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CAPACITY OF ACCOMODATION AREAS FOR WINTERING GEESE IN THE NETHERLANDS: FIELD TESTS OF FIRST PRINCIPLES

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Bos, D., Nolet, B.A., Boudewijn, T., van der Jeugd, H.P. &
B.S. Ebbinge 2008



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Alterra
Postbus 47
6700 AA Wageningen
Tel. 0317 - 478729

FOTO VOORPLAAT

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UITVOERDER

Altenburg & Wymenga ecologisch onderzoek bv
Postbus 32, 9269 ZR Veenwouden
Telefoon (0511) 47 47 64, Fax (0511) 47 27 40
e-mail: info@altwym.nl
web: www.altwym.nl

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Capacity of accommodation areas for wintering geese in the Netherlands: field tests of first principles

Daan Bos ^{a‡}, Bart A. Nolet ^{b,c}, Theo Boudewijn ^d, Henk P. van der Jeugd ^e and Bart S. Ebbinge ^b

^a Altenburg & Wymenga ecological consultants. P.O. Box 32, 9269 ZR Veenwouden, The Netherlands. d.bos@altwym.nl.

^b Alterra, Centre for Ecosystem Studies, PO Box 47, 6700 AA, Wageningen, The Netherlands.

^c Netherlands Institute of Ecology (NIOO-KNAW), Rijksstraatweg 6, 3631 AC Nieuwersluis, The Netherlands.

^d Bureau Waardenburg bv, PO Box 365, 4100 AJ Culemborg, The Netherlands.

^e Sovon Dutch Centre for Field Ornithology, Applied Research department. Rijksstraatweg 178, 6573 DG Beek-Ubbergen, The Netherlands.

[‡] Corresponding author: phone: 00-31-(0)511 474764, fax number: 00-31-(0)511 472740.

Abstract

The Dutch national policy for management of wintering goose populations has evolved into a system in which geese are hosted in large-scale accommodation areas. The evaluation of this policy requires basic ecological information on grazing pressure by wintering geese and factors affecting that. This study provides tests of some of the hypotheses formulated with regard to variation caused by soil type, distance to the roost, weather conditions, land management and disturbance. The analyses are based on estimates of grazing pressure derived from dropping counts and associated field information. Data have been collected on 145 unique sample locations, some of which had been sampled over multiple years. On a seasonal basis, intensively managed grassland did not accommodate more geese than extensively managed grassland. Fields that were near to a roost accommodated more geese than fields further away, all else being equal. Evidence for the effect of disturbance on grazing by geese were found at both small and large spatial scales; Effects of disturbance are relevant, and geese appear to need time to get used to a reduction in disturbance. Generally, the highest cumulative grazing pressure was found in the North, but locally grazing pressure reached similar levels in the East and West of the country. The measured values of grazing pressure are, on average, higher than those found thus far. From this information we estimated the available capacity on accommodation grassland in the Netherlands per region. The estimated available capacity on accommodation grassland in the Netherlands in 2007 fits well with the required capacity in the Northern region, but in the West there is likely a shortage.

Key words: Barnacle geese, White-fronted Geese, Greylag Geese, Wigeon, farming, foraging areas, Beleidskader Faunabeheer (policy framework fauna management).

Introduction

Due to changes in land use and hunting practices goose populations world-wide have nearly all increased dramatically over the last decades (Abraham *et al.* 2005, van Eerden *et al.* 2005). On a European scale the Netherlands are the most important wintering area for geese (Madsen *et al.* 1999). Many people enjoy the sight of so many geese, but as these birds are feeding to a large extent on agricultural fields, the conflict with agriculture has also intensified. In an attempt to formulate a sustainable solution, the Dutch policy to handle this conflict has changed gradually over the past decade. Officially from 2003 onwards, large areas have been designated as so-called 'goose foraging areas' for wintering geese. This policy builds upon local initiatives by groups of farmers to 'host' geese, rather than scaring them. Farmers within such designated areas are expected not to disturb staging geese until April 1st, while farmers outside these areas are expected to scare them in order to reduce damage to their crops.

This new policy has a bearing upon European and National law, with regard to Natura 2000 (N2000) legislation. The Dutch government is in the process of designating a total of 162 N2000 sites, 53 of which have conservation objectives related to geese. Many of these nature areas are already secured under the Dutch law. Future projects, often economic developments, which may affect the N2000 conservation objectives will be and are being evaluated most carefully. Future projects that affect foraging conditions of wintering geese near N2000 sites may have negative impact on the conservation objectives of that site. Such developments may or may not be implemented depending upon the degree to which foraging conditions for wintering geese in and around the site have been secured.

An important question is thus how much foraging area has to be designated as accommodation area in order to reach the conservation objectives for wintering geese at national and local scale. The term accommodation areas here refers to 'goose foraging areas', N2000 areas and other conservation areas combined. Strategies for estimating the required surface, quality and position of accommodation areas include the use of computational models. In relation to staging geese, for example, Individual Based Models have been applied (Pettifor *et al.* 2000, Amano *et al.* 2006b) as well as more simple Depletion models (Vickery *et al.* 1995). Goss-Custard *et al.* (2003) classify the models as Spatial Depletion Models (Sutherland *et al.* 1994) or Daily Ration Models e.g. (e.g. Michot 1997), and discuss the difference between these approaches. In any case, these models are based on certain premises about the factors and processes that determine terrain use by wintering geese. In this paper we aim to test these premises. We also provide empirical estimates of grazing pressure for different regions in the Netherlands and estimate the area of grassland that needs to be designated based on these values with an Empirical Grazing pressure Model. The term 'grazing' refers to goose grazing throughout this paper. When grazing with livestock is meant, the term livestock-grazing is used.

Terrain use by wintering geese is different between species. The Dark-bellied brent geese *Branta b. bernicla* on the one hand predominantly use mudflats and coastal grasslands, including salt marshes (Vickery *et al.* 1995, Bos *et al.* 2003). They do feed on inland pastures however when food resources become scarce. Greylag geese *Anser anser* on the other extreme forage to a large extent in freshwater marshes and often frequent cropland to eat harvest remains. The majority of feeding by wintering geese in the Netherlands, however, is on inland pastures by the numerous Barnacle goose *Branta leucopsis* and White-fronted goose *Anser albifrons*. The geese are generally hypothesized to preferentially feed near their traditional roosting places. Field data for White-fronted geese in Japan, support this (Amano *et al.* 2006a). Each species has its own feeding characteristics based on size, physiology and bill morphology (Durant *et al.* 2003), but all of them are able to cope with grass over a wide range of quality and quantity. Theoretically, the number of geese that can be supported in a given study area is determined by the amount of standing biomass and the grass production over the period of staging (Vickery *et al.* 1995). Production will vary, amongst other things, among years, soils and with grassland management. Disturbance by man (willing or unwilling) will negatively affect the time available for foraging on a given parcel of grass and result in lower grazing pressure when foraging can be done elsewhere (Madsen *et al.* 1995, Madsen 1995, Kruckenberg *et al.* 1999). Our study aims to test some of these hypotheses for the situation in the Netherlands.

Our specific hypotheses are the following:

- 1) Realised grazing pressure by geese depends on grass production and standing biomass of grass. Thus, intensively managed grasslands will be able to accommodate more geese than extensively managed fields, all else being equal. Even so, there will be differences that can be attributed to other factors that affect grass production, for example weather conditions and soil type.
- 2) Fields near roost sites will be used by geese with a greater intensity than fields further away.
- 3) Different types of grassland will be used in order of preference, as depletion during winter progresses, and vice versa, when grass production starts in spring.
- 4) Disturbance negatively affects cumulative grazing pressure. Outside accommodation areas the grazing pressure will be lower than inside, and geese will tend to feed less near busy roads.

Methods

Study areas

We have collected data in twelve study areas in the Netherlands (figure 1). We distinguished three regions within the Netherlands, North, East and West (cf. van Roomen *et al.* 2005). Each study area consists of multiple sample locations, totalling 145 unique locations. Study areas are named using their abbreviations throughout the paper (see table 1 for the full names). All locations are in the low lying parts of the Netherlands near the big rivers or near the coast. The sample locations have been tabulated on the basis of land use and status as an accommodation area (table 1). Most sample locations were located within an accommodation area, but 15% of the locations were fields outside. The majority of locations was either intensive or extensively managed grassland. A few extensively managed locations were managed for botanical purposes and these were treated separately. Our data set also included four sample locations on a livestock-grazed salt marsh. Intensive management refers to high levels of fertilisation, high stocking rate and early application of fertilisers in relation to extensive management (see table 2 for average values of these parameters). Extensive management is equivalent to management by conservation bodies in 97% of the cases, and in the sample of our study geese and farmland birds are part of the conservation goal of these grasslands. The management of botanic grasslands has a floristic main focus. The grasslands in our study are commonly managed by grazing and mowing. Over 90% is livestock-grazed, 75% with cattle or a combination of cattle and sheep and 17% by sheep or horses. Only 8% is ungrazed. In addition 79% of the fields is cut for hay or silage. One-fifth of the plots has a Clay soil, 37% is on Sand or silt and 43% is classified as Peat. The average distance to a roost is 3.9 km (2.1 km sd.). The vegetation of all grasslands falls within the LOLIO-POTENTILLION ANSERINAE, except for the salt marshes (Schaminée *et al.* 1996). Sample locations under a nature conservation regime differ in terms of disturbance to geese from locations managed otherwise. Geese are never deliberately scared from conservation areas, while scaring is allowed and practised after the first of April in accommodation areas managed by farmers or at all times on locations that are not accommodation areas. Besides that, conservation areas also do not have a recent history of scaring in contrast to some of the accommodation areas managed by farmers. Detailed information for some of the sample locations can be found in van Duin *et al.* (2007) for NFB, Bos *et al.* (2006) and Koopmans *et al.* (2007) for OD, Strucker *et al.* (2008) for OVS and Boudewijn *et al.* (2007a, 2007b, 2008a, 2008b) for AW, RG, PD and AH.

