increase the risk of losses of clutches and chickens due to the chance of less favourable weather conditions, food availability and predation. On the other hand, outside the reserve areas and agricultural areas with management contracts, it may increase the chance to escape from grassland management activities, mowing and trampling by cattle. In the case of later breeding, the situation is the other way around.

The *idea that illumination may promote (mating and) breeding* is plausible due to:

1 the possible influence of an artificially lengthened daily light period on endocrinology;
2 the possible influence on endocrinology resulting in a more rapid recovery of the condition of the birds returning from spring migration which, influenced by light and attracted by light or otherwise, are able to forage during a longer daily period and more successfully;
3 the attraction of conditionally 'better', early arriving birds.

The idea that the effect of illumination may cause a delay in the (mating and) breeding is plausible as a result of the repulsion of conditionally 'better', early arriving birds.

The possible effects of the separate mechanisms cannot be distinguished by the observed effect. The effect was traced by comparing the spatial pattern in the start of breeding in 1998 and 1999.

8.2 Starting date

The procedure for establishing when the breeding begins is described in § 4.5. Starting with the resulting date, it is then determined whether or not the grassland suitability had any influence on that date. Next, the spatial distribution of the date is calculated and studied in relation to the distance to the illumination.

The temporal distributions are given in table 8.1. Regarding the influence of illumination, there are some remarks worth mentioning (see § 7.1).

In 1998, a considerable number of black-tailed godwits were back in the Netherlands again around the middle of February. Considering the usual lapse of time between returning and the beginning of egg laying (see § 3.1), and the cold and wet period that lasted from February into early April, one might expect the first eggs to be laid in the first week of April and that the median date of laying the first egg is shortly after the middle of April.

Table 8.1.
Relative distribution of the dates of laying of the first egg in each clutch; in percentages, rounded off

Year	April						Mei
	1-5	5-10	11-15	16-20	21-25	26-30	1-5
1998	0	17	29	34	15	3	1
1999	10	25	39	13	4	3	2

Table 8.1 suggests that 1998 was a late year. Nevertheless, the median date of laying the first egg was at the beginning of the fourth pentade of April, hardly later than usually. In 1999, the birds started earlier, despite the weather, but the median date was just a fraction earlier.

8.3 Analysis

To test the assumption that the first birds have first choice regarding nest position, a linear regression is carried out. This is done by correlating the quality of the plots (the relative chance of occupation) on which nests are found, to the dates of laying the first egg; see figure 8.1 and 8.2.

These two figures demonstrate that the dates of laying the first egg and the quality of the plots c.q. the relative chance of occupation cannot be related (an almost horizontal line). In consequence, the possible relation between the distance to the illumination and the dates of laying the first egg is traced without a correction for the quality of the plots/relative chance of occupation.
The assumption that early birds choose their nest position further away from the lights, while later birds have to nest closer to them, is also tested with linear regression. In 1998, these distances should not correlate since the light was not switched on or absent. Indeed, the relation between the distance to the illumination and the dates of laying the first egg does not appear to be

Figure 8.1
Relation between the relative chance of occupation and the dates of laying the first egg in 1998; Y = -0.0077 * X – 4.08; non-explaining variance is larger then Y variance

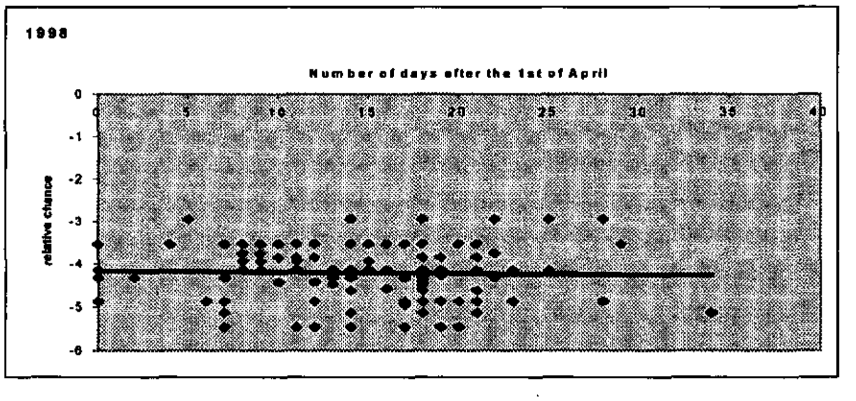


Figure 8.2
Relation between the relative chance of occupation and the dates of laying the first egg in 1999; Y = -0.0159 * X – 4.327; explaining variance = 2.5

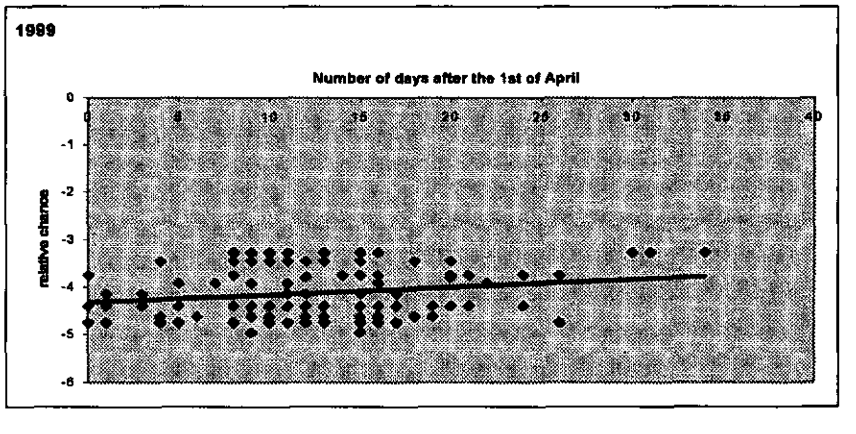


Figure 8.3
Correlation between the distance to the light poles and the dates of laying the first egg in 1998; Y = 8,16 * X + 384.8; explaining variance = 1.0.

