Characterisation of Greylag Goose *Anser anser* breeding areas in the Netherlands with special regard to human land use

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Within the last decades, a strong increase of breeding Greylag Geese occurred in the Netherlands. By means of a questionnaire, information about breeding and brood-rearing habitat characteristics and breeding biology was collected. Breeding sites are predominantly characterised by reed beds and grassland with higher vegetation, whereas feeding mainly takes place on cattle grazed pastures. Statistical analysis revealed that management has a high impact on site use by geese. Multivariate analyses showed that the type of management (mowing, grazing or fertilisation), mowing frequencies and species of livestock grazing were strongly correlated with colony size, colony growth and density on brood-rearing sites. In contrast, predation and human disturbance showed less or no correlation at all.

Key words: Greylag Goose *Anser anser*, grazing, herbivory, management schemes, predation.

1. Introduction

Several hundred years ago the Greylag Goose was a common breeding bird in the Netherlands. Since the 16th century the number decreased continuously until the beginning of the 20th century. In the first half of the last century, this goose species had disappeared as a regular breeding bird in the Netherlands, and the western natural border of the breeding range was formed by the Elbe River. During the 1960s and 1970s, reintroduction of birds and the creation of large nature reserves like, for instance, the Oostvaardersplassen marked the start of a successful recolonisation of the country (van den Bergh 1991). The number of breeding pairs (BP) in the Netherlands was estimated at only 150 in the 1970s (Teixeira 1979). From then on, a spectacular increase started: in 1990 numbers amounted to 1,150-1,200 BP and in 2001 already to 8,000-9,000 BP (Voslamber 2002). In 2005, 100,000 birds with 25,000 breeding pairs were recorded (Voslamber *et al.* 2007). Today the Greylag Goose is by far the most frequent goose species breeding in the Netherlands, followed by the Barnacle Goose *Branta leucopsis* (6,000 BP), the Domestic Goose *Anser anser* f. *domestica* (3,700–5,000 BP) and the Grater Canada Goose *Branta canadensis* (3,000 BP). The strong increase of breeding numbers of Greylag Geese in the Netherlands mirrors the overall population increase (Voslamber *et al.* 2007).

Greylag Geese have a wide food range (Voslamber *et al.* 2004) and occur in many different habitats, ranging from salt marshes and estuaries to farmland (Berndt & Busche 1991) Generally, natural food sources rank much lower in the diet of Greylag Geese compared to food which is available from croplands and grassland (van der Wal

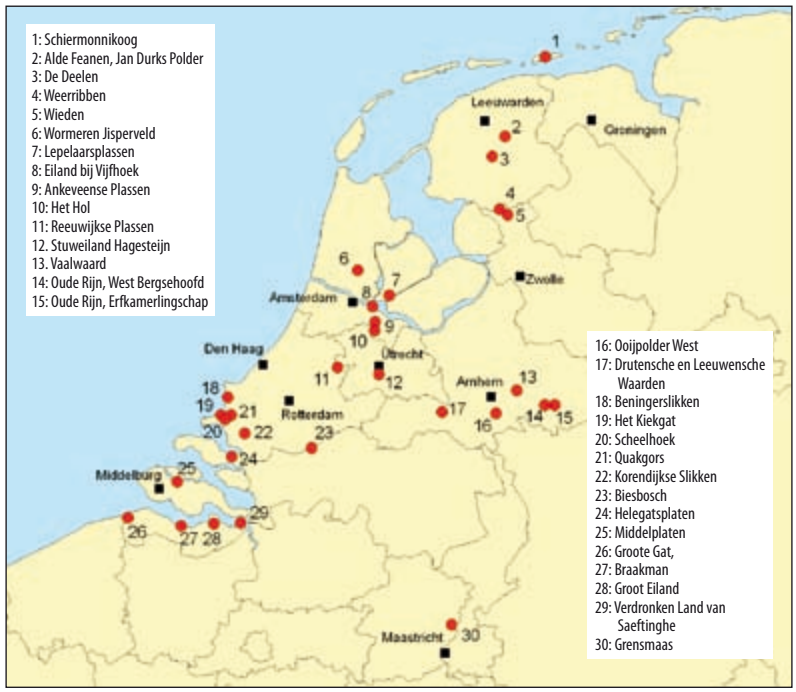

Fig. 1: Study sites of Greylag Goose breeding areas in the Netherlands. Note: the area northeast of point 7 is still water! = Markermeer. – Untersuchte Graugans-Brutgebiete in den Niederlanden (beachte: das Gebiet nordöstlich Punkt 7 ist immer noch Wasser!).

Table 1: Overview of Greylag Goose breeding areas (2005 situation) included in the analysis. Within one breeding area the geese of the brood-rearing sites are usually the same as the geese of the breeding sites. Some breeding areas are visited additionally by brood rearing geese of other breeding areas. – *Übersicht über die Graugans-Brutgebiete (Stand 2005), die in diese Auswertung einflossen. Innerhalb eines Brutgebietes sind die Gänse des Aufzuchtgebietes normalerweise dieselben wie die der Brutplätze. Einige Brutgebiete werden zusätzlich von Familien anderer Brutplätze aufgesucht.*

Name of breeding area – *Name des Brutgebietes*	BP in the whole breeding area – *BP im gesamten Brutgebiet*	first year of breeding – *Jahr der ersten Brut*	colony growth – *Kolonie-Wachstum (λ)*	number of breeding sites – *Anzahl Brutplätze*	number of BP at breeding sites – *Anzahl BP an den Brutplätzen*	number of brood-rearing sites – *Anzahl Aufzucht-Gebiete*	number of BP at brood-rearing sites – *Anzahl BP in den Aufzucht-Gebieten*	number of non-breeding sites – *Anzahl von Nichtbrutgebieten*
Alde Feanen, Jan Durks Polder	25			2	25	1	25	1
Ankeveense Plassen	186	1992	1.21	1	186	2	183	1
Beningerslikken Nr.1 GG	127	1992	1.30	1	102	1	128	1
Biesbosch	225	1986	1.16	3	90	3	169	3
Braakman	83	1973	1.11	2	83	2	69	3
De Deelen	240	1972	1.07	1	96	1	48	1
Drutensche en Leeuwensche Waarden	283	1994	1.15	1	283	1	245	0
Eiland bij Vijfhoek	125	1992	1.38	1	125	1		0
Grensmaas	129			2		1	129	1
Groot Eiland	386	1974		1	386	1	386	1
Groote Gat, Oostburg	63	1970	1.45	1	63	1	80	1
Hellegatsplaten	45			6		1	45	3
Het Hol	22		1.02	1	22	2	22	2
Kiekgat	73	1991	1.10	1	58	3	83	1
Korendijkse Slikken	93	1991	1.44	1	74	1	93	1
Lepelaarsplassen	9	1993	1.55	2	9	3		2
Middelplaten	51	1977	1.31	2	50	2		1
Ooijpolder West	316	1975	1.01	5		4		2
Oude Rijn, Erfkamerlingschap	55	1984	1.07	1	55	1	27	1
Oude Rijn, West Bergsehoofd	87		1.11	1	87	1		1
Quackgors	61	1990	1.34	2	61	2	42	0
Reeuwijkse Plassen e.o.	534			1	481	0		0
Scheelhoek	559		1.15	1	391	2	503	1
Schiermonnikoog	18	1998	0.89	2	18	1	18	1
Stuweiland Hagesteijn	44			2	27	1		1
Vaalwaard	245	1997	1.80	1	245	0		0
Verdronken Land van Saeftinghe	312	1976		1	312	1	312	1
Weerribben	83	1988	1.14	1	54	5	63	1
Wieden	90	1994		3	78	3	78	0
Wormer- en Jisperveld	700			1	700	1	700	0
Total – *Summe*	5269			51	4161	49	3448	32