Temporal intensity of sampling

Most study areas have been sampled for one complete sample season, in the period 2005-2007. A sample season refers to the period October until May, although the sample season has been shorter locally. In two study areas data have been collected for multiple years. In

this paper we use data for NFB (12 sample locations from 1999 until 2004) and two datasets for OD (two sample locations from 1999 until 2007 and seven additional sample locations from 2004 until 2007) to analyse variation among years.

Regular Dropping counts

Droppings have been counted in circular plots of 4m² and removed at bi-weekly intervals in each of the sample locations. Dropping rates provide a reliable measure of the amount of time spent by geese in a certain area (Owen 1971, Ebginge *et al.* 1975), but see Bos *et al.* (2008a), Bédard & Gauthier (1986) and Amano *et al.* (2004). Dropping plots have been marked with small inconspicuous sticks in the centre of the plot. All plots were located away from obvious sources of disturbance and at a minimal distance of 50 m from roads.

Cumulative dropping counts

In March 2007 we performed a survey in the accommodation area OD to examine the effect of disturbance from roads on grazing pressure by geese. We located transects perpendicular to roads and counted all goose droppings in plots (4 m²) every ten meters along these transects. No distinction was made between old (e.g. up to 14 days old) and fresh droppings. The roads had been classified into three classes of disturbance on the basis of traffic counts by the local government and road type on the topographical map, busy (1500-4000 vehicles.d⁻¹), intermediate and quiet (< 250 vehicles.d⁻¹).

Sward height and grass growth

Sward height was measured with a 24 g, 20 cm diameter polystyrene disc that was dropped on the vegetation and slid along a calibrated stick that rested on the ground. For each sample location at least twenty measurements were taken in November, January and March. At some of the sample locations the sward height was measured more frequently. For reference, a calibration line was constructed by taking a sample of above-ground biomass for a number of plots where also the sward height had been measured in May 2008. Above-ground biomass was estimated by randomly cutting one sod of 10 cm x 20 cm per plot to ground level. The material was sorted into live and dead material, washed, dried at 60 °C for 48 hours and weighed.

Forage quality

In order to determine forage quality a mixed sample of the green leaf tips of the grasses was taken at each sample location in November, January and March in three winters (2005/06 till 2007/08). At some of the locations samples were taken more frequently. The plant material was sorted into live and dead material. In 2007/08 at the same time also goose droppings were collected in the same plots of three study areas (OvS, AH and RG). In some other study areas, goose droppings were occasionally sampled at the same time as grass. Subsequently,

the samples were analysed for dry matter (dried at 60°C for 48 hours), organic matter (burnt at 550°C), nitrogen concentration N (Kjeldahl destruction and measurement on auto analyzer), and neutral-detergent fibre (NDF) and acid-detergent fibre (ADF, only in 2007/08; ANKOM 220 fibre analyzer). All plant samples taken in 2005/06 and 2006/07 were chemically analysed (106 and 81 samples, respectively). Of the 311 samples collected in 2007/08, a stratified random selection yielded 101 samples (49 grass and 51 dropping samples) which were chemically analysed. Chemical analyses were performed at the lab of Resource Ecology at Wageningen University. Of the remaining 210 samples of 2007/08 the above concentrations were estimated with calibrations obtained from near-infrared reflectance spectroscopy (Foley *et al.* 1998) on a MPA FT-NIR using the OPUS 5.0 software package (Bruker Optics BV, Wormer, The Netherlands). NIR spectroscopy was done at the NIOO.

The digestibility d of dry matter of grass was estimated with ADF as an undigestible, internal marker as: $d (\%) = (1 - (ADF_{grass}/ADF_{drop})) \times 100$, where ADF_{grass} and ADF_{drop} are ADF concentrations (%dw) of grass and droppings, respectively (Durant *et al.* 2003). For this analysis data per study area per month were averaged as no one-to-one match could be made between individual droppings and grass samples. N and d were arc-sine transformed for statistical analyses.

Sample location parameters

Accommodation status (yes/no) of each sample location was obtained from maps. Accommodation areas include all N2000 areas, other conservation areas, and all private land in so-called 'goose foraging areas'. Soil types were classified into three main categories, based on lutum content and the amount of organic material: Sand & Silt (lutum < 25%), Peat (organic material > 35%) and Clay. Information on grassland management was derived from questionnaires sent to land managers in 2008. For 52% of the sample locations the questionnaires yielded information on amounts and timing of fertilisation, stocking rates and management objectives. The distance to the nearest roost was estimated from a map of known waterfowl roosts, adapted from Koffijberg *et al.* (1997). The approximate locations of the roosts had been digitised as a point on this map.

Goose counts

In order to be able to correlate goose droppings to real goose numbers we used the census data from van der Jeugd (in prep). These data are derived from monthly goose counts.

Variation between years

To characterise the winters in each sample season we used the Hellmann index (H, <http://www.knmi.nl/klimatologie/lijsten/hellmann.html>), which is a measure for coldness in the

period November 1st until March 31st. It is obtained by summing all daily average temperature values below 0 °C, without the negative sign.

Statistical analyses

The main dependent variables in this study are grazing pressure (droppings.m⁻².d⁻¹), cumulative grazing pressure (droppings.m⁻²) and grass growth (cm.d⁻¹). In this section we will elaborate upon the calculation and use in subsequent statistical analyses.

For all valid measurements, we calculated grazing pressure by dividing dropping numbers by plot area (m²) and interval between successive counts (d). After averaging per sampling location and date of counting, the grazing pressure was averaged again per month over successive counts. At this stage the data were subjected to temporal analyses (see below). To be able to answer more spatially oriented questions, we calculated a cumulative grazing pressure by multiplying monthly values of grazing pressure by the number of days per month and summing this over the period November 1st till May 15th. For one sample location (OvS) this yields an unknown, but probably small, underestimation since the counting of droppings here ended while the geese were still visiting the area.

Each of the questions tackled in this paper required a slightly different selection of the data. For questions with a temporal aspect across seasons, the dataset was limited to those sample locations for which more than a single year of information was available (NFB and OD). For questions with a spatial aspect, each location was included in the selection only once. For OD we selected the season 2007-08, the last season of sampling, for NFB we selected 2002-03, because later seasons had slightly less complete data for the winter months. The independent variables land use, conservation status and distance to the roost are confounded for some of the sample locations. Depending on the hypothesis to be tested we disregarded these locations.

Dropping count data were square root transformed while vegetation height was log-transformed, in an effort to arrive at normality and homogeneity of variances. As these data transformations did not make a difference for the final conclusions, the untransformed data are presented in figures and tables. All statistical analyses were performed using SPSS 15.0 (SPSS inc.)

Within-season temporal analysis

The within-season temporal analysis aimed at describing patterns in grazing pressure *within* seasons, in relation to land use. We applied General Linear Modelling (GLM) with sample location, month, land use and the interaction month*land use as fixed factors. We limited the dataset to sample locations that had continuously been part of accommodation areas, and

included botanical grassland and salt marsh. Non-significant factors or co-variables were removed from the model, in all of the GLM analyses presented here.

Across-season temporal analysis

The across-season temporal analysis aimed at examining differences *among* years in cumulative grazing pressure, in relation to land use. We applied a GLM with season, series, land use, and the interaction series × land use as fixed factors. The factor series refers to the three series of sample seasons available for this analyses from NFB and OD (see above). The correlation between winter coldness (H) and average seasonal cumulative grazing pressure was tested afterwards. We limited the dataset to sample locations that had continuously been part of accommodation areas (botanical grass land is not present in this sample but salt marsh is included).

Spatial analyses

We tested for effects of soil type on cumulative grazing pressure, while correcting for sample location and land use, in a GLM. We limited the dataset to five study areas where sample locations with multiple types of soil occurred, that had continuously been part of accommodation areas, and we discarded botanical grassland and salt marsh.