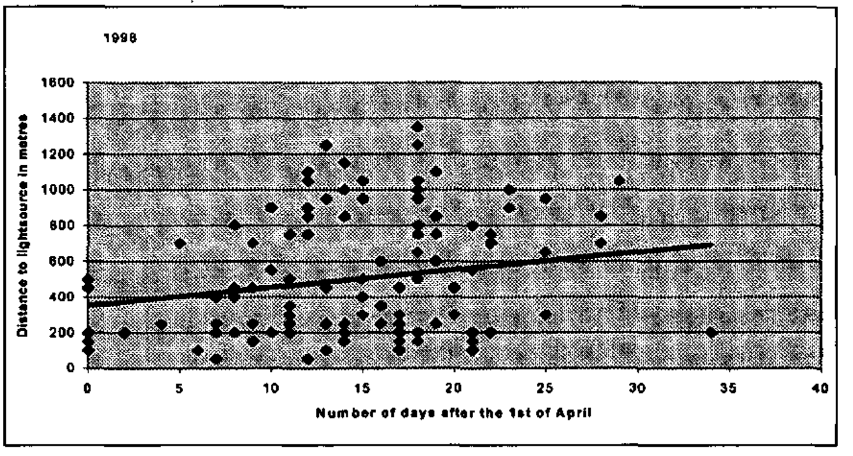
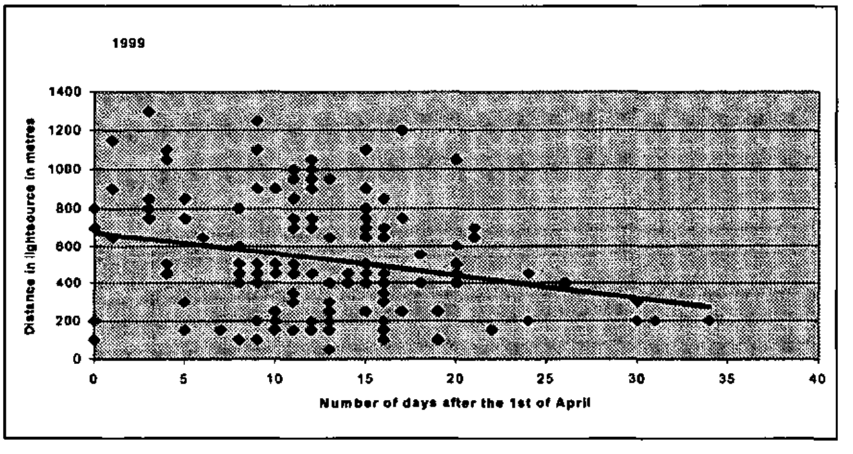


Figure 8.4
Correlation between the distance to the illumination and the dates of laying the first egg in 1999; Y = =14.21 * X + 713.5; explaining variance = 7.6



significant and the explained variance is a mere 1.0 (figure 8.3). In 1999, this relation is distinctly significant and the explained variance is 7.6 (figure 8.4). Although the spread is considerable, the findings suggest that early birds nest further away from illumination than birds arriving later.

8.4 Conclusion

Referring to the remarks made in § 7.4, the following can be said. A relation between the dates of laying the first egg and the quality of the plots (the relative chance of occupation) cannot be demonstrated. Both early birds and late birds seem to be able to choose the most suitable place for their nests.
The relation between the distance to the light poles and the date of laying the first egg is not significant in the first year, when the lights were not switched on or absent. However, in the second year, when the lights were switched on, this relation was significant. In spite of a considerable spread, this indicates that early birds choose their nest further away from illumination than birds arriving later. The considerable spread may be explained, among other things, by nest fidelity and the demonstrated insignificant relation between the dates of laying the first egg and the quality of the plots.
Other than that, the insignificant relation between the dates of laying the first

egg and the quality of the plots might indicate that the area is not completely occupied. The extent to which uninvestigated site factors or other aspects of the bird's behaviour may play a role, remains unknown.

9 Illumination and breeding suces

9.1 Possible influence of illumination

The third question is: does road illumination influence the condition of the breeding birds and, as a consequence, the breeding success? This is indirectly traced by establishing the condition of the clutches on the basis of the egg volume and then relating this to illumination.
It is imaginable that illumination may facilitate feeding (daily light period is longer), thus improving the recovery of the condition of the birds and, in consequence, enhancing the condition of their clutches. It is also imaginable that birds in a better condition are more attracted or repulsed by light and/or illumination than birds in a less optimal condition. These possibilities cannot be distinguished by merely comparing the spatial distribution of average egg volumes in 1998 and 1999.

