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DIPLOMARBEIT

Shifts of the breeding range of Barnacle Geese (*Branta leucopsis*) and Greylag Geese (*Anser anser*) in north-western Europe with special regard to human land use changes

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Data on CD

Data base Greylag Geese
Data base Barnacle Geese
Questionnaire
Text

Preliminary remark

This diploma-thesis was done in cooperation with the University of Groningen, the Netherlands, and SOVON, The Dutch Centre for Field Ornithology.

The study about Barnacle Geese was integrated into the dissertation-thesis of A. J. VAN DER GRAAF (2006) "Geese on the green wave: Flexible migrants in a changing world".
A manuscript of the results is submitted to a journal:

> VAN DER GRAAF, A., FEIGE, N., VAN DER JEUGD, H. P., LEITO, A., LARSSON, K., LITVIN, K., DRENT, R. H., BAKKER, J. P. & STAHL, J. (submitted): Has the recent breeding range expansion of arctic geese been facilitated by changes in human land use?

The studies about Greylag Goose and Barnacle Goose breeding areas in the Netherlands were done in cooperation with SOVON. The results are presented in the SOVON-report:

> VAN DER JEUGD, H. P., VOSLAMBER, B., VAN TURNHOUT, C., SIERDSEMA, H., FEIGE, N., NIENHUIS, J. & KOFFIJBERG, K. (2006): Overzomernde ganzen in Nederland: grenzen aan de groei? Sovon-onderzoeksrapport 2006/02. SOVON Vogelonderzoek Nederland, Beek-Ubbergen.

Download: www.sovon.nl/pdf/upload/Overzomerende_ganzen_SOVON.pdf

Two manuscripts were accepted by "DIE VOGELWELT":

> FEIGE, N., VAN DER JEUGD, H. P., VAN DER GRAAF, J.A. , LARSSON, K. LEITO, A. & STAHL, J: "Shifts of the breeding range of Barnacle Geese (*Branta leucopsis*) in north-western Europe with special regard to human land use changes"

> FEIGE, N., VAN DER JEUGD, H. P. & STAHL, J.: "Characterisation of Greylag Gosse (*Anser anser*) breeding areas in the Netherlands with special regard to human land use"

They will be printed in a supplement of the Conference "Xth Meeting of the Goose Spezalist Group of Wetlands International "Goose 2007" in Xanten, Germany, 26 - 31 January 2007, where I presented my results in an oral presentation.

1. Introduction

In North-western Europe, fragmentation, urbanization and conversion of natural habitats into farmland and forest plantations threatened a number of primary ecosystems and their species assemblages during the last two centuries (SUTHERLAND, 1996, SUTHERLAND, 1998, WILSON, 1999). Whereas many species were able to survive the earlier, less intense anthropogenic changes, the establishment of industry since the 1850's and the recent industrialisation of agriculture resulted in tremendous habitat and species losses (BEZZEL & PRINZINGER, 1990, ROBINSON & SUTHERLAND, 2002, VAN EERDEN et al., 2005). Changes in the modern landscape have also led to changes in the species composition (GATTER, 2004, HÖTKER, 1994, SCHERZINGER & SCHUMACHER, 2004). Locally, species responded with increasing or decreasing numbers to the fragmentation or expansion of areas (FLADE & SCHWARZ, 2000, GATTER, 2000, HÖTKER & KÖLSCH, 1993, SUTHERLAND, 1996, ZANG, 2004).

Among the species group of birds, ground-breeding meadow birds are especially vulnerable to the recent changes in agricultural practices (BAUER et al., 2005, BOSCHERT, 2005). They suffer from drainage, intensive mowing regimes, big soil cultivating machinery and the large-scale application of fertiliser and biocides. Other effects act more indirectly like the changes in water quality as a result of pollutants or eutrophication (FLADE & BAUER, 1996). However, some species were able to compensate losses of primary habitats by behavioural adaptations. Geese even benefited from the creation of man-made habitats (VULNIK, 1991).

Particularly in the wintering grounds conditions improved and, thereby, carrying capacity of feeding areas for geese has increased (VAN EERDEN, 1998, VAN EERDEN et al., 2005). The majority of goose species has responded with increasing numbers. In Western Europe, e.g. Pink-footed Geese *Anser brachyrhynchus*, Greenland White-fronted Geese *Anser albifrons flavirostris*, Bean Geese *Anser fabalis* and Greylag Geese *Anser anser* have increased in numbers since the 1960's (FOX, 2005, MADSEN, 1991, VAN EERDEN et al., 2005). Simultaneously the number of exotic species such as Egyptian Geese *Alopochen aegyptiacus,* Canada Geese *Branta canadensis* and Bar-headed Geese *Anser indicus* grew considerably (LENSINK, 1996, LENSINK, 1998, VAN HORSSEN, 2000, VAN ROOMEN et al., 2002). Along with the increasing numbers, Palearctic species expanded their breeding range towards temperate regions (VAN DER GRAAF et al., submitted).

Against this background, my study aims in the analyses of breeding habitat characteristics in two European goose species, the Barnacle Goose *Branta leucopsis* and the Greylag Goose *Anser anser*. The Greylag Goose presently repopulates former breeding areas within North-western Europe. Some decades ago the Barnacle Goose has started to expand its traditional breeding range in the high Arctic towards temperate regions in the Baltic Sea and the North Sea (BAUER et al., 2005).

By help of a questionnaire, experts from Estonia, Sweden, Denmark, Germany and the Netherlands were asked to give detailed information about site characteristics and all available data on breeding numbers since the establishment of the colonies.

The aim was to find out, if there are any intrinsic site characteristics which have a significant influence

a) on the establishment of a successful Greylag Goose breeding colony in the Netherlands,
b) on the establishment of a successful Barnacle Goose breeding colony outside of Russia,

both measured by the total number of sites, the total number of geese and in relation to colony size, colony growth and density. Special intention is paid to the human impact such as land use and land surface construction. Further, this study presents an overview on the current population development of the Barnacle Goose outside of the traditional breeding grounds in Russia and describes the North-western European breeding habitats.

I discuss which habitat characteristics have been subject to changes during the last decades and, therefore, might be triggering factors for the shifts of breeding range.

2. Material & Methods

2.1 Studied species

2.1.1 Greylag Goose (*Anser anser*)

The Greylag Goose *Anser anser* has a wide breeding range reaching from the northern and temperate marshlands of Europe to North-western and eastern Asia. Two subspecies can be distinguished: *Anser a. rubirostris* which is found in south-east Europe and Asia and the nominal species *Anser a. anser* populating the rest of Europe with an emphasis on east- and north-eastern Europe. The Greylag Goose is divided into six breeding populations within the Western Palearctic (BAUER et al., 2005). The Northwest European Greylag Goose population is subject of this study. The breeding grounds are along the Norwegian coast, in Denmark, southern Sweden, northern Germany, Poland, the Netherlands and Belgium. Two groups following a different migration corridor can be distinguished: The first group migrates from Norway through staging areas in Denmark and the second group from the southern Baltic to staging areas in the Netherlands. Both groups have their winter quarters either in the Netherlands or in south-western Spain and mix there (NILSSON et al., 1999).

The Greylag Goose is a native species in many countries of its recent distribution. New breeding sites have been established since 1991 in southern France (Camargue, Rhonedelta) after introduction in parks and natural water sites. At the same time, breeding populations in Romania and other south-east European regions decreased (RUTSCHKE, 1997). The Netherlands form the southern border of the breeding population (VAN DER JEUGD et al., 2006) and are one of the traditional breeding areas. Since the 16th century the number of Greylag Geese decreased slightly and in 1907 the last breeding pair was seen. In the first half of the last century, this goose species had disappeared as a breeding bird and the western natural border of the breeding range was formed by the River Elbe. In the 1950's repopulation began. It was supported by occasional introduction (RUTSCHKE, 1997) and finally the first breeding pair was recorded again in 1961 (VAN DER JEUGD et al., 2006). The number of breeding pairs in the Netherlands was estimated at only 500 pairs in the 1970's. From then on, a spectacular increase started: in 1990, numbers amounted to 1,150 - 1,200 and in 2001 already to 8,000 - 9,000 (VAN ROOMEN et al., 2002). In 2005, 100,000 birds with 25.000 breeding pairs were recorded during the summer (Fig1.1). By that the Greylag Goose is by far the most frequent goose species breeding in the Netherlands, followed by the Barnacle Goose (6,000 BP), the Domestic Goose (3,700 – 5,000 BP) and the Great Canada Goose (3,000 BP). The strong increase of breeding numbers in the Netherlands mirrors the increase of the population as a whole (VAN DER JEUGD et al., 2006).

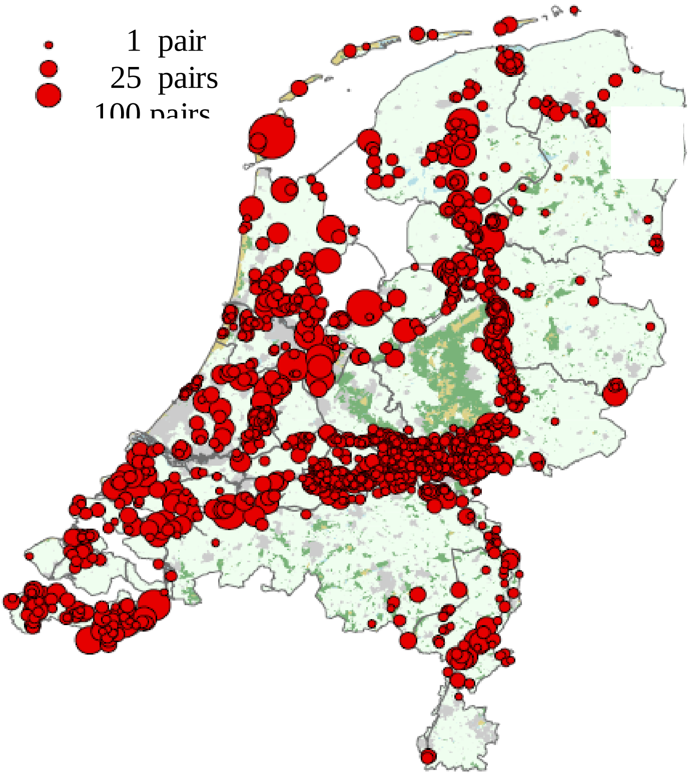

Fig. 2.1: Distribution of breeding Greylag Geese in the Netherlands (2001-2005, VAN DER JEUGD et al, 2006).