1998). Greylag Geese are also very flexible in the choice of breeding sites. They breed in natural habitats such as reed beds and scrubland close to shores, but also on meadows and pastures, and obviously have adapted their breeding behaviour to our modern cultural landscape (Berndt & Busche 1991; Rutschke, 1997; Kalchreuter, 2000; Bauer *et al.* 2005). Recently, conflicts between summer staging geese and farmers grow and damage compensation claims rise not only for the wintering period but also during summer.

Against the background of growing population numbers the aim of our study was to distinguish intrinsic site characteristics that have a significant influence on the establishment of Greylag Goose breeding colonies in the Netherlands. Special attention is paid to the impact of land use.

2. Methods

In 2005, information about habitat characteristics and the local breeding biology of Greylag Geese was collected from various breeding areas in the Netherlands. Data were gathered with the help of a questionnaire sent to nature agencies, volunteer bird counters, farmers and ornithological institutes. Additional information was gathered through interviews with local experts. We were able to compile data of 30 breeding areas, including 17 % of all breeding pairs in the Netherlands (Table 1, Fig. 1).

Definitions

A "*breeding area*" was defined by a region with one or more breeding colonies of Greylag Geese. The boundaries of an area were defined by its surroundings where no or only a few geese were present. Within a breeding area, geese used specific parts for breeding (= "*breeding sites*") or brood-rearing (= "*brood-rearing sites*"). Non-breeders were defined as geese, which were either immature and too young to breed or adult birds that did not breed, have failed in breeding or have lost their partner. They often mix with the breeding birds and young families, but they might also use completely different sites (= "*non-breeding sites*"). A "*colony*" was defined as a site with distinct habitat characteristics used by breeding or brood-rearing geese. We were able to analyse data on 51 breeding sites, 49 brood-rearing sites and 39 non-breeding sites.

Sites characteristics

In the questionnaire we asked for information on location (mainland, islands, peninsulas, wetlands and sites outside the seawall), the proximity of water bodies, the spatial pattern of breeding and brood-rearing sites within a breeding area, vegetation types, the presence of plant species that characterise a site and the vegetation height. To characterise management, the *livestock species* assemblage, *grazing pressure and grazing periods, mowing frequency* and *time of mowing* as well the *usage of fertiliser* were investigated. Further, we explored human disturbances (sources of disturbances and frequencies), the influence of predation (predator species, predation pressure), protection status of an area, and for habitat conversion shortly before the geese were present or after the colony was established.

Population parameters

Site characteristics were related to the population parameters colony size, colony growth and density. Additionally the number of sites with same characteristics and the total number of geese at each site were compared to each other.

The *numbers of geese* represent the most recent numbers (usually counts from 2005) and always refer to breeding pairs (BP). *Colony size* is defined as the number of pairs per site in 2005. *Density* can be used as an approximation for carrying capacity. It was measured in geese/ha. Data about gosling survival and fledging success were not available, but *colony growth* can be used as an approximate value for reproductive rate. It is based on data of the last six years (2000-2005) and was measured according to the formula: colony growth $\lambda = (N_t/N_0)^{1/T}$ with N being the number of BP, t being the last year and 0 being the first year of the period for which colony growth is calculated, and T the length of the time period (in years). Colony growth was determined for the whole breeding area. Thus, all colonies within one area are characterised by the same growth.

Statistical analyses

Sample size may differ between analyses as some specific site characteristics or population parameters were not always available. Single habitat factors were related to colony growth, colony size and density of Greylag Geese using One-way-ANOVA. Data were tested for normal distribution using a Kolmogorov-Smirnov test and, whenever appropriate, transformed logarithmically to meet criteria of normal distribution. In a second step, habitat factors, which showed significance in the One-way-ANOVA test, were included into a multivariate linear model in a stepwise procedure with colony size, colony growth and density as fixed factors.

3. Results

3.1. Variation in population parameter

Colony sizes

The breeding area of Wormer en Jisperveld hosts the largest colony (700 BP, but probably mainly Domestic Geese). The next largest colonies are in Reeuwijkse Plassen (481 BP) and Scheelhoek (391 BP). Smallest colony size is recorded for Lepelaarsplassen (9 BP), followed by Schiermonnikoog, Het Hol and Alde Faenen with a maximum of 25 pairs each (Table 1). The mean colony size is 112 BP (Table 2)

Table 2: Colony growth, colony size and density of Greylag Goose breeding areas. – *Koloniewachstum, -größe und Dichte der Graugans-Brutgebiete.*

	mean value – *Mittelwert*	SD	n =	minimum	maximum
breeding sites – *Brutplätze*					
colony size – *Koloniegröße (BP)*	112	± 159	37	2	700
colony growth – *Koloniewachstum (λ)*	1.20	± 0.21	32	0.89	1.8
density (geese/ha) – *Dichte (Gänse/ha)*	4.1	± 5.8	28	0.13	25
brood-rearing sites – *Aufzuchtgebiete*					
colony size – *Koloniegröße (BP)*	96	± 140	36	4	700
colony growth – *Koloniewachstum (λ)*	1.19	± 0.16	39	0.89	1.55
density (geese/ha) – *Dichte (Gänse/ha)*	1.4	± 2.1	23	0.05	8.0

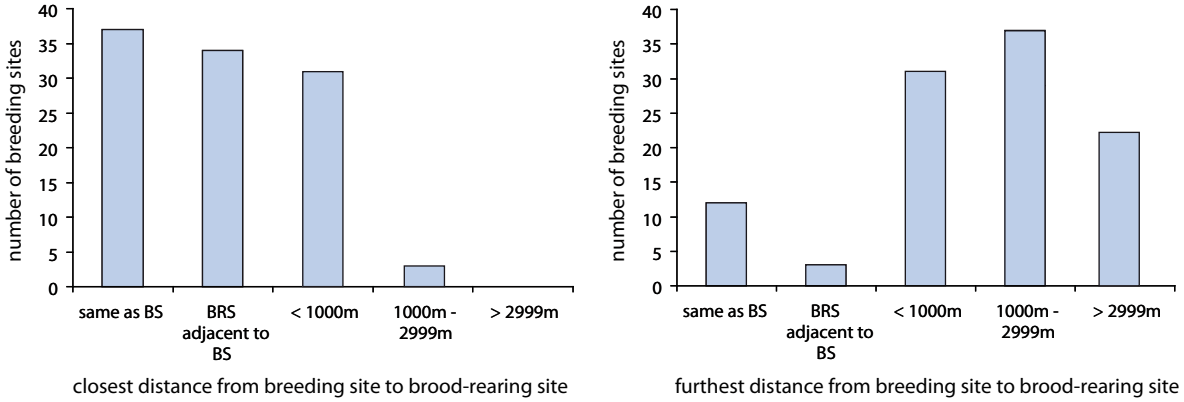

Fig. 2: Distances from breeding sites (BS) to brood-rearing sites (BRS) (n = 105 due to overlap between breeding and brood-rearing sites). Left: closest distance, right: farthest distance. – *Entfernungen zwischen Brutplätzen (BS) und Aufzuchtgebieten (BRS) (n = 105 wegen Überschneidung von Brutplätzen und Aufzuchtgebieten).*