The effect of distance to the roost on cumulative grazing pressure was tested in a GLM with sample location as a factor and distance to the roost as a co-variate. The dataset was limited to those study areas where sample locations sufficiently differed in distance to the roost (range > 3.7 km), that had continuously been part of accommodation areas, and again we discarded botanical grassland and salt marsh.

The effect of accommodation status on cumulative grazing pressure was examined using a GLM, while correcting for distance to the roost and sample location. For this analysis we used study areas that had sample locations in and outside accommodation areas.

Estimates of goose density as calculated from dropping rates were validated against the results of goose counts in the same areas (mean ± sd.: 1100 ± 1200 ha), by recalculating both measures to goose density (no of goosedays.ha⁻¹.month⁻¹ and no of goosedays.ha⁻¹.season⁻¹). For this we used an average number of droppings deposited on the grazing area per goose per day (DR) of 135 (Ebbing et al. 1975). Observed goose density as obtained from goose counts was calculated by dividing the number of goose days by the available area of grassland (ha). We tested for an effect of month on observed monthly density in a linear regression with density calculated from dropping rates as independent variable, this in order to judge whether using a seasonal average value for the number of droppings per goose is

appropriate. The final calibration line was made at the seasonal level using linear regression and geometric mean regression (Ricker 1984) and this yielded a Calibration Ratio (CR).

We calculated grass growth ($\text{cm}\cdot\text{d}^{-1}$) to examine within season differences in growth and effects of grazing. All measurements of vegetation height (cm) were averaged per sample location and date. We subtracted the previous average value and divided the difference by the interval between the measurements (d) for intervals < 65 days. Grass growth was coupled to grazing pressure in the same month of the same season. The effects of month, land use (fixed factors) and grazing pressure (covariate) were tested in a GLM for the months of November until April. Botanic grassland and salt marsh were ignored in this analysis.

Disturbance from roads

The effect of disturbance from roads on grazing pressure by geese was tested using GLM with disturbance class as a fixed factor and distance perpendicular to the road as a co-variate.

Association between geese and Wigeon

We tested for an association between geese and Wigeon using linear regression.

Empirical Grazing pressure Model

We compared the available capacity in accommodation areas to the required capacity in order to judge whether sufficient accommodation areas have been assigned. The required capacity for the various species of wintering geese and Wigeon at the regional scale (N, E and W see figure 1) in number of 'White-fronted goose days' (WF-goose days in the rest of the text) was taken from Ebbinge & van der Greft-Rossum (2004). They had calculated the required capacity from the highest seasonal maximum numbers of geese present per region for the period 1995-2001 (van Roomen et al. 2003), using the observed phenology in numbers per species per month and correcting for body size. The relevant information taken from Ebbinge & van der Greft-Rossum (2004) is given in Appendix 1.

In addition to this, we calculated the required capacity per N2000 area and summed the results to arrive at a second regional estimate, this time as a cumulative of local N2000 conservation goals. The local conservation goals are given in terms of average number or as a seasonal maximum. Similar to the calculations by Ebbinge & van der Greft-Rossum (2004) we converted and scaled these goals to number of 'WF-goose days'. The second regional estimate of required capacity is smaller, relative to the first, as it ignores geese outside N2000 areas as well as goose species without a formulated conservation objective. From a political/juridical point of view it is however a relevant estimate. The recalculation from goose days per species to White-fronted goose days is performed using conversion factors provided by Ebbinge & van der Greft-Rossum (2004) which are based on allometric relationships

(Bruinzeel *et al.* 1997). In both cases we corrected for the fact that some goose species forage part of the time on harvest remains and cropland (Ebbing & van der Greft-Rossum 2004).

The available capacity in accommodation areas was calculated in our 'Empirical Grazing pressure Model' by multiplying empirical estimates of capacity per unit grassland per region with the available area of grassland in accommodation areas, under a few assumptions related to distance to the roost and disturbance. We calculated regional Estimates of Capacity to be used in this model according to the following formula: $EC_{reg} = EG_{reg,g} * PB_{reg} * CFWF_b * CR * 10^4 * DR_g^{-1} + EG_{reg,g} * (100 - PB_{reg}) * CR * 10^4 * DR_g^{-1} + EG_{reg,w} * CFWF_w * CR * 10^4 * DR_w^{-1}$. Here, EC_{reg} (WF-goosedays.ha⁻¹.season⁻¹ (Oct-May 15th)) is the regional Estimate of Capacity. EG_{reg} is the regional empirical value of grazing pressure derived from dropping counts (droppings.m⁻².season⁻¹ (Oct-May 15th)) for geese (subscript g for all geese and subscript b for Barnacle geese) and Wigeon (subscript w). PB_{reg} (%) is the regional percentage of Barnacle goose-days out of the total number of goose days, as estimated from the goose counts in the same areas (see above). CFWF (no unit) is the conversion factor to White-Fronted goose per species, as mentioned above. CR is the Calibration Ratio (see above). DR is the Dropping Rate (droppings.d⁻¹) or the average number of droppings deposited on the grazing area per species group per day. For Wigeon we used a value of 220 droppings.d⁻¹, calculated from Durant *et al.* (2006), for geese we took a value of 135 droppings.d⁻¹ (Ebbing *et al.* 1975). In words: the regional Estimates of Capacity were calculated from grazing pressure by Wigeon and geese using dropping rates, a calibration ratio, by scaling all species relative to White-fronted geese, and by taking into account the regional differences in species presence.

The total available area of grassland in accommodation areas was extracted from national land cover maps (LGN year 2006) and includes the categories grassland and 'open nature areas'. As yet, this may locally include vegetation communities that are unsuitable for geese, such as unmanaged salt marshes and plant communities dominated by *Juncus effusus*. All areas smaller than 5 contiguous hectares were excluded. A second estimate of available capacity was made for grassland (same data source in each scenario) within a range of 5 km from roost sites, assuming -following our hypothesis- that geese prefer to forage near their roost. The distance of 5 km is an arbitrary measure derived from a ministerial document (Werkgroep Foerageergebieden ganzen en Smienten 2004). The third estimate also refers to grassland within a range of 5 km from roost sites, but also ignores grass within 100 m from roads, power lines and urban development, as estimated from a topographical map scale 1:250.000. This rigorous scenario assumes that geese are disturbed by these features in such a way that the potential grazing pressure cannot be achieved near them. The fourth and fifth estimates focus on the conservation goals for geese in N2000 areas and refer to all grassland within 5 km from a N2000 area, with and without presumed effects of disturbance (as above).

Results

Grazing pressure strongly differed among sample locations ($F_{11,667} = 24$ $p < 0.001$) while there was a significant interaction between land use and month ($F_{11,667} = 3.6$, $p < 0.001$, see figure 2). The grazing pressure on intensive grassland is higher in winter than on extensive land or salt marsh, but in spring the situation is reversed.

The cumulative grazing pressure increased over the sample seasons for OD, while there was no significant trend for BHB or NFB (interaction season*series $F_{2,120} = 5.6$, $p = 0.005$, see figure 3). Land use had no significant effect and variation between years was not correlated to winter coldness (Spearman rank n.s.).

Generally the highest values of cumulative grazing pressure were found in the northern region (all areas above 40 droppings.m⁻².season⁻¹ on average). However, the information from one eastern and one western sample location (OvS & FW, 45 droppings.m⁻².season⁻¹ each, see table 1) proves that locally grazing pressure can be very high in these regions.

There were no significant differences between soil types ($F_{2,64} = 1.5$, n.s.).

The data do not allow for a strong test of the effect of accommodation area as it is confounded with distance to the roost and study area. There are four study areas (OD, AH, RG en PD) that have sample locations both inside and outside accommodation areas. The sample locations inside have higher grazing pressure than outside, but this is only marginally significant ($F_{1,49} = 3.8$, $p = 0.057$) when corrected for study area ($F_{3,49} = 28.0$, $p < 0.001$) and distance to the roost ($F_{1,49} = 30.9$, $p < 0.001$ see below for a test on a different set). In the dataset there are, however, no sample locations outside accommodation areas that have high grazing pressure (mean value is 4.3 ± 1.4 droppings.m⁻².season⁻¹ outside, versus 31.2 ± 6.2 inside accommodation areas in this sub-sample). As mentioned, there is a significant effect of distance to the roost which could even better be estimated in a different selection of study areas (OD, PI, AW en OvS). The effect of distance to the roost is negative in each of these four areas ($F_{1,54} = 25.3$, $P < 0.001$, see figure 4). The relation is weak in PI ($R^2 = 0.08$), but moderate to strong in OvS, AW and OD ($R^2 = 0.3$, 0.4 en 0.6). Overall, each kilometre further from the nearest roost corresponds to a decline in cumulative grazing pressure of 9 droppings.m⁻² season⁻¹. Given that the overall mean cumulative grazing pressure in this sample is 44.8 ± 2.4 s.e. droppings.m⁻² season⁻¹, this is a considerable effect. The northern region on average has higher cumulative grazing pressure than the eastern and western regions, and goose grazing was much more prominent in our study than grazing by Wigeon (see table 3). Of all droppings, 87% were identified as goose droppings. There was no association between geese and Wigeon ($F_{1,127} = 0.56$, n.s.).