Breeding biology

Greylag Geese are mainly monogamous and can enter into a lifelong partnership. Mating mainly takes place in the second year, but breeding starts in the third or fourth year when the young geese become mature (BAUER et al., 2005).

Greylag Geese are very flexible in the choice of breeding sites. In north-western Europe they prefer eutrophic water bodies. They breed in reed beds, among sedges and rushes, in scrubland close to shores, in willow scrubs in flood lands, but also on grasslands or mown pastures and occasionally even in trees. Nests are built of plant material, often raised and reach 1m in diameter. The nest is covered with nest down feathers. Egg laying starts at the end of February/beginning of Marsh and can last until mid of May. Greylag Geese usually do not breed very close to each other, but in dense colonies they can share nests and joint clutches with more than 12 eggs are not rare then. Normally, the female lays about 4-6 eggs (mean value) and breeds for 27-29 days. Only the female breeds while the male stays close to the nest for guarding and protecting. After hatching the family stays a few days in the surroundings of the nest and then moves to brood-rearing sites. Raising of young takes about 50-60 days until fledging. During this time the adults moult and recover flight capacity after 3.5-4 weeks right in time with fledging of the young. The family stays together until departure and flies jointly to the wintering quarters (BAUER et al., 2005, BERNDT & BUSCHE, 1991, KALCHREUTER, 2000, RUTSCHKE, 1997).

Feeding behaviour

Greylag Geese have the widest range of food of all goose species (VOSLAMBER et al., 2004). This is connected with their appearance in a big number of different habitats.
In natural habitats they forage on the leaves and rhizomes of plants in salt and brackish marshes. Besides, they feed on eutrophic vegetation, buds of *Salix spec*. or dabble on submerse plants like *Potamogeton spec.* (RUTSCHKE, 1997, VOSLAMBER et al., 2004). On average, natural food sources rank much lower in the diet of Greylag Geese compared to food which is available from farmland (VAN DER WAL, 1998). Greylag Geese often feed on pastures and meadows. In summer and autumn they also forage on cereals, potatoes and sugar beets and in spring on autumn-sown cereals (VOSLAMBER et al., 2004).

2.1.2 Barnacle Goose (*Branta leucopsis)*

Three populations of the Barnacle Goose can be distinguished: The Greenland population (32,000 birds), which breeds on the eastern coast of Greenland and winters in Scotland and Ireland, the Spitsbergen population (12,000 birds) with breeding grounds on the island of Svalbard and wintering areas in Scotland and the Russian population, traditionally breeding in the Barents Sea in North Russia and wintering in north-western Europe (400,000 birds; (GANTER et al., 1999).

At the beginning of the 1950's, the Russian population only numbered at about 10.000 individuals. After having reached this all time-low, the population started to increase steadily. For a long time, Barnacle Geese have been considered to be breeding birds of the high Arctic (north of 69°N, (LARSSON et al., 1988, VAN DER JEUGD et al., 2003). They were very rare in North-western Europe even during the winter. From the 1970's on, increasing numbers of wintering geese along the coasts of the North Sea and Baltic Sea were recorded. In addition, geese also stayed during the whole summer period in these temperate regions. In 1971, the first breeding pair in the Baltic was seen on the island of Gotland in Sweden (Fig. 2.2). Since this establishment, further colonies were established in the Baltic on Gotland and Öland and along the coast of the Swedish mainland, in southern Finland and in western Estonia (LEITO, 1996) as well as on the Danish island of Saltholm (1989, MORTENSEN, pers. comm.). During the same time, breeding colonies established along the coast of the Wadden Sea in the Netherlands (first breeding pair in 1982, (MEINGER & VAN SWELM, 1994, OUWENEEL, 2001) and at the end of the 1980's also in Germany (KOOP, 1998, KRUCKENBERG & HASSE, 2004). Furthermore, in the 1980's new breeding sites in the surroundings of the traditional breeding grounds in the Russian Arctic were founded (FILCHAGOV & LEONOVICH, 1992, SYROECHKOVSKY JR., 1995). Almost all new colonies increased rapidly in size.

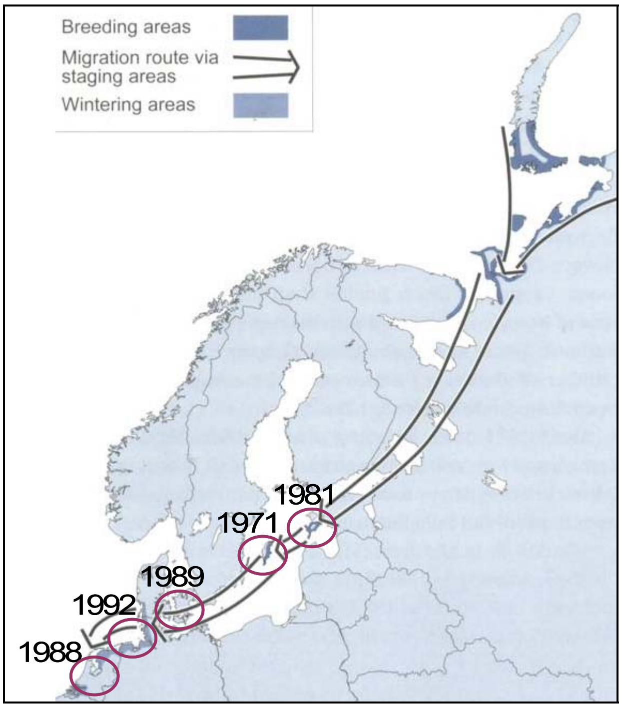

Fig. 2.2: Establishments of new Barnacle Goose breeding areas along the traditional flyway. 1971: Gotland, Sweden, 1981: Estonia, 1988: the Netherlands, 1989: Denmark, 1992: Germany (GANTER et al., 1999, altered).

Currently the population outside of Russia numbers up to 42,000-55,000 birds (BAUER et al., 2005) and the geese seem to have adapted to breed in more southern habitats in the temperate zone (LARSSON et al., 1988, VAN DER JEUGD et al., 2003). The Dutch Barnacle Goose sub-population is with an annual growth rate of 46% the fastest growing goose sub-population of the world (VAN DER JEUGD et al., 2006).

Breeding biology

Barnacle Geese usually start breeding with an age of three years though mating often happens one or two years before. Like all geese they are very faithful and as Greylag Geese the pairs normally stay together for the whole lifetime. When the pair arrives on the breeding grounds, the female is almost ready to lay her eggs. Depending on the breeding region nests either are constructed on cliff edges, rocky outcrops (mainly in North Europe), on small islands, spits with driftwood and dunes or sites poor of vegetation. Breeding sites can be found in vast lowlands, coastal salt marshes and deltas of rivers, but they are always close to the shore of the sea, fjords or lakes (BLACK et al., 2007, GANTER et al., 1999, PROP et al., 1980). Barnacle Geese typically breed in colonies of up to 1000 nests, often in association with other goose species, but also with other birds like Rough-legged Buzzards *Buteo lagopus,* Kittiwakes *Rissa tridactyla or* Herring Gulls *Larus argentatus*. Nests are rather bare, the flat hollows scratched in the ground might be padded out with twigs or branches and sometimes mosses but they are always covered with downy feathers (BAUER et al., 2005, GANTER et al., 1999, SYROECHKOVSKY JR., 1995). Breeding also may occur in old nest cups, not seldom in nests of Greylag Geese. Intra- and interspecific nest parasitism occurs which sometimes can be rather high (POUW et al., 2005).

Egg laying starts at the end of April in North-western Europe, in North-Europe at the end of May or beginning of June. Normally, the geese have one brood per year (clutch size: 4-5 eggs on average). Breeding takes 24-25 days. Only the female breeds, but the male stays close to the nest guarding the area around. Since the female has almost fasted the whole time through incubation, it is in very poor condition and needs to fill up reserves after the young have hatched. The family soon moves to the feeding grounds where they gather with other families and the non-breeders that have already moulted. The goslings fledge after 40-45 days, in the meantime moulting of the parents takes place. The family stays together during the whole summer and migrates to the wintering quarters together (BAUER et al., 2005, GANTER et al., 1999, OWEN, 1990, VAN DER JEUGD et al., 2006a).

Feeding behaviour

Barnacle Geese feed on expensive stretches of tundra, sea-swept marshes, and a variety of natural and man-made wetlands. In the Arctic, they forage on more than 51 species including seeds, tubers, leaves, forbs and aquatic vegetation (PROP et al., 1980). In lower latitudes they mainly feed on plants of salt marshes (BAUER et al., 2005, OWEN, 1990). They also forage on agriculture crops, pastures and meadows (BLACK et al., 2007, THYEN et al., 2000).

2.2 Data collection

Information about habitat characteristics and breeding biology of Greylag Geese and Barnacle Geese were collected from various regions around the North Sea and the Baltic Sea in 2005. To get information about as many breeding areas as possible, I gathered all data with the help of a questionnaire. It was either sent to nature agencies, volunteer ornithologists, farmers and ornithological institutes or filled in following personal interviews with local experts. The development of the questionnaire and the survey was done in cooperation with the University of Groningen and SOVON, the Dutch Centre for Field Ornithology.