Colony growth

Mean colony growth on breeding sites is λ = 1.20 (Table 2). By far the highest colony growth (λ = 1.8) is recorded in the breeding area of Vaalward. In four breeding areas colony growth is lower than λ = 1.10. Whereas in two of these colonies (Oude Rijn/Erfkamerlingschap and Het Hol) breeding numbers have been low since the beginning of colony establishment, breeding numbers of the remaining (De Deelen and Ooijpolder West) were growing first and seem to stabilise now. The colony of Schiermonnikoog is the only one decreasing. There, breeding numbers have been traditionally low.

Density

Mean density at breeding sites is 4.1 geese/ha. Breeding sites show higher densities than brood-rearing sites (1.4 geese/ha). The highest density for a breeding site is recorded on a small island in the breeding area of Braakman (25 geese/ha). The highest density for a feeding site is in Grote Gat (8 geese/ha). There is a positive relationship between site size and goose density (breeding sites: R^2 = 0.396, p <0.05, n = 28; brood-rearing sites: R = 0.235, p <0.01, n = 23).

The relationships between colony age and colony size, as well as colony growth and density, are not significant.

3.2. Spatial pattern of brood-rearing sites

In most of the investigated breeding areas, more than one feeding site is available. The usage of a site as a breeding site, feeding site or non-breeding site is not mutually exclusive: more than 50 % of the area of the breeding sites are also used as brood-rearing sites and 27 % of the breeding sites by non-breeding geese. From the brood-rearing sites 37 % are simultaneously used by families and non-breeders. The geese can reach the brood-rearing sites by land or by water, but most of the sites are only accessible by land. Brood-rearing sites that are not located adjacent to a breeding site are largely situated at a distance of less than 1,000 metres. In order to reach the closest feeding site, geese of three colonies have to cover a distance of at least 1,000 metres. For the farthest feeding site, a distance of at least 3,000 m has to be covered by families of 22 colonies (Fig. 2). The farthest distances are recorded for the breeding area of Eiland Vijfhoek, from where the geese move to the region of Waterland by covering distances up to 10 km.

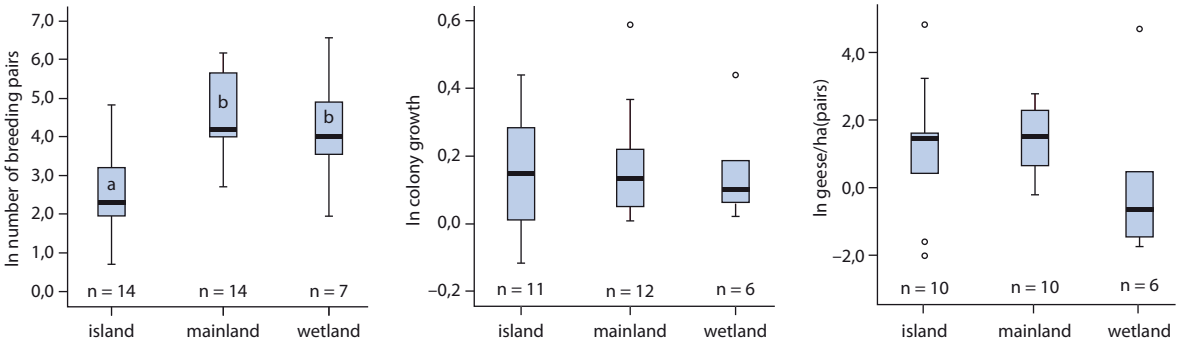

Fig. 3: Colony size, colony growth and density at breeding sites in relation to the location (One-way-ANOVA letters indicate subgroups according to post-hoc Tukey-test, p <0.01). – *Koloniegröße, Koloniewachstum und Dichte an Graugans-Brutplätzen im Verhältnis zur Lage. One-way-ANOVA-Buchstaben zeigen Untergruppen an, nach post-hoc Tukey-Test, p <0,01.*

Table. 3: Number of breeding, feeding and non-breeding sites, total number of geese, colony size, colony growth and density in relation to habitat parameters (One-way-ANOVA. *p< 0.5; **p< 0.01; ***p< 0.001; n.s.: not significant; n.i.: not investigated). – *Anzahl von Brut-, Nahrungs- und Nichtbrutgebieten, Gesamtzahl an Gänsen, Koloniegröße, Koloniewachstum und Dichte im Verhältnis zu Habitatparametern (Signifikanzniveau siehe oben; n.s. = nicht significant, n.i. = nicht untersucht).*

feeding on crops – *Nahrungsaufnahme auf Feldern*	no – *nein*		yes – *ja*		significance – *Signifikanz*
brood-rearing sites – ***Aufzuchtgebiete***					
number of sites – *Anzahl Gebiete*	42		7		
total number of geese – *Gesamtzahl an Gänsen (BP)*	2684	n = 31	764	n = 5	
colony size – *Koloniegröße (BP)*	87 ± 137	n = 31	153 ± 161	n = 5	n.s.
colony growth – *Koloniewachstum (λ)*	1.17 ± 0.13	n = 33	± 1.28 ± 0.27	n = 6	n.s.
density (geese/ha) – *Dichte (Gänse/ha)*	1.1 ± 1.6	n = 20	n.i.		n.i.
non-breeding sites – ***Nichtbrutgebiete***					
number of sites – *Anzahl Gebiete*	26		12		
Habitat – *Habitat*	natural – *natürlich*		artificial – *künstlich*		significance – *Signifikanz*
breeding sites – *Brutplätze*	51		0		
brood-rearing sites – ***Aufzuchtgebiete***					
number of sites – *Anzahl Gebiete*	17		29		
total number of geese – *Anzahl Gänse (BP)*	1103	n = 11	2301	n = 23	
colony size – *Koloniegröße (BP)*	100 ± 99	n = 11	100 ± 162	n = 23	n.s.
colony growth – *Koloniewachstum (λ)*	1.14 ± 0.12	n = 13	1.22 ± 0.18	n = 25	n.s.
density (geese/ha) – *Dichte (Gänse/ha)*	2.0 ± 2.0	n = 8	1.1 ± 2.2	n = 14	n.s.
non-breeding sites – ***Nichtbrutgebiete***					
number of sites – *Anzahl Gebiete*	15		23		
vegetation height – *Vegetationshöhe*	> 40 cm		< 40 cm		significance – *Signifikanz*
breeding sites – ***Brutplätze***					
number of sites – *Anzahl Brutplätze*	26		19		
total number of geese – *Anzahl Gänse (BP)*	2270	n = 22	1668	n = 9	
colony size – *Koloniegröße (BP)*	103 ± 123	n = 22	185 ± 251	n = 9	n.s.
colony growth – *Koloniewachstum (λ)*	1.17 ± 0.23	n = 17	1.22 ± 0.21	n = 9	n.s.
density (geese/ha) – *Dichte (Gänse/ha)*	4.6 ± 6.8	n = 16	3.3 ± 5.8	n =7	n.s.