Estimated goose density as calculated from grazing pressure (x) relates significantly to goose density as obtained from goose counts (y) in the same areas (Fig 5. linear regression through origin $y = 0.69x$, $F_{1,23} = 81.4$, $p < 0.001$; $R^2 = 0.77$). Month did not have a significant effect ($F_{6,31} = 1.6$ n.s.), so there is no reason to assume that dropping rates differ among months. The coefficient (slope) for the geometric mean regression line (v, Ricker 1984) is 1.04. Calculations using grazing pressure tend to overestimate the observed goose density; at the geometric mean of our validation data the ratio is 0.69.

Grass growth differs among months (Fig 6A; $F_{6,529} = 33.3$, $p < 0.001$), but was not affected by land use ($F_{1,528} = 0.36$ $p = 0.5$). Grass growth is negative from October onwards and positive at ungrazed locations as of March. Grazing has a measurable impact on grass growth (co-variate grazing $F_{1,529} = 55.2$, $p < 0.001$). Intense grazing at 1 dropping.m⁻².d⁻¹ results in a decline of 1.8 cm.month⁻¹ in April. Interestingly, the grazing pressure in April can locally be such that the entire production is consumed. Sward height (cm) is significantly related to biomass (g dry.m⁻²; $y = 55.2 \pm 15.8 + 13.2 \pm 1.3 \times$ sward height, $F_{1,34} = 103$, $p < 0.001$).

Forage quality

The N concentration (%dw) differed among region and land use (intensive or extensive grassland), but not among months (ANOVA: month: $F_{5,409} = 1.25$, $p = 0.3$, region: $F_{2,409} = 9.63$, $p < 0.0001$, land use: $F_{1,409} = 61.12$, $p < 0.00001$). Excluding month, and including the interaction region \times land use, revealed that the latter was also highly significant (ANOVA: $F_{2,412} = 21.97$, $p < 0.00001$), because on intensive grasslands N was lowest in the North, while on extensive grasslands it was lowest in the West. So, no clear picture was emerging from the differences among regions. Moreover, the differences among regions were small compared to the difference in land use (Fig 7, tests include wintergreens on arable fields, which were only sampled in the East: ANOVA: land use: $F_{2,412} = 55.44$, $p < 0.00001$).

The digestibility d (%dw) of grass was positively correlated with N concentration (%dw) in grass: $\text{asin}(d) = -15.9 (\pm 19.5) + 4.99 (\pm 1.92) \text{ asin}(N)$ ($n = 15$, $R^2 = 0.34$, $p < 0.03$). The digestibility of grass did not change in the course of the winter (ANOVA $\text{asin}(d)$ with month: $F_{2,12} = 0.207$, $p = 0.8$).

Disturbance from roads

The presence of busy roads nearby affects cumulative dropping numbers, but quiet roads do not have an effect (fig 8, interaction $F_{2,175} = 5.9$, $p = 0.003$). Near busy roads the grazing pressure is low, but after 85 m the grazing pressure was no longer suppressed.

Empirical Grazing pressure Model

The conservation goals applied by Ebbing & van der Greft-Rossum (2004) amount to 2.1×10^8 WF-geese days, whereas the cumulative conservation goals of N2000 areas add up to 1.5×10^8 WF-geese days, this is 26% less. The estimations of required capacity in relation to the available capacity are given in figure 9. The summed conservation goals of the N2000 areas are most ambitious in the North (6.9×10^7) and the West (5.7×10^7). Available grassland within accommodation areas is 1.5×10^5 ha, most of it (41%) in the north of the country. 64% is within 5 km from a roost and also 64% is within 5 km from a N2000 area with a conservation goal for geese. The Regional estimates of Capacity are given in table 3 and these have been multiplied with the estimated areas of grassland. In the North the conservation ambition is met, in theory, given that both the available area of grassland in accommodation areas and the estimates of grazing intensity are high. Under each assumption the available capacity is above the required capacity. In the West however, the estimated capacity is below the required capacity under each scenario.

Discussion

Geese realized very intense grazing pressure in the north of the country in undisturbed areas near traditional roosts. On average, the cumulative grazing pressure here arrived at 51 droppings.m⁻² from October until May. This is more than double the values found in one of our study areas (PI, mean $11,3 \pm 2,3$ - $23,5 \pm 4,1$ droppings.m⁻²) in the period 1982-1984 at similar or higher levels of fertilisation (275 vs. 320 kg N.ha⁻¹; Groot Bruinderink 1987), and also considerably higher than the mean value of 35 Barnacle Goose droppings.m⁻² found in 1972-73 by Ebbing *et al.* (1975) in the Bantpolder. Soil type nor weather conditions affected grazing pressure. The winters all have been quite mild in our study period though. We did not find evidence that extensive grassland, managed for farmland- or water birds, accommodates less geese than intensively managed land, but the timing of grazing differs between these categories. This is in spite of the fact that the level of fertilisation is much higher on intensive grassland. We strongly believe that fertilisation has positive effects on foraging conditions for geese, as has been demonstrated for wintering (Percival 1993, Hassall *et al.* 2001) and spring staging geese (Bos *et al.* 2008b, Bos *et al.* 2005), but it appears more important that there is an absence of disturbance judging from the following observations: 1) outside accommodation areas the grazing pressure is often low, but note that this is partly so because accommodation areas were located where geese have historically been present in high numbers. 2) The grazing pressure within the accommodation area OD has doubled in four years, even though it had been functioning as a goose foraging area since before 1999. This increase coincides with the overall increase of the world populations of Barnacle and White-fronted geese. Another important phenomenon is that the duration of the spring staging period has lengthened over the past decade (Engelmoer *et al.* 2001), allowing the geese to profit from

new growth in spring. But this cannot be the main reason given that the grazing pressure on BHB and NFB does not significantly increase in this time frame. In our view it is more likely that the increase is related to its status as an accommodation area, and that the geese get habituated to that. 3) Extensively managed land harbours many geese in April and May, while grazing pressure on most intensively managed locations becomes negligible near the end of the season. The shift from geese to extensive land and salt marsh is certainly attributable to disturbance to some extent, as was shown in a large scale experiment by Bos & Stahl (2003); After the 1st of April scaring is allowed on grassland in privately managed accommodation area. 4) Near busy roads the grazing pressure is much lower than at a distance of 100 m.

The relation between goose density calculated from dropping rates with observed goose density from counts is very significant, but tends to overestimate the observed goose density by 31%. If we would correct for droppings missed during counting (Bédard & Gauthier 1986) the discrepancy would even be somewhat bigger. The overestimation may be explained by an erratic estimate of the dropping rate, the area of grassland per count unit, discrepancies on spatial and temporal scale, and undercounting of birds present. Especially the bias of sample plots for undisturbed grass appears relevant in this respect. A careful inspection of the validation data on a per-area basis (figure 5), shows that variation in the counting data among years is much larger than variation in the dropping data. We believe that the variation in grazing pressure as measured using droppings is biologically more meaningful and less prone to random variation than variation in the counting data at these levels of spatial scale. For the testing of hypotheses like ours, dropping counts provide a suitable and effective method. We will not elaborate upon this issue further here, but conclude that cumulative grazing pressure can safely be used as an estimator of capacity, as long as it is corrected for over-estimation and sample plots are carefully placed at representative sites.

Our estimates of available capacity provide insight in the degree to which sufficient land has been designated for geese to comply with the conservation goals. The model is simple and assumes that geese are mobile, that all grassland available is of the same type as the grass in our sample locations and that grazing by other animals is negligible. The model resembles the analysis by Vickery *et al.* (1995) in the sense that the total number of goose days on a certain habitat is limited, and can be explained from depletion and production. In the classification of Goss-Custard (2003) it is neither an SDM nor a DRM approach. Goss-Custard points out that model results from SDM or DRM models may be different, depending on the strength of interference effects in the species concerned. The EGM uses empirically measured values of grazing pressure and –as such- incorporates interference effects without making assumptions about their magnitude. Note that the values of regional capacity, used in the calculations, still may increase in the future as has been the case over the past. Current regional differences in grazing pressure may largely be the result of migration patterns that

historically have developed at given levels of world population size. Maybe, current grazing pressure is close to maximal capacity in some intensively grazed sample locations, as can be judged from the developments in vegetation height. But there are no clear-cut reasons why regional capacity could not be higher, especially in the West and East.