All questionnaires sent to the local experts were returned except for some areas in the Netherlands. From there, I received information of 30 out of 52 Greylag Goose areas and of 15 out of 26 Barnacle Goose breeding areas. In total, 88 questionnaires were evaluated. A list of all contact persons that supplied the data is added to the Appendix (Tab. A1).

Definitions

Breeding areas were divided into breeding sites, brood-rearing sites and non-breeding sites. A "*breeding area*" was defined by a region with one or more breeding "*colonies*" (see below) of the same species. 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*"). Further, I considered non-breeding geese that might be present in the area. Non-breeders were defined as geese which were either immature and too young to breed or which have failed in breeding or lost their partner. They often mixed with the breeding birds and young families but they might also use completely different sites (="*non-breeding sites*").

A "*site*" was defined by a combination of site characteristics according to the specific behaviour of geese (either breeding or brood-rearing or non-breeding) and not distinguished by its spatial distribution in an area. To keep the questionnaire as simple as possible the respondents were requested to summarise multiple sites in the same breeding area (e.g. if there were four brood-rearing sites and three are grazed by cattle but the remainder is ungrazed, they would all receive the designation 'cattle grazed'). Further, sites that were located apart from each other but had exactly the same characterisation in terms of habitat characters, were merged into one site. A "*colony*" was defined by all geese using the same site and therefore also not by its spatial distribution.

2.3 Study area

The study includes breeding areas of Greylag Geese in the Netherlands and breeding areas of Barnacle Geese in Estonia, Sweden, Denmark, Germany and the Netherlands. All areas with at least 4 breeding pairs in 4 consecutive years (last breeding must be 2005) were included. By this selection, sporadic breeding attempts were excluded and only stable colonies are considered. Data of Sweden were only collected from the islands of Gotland and Öland which harbour the most important breeding sites of Sweden (FORSLUND & LARSSON, 1991). In the Netherlands, Barnacle Goose and Greylag Goose breeding areas are numerous throughout the country. All areas of which local experts for data supply were available were included. Breeding sites in very artificial habitats like municipal parks (e.g. Nymphenberger Park in Munich, Germany) where the colonies have been established by birds escaped from a waterfowl collection nearby were not considered.

I compiled data of 30 Greylag Goose breeding areas including 17% of all breeding pairs in the Netherlands (Tab. A2, Fig. 2.3). The investigated areas are distributed over the whole of the Netherlands: 11 areas are in Zeeland, one is on the island of Schiermonnikoog (Wadden Sea) and the remainder are mainly found inland in the vicinity of big rivers or in wetlands (some of which were recently embanked and drained). The areas were divided into 51 breeding sites, 49 brood-rearing sites and 39 non-breeding sites (Tab. 2.1). For the Barnacle Geese information of 51 breeding areas including about 85% of all breeding pairs outside their traditional breeding grounds in Russia was available. The areas were divided into 54 breeding sites and 53 foraging sites (Tab 2.1).

Tab. 2.1: Number study sites and number of analysed geese. BP: breeding pairs, n.i.: not investigated

Country	total BP in 2005	analysed BP	breeding sites	brood-rearing sites	non-breeding sites
Barnacle Geese					
Estonia	113	85	3	6	n.i.
Sweden	5,170	5,139	21	17	n.i.
Denmark	504	504	1	1	n.i.
Germany	184	178	7	10	n.i.
The Netherlands	6,000	4,128	22	19	n.i.
total	11,971	10,034	54	53	n.i.
Greylag Geese					
The Netherlands	25,000	5,269	51	49	39

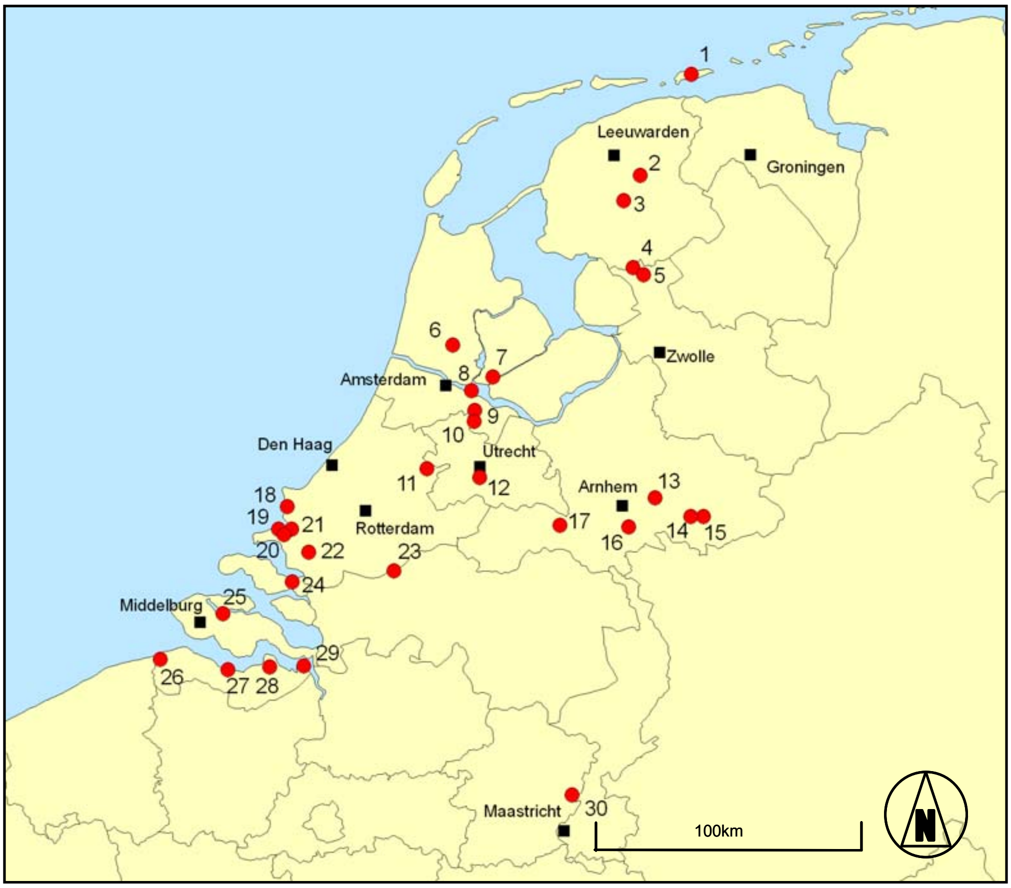

Fig. 2.3: Study sites of Greylag Goose breeding areas in the Netherlands.

1: Schiermonnikoog, 2: Alde Feanen, Jan Durks Polder, 3: De Deelen, 4: Weerribben, 5: Wieden, 6: Wormer- en Jisperveld, 7: Lepelaarsplassen, 8: Eiland bij Vijvhoek 9: Ankeveense Plassen, 10: Het Hol, 11: Reeuwijkse Plassen, 12. Stuweiland Hagesteijn, 13. Vaalwaard, 14: Oude Rijn, West Bergsehoofd, 15: Oude Rijn, Erfkamerlingschap, 16: Ooijpolder West, 17: Drutensche en Leeuwensche Waarden, 18: Beningerslikken, 19: Het Kiekgat, 20: Scheelhoek, 21: Quarkgors, 22: Korendijkse Slikken, 23: Biesbosch, 24: Helegatsplaten, 25: Middelplaten, 26: Groote Gat, 27: Braakman, 28: Groot Eiland, 29: Verdronken Land van Saeftinghe, 30: Grensmaas.

2.4 Data basis

The complete questionnaire can be viewed in the appendix on the computer disc (file “Questionnaire”). Each questionnaire contained a map of the respective breeding area to indicate the exact locations of the sites. The results of the questionnaires were put into a data base which is added to the CD (files “data base Greylag Geese” and “data base Barnacle Geese”). In the following the relevance of the specific site characteristics which were asked for (gothic letters) will be explained with regards to the geese’s site choice.

2.4.1 Sites characteristics

Location

The location distinguished between sites on the *mainland, islands, peninsulas, wetlands and sites outside the seawall***.** Wetlands were defined as areas of former peat extraction with a fluctuating water table and narrow elongated peat remnants which are similar to small "islands" with mostly short distances to the mainland (between 5-50m). After the period of peat extraction, reed often started to dominate. Nesting primarily takes place on the small "islands" and brood-rearing on surrounding meadows. Geese on islands or in wetlands can benefit from ground predator-free or disturbance-free sites due to the isolation of this location. Further, the *proximity of water bodies* guarantees shelter in case of danger and it is important for the supply of drinking water and night-roost sites. The *spatial pattern of breeding and brood-rearing sites within a breeding area* gives details about how intensively the area can be used by the geese.

Habitat and vegetation

All habitats can be ascribed to *"natural habitats"* or "*man-made habitats*" "Natural habitats" were defined as habitats in which natural processes dominate although the site itself may have been developed artificial (e.g. by embankment). Natural habitats are either not managed or managed in a less intensive way. In contrast, "man-made habitats" are characterised by high management levels (fertilization, mowing at least three times during the vegetation period and a strong grazing pressure ($\geq$ 2 animals/ha). *Vegetation types, the presence of plant species that characterize a site and the vegetation height* are indicators for the forage quality, visibility and the presence of shelter.

Natural grazing facilitation

Natural grazing by deer, hare or other wild herbivores retards vegetation succession, prevents tall plants species from becoming dominant and results in a higher forage quality of grasses than without grazing. Thereby geese can benefit from facilitation (= the improvement of the condition for one herbivore by another, (BOS, 2002). At least temporally, it provides a good feeding habitat and guarantees a clear visibility.