3.3. Location

Breeding sites

The majority of the breeding sites are located on the mainland. One third of the breeding sites are on islands. On islands, colony size is about 6 times lower than on the mainland and in wetlands (Fig. 3). Density is significantly lowest in wetlands. Half of the breeding islands are located at a short distance (5-50 m) from the mainland. On islands located >50 m from the mainland, geese breed in a higher density than on islands located up to 50 m from the mainland ($density_{5\text{-}50m}$: 0.6 ±0.5 geese/ha, n = 6, vs. $density_{>50m}$: 6.5 ± 8.4 geese/ha, p <0.5, n = 8). Additionally on islands at a low distance to the mainland, colony size is about 6 times higher than on islands located at a greater distance. The majority of all sites has a clear escape to water (number of $sites_{clear\ escape}$: n = 46, number of $sites_{no\ clear\ escape}$: n = 5).

Feeding site

For brood-rearing, the geese mainly use sites on the mainland. Despite the fact that less than 10 % of all sites are located outside the seawall, more than 25 % of the geese feed there. A clear escape to water is guaranteed ($FS_{clear\ escape}$: n = 32, $FS_{no\ clear\ escape}$: n = 1).

Non-breeding sites

Also non-breeding sites are mainly located on the mainland (Fig. 3). A large part of the non-breeding sites has no clear escape to water ($NBS_{clear\ escape}$: n = 19, $NBS_{no\ clear\ escape}$: n = 13.).

3.4. Vegetation

Breeding sites

All breeding sites can be described as "natural habitats", in which natural processes dominate although the site itself may have been developed artificial (e.g. by embankment). They are either not managed or managed in a less intensive way than "man-made habitats". Those can be characterised by high management levels (fertilisation, mowing at least three times during the vegetation period and a strong grazing pressure of ≥ 2 animals/ha). The vegetation is mainly characterised by grassland or wetlands with reed beds (Table 3, Fig. 4). Eutrophic vegetation (perennial herbs) grows at one quarter of the breeding sites. Further, reed *Phragmitis australis* and willows *Salix spec.* are common plants on breeding sites (Fig. 5). Reed grows on 50 % of all breeding sites and these sites are used by more than 70 % of all geese. Density of breeding geese is twice that high in reed than in other vegetation (Table 3).

Brood-rearing sites

Contrarily to the breeding sites, 60 % of the brood-rearing sites are in artificial habitats, dominated by intensively used grazed pastures (Fig. 4, Table 3). Vegetation height ranges between 11 to 40 cm. Highest colony growth is recorded for colonies using brood-rearing sites on farmland (grassland and cropland) and grassland with higher vegetation. On 14 % of all brood-rearing sites crops occur and about 20 % of all geese feed on these sites. They feed

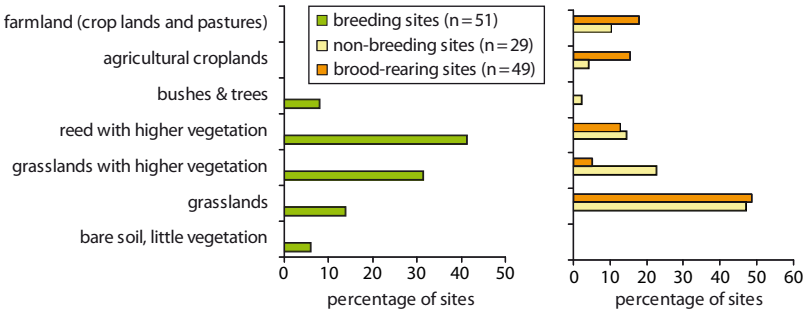

Fig. 4: Main vegetation at Greylag Goose sites. Left: breeding sites (n = 51), right: brood-rearing sites (n = 49) and non-breeding sites (n = 39). "Higher vegetation" can include reed and shrubs or trees. – *Vorherrschende Vegetation in den Graugans-Gebieten. Links: Brutplätze (n = 51), rechts: Aufzuchtgebiete (n = 49) und Nichtbrutgebiete (n = 39). "Higher vegetation" schließt Schilf, Gebüsche oder Bäume ein.*

on winter wheat, wheat, corn and oat and rarely on potatoes, sugar beets, bulbs and cabbage. Colony size of geese feeding on crops is almost twice as high compared to geese not feeding on crops. Reed and willows occur more seldom on brood-rearing compared to breeding sites (Fig. 5).

Non-breeding sites

The larger part of the non-breeding sites is short grazed pastures in artificial habitats. Non-breeders feed on crops on 30 % of all sites (Table 3).

3.5. Management of the sites

Breeding sites

Half of the breeding sites is managed. Most of the managed sites are on the mainland. Only 20 % of the islands used by geese are managed. Almost all managed sites are grazed by livestock, predominantly by cattle or a combination of cattle with horses or sheep. Though sheep are grazing at only four sites, 40 % of all breeding geese use these sites. Colony growth is statistically significantly higher on sites that are grazed by cattle only than on sites that are grazed by a combination of cattle with horses or sheep (colony $growth_{cattle}$: $\lambda = 1.50 \pm 0.32$, n = 3 vs. colony $growth_{cattle\ \&\ other}$: $\lambda = 1.14 \pm 0.11$, n = 9, $p < 0.01$, Table 4).

Mowing occurs at 11 sites and mainly in combination with grazing. Though colony size is much smaller on non-mown sites, colony density is almost 5 times higher compared to non-mown sites.

Brood-rearing sites

The majority of the brood-rearing sites are grazed and mown. Mowing hardly ever occurs exclusively, but is commonly practised in combination with grazing and/or fertilisation (Fig. 6). Colony growth and density on brood-rearing sites are significantly higher on sites that are both grazed and mown ($p < 0.05$, Fig. 7).

Colony size is significantly higher on sites grazed by a combination of cattle and sheep/horses (249 ±192 BP, n =9) than on sites only grazed by cattle (58 ±80 BP, n= 18, $p < 0.001$). One third of the brood-rearing sites is grazed year round. On all other sites livestock grazing starts in April or May. Thereby, geese find pastures with short swards for feeding after the young are hatched. Most geese feed on sites with a low grazing pressure (≤0,5 animals/ha). Sites with a high grazing pressure (>2 animals/ha) are used less intensively and there colony growth is lowest (Table 4).