9.2 Condition of the clutches

The procedure is described in § 4.4. Starting with the resulting average egg volume of each nest, it is traced whether or not the grassland suitability (relative chance of occupation) has any influence on that parameter. Next, the spatial distribution of the average egg volumes is calculated and expressed in relation to the distance to the illumination.

9.3 Analysis

If the habitat conditions or the illumination indeed influence the breeding success, then the relation between egg volume and 'chance of occupation' (figure 9.1 and 9.3) or 'distance to the light' (figure 9.2 and 9.4) should show a certain trend.

It was expected that the habitat conditions would influence the breeding success in both years. In 1998, the trend line for 'chance of occupation' (figure 9.1) runs almost horizontal. The explaining variance is very small and the relation is not significant. Breeding success, in terms of egg volume, is thus independent of habitat quality. This is the case in 1999 as well (figure 9.3).

It was also expected that the distance to the light would not have any influence in 1998, since it was not turned on or it was not present in that year. Indeed, the 1998 trend line for 'distance to the light' runs nearly horizontal, the explaining variance is very small and the relation is not significant as well (figure 9.2). In 1999, the 'distance to the light' shows a significant relation, but the explaining variance is only 3.5% and thus very small (figure 9.4). The relation is negative. The condition of the clutches decreases with increasing distance. Apparantly, the birds closer to the illumination have larger eggs.

9.4 Conclusion

Bearing again in mind the remarks made in § 7.4, the following is concluded. The clutch-wise average egg volume, taken as an indication for the condition of

Figure 9.1
Correlation between relative chance and egg volume, Y=0,126X + 40,51 Residual variance surpasses variance of Y

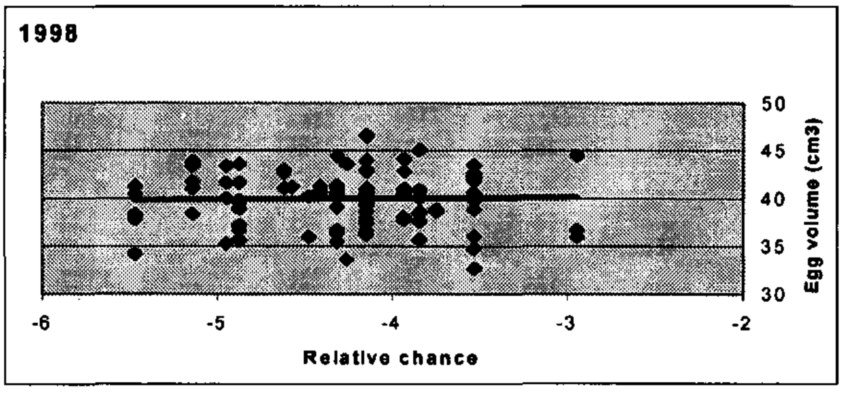


Figure 9.2
Correlation between distance to light source and egg volume. Y=-0,0017 + 40,7; explained variance = 2,4

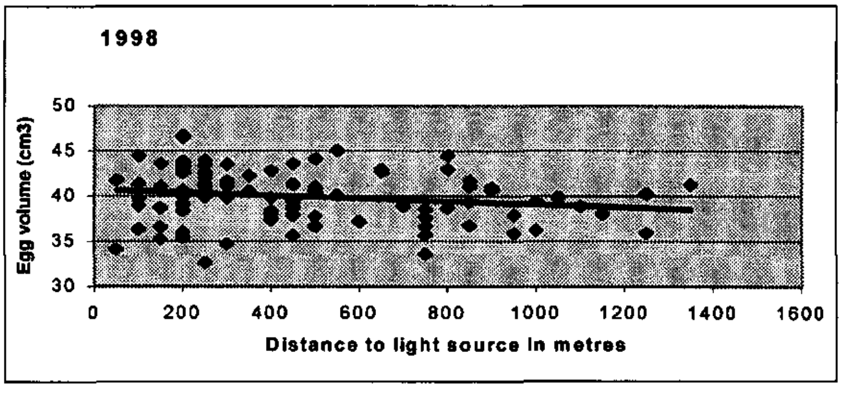


Figure 9.3
Correlation between relative chance and egg volume. Y = 0,749X + 43,15; explained variance = 1,1