The result of our Empirical Grazing pressure Model is that –in theory- sufficient accommodation land is available in the North, but too little in the West and maybe too little in the East. In practice, large numbers of geese forage outside these accommodation areas, even in the North (van Roomen *et al.* 2005). This should not come as a surprise, since accommodation status is not very clearly signposted for geese everywhere. Besides, the scaring efforts outside accommodation areas have not at all been consistent over the past four years and geese probably need time to learn there can be a difference in- and outside. Experiences elsewhere positively demonstrate that geese can learn where scaring and hunting do not take place (Madsen 1998, Bos *et al.* 2003), and that this may enhance residence time dramatically.

Conclusions

- Intensive grassland has not been shown to accommodate more geese than extensively managed grassland
- Fields that are near to the roost accommodate more geese than fields further away, all else being equal.
- Effects of disturbance on geese are relevant, and geese appear to need time to get used to a reduction in disturbance.
- Our study yields empirical estimates of capacity that are higher than found and used thus far. Generally the highest values of cumulative grazing pressure were found in the North, but locally grazing pressure reached similar levels in the East and the West.
- The estimated available capacity on accommodation grassland in the Netherlands in 2007 fits well with the required capacity in the northern region, but in the West there is likely a shortage.

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Figure captions

*Fig. 1. Location of the twelve study areas. RG is represented by three dots as sample locations within this area were more widespread than in the other areas. The dashed line gives a subdivision of the country in regions (N = North, W = West and E = East) according to van Roomen *et al.* (2005).*

Fig. 2. Grazing pressure (droppings.m⁻².d⁻¹) in relation to land use and month over all study plots in accommodation areas in the Netherlands (n = 3, 4, 54 and 57 for botanical grassland, salt marsh, intensive grassland and extensive grassland respectively).

Fig 3. Cumulative grazing pressure (droppings.m⁻².season⁻¹; Nov 1- May 15) over the years of study (season 2001 refers to the winter 2001-2002; n=18 from 2001-2003, n = 26 in 2004 and n = 10 from 2005-2007).

Fig. 4. The cumulative grazing pressure (droppings.m⁻².season⁻¹) declines with distance from the nearest roost.

Fig. 5. The relation between goose density calculated from dropping rates and observed goose density as derived from bird counts (linear regression through origin $y = 0.68x$; $F_{1,23} = 81,4$ $p < 0,001$; $R^2 = 0.77$). Each data point refers to one goose count area in one season, and is labelled with its abbreviation (table 1 and figure 1) and year (exceptions are NFB: only the summer polders at NFB, marsh: salt marsh at NFB; OD only the goose foraging area at OD excluding BHB).

Fig. 6. Net grass growth (cm.d⁻¹) differs between months (panel A) and is affected by goose grazing (panels B-G).

Fig. 7. Box plot (medians, 25 and 75% quartiles and outliers) of nitrogen concentration in grass and wintergreens in relation to land use in the Netherlands.

Fig 8. Realised grazing pressure (droppings.m⁻²) on grass fields in relation to distance from the road for three different classes of disturbance. March 2007, survey of cumulative droppings within accommodation area OD.

Fig 9. Estimation of available capacity on grassland in accommodation areas in relation to required capacity at the Dutch national scale for the three different regions (see fig 1) and under five different assumptions. Open diamonds: all grassland within accommodation areas. Shaded triangles: all grassland within accommodation areas, within 5 km. from a roost. Closed triangles all grassland within accommodation areas, within 5 km. from a roost and without grassland near (<100m) roads, power lines and urban development. Open circles: all grassland within accommodation areas, within 5 km from N2000 areas. Closed circles: all grassland within accommodation areas, within 5 km. from N2000 areas but without grassland near (<100m) roads, power lines and urban development. The latter two estimates relate to the cumulative conservation goals for geese and Wigeon in N2000 areas.

Table 1. Number of sample locations per study area, abbreviations, land use and status as accommodation area. OD includes the Bantpolder & Hoek van de Bant (BHB). NFB and OD (incl. BHB) were sampled during multiple years. For comparison, the cumulative grazing pressure (droppings.m⁻².season⁻¹; Nov - May 15th) over all data per study area is given.

Table 2. Management characteristics for the different land use types in our dataset.

Table 3. Cumulative grazing pressure on grassland within accommodation areas (droppings.m⁻².season⁻¹; Okt- May 15th) for the three different regions in the Netherlands (see fig 1) and resulting estimates of capacity (no WF-goosedays.season⁻¹). Calculations see text. Species presence (%) is based on goose counts in the same areas and years as the dropping counts.

Appendix 1. The relevant information taken from Ebbing & van der Gref-Rossum (2004). The required capacity for the various species of wintering geese and Wigeon at the regional scale (N, E and W) in number of WF-goose days, and the correction factors for body size (CFWF no unit) and for foraging part of the time on harvest remains and cropland (% time foraging on grass).

Table 1. Number of sample locations per study area, abbreviations, land use and status as accommodation area. OD includes the Bantpolder & Hoek van de Bant (BHB). NFB and OD (incl. BHB) were sampled during multiple years. For comparison, the cumulative grazing pressure (droppings.m².season⁻¹; Nov - May 15th) over all data per study area is given.

Sample location	Abbreviation	Accommodation					Cumulative grazing pressure droppings.m ² .season ⁻¹		
		Not accom- modation	Intensive grassland	Extensive grassland	Botanic grassland	Salt marsh	Mean	S.e.	Valid N
Noord Friesland Buitendijks	NFB			12			43	2	N=80
Oost Dongeradeel	OD (incl BHB)	4	10	3			41	4	N=78
Piaam	PI		15	5			51	4	N=20
Sneekerveer	SN		3	3			51	5	N=6
Deelen	DE		2	2			47	8	N=4
Ijsseldelta	IJD		4	4	2		16	3	N=10
Fraterwaard	FW		7		1		45	6	N=8
Arkemheen	AH	6		4			4	1	N=10
Rivierengebied	RG	3	2	9			14	3	N=14
Polder Demmerik	PD	10		4			2	1	N=14
Alblasserwaard	AW		14	1			13	3	N=15
Oudeland van Strijen	OvS			11			45	4	N=11

Table 2. Management characteristics for the different land use types in our dataset.

Landuse	intensive grassland (n = 44)		extensive grassland (n= 24)		botanic grassland (n=3)		salt marsh (n=4)	
	Mean	s.e.	Mean	s.e.	Mean	s.e.	Mean	s.e.
N-input (kg N.ha ⁻¹)	303	24	62	16	0	0	0	0
weeknumber first fertiliser application	12	1	24	3	-	-	-	-
Stocking rate (LU.ha ⁻¹)	2.1	0.1	1.3	0.1	0	0	0.6	-

Table 3. Cumulative grazing pressure on grassland within accommodation areas (droppings.m².season⁻¹; Okt- May 15th) for the three different regions in the Netherlands (see fig 1) and resulting estimates of capacity (no WF-goosedays.season⁻¹). Calculations see text. Species presence (%) is based on goose counts in the same areas and years as the dropping counts.

Region	Dropping counts				Goose counts			Calculated capacity			
	Wigeon (EG _w , droppings.m ² .season ⁻¹)	s.e.	n	Geese (EG _g , droppings.m ² .season ⁻¹)	s.e.	n	Barnacle goose (PB)	White-fronted goose	other species	C _{reg} (no WF-goosedays-season ⁻¹)	st dev
North	3	1	62	51	2	140	70%	26%	4%	2654	165
East	5	2	30	23	3	30	2%	73%	25%	1221	144
West	6	2	30	25	4	30	32%	62%	6%	1359	157

Appendix 1. The relevant information taken from Ebbing & van der Greft-Rossum (2004). The required capacity for the various species of wintering geese and Wigeon at the regional scale (N, E and W and total for the Netherlands) in number of WF-goose days (* 10^6), the conversion factor to White-Fronted goose (CFWF no unit) and the correction factor for foraging part of the time on harvest remains and cropland (% time foraging on grass).

Species	Region				CFWF	% time foraging on grass
	N	E	W	NL		
<i>Anser anser</i>	3	5	15	23	1,27	63
<i>Anser albifrons</i>	29	26	16	71	1,00	100
<i>Anas penelope</i>	14	6	35	55	0,45	100
<i>Branta leucopsis</i>	31	1	8	41	0,76	100
<i>Anser brachyrhynchus</i>	3	0	0	3	1,06	100
<i>Anser fabalis fabalis</i>	6	3	1	10	1,22	68
<i>Branta bernicla</i>	5	0	3	7	0,66	79
Total	90	42	78	209		

Fig. 1.