Three quarter of the brood-rearing sites are only mown between April and June. Colony size on sites mown only between April and June is two times higher than on sites mown later in the season. A difference in population parameters can be noted for sites with different mowing frequencies: on sites that are mown 1-3 times during April and September the density of 2.0 ±2.6 geese/ha (n = 14) is significantly higher than on sites that are mown more often (0.1 geese/ha ± 0.1, n = 5, $p < 0.001$, Table 5).

One third of all brood-rearing sites are fertilised, predominantly by manure. Goose numbers and all popula-

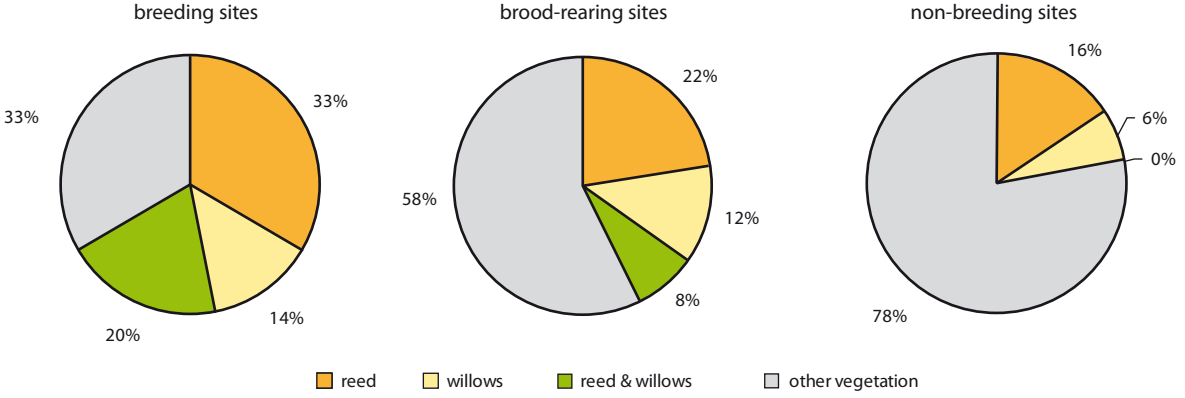

Fig. 5: Vegetation composition of goose sites: reed and willows as typical elements of Greylag Goose habitats (breeding sites: n = 51, brood-rearing sites: n = 49, non-breeding sites n = 39). – *Zusammensetzung der Vegetation in den Graugans-Gebieten: Schilf und Weiden als typische Elemente von Graugans-Lebensräumen (51 Brutplätze, 49 Aufzuchtgebiete, 39 Nichtbrutgebiete).*

tion parameters show higher values on non-fertilised sites. Colony size on brood-rearing sites is significantly larger on non-fertilised brood-rearing sites than on fertilised sites (Table 5). In some of the breeding areas, fertilisation occurs naturally due to nutrient rich water of the rivers in the surroundings (e.g. Hellegatsplaten).

Non-breeding sites

The management of the non-breeding sites is similar to that of the brood-rearing sites. However a more frequent use of artificial fertiliser on non-breeding sites compared to brood-rearing sites can be noted. Compared to the feeding families, non-breeders do not feed at all on sites with high mowing frequencies. Further, they use pastures with year round livestock grazing less intensively.

3.6. Presence of predators

At the majority of the sites predators are present, but there is no significant relation between any of the population parameters and the presence of predators and predation pressure. However, colony growth, colony size and density are higher on sites without predation than on sites where predators occur. At non-breeding sites, predators are least frequently present compared to breeding and brood-rearing sites. The Red Fox *Vulpes vulpes* is the most frequent predator. Questionnaire respondents gave Carrion Crows *Corvus corone* as the second most common predator species at breeding sites, followed by raptors, large gulls (Herring Gull *Larus argentatus* and Greater black-backed Gull *Larus marinus)*, rats, other small mammals, stray dogs and cats.

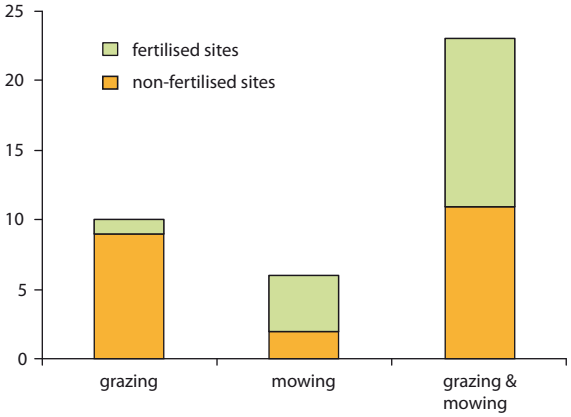

Fig. 6: Management at brood-rearing sites. – *Bewirtschaftung der Aufzuchtgebiete.*

3.7. Human disturbance

Breeding sites

The majority of the geese breed at sites with a low frequency of disturbance (disturbance up to once a week). At about 20 % of the breeding sites, goose chasing takes place (mainly by shooting of flares). Colony growth is signifi-

Table 4: Number of breeding, feeding and non-breeding sites, total number of geese, colony size, colony growth and density in relation to livestock grazing (One-way-ANOVA. *p< 0.5; **p< 0.01; ***p< 0.001; n.s.: not significant; n.i.: not investigated.). – *Anzahl Brut-, Nahrungs- und Nichtbrutgebiete, Gesamtzahl an Gänsen, Koloniegröße, Koloniewachstum und Dichte in Bezug auf Beweidungsintensität (Signifikanzniveau siehe oben; n.s. = nicht significant, n.i. = nicht untersucht).*

grazing pressure by livestock – *Beweidungsdruck (Tiere/ha)*	> 0.5 animal/ha		<0.5-2 animals/ha		> 2 animals/ha		significance - *Signifikanz*
brood-rearing sites – *Aufzuchtgebiete*							
number of sites – *Anzahl Gebiete*	14		6		7		
total number of geese – *Anzahl Gänse (BP)*	1459	n = 11	903	n = 6	39	n = 5	
colony size – *Koloniegröße (BP)*	133 ± 117	n = 11	180 ± 292	n = 5	n.i.		n.s.
colony growth – *Koloniewachstum (λ)*	1.20 ± 0.18	n = 10	1.37 ± 0.14	n = 5	1.16 ± 0.09	n = 7	n.s.
density (geese/ha) – *Dichte (Gänse/ha)*	2.9 ± 2.9	n = 8	1.1 ± 1.3	n = 5	n.i.		n.s.
non-breeding sites – ***Nichtbrutgebiete***							
number of sites – *Anzahl Gebiete*	10		3		7		