Management of sites

Management of the sites differ in quality and quantity of livestock *grazing, mowing and fertilisation*. On breeding sites, high management schemes reduce higher vegetation which offers shelter during nesting. On brood-rearing sites, livestock grazing and mowing can also facilitate goose grazing (BOS, 2002). Different *livestock specie*s (cattle, horse and sheep) graze plants in differing ways, show specific patterns of spread in an area and create specific trampling patterns resulting in a different structure of the vegetation (WEIGT, 2001). Further, *grazing pressure and grazing periods* have a different impact on the vegetation. E.g. summer grazing at high densities prevents the expansion of tall grasses and herbs whereas year-round grazing slows down the expansion of shrubs (ESSELINK, 2000, VULNIK, 1991). Continuous low grazing or mowing keeps the vegetation in a high forage quality. The effects of mowing depend on the *mowing frequency* and the *time of mowing* (BOS & STAHL, 2003, VICKERY et al., 1994)*. Artificial fertilisation* produces a higher food quality depended on the *frequency of application, amount and type of fertilizer*.

On top of that, grazing by livestock and the presence of machinery due to mowing and fertilisation may be a source of disturbance, especially at breeding sites where nests can be easily destroyed.

Disturbance by man

Disturbance by man differs in *quantity* and *quality*. The use of an area is severely influenced by human disturbance. Human activities directly reduce the number of geese: in some breeding areas in the Netherlands special permission is given for shooting and breeding control is a common practice to minimize colony sizes. Breeding control (=nest manipulation by collecting or destroying eggs) was evaluated by the dimensions and methods of nest disturbance.

Scaring and disturbance by human off-road activities have at least negative effects concerning the energy budget of geese as geese tend to show rather large flight distances (KOWALLIK, 2000, SPILLING, 1998). Frequent interruption of breeding leads to a lower breeding success and areas with high disturbance levels get abandoned (VAN NUTGEREN, 1997). Chasing was investigated by determining the methods *(optical and acoustical scaring)* and *frequency.* Disturbance by *off-road activities* distinguished between *farming activities, activities of nature wardens or people on recreation* and quantified the *frequencies of disturbance.* Disturbance by *buildings and human settlements* was measured by the *distance* from those to the breeding, brood-rearing and non-breeding sites.

Predation

Predation is a limiting factor in the distribution of the geese. Predators directly reduce the number of geese by capture and indirectly have negative effects on energy budgets and mortality rates: Foraging under high predation pressure influences the food intake as the birds more often show vigilant behaviour and escape in case of danger. Thereby, they lose energy and time otherwise available for foraging which is reflected in lower body condition and finally in lower survival during winter (DROST et al., 2001, STAHL et al., 1998). The impact of predation was characterised by the *predator species* and a quantification of *predation pressures*.

Protected areas

The location of a site in a *protected area* usually provides a habitat free of human disturbance. Often *special management measures adapted to breeding birds* support goose suitable habitats.

Conversion of habitats and changes during the past

Breeding areas might have been influenced very intensively by human land use. G*rasslands were converted into arable fields* and places like wetlands were *drained or* coastal sites *embanked*. Further, prior to geese establishment or colony growth*, changes in management, predation pressure or human activities that could have affected site choice* were studied.

For the analyses of the Greylag Goose habitats all site characteristics were investigated. For that of the Barnacle Geese a more specific analysis was used: location (island/mainland and distance between brood-rearing and breeding site), presence of water, plant species and the vegetation type, management of the site (mowing, grazing or fertilization), safeguard (nature protection measures and allowance of hunting) and frequencies of human disturbance.

2.4.2 Population parameters

Site characteristics were related to the population parameters colony size, colony growth and density. Additionally, the number of sites with same characterisations and the total number of geese were compared to each other. It was assumed that high numbers of geese and sites and high population parameters refer to optimal habitat conditions.

Number of geese

The *numbers of geese* represent the most recent numbers (usually counts from 2005) and always refer to breeding pairs (BP). In some areas goose counts did not distinguish between Domestic Geese (*Anser anser forma domestica*) and Greylag Geese and thus numbers of Greylag Geese may also include Domestic Geese. In other areas, number of geese are not available at all because goose counts were not conducted. The number of geese is not synonymous with colony size as the number of geese refers to all geese *distributed over all 30 breeding areas.*

Colony size

Colony size was defined as the number of pairs per site in 2005. “Colony size” is not synonymous with “number of geese” as the number of geese refers to all geese distributed over all 30 breeding areas.

Colony growth

Data about gosling survival and fledging success were not available, but colony growth was used as an approximate value for reproductive rate. It was based on data of the last consecutive 6 years (2000 - 2005) and was measured accordingly to the formula: $\lambda = (N_t/N_0)^{1/T}$. Colony growth was determined for the whole breeding area. Thus, all colonies within one area are characterised by the same growth. It should be kept in mind that in some Greylag Goose colonies low colony growth may basically be triggered by illegal breeding control such as nest disturbance. Besides, a low colony growth can indicate that carrying capacity is reached.

Density

Density was used as an approximation for carrying capacity. It was measured in geese/ha. On brood-rearing sites numbers did not consider further herbivorous bird species which use sites simultaneously. In some cases, densities of Greylag and Barnacle Geese might be lower than they could have been without other birds present. On breeding sites, further breeding *Anseriformes* do not occur in significant numbers. Since Greylag Geese breed earlier in season than Barnacle Geese these species are not in competition with each other.

Number of sites

The *number of sites* does not consider the actual number of all sites: as required in the questionnaire, sites that have the same characterisation within one breeding area but are located apart from each other, were summarized to one site only. It can only be an approximation, therefore.

2.5 Statistical analyses

Sample size differed from analysis to analysis as in some of the breeding areas individual site characteristics or population parameters were not available. To get an expressive result, statistical analysis with N<5 (in special circumstances 4) were not conducted.

Oneway-ANOVA

I used a Oneway-ANOVA (analysis of variance) to test for differences among two or more groups of the habitat characters (e.g.: management by grazing versus management by mowing) in relation to the population parameters. The test requires the normal distributions in each of the groups. I used the Kolmogorov-Smirnov to test normality. Since this revealed not normally distributed data, I transformed the data logarithmically to meet criteria of normal distribution.

Multivariate linear model

The multivariate linear model was only applied for Greylag Goose data. Application of multiple regressions need to meet the requirements of linearity and independence of cases (BACKHAUS et al., 2003). According to (LAMPRECHT, 1992), numbers of different habitat characters are to amount to a maximum of one third of the number of analysed sites (e.g. 9 sites for 3 habitat characters). Since in total data of more than 30 habitat characters for breeding and brood-rearing sites each were available, a small number of habitat characters had to be selected for the analyses. I decided to only include habitat characters into the multivariate linear model which showed significance in the Oneway-ANOVA test. Colony size, colony growth and density was tested with habitat characters as fixed factors in a step-wise model. I want to underline that by means of a multiple regression it is not possible to detect any obvious causal connections. The result only reveals coincidence not excluding the existence of correlations without any biological significance (BACKHAUS et al., 2003).

Cluster analysis

Similarity of habitat structure between breeding and brood-rearing sites of Barnacle Geese was analysed by hierarchical clustering and ordination of sites by multi-dimensional scaling (MDS). Information about habitat characters (location on an island or the mainland, distance to brood-rearing sites, vegetation cover, management, predation and human disturbance) was transformed into a presence/absence matrix (1/0). Parameters, which occurred at less than five sites (10% of the sampled sites) were

excluded from the analysis. The matrix for 49 breeding sites contained 15 parameters. The matrix for 43 brood-rearing sites contained 10 parameters.
According to recommendations by (BACKHAUS et al., 2003, CLARKE & WARWICK, 2001) I applied the following similarity coefficients when computing similarities between sites: Simple Matching, Jaccard, Bray-Curtis, and Kulczynski. Since the computation of coefficients revealed comparable similarity matrices, only Jaccard is presented in the results. The result of the hierarchical clustering is shown by a dendrogram with the x axis representing the set of sites and the y axis defining a similarity level at which two samples or groups are considered to have fused. Group-average-linkage was applied to avoid any weighing of similarities.

Non-metric MDS

To display the similarities between the sites more informatively, ordination by non-metric MDS was carried out. The non-metric MDS describes items (here: breeding and brood-rearing sites) founded on their (dis)similarities in a two- or multidimensional space. Usually, only those two dimensions are shown, which explain the most part of the variance. The distance between two points mirrors the (dis)similarity between two sites. The distance is non-metric but based on order statistics (in this case on a preceding cluster analysis, see above). As a result, the plot is without any dimension. Besides this spatial configuration, various indices give the grade of the analysis. I used the stress value. Principally, there are no exact rules which stress value is acceptable, but as guide value 0 describes a perfect grade of the analysis whereas 0.2 – 0.4 is a poor grade. A stress value between 0.1 and 0.2 still gives a potentially useful two-dimensional picture (BACKHAUS et al., 2003, BORG & STAUFENBIEL, 1997, CLARKE & WARWICK, 2001).

ANOSIM test

The similarity matrix can be used to test for differences between certain groups of sites. I tested for differences between two geographical regions: Baltic Sea and North Sea. A valid test was established by (CLARKE & GREEN, 1988) built on a simple non-parametric permutation procedure, applied to the similarity matrix underlying the ordination of sites, and therefore termed an ANOSIM test (analysis of similarities). Average rank similarities within pairs of replicates (Baltic *versus* North Sea) are compared with the average rank similarities between sites of different replicates. The test statistic R lies within the range -1 and 1. R=1 only if all replicates within sites are more similar to each other than any replicates from different sites. R is approximately zero if the similarities between and within sites will be the same on average (=representing the null hypothesis). R will usually fall between 0 and 1.