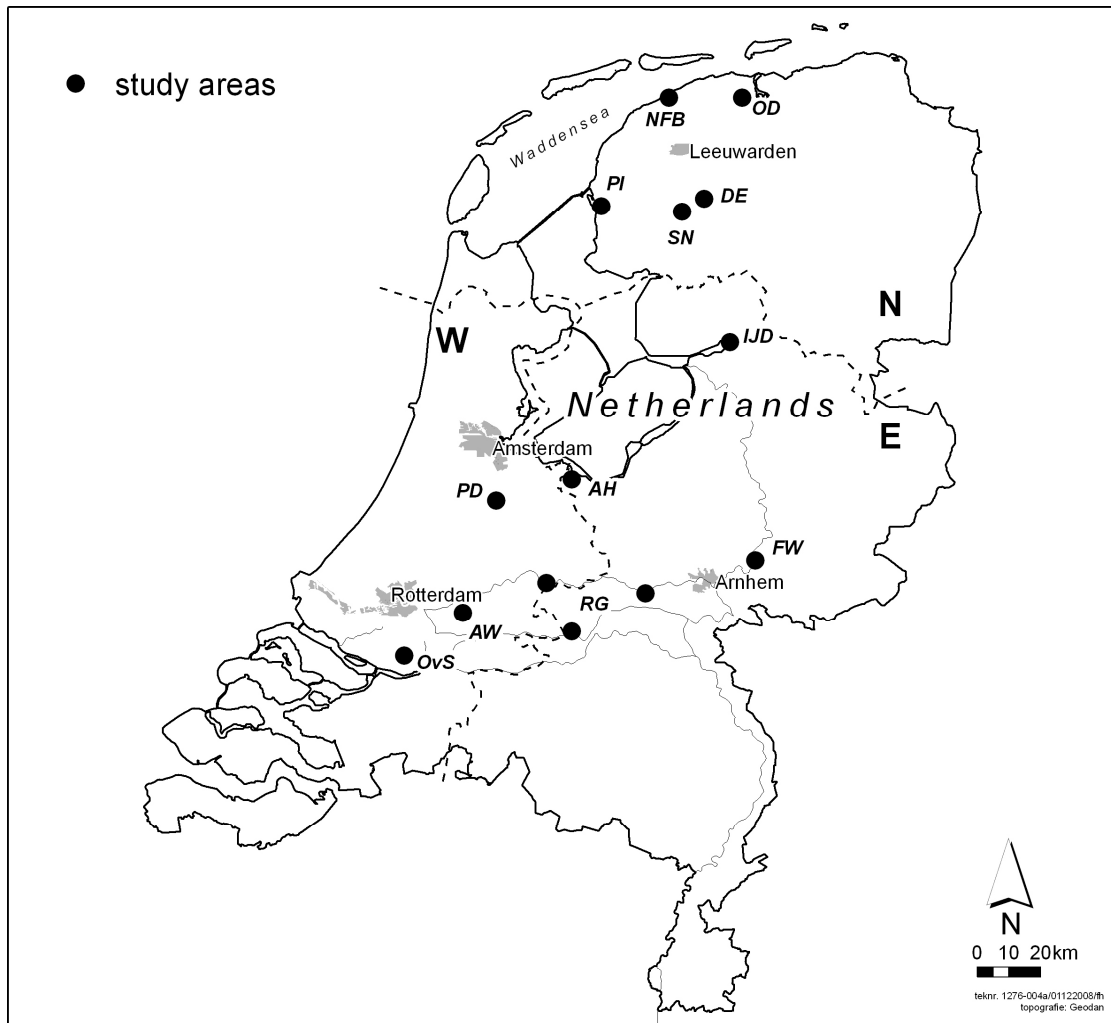


Fig. 2.

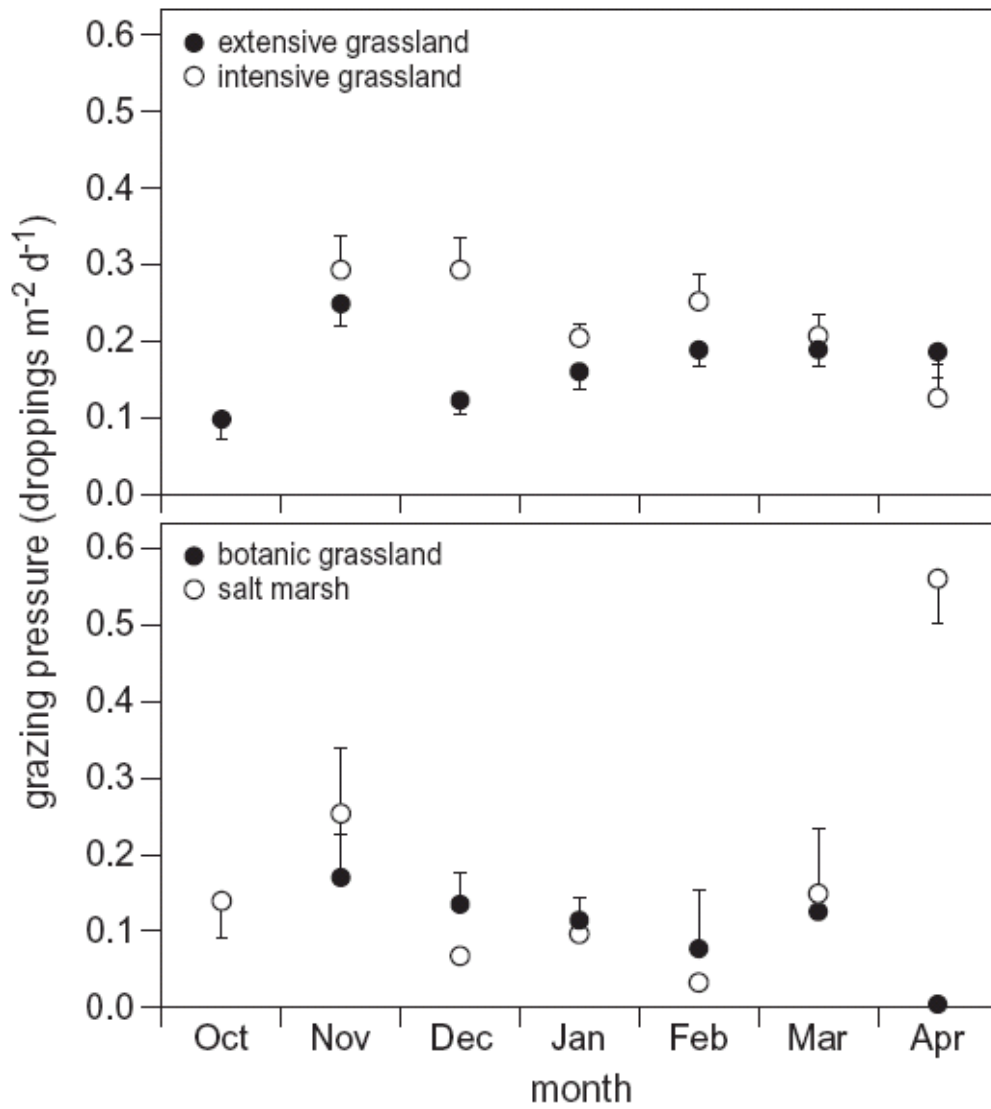


Fig. 3.

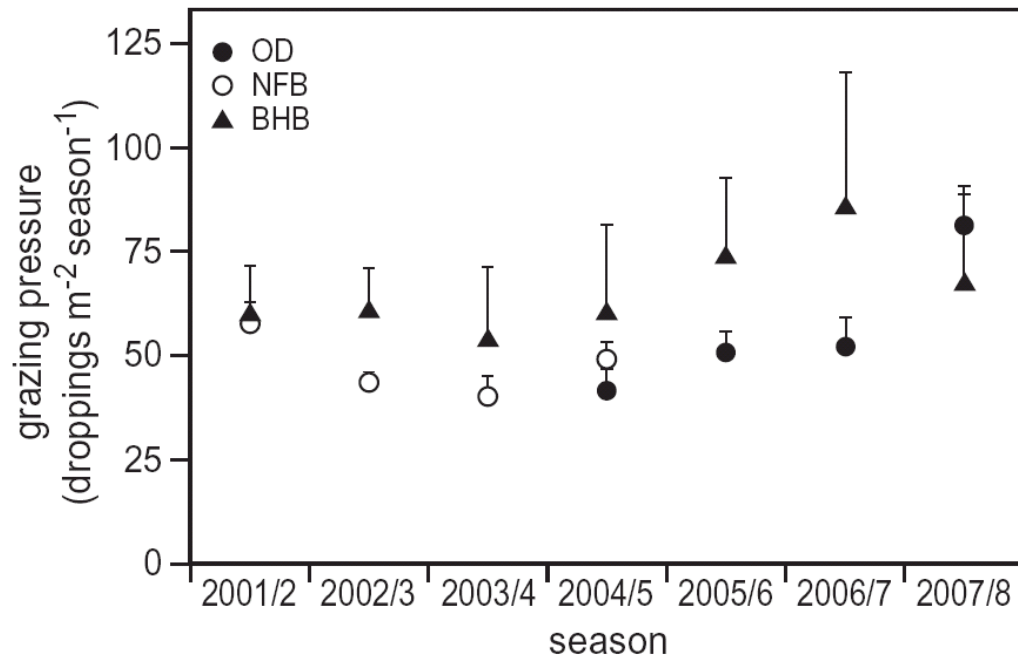


Fig. 4.