grazing by different livestock species – *Beweidung durch verschiedene Tierarten*	cattle – *Rinder*		cattle & other – *Rinder und andere*		significance – *Signifikanz*
breeding sites – *Brutplätze*					
number of sites – *Anzahl Brutplätze*	9		10		
total number of geese – *Anzahl Gänse (BP)*	1056	n = 5	1330	n = 8	
colony size – *Koloniegröße (BP)*	211 ± 204	n = 5	166 ± 231	n = 8	n.s.
colony growth – *Koloniewachstum (λ)*	1.50 ± 0.32	n = 3	1.14 ± 0.11	n = 9	**
density (geese/ha) – *Dichte (Gänse/ha)*	5.3 ± 7.3	n = 5	3.4 ± 5.7	n = 6	n.s.
brood-rearing sites – *Aufzuchtgebiete*					
number of sites – *Anzahl Gebiete*	21		15		
total number of geese – *Anzahl Gänse (BP)*	1044	n = 18	2162	n = 9	
colony size – *Koloniegröße (BP)*	58 ± 80	n = 18	240 ± 192	n = 9	***
colony growth – *Koloniewachstum (λ)*	1.20 ± 0.18	n = 15	1.20 ± 0.17	n = 11	n.s.
density (geese/ha) – *Dichte (Gänse/ha)*	1.4 ± 2.4	n = 11	2.2 ± 2.4	n = 6	n.s.
non-breeding sites – *Nichtbrutgebiete*					
number of sites – *Anzahl Gebiete*	18		12		

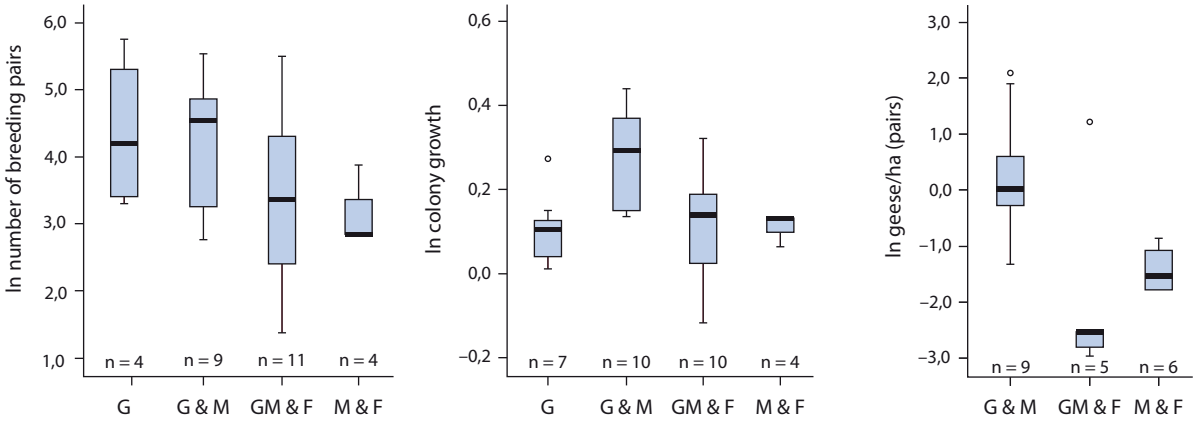

Fig. 7: Colony size, colony growth and density at breeding sites in relation to management (G = grazing, M = mowing, F = fertilisation). – *Koloniegröße, Koloniewachstum und Dichte an den Brutplätzen in Bezug zur Bewirtschaftung (G = Beweidung, M = Mahd, F = Düngung).*

cantly higher on sites without chasing than on sites where chasing occurs (sites without chasing: λ = 1.24 ± 0.22, *n = 22;* sites with chasing: λ = 1.09 ± 0.14, *n = 6,* p <0.05). Disturbance by breeding control (nest manipulation) is known for five breeding areas, but it is assumed that illegal nest manipulation takes place at further sites.

Brood-rearing sites

In contrast, at the majority of feeding sites disturbance events occur more than once a week. The One-way-ANOVA revealed significantly highest colony growth at sites with an everyday-disturbance (disturbance frequencies up to once a week: λ = 1.17 ± 0.13, n = 19; disturbance frequencies 2-6

Table 5: Number of breeding, feeding and non-breeding sites, total number of geese, colony size, colony growth and density in relation to mowing and fertilisation, according to One-way-ANOVA test. *p< 0.5; **p< 0.01; ***p< 0.001; n.s.: not significant. – *Anzahl an Brut-, Nahrungs- und Nichtbrutgebieten, Gesamtzahl an Gänsen, Koloniegröße, Koloniewachstum und Dichte in Bezug zu Mahd und Düngung.*

mowing frequencies (April - October) – *Mahdfrequenz (April-Oktober)*	1-3x		4-7x		significance – *Signifikanz*
brood-rearing sites – *Aufzuchtgebiete*					
number of sites – *Anzahl Gebiete*	18		8		
total number of geese – *Anzahl Gänse (BP)*	1179	n = 16	354	n = 7	
colony size – *Koloniegröße (BP)*	74 ± 78	n = 16	51 ± 86	n = 7	n.s.
colony growth – *Koloniewachstum (λ)*	1.23 ± 0.16	n = 17	1.17 ± 0.21	n = 6	n.s.
density (geese/ha) – *Dichte (Gänse/ha)*	2.0 ± 2.6	n = 13	0.1 ± 0.1	n = 5	***
non-breeding sites – *Nichtbrutgebiete*					
number of sites – *Anzahl Gebiete*	16		0		
time of mowing – Mahdzeitpunkt	April-June – *April-Juni*		July-October – *Juli-Oktober*		significance – *Signifikanz*
brood-rearing sites – *Aufzuchtgebiete*					
number of sites – *Anzahl Gebiete*	20		6		
total number of geese – *Anzahl Gänse (BP)*	953	n = 18	580	n = 5	
colony size – *Koloniegröße (BP)*	953 ± 53	n = 18	116 ± 124	n =5	n.s.
colony growth – *Koloniewachstum (λ)*	1.19 ± 0.17	n = 17	1.23 ± 0.11	n = 6	n.s.
density (geese/ha) – *Dichte (Gänse/ha)*	22.4 ± 1.6	n = 14	0.901 ± 0.4	n = 4	n.s.
non-breeding sites – *Nichtbrutgebiete*					
number of sites – *Anzahl Gebiete*	14		3		

management by fertilisation – *Einsatz von Düngemitteln*	no – *nein*		yes – *ja*		significance – *Signifikanz*
brood-rearing sites – *Aufzuchtgebiete*					
number of sites – *Anzahl Gebiete*	29		14		
total number of geese – *Anzahl Gänse (BP)*	2580	n = 17	667	n = 13	
colony size – *Koloniegröße (BP)*	93 ± 94	n = 17	51 ± 102	n = 13	*
colony growth – *Koloniewachstum (λ)*	1.23 ± 0.18	n = 24	1.11 ± 0.12	n = 11	n.s.
density (geese/ha) – *Dichte (Gänse/ha)*	2.16 ± 2.58	n = 12	0.52 ± 1.09	n = 9	n.s.
non-breeding sites – *Nichtbrutgebiete*					
number of sites – *Anzahl Gebiete*	16		21		