Outliers

Outliers are extreme cases within one habitat character or goose parameter which have a strong influence on the calculation of statistics by causing problems with linearity. I checked if one or more sites had the strongest influence on the population parameter and considered deletion of the following sites for the analyses of density: Barnacle Goose breeding sites: Reeser Meer (1300 geese/ha) and Beltringharder Koog (4900 geese/ha); Barnacle Goose brood-rearing sites: “Beltringharder Koog - islands” (1600 geese/ha), Greylag Goose breeding sites Eiland Vijfhoek (125 geese/ha) and Het Hol (110 geese/ha).

2.6 Software

Statistics

The Oneway-ANOVA-test, multivariate linear model and the Kolmogorov-Smirnov test were performed with the help of the statistical package (SPSS, 2004).

Cluster analysis, non-metric MDS and ANOSIM test were computed by PRIMER v6 (CLARKE & R.N., 2006).

Graphs and maps

Graphs were constructed with Excel and SPSS (2004). The maps were created with (ESRI, 1991).

3. Results

3.1. Greylag Goose

3.1.1 Overview of population parameters

Colony sizes

The breeding area of Wormer- en Jisperveld hosts the largest colony (700 BP). The next largest colonies are in Reeuwijkse Plassen (481 BP) and Scheelhoek (391 BP). Smallest colony size is recorded for Leepelarsplassen (9 BP), followed by Schiermonnikoog, Het Hol and Alde Faenen with a maximum of 25 pairs each (Tab A2). The mean colony size is 112 BP (Tab. 3.1).

Colony growth

Mean colony growth on breeding sites is λ= 1.20 (Tab. 3.1). By far the highest colony growth (λ= 1.8) is recorded in the breeding area of Vaalward. In 4 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) increased up to 240 and 316 pairs, respectively, and now seem to stabilize. The colony of Schiermonninkoog is the only decreasing one. Also there, breeding numbers have been low there ever since.

Density

Mean density at breeding sites is 4.1 geese/ha (Tab.3.1). 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 brood-rearing site is in Grote Gat (8 geese/ha). A positive relationship between site size and goose density can be revealed (breeding sites: R^2=0.396, $p \leq 0.05$, N=28; brood-rearing sites: R=0.235, $p \leq 0.01$, N=23).

Population parameters in relation to colony age

The relationship between colony age and colony size, colony growth and density, respectively, is not statistically significant (Fig.3.1). Neither a relationship is found when breeding areas are compared a) where breeding control by nest destroying, egg collection, etc. took place and b) without any breeding control at all.

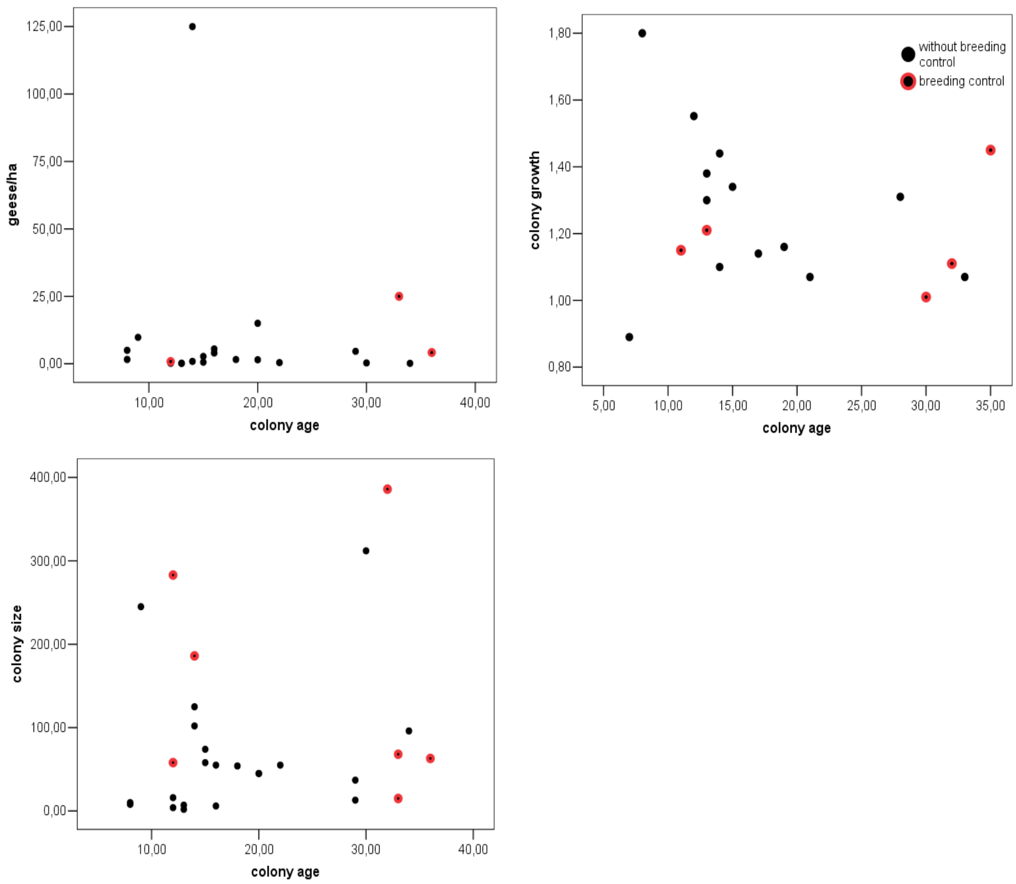

Fig. 3.1: Colony age within one breeding area in relation to density (N=21), colony growth (N=18) and colony size (N=26). Relationship is not statistically significant.

Tab 3.1: Colony growth, colony size and density of Greylag Goose sites.

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

3.1.2 Spatial pattern of breeding and brood-rearing sites

The usage of a site as a breeding site, brood-rearing site or non-breeding site is not mutually exclusive: more than 50% of the breeding sites are also used by the same geese as brood-rearing sites and 27% of the breeding sites by non-breeding geese. 37% of the brood-rearing sites are simultaneously used by non-breeders. On average in a breeding area, 11% of the brood-rearing sites also function as breeding sites.

The geese can reach the brood-rearing sites by land and/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 for the most part at a distance of less than 1000m. To reach the closest brood-rearing site, geese of 3 colonies have to cover a distance of at least 1000 meters. To reach the farthest brood-rearing site, a distance of at least 3000m has to be covered for families of 22 colonies (Fig. 3.2). The farthest distances are recorded for the breeding area of Eiland Vijfhoek, where the geese move to the region of Waterland. They cover distances either by land or by water up to almost 10km.

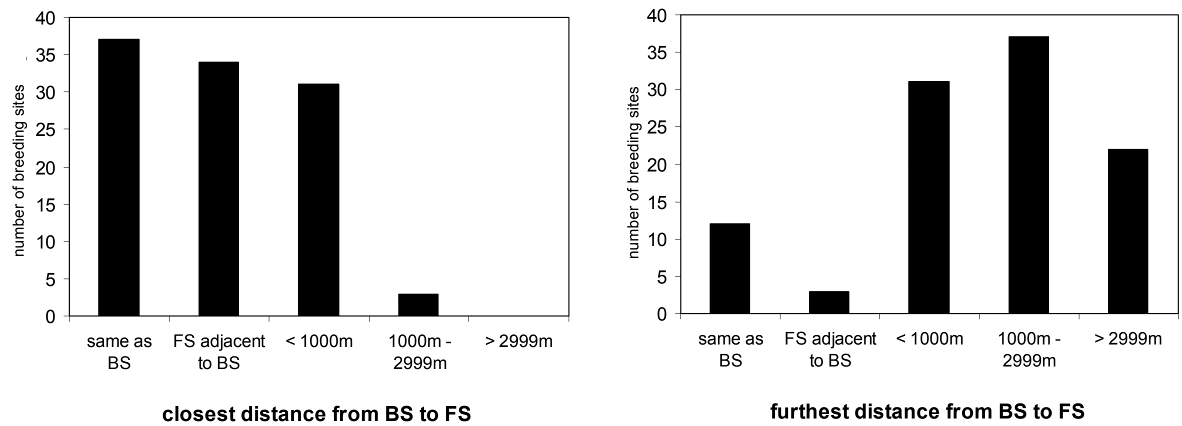

Fig. 3.2: Distances from breeding sites to brood-rearing sites. Left: closest distance, right: farthest distance. (Note, that some of the sites in the right figure are the same sites as presented in the left figure in case the breeding area only harbours one brood-rearing site. N=105. This higher sample size as usual results in the method of not merging similar or same breeding and brood-rearing sites together (see methods) to get a more precise result.

Tab.3.2: Number of breeding sites, total number of geese, colony size, colony growth and density in relation to the spatial pattern of brood-rearing sites according to Oneway-ANOVA test. *p≤ 0.5; **p≤ 0.01; ***p≤ 0.001; n.s.: not significant.

location of FS	BS same as BRS or BRS adjacent		BRS apart		significance
breeding sites					
number of sites	14		36		
total number of geese (BP)	1112	*N=10*	2766	*N=26*	
colony size (BP)	111 ± 156	*N=10*	106 ± 162	*N=26*	n.s.
colony growth (λ)	1.3 ± 0.31	*N= 5*	1.18 ± 0.19	*N=26*	n.s.
density (geese/ha)	9.6 ± 4.6	*N=6*	2.6 ± 3.3	*N= 22*	n.s.

3.1.3 Location

a) Breeding sites

The majority of the breeding sites are located on the mainland. One third of the breeding sites are on islands. Density is lowest in wetlands. On islands, colony size is about 6 times significantly lower than on the mainland and in wetlands (p≤ 0.01, Tab. 3.3, Fig. 3.3).