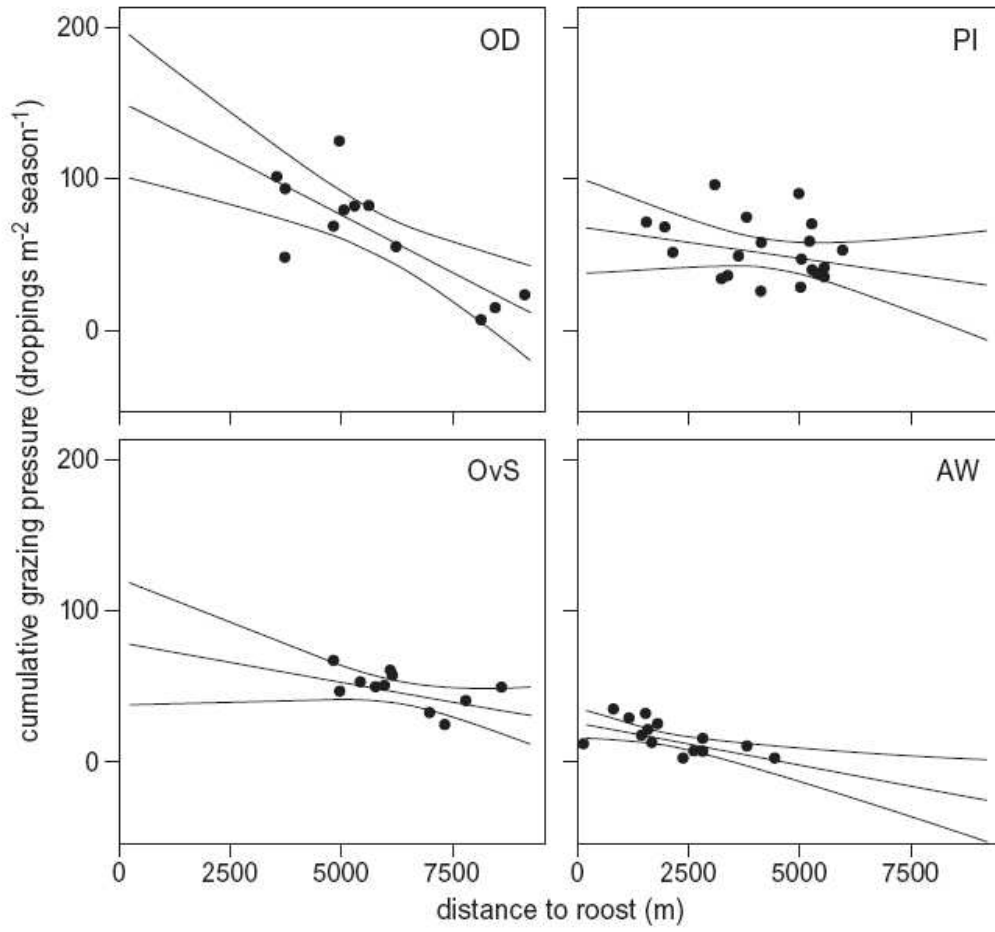


Fig. 5.

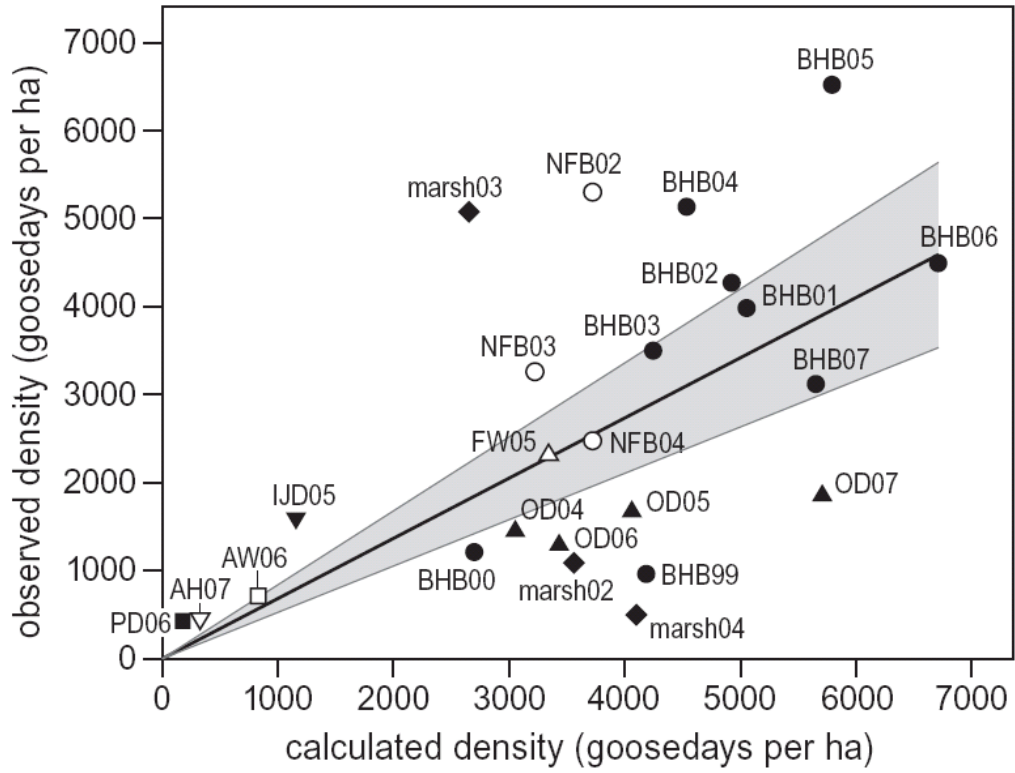


Fig. 6.

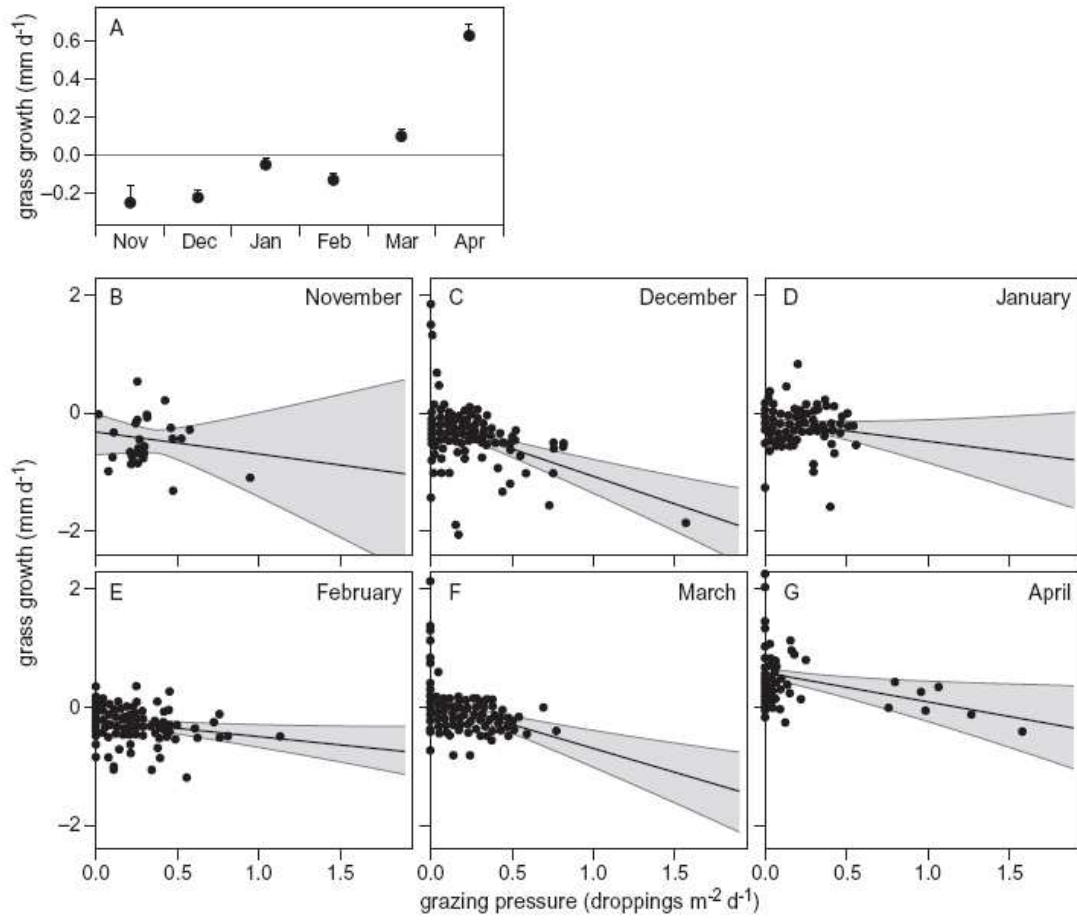


Fig. 7.