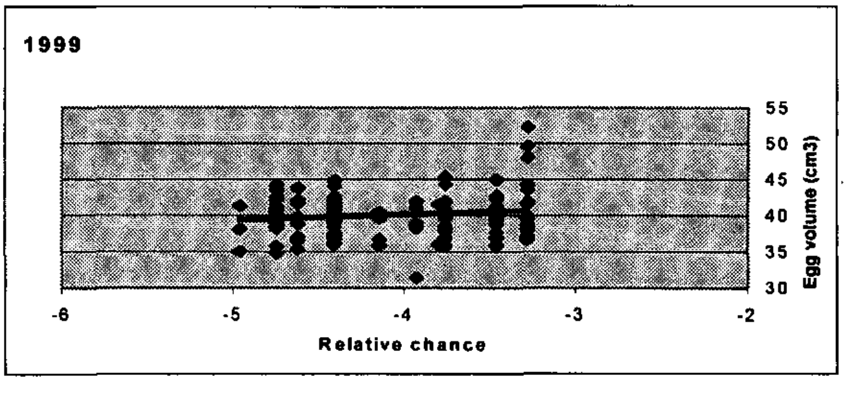
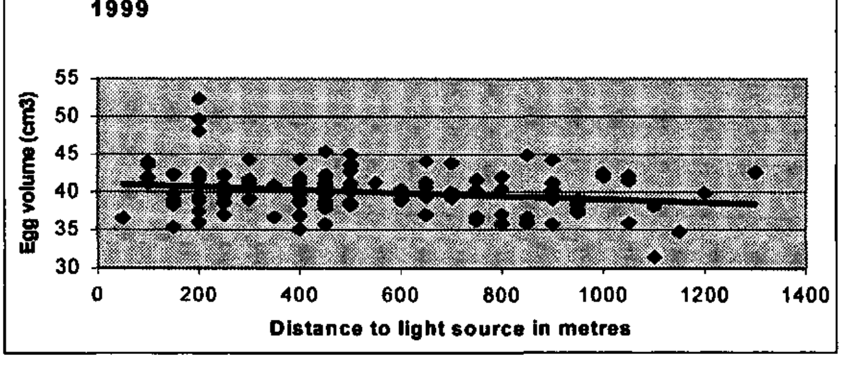


Figure 9.4
Correlation between distance to light and egg volume. Y=-0,002X+4,1; explained variance = 3,5



the parent birds and breeding success, seems to be independent of habitat quality. Next, there seems to be a positive, but statistically weak influence of illumination on the average egg volume. However, there are three extreme observations (average egg volumes over 46 cm^3; figure 9.4) that partly determine that weak relation. Taking this into consideration, it may be concluded that the egg volumes in the research area are most likely not influenced by the road illumination.

10 Illumination and predation

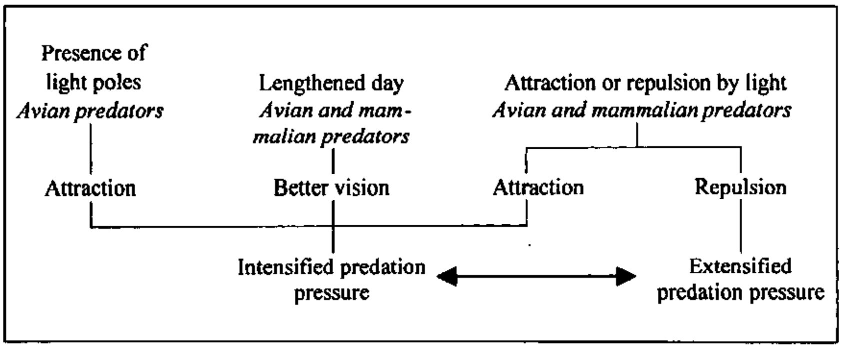
10.1 Possible influence of illumination

The last question is: does road illumination influence reproduction by facilitating nest predation by day-active birds (crows, gulls) and more twilight-active mammals (foxes, polecats, ermines, weasels)?

Facilitation of predation is imaginable due to:
1 the longer daily period in which predation can occur;
2 the attraction or repulsion of predators by the light (sources) and, in the case of attraction, implying a better sight;
3 the attraction of air predators that utilise light poles as to perch and as a look-out.

These three possibilities, which have been worked out in figure 10.1, cannot be distinguished on the basis of the observed traces of predation. As regards a possible attraction (2nd point), it should be noted that the lamps that were used most likely have little influence, owing to the minor component of short-wave radiation in their emission (*De Molenaar et al. 1997*).

Figure 10.1
Possible influence of (road) illumination on predation



The possible influence of illumination as such is spatially restricted (see § 7.1 and figure 4.1), but the visibility of the lights reaches much and much further. However, it is unknown from how far away attraction or repulsion may occur. The light poles can be seen from far away too. Whether or not, and to which degree, inspecting the field from a high perch is more efficient than searching the field flying around in the air has, as far as could be traced in literature, not been studied. In any event, it should in most cases be profitable, in terms of energy, to start by inspecting the field from a high look-out first. The behaviour of air predators indicates that the first may pay.

There is yet a fourth influence imaginable. Predators, such as herons, that (in part or mainly) prey on other species may also be attracted or repulsed by the light(sources). In the case of attraction, this may cause more commotion and more disturbance in the field, possibly to the effect that the black-tailed godwits leave their nest more frequently and for longer periods, thus increasing the risk for the breeding success.

10.2 Presence of predators

10.2.1 Avian predators

Predators operating from the air were seen on regular occasions during the fieldwork in 1998 and 1999. These were mainly carrion crows (*Corvus corone*). These birds are the main predators in many meadow bird areas (*Beintema 1995a*), but there was hardly any indication of this in the research area. The low predation pressure by this species can probably be attributed to the fact that it is kept at bay: there are ample possibilities for crows to nest in the vicinity of the research area. This also holds for magpies (*Pica pica*).
Herring gulls (*Larus argentatus)* and common gulls (*Larus canus*), which may visit the area from the nearby dune area to get their share, were seen only rarely during the fieldwork. That also holds for the blue heron (Ardea cinerea), the black-headed gull (*Larus ridibundus*) and the kestrel (*Falco tinnunculus*), which all three are known to occasionally take meadow bird chickens, as may the marsh harrier (*Circus aeroginosus*), the moorhen (*Gallinula chloropus*) and the Oystercatcher (*Haematopus ostralegus*) (*Beintema 1995a*). The latter three are all present in the area. However, predation by these species was not observed. The only observation of a predator with an egg was a lesser black-backed gull (*Larus fuscus*), which flew over in 1998 with the egg of a duck in its bill.