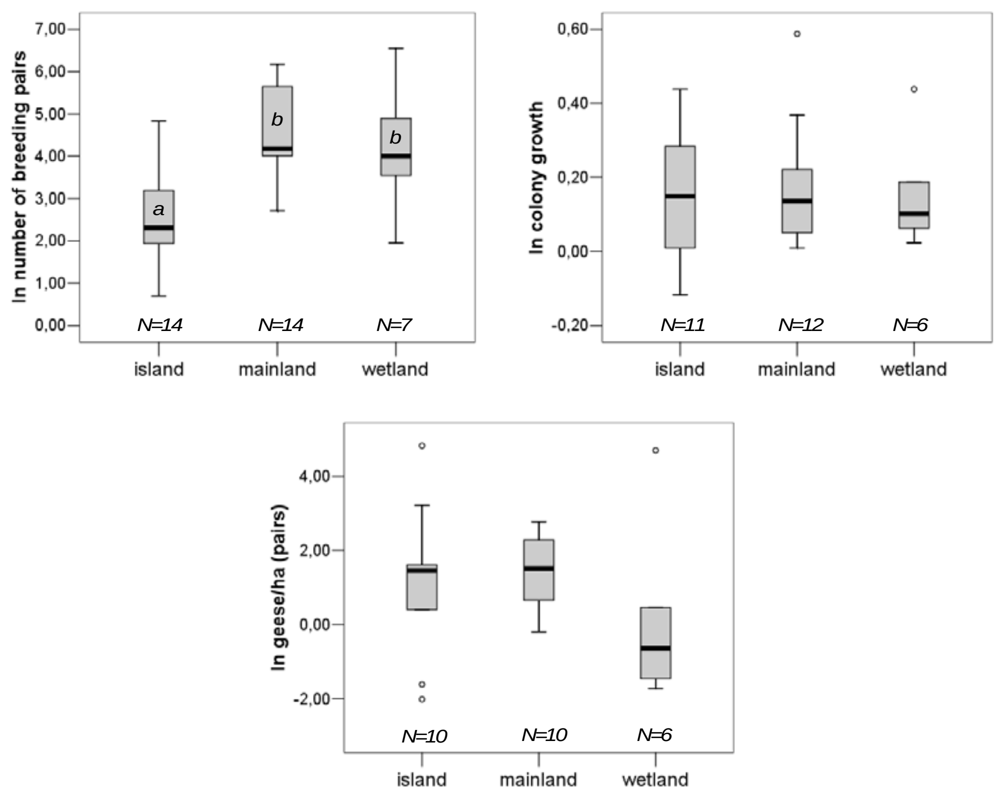

Fig. 3.3: Colony size, colony growth and density at breeding sites in relation to the location. Colony size is statistically significantly lower on islands than on the mainland and in wetlands (p≤ 0.01, according to Oneway-ANOVA test a,b: subgroups according to post-hoc test Tukey-test).

Half of the breeding islands are located at a short distance (5-50m) from the mainland (Tab. 3.3). On islands located >50m from the mainland, geese breed in a higher density than on islands located up to 50m from the mainland (density$_{5\text{-}50m}$: 0.6 geese/ha vs. density$_{>50m}$: 6.5 geese/ha, $p \leq 0.5$, N=13). Additionally on islands at a low distance to the mainland, colony size is statistically significantly higher than on islands located at a greater distance (colony size$_{5\text{-}50m}$: 142 pairs, colony size$_{>50m}$: 24 pairs; $p \leq 0.01$). The majority of all sites has a clear escape to water (number of sites$_{\text{clear escape}}$: N= 46, number of sites$_{\text{no clear escape}}$: N= 5).

Tab.3.3: Number of breeding, of brood-rearing and and non-breeding sites, total number of geese, colony size, colony growth and density in relation to the location according to Oneway-ANOVA test. *p≤ 0.5; **p≤ 0.01; ***p≤ 0.001; n.s.: not significant; n.i.: not investigated; a,b: subgroups according to post-hoc test Tukey-test.

location	islands			mainland			wetlands			peninsulas	outside of seawall		significance
breeding sites													
number of sites	18			19			7			3	4		
total number of geese (BP)	278	*N=14*		2253	*N=14*		1120	*N=4*		n.i.	501	*N=4*	
colony size (BP)	25 ± 36	*N=14*	a	161 ± 162	*N=14*	b	160 ± 245	*N=7*	b	n.i.	n.i.		**
colony growth (λ)	1.16 ± 0.21	*N=11*		1.2 ± 0.23	*N= 12*		1.18 ± 0.20	*N= 6*		n.i.	n.i.		n.s.
density (geese/ha)	5.2 ± 7.6	*N= 9*	a	6.2 ± 5.5	*N=10*	a	0.6 ± 0.6	*N= 5*	b	n.i.	n.i.		*
brood-rearing sites													
number of sites	6			32			3			0	4		
total number of geese (BP)	102	*N=3*		1745	*N=24*		440	*N=2*		n.i.	775	*N=3*	
colony size (BP)	n.i.			72 ± 95	*N=24*		n.i.			n.i.	n.i.		
colony growth (λ)	1.12 ± 0.24	*N=5*		1.15 ± 0.13	*N=25*		n.i.			n.i.	n.i.		
density (geese/ha)	n.i.			1.8 ± 2.7	*N=13*		n.i.			n.i.	n.i.		
non-breeding sites													
number of sites	3			28			2			0	2		

distance from breeding island to mainland	5 - 50m		> 50m		significance
breeding sites					
number of sites	11		12		
total number of geese (BP)	1136	*N=8*	217	*N=9*	
colony size (BP)	142 ± 233	*N=8*	24 ± 39	*N=9*	*
colony growth (λ)	1.15 ± 0.19	*N=7*	1.19 ± 0.25	*N=8*	n.s.
density (geese/ha)	0.6 ± 0.5	*N=6*	6.5 ± 8.4	*N=8*	*

b) Brood-rearing site

For brood-rearing the geese mainly use sites on the mainland. Despite sites outside of the seawall are used at less than 10% of all sites, more than 25% of the geese feed there (Tab. 3.3). Clear escape to water is guaranteed (FS$_{\text{clear escape}}$: N= 32, FS$_{\text{no clear escape}}$: N= 1).

c) Non-breeding sites

Also non-breeding sites are mainly located on the mainland (Tab. 3.2) but 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.). Usually, sites with a clear escape are not directly situated next to water bodies, but within a distance of 1km most of them can be reached, or at least a small part of the site has a clear escape.

3.1.4 Vegetation

a) Breeding sites

All breeding sites can be described as “natural habitats” (see 2.4.1 for definition). The vegetation is mainly characterised by grasslands or wetlands with reed beds (Fig. 3.5). 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. 3.6). Reed grows on 50% of all breeding sites and these sites are used by more than 70% of all geese. Nevertheless, density of breeding geese in other vegetation is more than twice that high than in reed (Tab. 3.4). At some places, nests are built in vegetation higher than 40cm or even in “forests” (fig 3.4).

Nests are built in all vegetation heights, but for the majority in vegetation taller than 40cm. (It has to be noted that questionnaire respondents described the vegetation at breeding sites often as a mixture of grass, reed, eutrophic perennial herbs, bushes and /or trees but then mean vegetation height was determined as <40cm.)

Fig. 3.4: Greylag Goose breeding sites. Left: Nests between bushes and trees (photo: B. Voslamber). Right: In the breeding area of Groot Eiland the geese breed in narrow reed stripes along the rivers. For brood-rearing they use agriculture fields in the close vicinity (photo: N. Feige).

Tab. 3.4: Number of breeding, of brood-rearing and and non-breeding sites, total number of geese, colony size, colony growth and density in relation to the vegetation according to Oneway-ANOVA test. *p≤ 0.5; **p≤ 0.01; ***p≤ 0.001; n.s.: not significant; n.i.: not investigated.

presence of reed	**no**		**yes**		**significance**
breeding sites					
number of sites	24		27		
total number of geese (BP)	1172	*N=12*	2989	*N=25*	
colony size (BP)	98 ± 155	*N=12*	120 ± 163	*N=25*	n.s.
colony growth (λ)	1.26 ± 0.25	*N=11*	1.16 ± 0.17	*N=21*	n.s.
density (geese/ha)	6.8 ± 8.7	*N=9*	2.8 ± 3.5	*N=21*	n.s.
brood-rearing sites					
number of sites	34		15		
total number of geese (BP)	2382	*N=26*	1066	*N=10*	
colony size (BP)	92 ± 150	*N=26*	107 ± 118	*N=10*	n.s.
colony growth (λ)	1.18 ± 0.17	*N=26*	1.20 ± 0.16	*N=13*	n.s.
density (geese/ha)	1.6 ± 2.5	*N=16*	0.8 ± 0.7	*N=7*	n.s.
non-breeding sites					
number of sites	34		4		
feeding on crops	**no**		**yes**		**significance**
brood-rearing sites					
number of sites	42		7		
total number of geese (BP)	2684	*N=31*	764	*N=5*	
colony size (BP)	87 ± 137	*N=31*	153 ± 161	*N=5*	n.s.
colony growth (λ)	1.17 ± 0.13	*N=33*	1.28 ± 0.27	*N=6*	n.s.
density (geese/ha)	1.1 ± 1.6	*N=20*	n.i.		n.i.
non-breeding sites					
number of sites	26		12		
habitat	**natural**		**artificial**		**significance**
breeding sites	51		0		
brood-rearing sites					
number of sites	17		29		
total number of geese (BP)	1103	*N=11*	2301	*N=23*	
colony size (BP)	100 ± 99	*N=11*	100 ± 162	*N=23*	n.s.
colony growth (λ)	1.14 ± 0.12	*N=13*	1.22 ± 0.18	*N=25*	n.s.
density (geese/ha)	2.0 ± 2.0	*N=8*	1.1 ± 2.2	*N=14*	n.s.
non-breeding sites					
number of sites	15		23		
vegetation height	**> 40cm**		**< 40cm**		**significance**
breeding sites					
number of sites	26		19		
total number of geese (BP)	2270	*N=22*	1668	*N=9*	
colony size (BP)	103 ± 123	*N=22*	185 ± 251	*N=9*	n.s.
colony growth (λ)	1.17 ± 0.23	*N=17*	1.22 ± 0.21	*N=9*	n.s.
density (geese/ha)	4.6 ± 6.8	*N=16*	3.3 ± 5.8	*N=7*	n.s.

b) Brood-rearing sites

Contrarily to the breeding sites, 60% of the brood-rearing sites are in artificial habitats, dominated by intensively used and short grazed pastures (Fig. 3.5, Tab. 3.4). 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 on potatoes, sugar beets, winter wheat, wheat, bulbs, corn, cabbage and oat. Colony size of geese feeding on crops is almost twice compared to geese not feeding on crops. Reed and willows occur more seldomly (Fig. 3.6) compared to breeding sites. Vegetation height is mostly between 11 and 40cm (Fig. 3.10).