Table 6: Multivariate linear model of population parameters and habitat features: R^2 indicates the habitat factor showing highest significance according to the stepwise multivariate linear model (*p< 0.5; **p<0.01; ***p< 0.001). – *Multivariates lineares Modell von Populationsparametern und Habitatfaktoren. R^2 zeigt den Habitatfaktor mit der größten Aussagekraft nach dem schrittweisen linearen Modell.*

	breeding sites – *Brutplätze*	brood-rearing sites – *Aufzuchtgebiete*
colony size – *Koloniegröße (BP)*	location - Lage * (R = 0.401, p < 0.01) distance from breeding island to mainland - *Entfernung von der Brutinsel zum Festland* * breeding control - *Bestandsregulierung* *	management: grazing by livestock species – *Beweidung*** (R = 0.642, p < 0.001) fertilisation - *Düngung* * conversion of site (none or drainage) – *mit/ohne Entwässerung* *
colony growth – *Koloniewachstum (λ)*	management: grazing by livestock species – *Beweidung*** (R = 0.591, p < 0.05) chasing – *Vergrämung* * special nature protection regulations – spezielle Naturschutzbestimmungen * type of nature protection regulations – *Art der Schutzbestimmungen* *	type of management (mowing, grazing, fertilisation) – *Art der Bewirtschaftung (Mahd, Beweidung, Düngung)* *** (R = 0.621, p < 0.001) frequency of disturbance by presence of man – *Störungsfrequenz* *
density (geese/ha) – *Dichte (Gänse/ha)*	not analysed – *nicht untersucht*	mowing frequency - Mahdfrequenz *** (R = 0.623, p < 0.05) location in nature reserve – *Lage in Naturschutzgebiet* ** type of management (mowing, grazing, fertilisation) – *Art der Bewirtschaftung (Mahd, Beweidung, Düngung)* *

days a week: λ = 1.127 ± 0.12, n = 13*;* disturbance frequencies every day: λ= 1.35 ± 0.24, n = 6, p <0.05). All brood-rearing sites are managed and farmers are present everyday. At more than half of the brood-rearing sites farmers make use of chasing. Significant effects of chasing on colony size, colony growth or densities were not detected.

Non-breeding sites

At two thirds of the non-breeding sites human disturbance occurs and chasing occurs on more than half of the sites. By this, non-breeding sites are the most frequently disturbed sites compared to breeding and brood-rearing sites. There is no statistically significant relationship found between distances to buildings and settlements and the population parameters. Breeding occurs at a minimal distance of 100 m and feeding at a minimal distance of less than 100 m of human buildings.

3.8. Nature conservation

Almost all sites are protected. The majority of the sites are protected as nature reserves, some sites are part of a National Park. Density on brood-rearing sites is significantly higher on sites that are in nature reserves compared to non-protected sites (density on protected sites: 1.2 ± 2.3 geese/ha, *n = 18;* density on non-protected sites: 0.2 ± 0.2 geese/ha, n = 5, p <0.01). At a lot of sites, even if they are not protected, special management measures aimed for breeding birds or nature development are in action. The majority of the sites is not accessible for the public.

3.9. Site conversion

Out of 47 sites used for breeding, at 27 sites habitat conversion took part: a) farmland was designated as a protected area with decreased management or the application of a special breeding bird management, b) wetlands were drained and c) rivers and coastal areas were embanked (Table 6). 30 % of the brood-rearing sites were converted from farmland into a protected area, drained or embanked.

3.10. Multivariate linear model

The multivariate linear model reveals that management has a high impact on the site use in geese (Table 6). At brood-rearing sites more than 60 % of the variation in each variable can be explained by management: the livestock species spectrum influences colony size (R^2 = 0.642, p <0.01), the type of management explains colony growth (R^2 = 0.621, p <0.001) and mowing frequencies affect density (R^2 = 0.623, p <0.05). The livestock species spectrum also influences most strongly colony growth at breeding sites (R^2 = 0.591, p <0.05). Only for colony size at breeding sites the location (mainland versus islands and wetlands) plays the most important role (R^2 = 0.401, p < 0.01).

4. Discussion

4.1. Habitat requirements for breeding and brood-rearing

The analyses rendered a broad overview of the main factors characteristic for the breeding, brood-rearing and non-breeding sites of Greylag Geese in the Netherlands. Management of the areas has a high impact on site use by geese as well as on population parameters such as colony growth, colony size and density.

Brood-rearing habitats play an important role for the population development as growth rate, body size and survival of the goslings depend strongly on the quality and quantity of forage (van der Jeugd 1999; van der Jeugd *et al.* 2006). Our study reveals an enormous variety of different habitat types used by Greylag Geese in summer. All breeding areas are closely linked with lakes, rivers or other water bodies and almost all breeding and brood-rearing sites have a clear access to water. This guarantees a supply of fresh water, an escape from predators and a night roost site. Within their traditional Scandinavian breeding range, Greylag Geese frequently use islands as breeding sites. In the southern Baltic, for instance, Greylag Geese mainly breed on inland lakes with extensive reed beds. At the east coast of Sweden and at the Norwegian coast they mainly nest on islands (Nilsson *et al.* 1999). Despite small colony sizes on islands in the Netherlands, islands make up one third of all breeding sites.

Breeding sites on islands have 20 % less ground predators than on the mainland. However, especially in years

with low water tables, breeding islands situated not far from the mainland can easily be reached by foxes. In addition, human disturbance plays a minor role on a breeding island, however, analyses did not reveal any significant differences in colony size, colony growth and density on sites with different frequencies of disturbances.
The vegetation on northwest-European breeding sites of Greylag Geese is very diverse. Typically, Greylag Geese breed in eutrophic habitats with reed beds, willows, shrubs or young trees (Berndt & Busche 1991; Nilsson *et al.* 1999; Bauer *et al.* 2005). Our study revealed that in the Netherlands willows and reed characterise the majority of breeding sites.

Most breeding sites are grazed or mown; however, goose densities are highest on sites without any management. Despite the threat of nest trampling by livestock or nest destruction by machinery, breeding takes place on managed sites. Locally, mowing or livestock trampling destroys nests. However, geese rather keep distance to livestock. They build their nests in vegetation which is not favoured by large herbivores. Colony growth is significantly higher on sites that are grazed by cattle only compared to sites grazed by a combination of cattle and horse or sheep. It was shown earlier (AK Feuchtwiesenschutz Westniedersachsen 1998) that cattle grazing does not have strong negative impacts on breeding birds compared to grazing by sheep and horses which graze more often as dense social herds.