The permanent facilitation of predation by birds due to the presence of perches such as buildings, meadow mills and the like, is almost absent (see § 2.2, 2.3). The use of these structures is hardly ever observed. As the temporary light poles in Groot-Limmerpolder in 1999 might have given cause for a temporary additional facilitation due to their use as look-outs by air predators, special attention is paid to the use of these poles. It appeared that they were only used to rest upon at irregular intervals.

10.2.2 Facilitation of avian predation by the fieldwork

The act of searching for meadow bird nests, then placing sticks to mark nests - even if this occurs some distance from the nests – and subsequently revisiting the nests for control, along with traces left behind in the high grass, all may draw the attention of air predators and give cause for increased predation – as may the instalment of protection against trampling by cattle. The fact that meadow birds are exposed to the risk of predation is normal, but fieldwork of this kind may inadvertently add to that risk. There were no indications of this during the fieldwork, but it cannot be completely ruled out.

10.2.3 Mammalian predators

During the fieldwork, ground predators were observed only a very few times; indications for their presence were encountered occasionally.
Rumours among meadow bird protectors in the area have it that at least 80% of the clutches are annually lost owing to predation by foxes (*Vulpes vulpes*). However, this was not observed. It is possible that a 'cleaning action' had recently been carried out. Foxholes were not found. According to one person of Het Noordhollands Landschap, traces show that foxes regularly pay a visit to the northern part of Groot-Limmerpolder. In 1999, a dropping from a fox was found

on a plot in Groot-Limmerpolder. No additional indications of the presence of foxes were observed here in 1998, nor where there any in Limmerpolder in 1998 and 1999.
In 1999, black-tailed godwits were observed chasing an ermine (*Mustela erminea*). A single dead female black-tailed godwit was found which, judging from the injuries to the neck and skull, had been bitten to death by a weasel (*Mustela nivalis*) or an ermine.
According to a hunter, stray cats can also be found in the area. These are eliminated if possible.

10.3 Observations of predation

The cause(s) of losses is determined on the basis of the condition and whereabouts of the eggs and clutches. Essentially, nests are considered to be predated when one or more of the eggs found in or near the nest are evidently damaged, or eaten by other animals, or when no traces of eggs or remnants of eggs are found. In the first case, the predator can be established by the way in which the egg or eggs are damaged. Eggs crushed by trampling are excluded from this. In the second case, the loss is attributed to an anonymous predator that will generally have been a bird. The observed predation is summarised in table 10.1. When a clutch was intact, but obviously abandoned, the loss is assumed to be due to unknown disturbance.

Table 10.1
Extent of predation of the nests of black-tailed godwit

	Number of nest		Number of predated clutches			
			Absolute		percentage	
	1998	1999	1998	1999	1998	1999
Limmerpolder	53	70	3	3	5,5	6
Groot-Limmerpolder	63	77	3	3	4	4
Total	116	147	6	6	5	4

In Limmerpolder in 1998, one nest was predated by a carrion crow. The predators of the two other lost clutches remain uncertain. In 1999, one clutch was consumed by an ermine, but again the predators of the other two clutches that were lost could not be established. The extent of predation was limited in Groot-Limmerpolder as well. In 1998, one clutch was lost when the female black-tailed godwit was killed by a weasel (or an ermine). There were no clues concerning the fate of the other two lost clutches. In 1999, there was no clear evidence concerning the identity of the violators of the predated clutches.

10.4 Other losses

Other aspects that may cause losses other than predation are also established on the basis of the damage to the eggs, complemented with other field evidence. In some cases, intact clutchs had been abandoned, apparently due to disturbance. The observed losses are summarised in table 10.2.

In Limmerpolder in 1998, one nest was abandoned for unknown reasons and three clutches were trampled by a cow, a sheep and a hired hand, respectively.

Table 10.2
Loss of clutches due to reasons other than predation

	Number of nests		Number of predated clutches			
			Absolute		percentage	
	1998	1999	1998	1999	1998	1999
Limmerpolder	53	70	4	5	7,5	7
Groot-Limmerpolder	63	77	6	5	9,5	6,5
Gehele gebied	116	147	10	10	8,5	7

In the following year, five clutches were lost due to abandonment for unknown reasons. In Groot-Limmerpolder in 1998, three clutches were lost as a result of abandonment, two were lost due to mowing, and one as a result of the application of fertiliser. In 1999, three clutches were abandoned. Two more clutches were lost because the nests were flooded after a drastic increase of the water level.