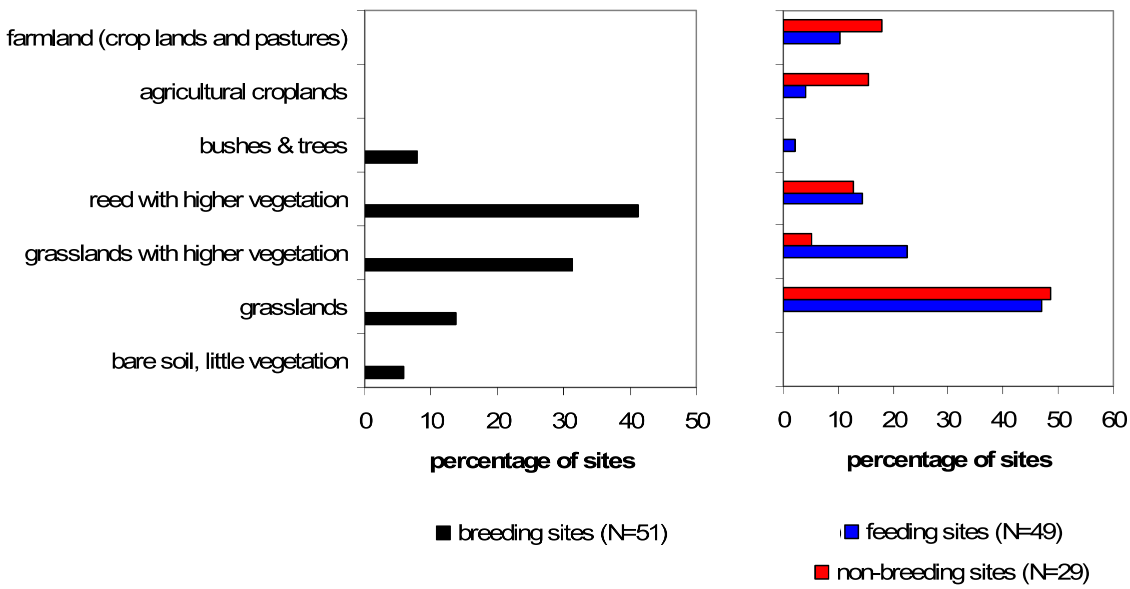

Fig. 3.5: Vegetation types at Greylag Goose sites. a) breeding sites (N=51), b) brood-rearing sites (N=49) and non-breeding sites (N=39). “higher vegetation“ can include reed and shrubs or trees.

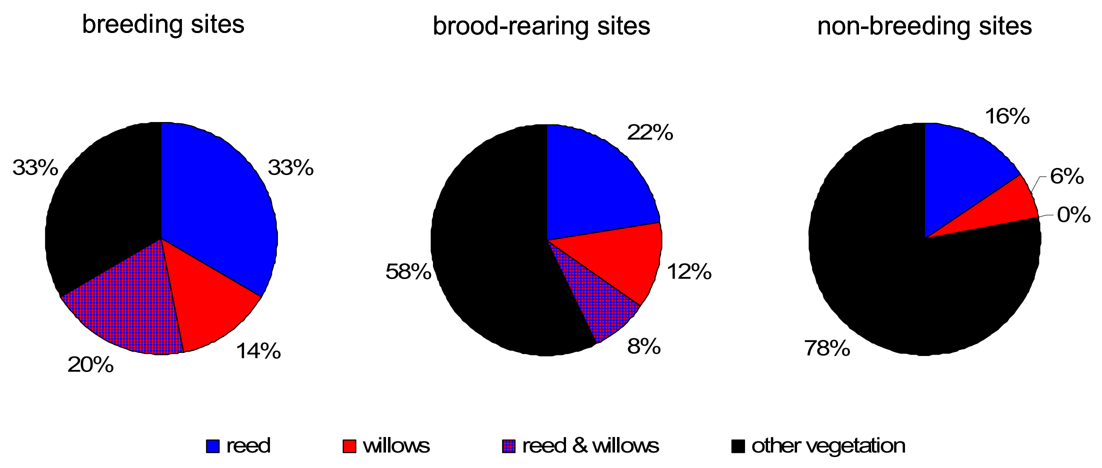

Fig. 3.6: Detail of vegetation: reed and willows as typical elements of Greylag Goose sites. Breeding site: N=51, brood-rearing sites N=49, non-breeding sites N= 38.

c) Non-breeding sites

Like the brood-rearing sites for families, the bigger part of the non-breeding sites are short grazed pastures in artificial habitats with a vegetation height between 11 and 40cm (Fig. 3.5, Tab. 3.4). Non-breeders feed on 30% of all sites on crops. Reed and willows occur much less on non-breeding sites compared to breeding and brood-rearing sites (about one quarter only, Fig. 3.6).

3.1.5 Management of the sites

a) Breeding sites

One half of the breeding sites is managed whereas most of them are on the mainland. Islands are only managed at 20%. Almost all managed sites are grazed by livestock, predominantly by cattle or a combination of cattle with horses or sheep (Fig. 3.9). Though sheep are grazing at only 4 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 which are grazed by a combination of cattle with horses or sheep (colony $growth_{cattle}$: λ=1.50 vs. colony $growth_{cattle\ \&\ other}$: λ= 1.14, $p \leq 0.01$, Tab. 3.6). Mowing occurs at 11 sites and mainly in combination with grazing. Only 2 sites are managed exclusively by mowing.

b) Brood-rearing sites

The majority of the brood-rearing sites are grazed. Sites which are additionally mown and fertilized are used most frequently. Mowing hardly ever occurs exclusively, but is commonly practised in combination with grazing and/or fertilization (Fig. 3.7).

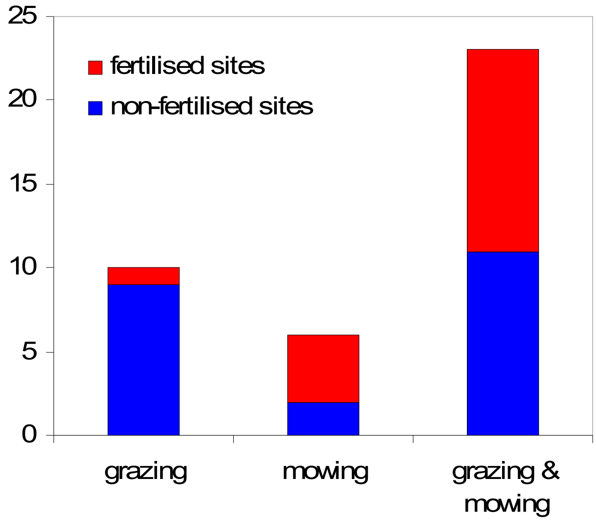

Fig. 3.7: Management at brood-rearing sites.

Colony growth and density on brood-rearing sites are significantly highest on sites that are both grazed and mown compared to sites with another combination of management (Tab.3.5, Fig. 3.8).

Tab.3.5: Number of brood-rearing and non-breeding sites, total number of geese, colony size, colony growth and density in relation to management according to Oneway-ANOVA test. *p≤ 0.5; **p≤ 0.01; ***p≤ 0.001; n.s.: not siginficant; n.i.: not investigated; a,b: subgroups according to post-hoc test Tukey-test.

management	grazing			mowing & fertilisation			grazing, mowing & fertilisation			grazing & mowing			significance
brood-rearing sites													
number of sites	9			4			12			11			
total number of geese (BP)	502	*N=4*		99	*N=4*		610	*N=11*		972	*N=9*		
colony size (BP)	126 ± 133	*N=4*		25 ± 16	*N=4*		55 ± 71	*N=11*		108 ± 90	*N=9*		n.s.
colony growth (λ)	1.11 ± 0.1	*N=7*	a	1.32 ± 0.04	*N=4*	a	1.13 ± 0.13	*N=10*	a	1.34 ± 0.16	*N=10*	b	*
density (geese/ha)	n.i.			0.3 ± 0.1	*N=4*		0.7 ± 1.5	*N=5*		2.4 ± 2.9	*N=9*		*
non-breeding sites													
number of sites	7			4			10			4			