Due to digestive limitation, geese generally select forage that is high in protein and carbohydrates but low in fibre (Gadallah & Jefferies 1995; Prop & Black 1997 Rutschke 1997; Prop 2004). By continuous grazing or mowing, the plants are kept in a young and palatable state with a higher tiller density and much higher in protein than ungrazed plants (Owen 1990). Where grassland is managed by livestock grazing, geese benefit from grazing facilitation. Bos & Stahl (2003) showed, that the number of geese can be four times higher on livestock-grazed salt marshes than on unmanaged salt marshes. In the Leybucht, the carrying capacity of grazed salt marshes for Barnacle Geese was even 10 times higher compared to ungrazed marshes (Borbach-Jaene 2001). Stock & Hofeditz (2000) reported a decline of 40-50 % in goose usage on the marshes of the Hamburger Hallig after reduction of sheep grazing. On sites were grazing was stopped totally, goose numbers even decreased up to 75 %. Our study shows that these results can be transferred to a larger scale. Many breeding areas in the Netherlands are also very popular staging areas during migration or wintering areas of Greylag Geese and other herbivorous birds (Voslamber *et al.* 2004). Where livestock is put out to pasture late in season (May or June), summer staging geese can profit from facilitation by wild herbivorous waterfowl.

The geese seem to tolerate a certain level of permanent livestock presence and to take advantages out of it. Sites with a grazing pressure of >2 animals/ha seem to be avoided. Disturbance of geese by livestock on brood-rearing sites is usually not known and seldom recorded (Ouweneel 2001). The majority of the sites are cattle grazed. The livestock species might influence the geese's site choice, as cattle select plants with a lower crude fibre content than horses due to their different digestion systems (Vulink 1991). However, domination of cattle grazing likely originates in the fact that livestock grazing generally is dominated by cattle in the Netherlands (Eurostat 2007). In other important Greylag Goose breeding areas, large numbers of feeding families and moulting geese are also attracted by pastures which are sheep grazed, e.g. in the Hauke-Haien-Koog at the western coast in Schleswig-Holstein (personal observation).

Sites with high mowing frequencies are apparently not favoured by the geese: Meadows mown more than three times during the vegetation period are less frequently used and have a significantly lower density as sites with a lower mowing frequency.

Greylag Geese do not preferably feed on fertilised sites. Colony size is significantly lower on fertilised sites compared to unfertilised site and only one fifth of the feeding Greylag Goose families use fertilised farming sites. Black *et al.* (1991) showed that the reproductive success of Barnacle Geese was not significantly higher in colonies feeding on fertilised farmland compared to geese feeding in natural habitats. However, for the staging period Bos (2002) found significant higher densities and higher grazing pressures of wintering Brent Geese on fertilised sites compared to unfertilised sites in early spring.

It should be noted that nitrogen inputs on the Dutch farmland are the highest ones in Europe and exceed to >250 kg fertiliser per ha and year (van Eerden *et al.* 2005). This high input led via indirect fertilisation to eutrophication of soils and finally to water bodies such as in the closed sea arms of the Dutch Delta (van der Graaf *et al.* in prep.). The nutrient-enriched water again provided natural grassland with nitrogen. Besides, aerial nitrogen deposition, which is strongly linked to the intensified dairy cattle industry, increased dramatically (Jefferies & Maron 1997; van Eerden *et al.* 2005). By this, nutrient poor vegetation types were replaced by nutrient rich vegetation types and vegetation influenced by fertilisation can be available for the geese also on non-managed sites all over the country.

In accordance with Rutschke (1997), we found no foraging preference for specific crops. As a result of crop rotation the supply of crops changes on the individual fields over the years while geese generally demonstrate high site fidelity. In most of the breeding areas the geese switch between meadows, pastures and arable fields. Feeding on crops alone seems not to provide all of the required nutrients (Prop 2004). On top of that, feeding on crops might lead to additional energy expenditures due to higher disturbance frequencies on farmed land (Black *et al.* 2007).

4.2. Human disturbance, site protection and land conversion

Frequencies of disturbance are not easy to quantify without permanent observations. Within this study, only the presence and frequency of disturbance was investigated but not the response of the geese. Our investigations do not

indicate a strong impact of observed human disturbance levels on site choice in Greylag Geese. These findings are supported by a study by Vulink (1991). Greylag Geese obviously are able to adapt to certain levels of disturbance (Bezzel & Prinzinger 1990). Spilling (1998) supposed that farming and recreational activities have a minor impact on medium-term site usage (but see (Kruckenberg *et al.* 1996) .

On the other hand, we observe that the presence of geese is closely linked with the protection status of an area. Most of the sites used by geese are located in nature reserves. Between 1950 and 1990, wetland areas in the Netherlands increased by 10 %. Although these "new nature" areas certainly affected numbers of breeding geese in the Netherlands, most of the Greylag Goose sites are situated in natural "old" wetlands (van der Jeugd *et al.* 2006). Areas in the Dutch Delta which were converted to wetland sites in the course of the large embankments (1954-1986), attracted high numbers of breeding birds shortly after reduction of the tidal influence. These sites soon gained the status of nature reserves. In our study, a third of the Greylag Geese use sites in flooded meadows formerly used for peat cutting. It is obvious, that the geese preferably exploit these man-made wetland habitats. On the other hand there are some urban areas in the country with growing populations of breeding Greylag Geese (van der Jeugd *et al.* 2006) comparable with the situation in, for instance, Copenhagen in Denmark (Kampp & Preuss 2005).

5. Outlook

Though recently the number of breeding Greylag Geese has stabilised in some Dutch areas (e.g. the Ooijpolder, Biesbosch), the majority of the colonies is still growing. Recent analyses showed that the Netherlands harbours suitable habitat for up to 90,000 Greylag Goose breeding pairs (Van der Jeugd *et al.* 2006). We used the method of a questionnaire to compile all data. More detailed information on population parameters requires extensive goose observations at individual sites. In addition, ringing programmes and resightings of marked individuals can reveal details on the distribution and usage of feedings sites. It will be important to record the current changes in agricultural land use and land management to be able to analyse the importance of these habitat changes for breeding and staging Greylag Geese.

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6. Zusammenfassung

Feige, N., H. P. van der Jeugd, B. Voslamber & J. Stahl 2008: Charakterisierung der Brutgebiete der Graugans *Anser anser* in den Niederlanden mit besonderer Berücksichtigung der Landnutzung durch den Menschen. Vogelwelt 129: 348–359.

In den letzten Jahrzehnten hat die Zahl brütender Graugänse in den Niederlanden stark zugenommen. Mittels einer Befragung wurden Informationen über die charakteristischen Eigenschaften der Brut- und Jungvogelaufzuchthabitate sowie zur Brutbiologie gesammelt. Die Brutgebiete werden vornehmlich durch Röhrichte und Grünland mit einer höheren Vegetation charakterisiert, während die Vögel für die Nahrungsaufnahme vornehmlich von Rindern beweidete Flächen bevorzugen. Die Art und Weise, wie die Gänse eine Fläche nutzen, wird von der Form der Flächenbewirtschaftung stark beeinflusst. Eine multivariate Analyse zeigte, dass die Form der Bewirtschaftung (Mähen, Beweidung bzw. Düngung) sowie Mähfrequenz und Art der Weidetiere (Kuh, Schaf, Pferd) eng mit der Größe sowie dem Wachstum der Kolonien und der Dichte in den Jungvogelaufzuchthabitaten korrelieren. Dagegen zeigten Prädation und Störung durch Menschen wenig oder keine Korrelationen.

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