The number of losses due to trampling is very small, as the extent of cattle grazing is very limited. With the exception of sheep grazing, which is practised throughout the year, cattle was not allowed to graze in the field until in the course of May. Sheep were pastured on the drier plots, which had a very short sward due to the heavy grazing pressure and, in consequence, were devoid of breeding meadow birds. One clutch was trampled by sheep because the flock was transferred to a plot that had not been grazed up until that time. As a precautionary measure, save for a few exceptions, protectors were placed over the nests that were located on plots where grazing was to be expected in the breeding period.
A special, already mentioned case of trampling concerned a nest close to where

Figure 10.2 Distribution of predated nests in 1998 (●) and 1999 (♦).

a machine was to do reallotment work. The driver was apparently attracted by the nest marking stick, he subsequently went to have a look, and thus happened to step on the nest.
In spite of the fact that the nests were marked, two were lost due to mowing. The nests concerned were not mowed to pieces. On the contrary, a clump of grass around the nests was carefully left untouched. The clutches were lost as a result of abandonment owing to the fact that mowed grass then covered the spared clump and buried the nests as it were.

10.5 Analysis

The distribution of predation over the area is wide and arbitrary. The drawback to the limited extent of predation is that the number of cases is too small for statistic analysis.
In 1998, the level of predation and abandonment appear to be concentrated in the first week of breeding, which is usual (*Beintema 1995a*). This corresponded to the second half of April. In 1999, predation occurred somewhat later, in the first and second week of May. This may have been caused by less favourable weather. The small numbers leave little scope for distinction between Limmerpolder and Groot-Limmerpolder.
The map in figure 10.2 shows that the predated nests were mainly situated along the ditches in the verges of the plots. This suggests a relation with the way in which predators move through the field (mammals) and take their bearings (mammals and birds).

10.6 Conclusion

The number of cases in which lost eggs and/or clutches could be observed is small in both years. The larger part of the losses is due to predation (average 4.6%) and abandonment (average < 4%, excluding the drowned nests). The extent is amply within the margin of the extent of predation of clutches of black-tailed godwit, and more in general meadow bird clutches, elsewhere in the Netherlands.
Considering the total number of nests, the predation is neglectable. The statistic significance of a possible influence of illumination on predation cannot be demonstrated. Given the set-up and the extent of the experiment, this is not entirely unexpected. Consequently, the observations do not offer any grounds for suggestions either in favour or against the possible influence of illumination.

11 Conclusion

11.1 Results

As a consequence of the limited set-up of the experiment, it can only result in indications for the possible effects of road illumination on the development of the black-tailed godwit population in the research area. Nest fidelity and weather conditions at the beginning of the reproduction season appeared to be major complications. The indications are:

- Road illumination appears to have a statistically significant effect on the spatial use of grassland for breeding by the local black-tailed godwit population. This effect on the breeding habitat quality is negative. The repulsion appears to reach over several hundreds of meters.
- Road illumination appears to have a statistically significant effect on the spatial distribution of the start of breeding by the local black-tailed godwit population as well. This effect proves to be negative as well. Early starters build their nests further away from the illumination than birds that begin to breed later in the season.
- An influence of road illumination on the average egg volume per nest, as an indication for breeding success and the condition of the parent birds, does not seem to be demonstrable.
- The observations do not permit any conclusions about a possible effect of road illumination on nest predation.

All in all, the findings indicate that road illumination affects the local black-tailed godwit population. It should be noted that the effects of the visibility of the burning lights (luminance intensity), the illumination of the surroundings (illuminance intesity) and the presence of light poles cannot be distinguished with the set-up of this experiment. The apparent absence of endocrinologic effects might be explained by the limited reach of illumination.

Additional indications are:

- A statistically significant effect of the road (i.c. road traffic) on the breeding habitat quality near the A9 motorway is absent. It appears that such an effect can more or less be compensated for by site factors, such as grass height, sward structure and fertilising with stable dung.
- A relation between the start of egg-laying and the quality of the plots where the nests are found, in terms of relative chance of occupation, is not demonstrable. Both early and late starters can choose the most suitable plots to nest, but they are apparently also influenced by nest fidelity and/or other, unknown factors.

Furthermore:

- The nest choice is first of all a matter of sward structure, moisture conditions, grass height and fertilising with stable dung. Sward structure and grass height are dependent upon the grassland management and the use (especially grazing, fertilising, drainage) prior to the reproduction season of the birds. Black-tailed godwits prefer to nest in grass tufts. When the sward is smooth, at the beginning of the reproduction season, the birds prefer high grass to short grass.
- Nest fidelity was not studied. However, taking into account the disturbance by the illumination experiment, weather conditions and the distribution of the breeding habitat quality, a comparison between the nest choices in 1998 and

1999 suggests a degree of nest fidelity that largely corresponds to the findings of Groen (§ 3.1).

- The statistically significant effect of road illumination on the breeding habitat quality indicates that the influence of this illumination is less compensated for by the site factors mentioned, than by the influence of the road. However, this does not justify the conclusion that the influence of road illumination is more significant than the influence of road traffic.

These indications primarily hold for the research area. Broader and prolonged investigations will have to establish their general validity.

11.2 Remarks

Birds show a preference for establishing themselves in habitats of an optimal quality. That quality is determined by a complex of factors that are - at least in part - interactive. As a result, a certain negative factor can more or less be compensated for by one or more other, positive factors. As regards the influence of road traffic, this seems to be so in the research area.