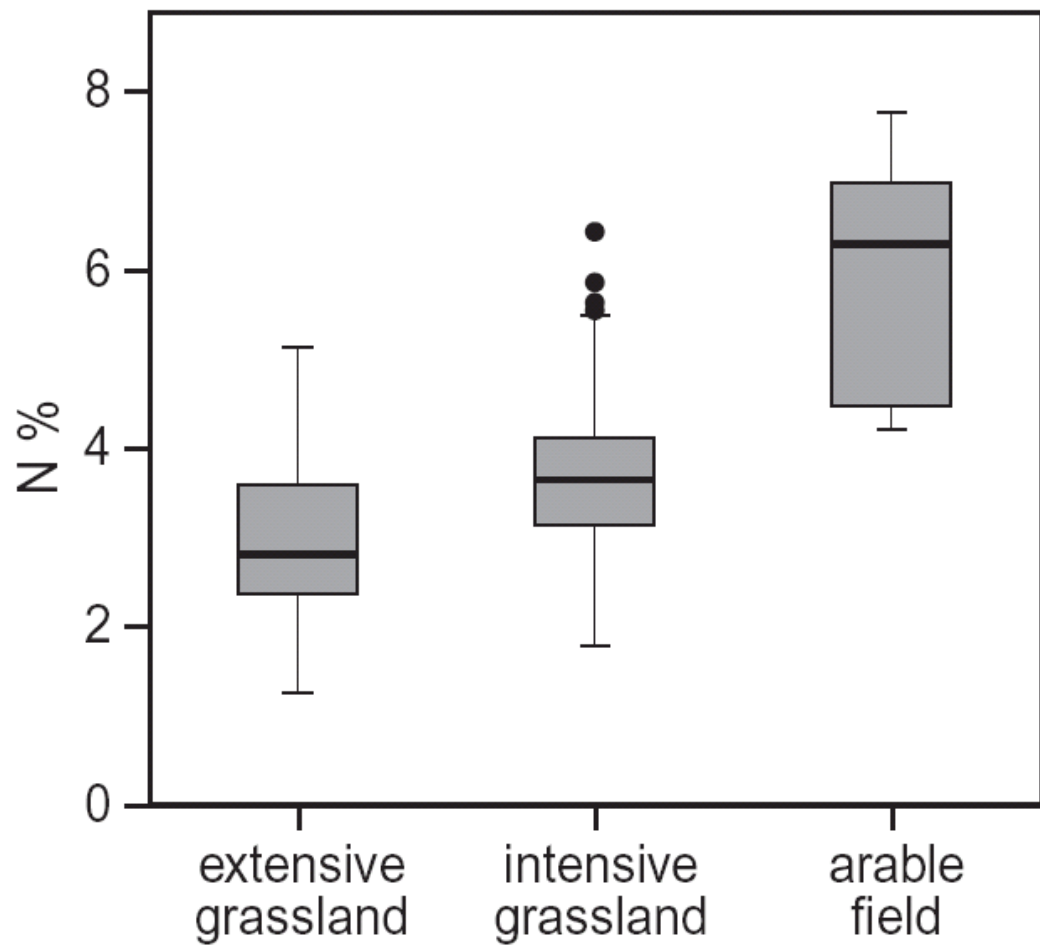


Fig. 8.

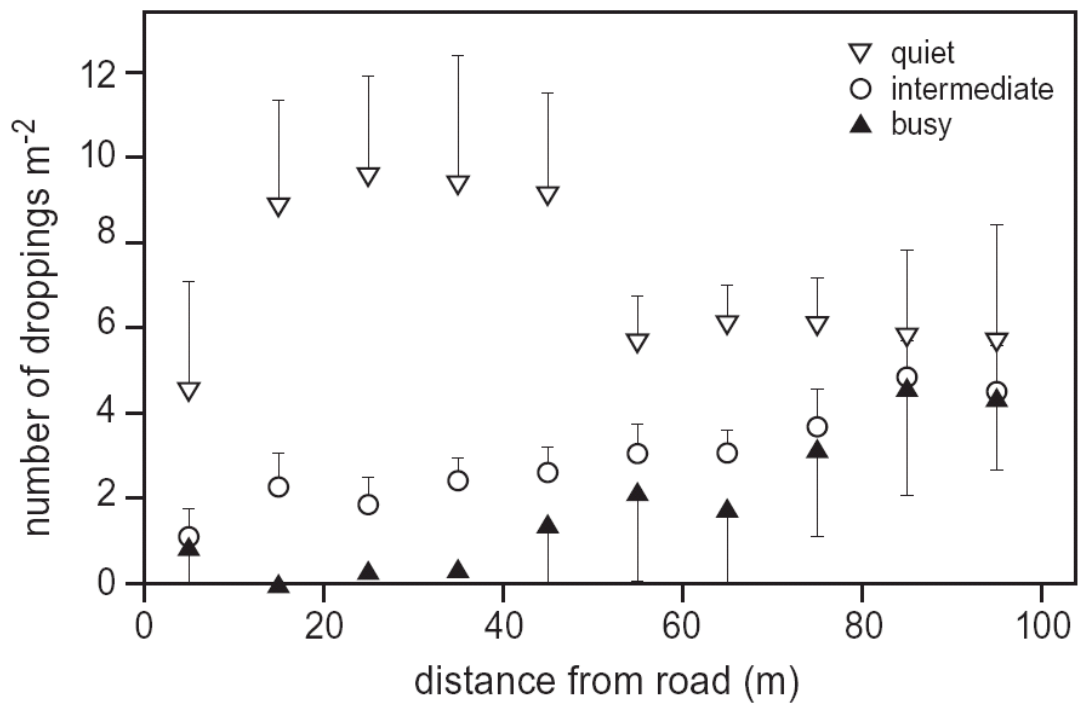
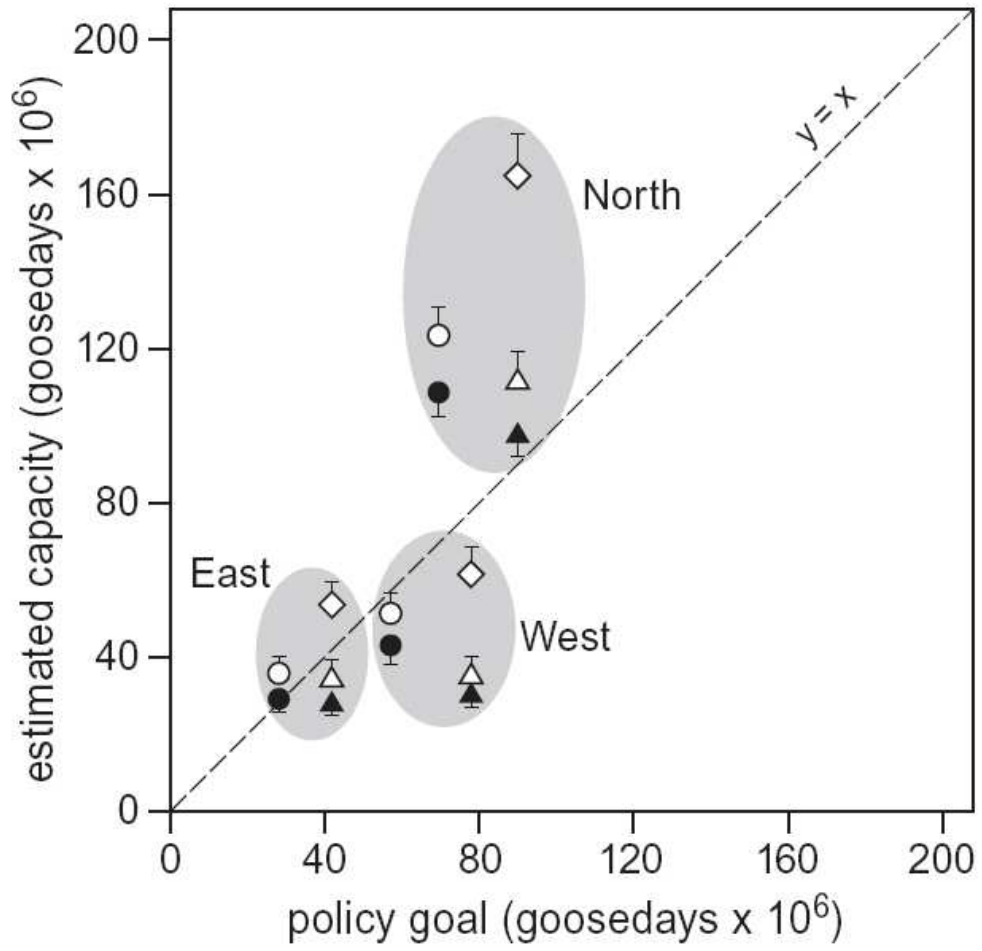


Fig. 9.



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