It is known that the population density is not always a reliable parameter to measure habitat quality. This is a matter of degree of density: with increasing density, a larger number of birds will occupy less favourable, marginal habitats (see *Reijnen et al. 1992, Reijnen 1995*). In this respect, it should be noted that the population density in the research area is relatively high (see § 5.2). However, the distribution pattern (§ 7) and the general analysis of nest choice and dates of egg-laying (§ 8.4) show that the general spatial aspects of external disturbance are particularly complicated by the habitat quality. The change in the distribution pattern from 1998 to 1999 furthermore suggests that the research area was not 'filled up'.

In conclusion, it should be remarked that an inventory of territories provides a weak basis for the purpose of investigating the spatial effects of possible influences on local breeding populations of black-tailed godwit.

11.3 Recommendations

The limited set-up of the experiment justifies the recommendation to repeat the research over a longer series of years, and in more areas if possible, and to include a second, common meadow bird species (lapwing or redshank) of which, in so far as this is known, the nest fidelity is less developed. Lapwing is more suitable for this purpose than redshank.
It is desirable to include the aspect of nest fidelity in any future repetitions of the research. This implies an essential extention with an aspect of which little is known (see e.g. *Moedt 1995b*).

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Annexes

Annex 1: Estimation of the breeding stage

The estimation of the breeding stage of the eggs of black-tailed godwit (in days) with the help of an incubometer is given in the first table. This incubometer is a refined variant of the common immersion test. The estimation with the immersion test is given in the second table (in accordance with Beintema 1995a).

A single test may give a certain spread in the estimated day on which breeding started. This spread can be narrowed down by repeated testing. An example is given in the third table.

INCOBUMETER DATA FOR BLACK-TAILED GODWIT EGGS

Stage	Egg behaviour	Inclination of the egg's axis	Emergence of the egg, in mm	Breeding stage in days
1	sinks	30°	–	0-3
2	sinks	35°	–	1,5-4
3	sinks	40°	–	3-5
4	sinks	45°	–	4-5
5	sinks	50°	–	5-5,5
6	sinks	60°	–	5-6,5
7	sinks	70°	–	6,5-8,5
8	sinks	80°	–	9-10
9	is suspended	80-90°	–	11
10	floats	90°	1	12-14
11	floats	90°	2	14-15,5
12	floats	90°	3	15,5-17,5
13	floats	90°	4	17,5-19,5
14	floats	90°	5	19,5-21,5
15	floats	90°	6	22-25

EMERSION TEST FOR MEADOW BIRD EGGS

Stage	Egg behaviour	Breeding stage in days
1	Egg lies flat on the hand or bottom	0-5
2	Egg stads oblique on the hand or bottom	5-7
3	Egg stands upright on the hand or bottom	8-11
4	Egg is suspended in the water	11
5	Floating egg touches on the water surface	12-16
6a	Egg well (up to 10%) above the water surface	16-22
6b	Egg amply (> 10%) above the water surface	22-25

HYPOTHETICAL EXAMPLE

Date of observation	Breeding stage,	First breeding day
April 20	3	April 15-17
April 27	8	April 8-12
May 3	12	April 16-17
May 10	– (clutch hatched)	April 16, or later
	First breeding day most likely April 16	

Annex 2: Remarks on meadow bird inventories

In the Netherlands, with exception of the province of Friesland, the majority of meadow bird inventories is carried out by mapping the breeding birds based on the identification of territories (cf. § 5.2, note 3). In Friesland, where a long tradition of meadow bird protection exists, most of the inventories are based on nests that are actually found.

A transversal and longitudinal comparison of inventories based on meadow bird territories, i.e. of different areas and one area over a number of years, is not simple. In general, this is especially true if the inventories are conducted by different observers, as differences in individual observing and in the interpretation of the birds' behaviour may easily produce incomparable results. At the best, such inventories give an indication of the number of breeding pairs that are present during a certain year, or a series of years. This is particularly the case with data that was collected before the establishment of SOVON (Samenwerkende Organisaties Vogelonderzoek Nederland).
Later, the method for inventories based on meadow bird territories was standardised (*Van Dijk 1993*). It is recommended to conduct inventories of the black-tailed godwit from early March to the end of June. The best period is from the second week of April to the first week of May. Two observations in one spot of: a male, a pair, territory-indicating behaviour, nest-indicating behaviour or the discovery of a nest, one of which is observed in the period April 15 to May 10, are already considered sufficient to ascertain a territory (or a breeding pair) (*op. cit.*). However, this procedure poses some problems. For instance, black-tailed godwit tend to breed more or less clustered. The nests are sometimes found less than 15 m from each other (see cluster map following chapter 6). As a result, it is almost impossible to tell the pairs apart. In consequence, the established number of pairs or territories may turn out to be (far) to low. Besides that,
black-tailed godwit often make nest hollows and mate in different places. Moreover, it is also possible that black-tailed godwit have non-coinciding pairing and breeding territories (*Moedt 1995b*). In view of the frequent clustering, the question is then whether or not the black-tailed godwit have a real breeding territory. This behaviour can easily lead to an overestimation of the number of pairs, 'breeding territories, and real instances of breeding.

As a result, this method for a territories inventory produces but an indication of probable breeding and it leaves the exact site of the nest literally and figuratively in the middle. It therefore provides a weak basis for research that requires e.g. by approximation exact numbers, mutual distances between pairs and nests, or, if there is a possible external influence involved, distances to a certain point or line. In such cases, it is essential that the inventory of the nests is as complete as possible.

The are a number of ways to search for nests. Sometimes it is done by having one or more persons systematically walk along a fixed pattern of lines, plot-wise, to look for nests. This procedure can only be followed if the grass is not too high. The reason is that the nests are very difficult to find in high grass. In addition, one should avoid leaving traces of trampled grass that may attact pradators. Another restriction is that the number of repeated searches is limited to a few times, whereas the period in which nesting starts takes weeks. As a result, an unknown number of nests - sometimes a considerable number - may

be overlooked. Searching for nests without a prefixed procedure, as meadow bird protectors may do, has similar drawbacks.
Another method is to keep an eye on plots to see where birds that seem to fly away from their nest come from and/or where birds that seem to return to their nest disappear in the grass, and then determine where the nest can be found.
The best method, followed in the research described in this report, is a kind combination: first, a single general inventory of possible territories, then one or two systematical searches along fixed lines, followed by repeated searches for nests by ourselves - in which the results of nest searching by volunteer meadow bird protectors were gratefully used. Our searches were conducted plot-wise by looking for birds which, either after being disturbed or not, returned to their nest or flew away after being alarmed by approaching predators. In the entire course of the fieldwork, each plot was thus visited weekly (see table 4.1). The necessity of this was proven by plots where new nests could still be found late in the season. Sometimes this happened on plots where various signs of nest indication behaviour had already been observed early in the season. New nests also appeared on the other plots time and again.

Annex 3: Discription of the plots

The following three tables present the classifications for the description of the general conditions of the grassland and the moisture or drainage condition of the plots. In the same way, notes are taken on grazing (present/absent, type of cattle, stocking rate), fertilising (absent/stable dung/injection of slurry/artificial fertiliser), grassland treatment (absent/plouged/herbicides/mowed/re-sown) and proprietor (Het Noordhollands Landschap/private).

GRASS HEIGHT

Stage	Description
1	short / low = 5 – 10 cm high
1/2	intermediary between stage 1 and 2
2	medium high = 15 – 20 cm high
2/	3intermediary between stage 2 and 3
3	high = 25 - 30 cm high

SWARD STRUCTURE

Stage	Description
1	smooth/even
2	with some clumps/tussocks (up to 10 clumps/10 x 10 m)
3	predominantly tussocky (> 10 clumps/10 x 10 m)

DRAINAGE CONDITIONS

stage	Description
1	rather dry/moist = firm ground; trenches are dry; ditch water level about 5 dm or more below ground surface
2	intermediary between stage 1 and 3, or alternatingly 1 and 3
3	moist = ground is springy on treading; trenches: soil water-saturated to holding some water; ditch water level about 4 (3-5) dm below ground surface
4	intermediary between stage 3 and 5, or alternatingly 3 and 5
5	wet = ground sops on treading (is water-saturated); trenches hold water; ditch water level about 3 dm below ground surface
6	very wet / intermediary between stage 5 and 7, or alternatingly 5 and 7
7	wet to very wet with puddles; trenches full with water to running over; ditch water level about 3 dm or less below ground surface

Annex 4: Regression analysis for determination of the chance of presence or preference of nest choice, based on habitat factors

The habitat factors proven to be significant by the statistic test (one or more asterisks) are used for the logit regression analysis. The influence of the classes is expressed by the estimate value, s.e. gives the confidence interval of the estimate and t(*) > 2 means that the class differs significantly from the first class (incorporated in the constant).
The numbers were filled in in the GIS for the plots where the habitat factor class in question could be found (e.g. str2) and then added up. The outcomes of this procedure are the maps for chance of occupation.

1998

	estimate	s.e	t(*)
Constant	-5.471	0.295	-18.53
str 2	0.330	0.235	1.41
str 3	0.899	0.381	2.36
hgt 2	0.265	0.272	0.97
hgt 3	1.210	0.299	4.05
ontw 5	0.729	0.219	3.33
ontw 7	0.257	0.297	0.87
mest 2	0.730	0.373	1.96

1999

	estimate	s.e.	t(*)
Constant	3.799	0.281	-13.52
str 2	0.339	0.220	1.54
str 3	0.817	0.283	2.88
Ontw 3	-0.946	0.265	-3.57
ontw 5	-1.161	0.322	-3.60
ontw 7	-0.299	0.328	-0.91

EXPLANATION

Estimate, s.e., t(*) and constant: see text		
hgt	grass height	1=short, 2=medium, 3=(relatively)high
str	sward strictire	1=even, 2= somewhat tussocky, 3=predominantly tussocky
ontw	drainage conditions	1=rather dry, 2=dry/moist, 3=moist, 4=mpoist/wet, 5=wet, 6=very wet, 7=wet/very wet with puddles
mest	fertilising	1=no fertilisation, 2=stable dung

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