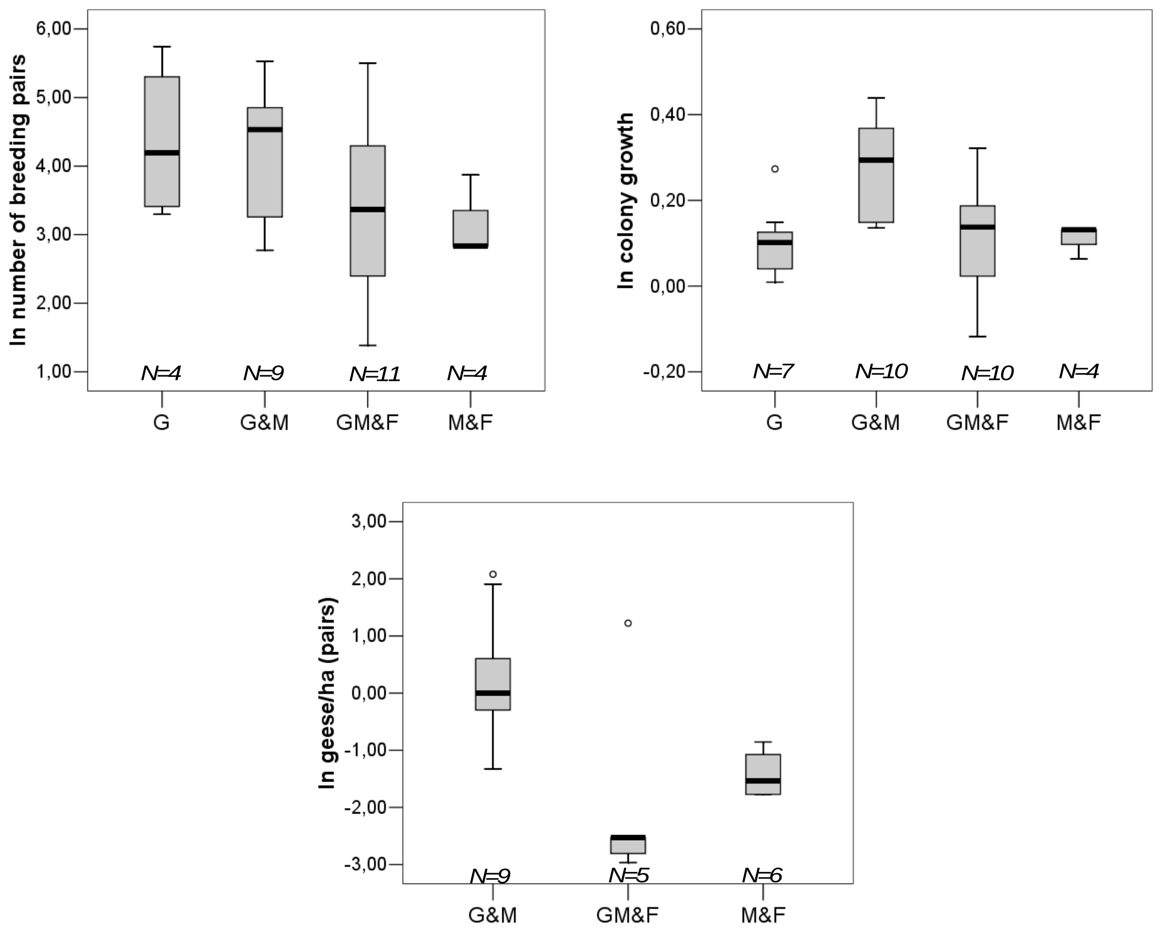

Fig. 3.8: Colony size, colony growth and density at brood-rearing sites in relation to management (G= grazing, M= mowing, F= fertilisation). Colony growth and density are statistically significantly highest on sites that are grazed and additionally mown (p≤ 0.05, according to Oneway-ANOVA test).

Grazing is always dominated by cattle (Fig. 3.10) and we find the same pattern of the livestock species distribution as on the breeding sites (Fig. 3.9). Colony size is significantly higher on sites grazed by a combination of cattle and sheep/horses (249 BP) than on sites only grazed by cattle (58 BP). One third of the brood-rearing sites is grazed year round. On most sites livestock is put out to pasture from April or May (Fig. 3.9). That way the geese find pastures with short vegetation heights for feeding after the young are hatched. Most geese feed on sites with a low grazing pressure (medium pressure: ≤0,5 animals/ha). Significant differences between low and medium grazing pressure (>0.5 - 2 animals/ha) are not found. Sites with a high grazing pressure (>2 animals/ha) are used less intensively and there colony growth is lowest (Tab. 3.6).

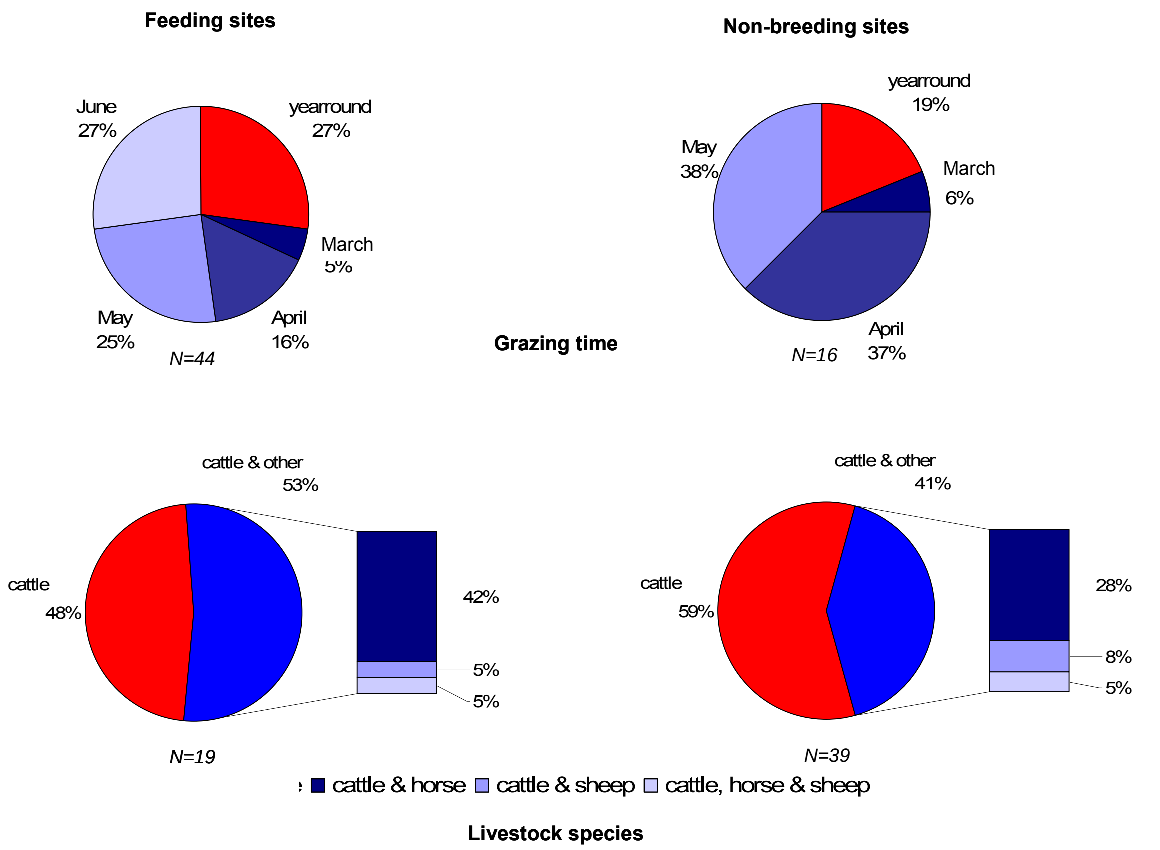

Fig. 3.9: Management by grazing. a) Species spectrum of livestock at breeding and brood-rearing sites and b) times where livestock is put out to pasture at brood-rearing sites (N=44) and non-breeding sites (N=16).

32 out of 44 brood-rearing sites are mown during April and October. Three quarter of the brood-rearing sites are only mown between April and June. Colony size on these sites is 2 times higher than on sites mown later in the season. A statistically significant difference in

population parameters is revealed when sites with different mowing frequencies are compared to each other: on sites that are mown 1-3 times during April and September density ha is significantly higher than on sites that are mown more ($density_{mown\ sites}$: 2.0 geese/ha vs. $density_{unmown\ sites}$: 0.01 geese/ha $p \leq 0.001$, N=18, Tab. 3.7).

One third of all brood-rearing sites are fertilised, predominantly by manure. Goose numbers and all population parameters show higher values on non-fertilised sites. In some of the breeding areas, fertilisation occurs naturally due to nutrient rich water of the rivers in the surroundings (e.g. Hellegatsplaten).

Fig. 3.10: Vegetation and management on brood-rearing sites. Left: Typical vegetation of grass with eutrophic vegetation. Vegetation height is 11.40cm (photo: B. Voslamber). Right: Cattle grazing and vegetation type “grasslands with higher vegetation” (Groot Eiland, photo: N. Feige).

About half of the brood-rearing sites are grazed by deer. Grazing pressure by deer is unknown, but likely lower than that of domestic animals. It is doubtful whether this has an important influence on the geese. The actual influence of natural grazing by deer, hare or other herbivores is principally unknown. Thus, it is not further considered.

c) Non-breeding sites

The management of the non-breeding sites is similar to that of the brood-rearing sites. Differences are in the use of fertiliser: A higher number of fertilised sites and the more frequent use of artificial fertiliser on those 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 less pastures with year-round livestock grazing.

Tab. 3.6: Number of breeding, brood-rearing and non-breeding sites, total number of geese, colony size, colony growth and density in relation to livestock grazing according to Oneway-ANOVA test. *$p \leq 0.5$; **$p \leq 0.01$; ***$p \leq 0.001$; n.s.: not significant; n.i.: not investigated.

management by livestock grazing	**no**		**yes**		**significance**
breeding sites					
number of sites	28		23		
total number of geese (BP)	1619	*N=20*	2542	*N=17*	
colony size (BP)	81 ± 115	*N=20*	150 ± 196	*N=17*	n.s.
colony growth (λ)	1.15 ± 0.29	*N=18*	1.26 ± 0.22	*N=14*	n.s.
density (geese/ha)	4.4 ± 6.2	*N=14*	3.8 ± 5.6	*N=14*	n.s.
brood-rearing sites					
number of sites	11		38		
total number of geese (BP)	189	*N=7*	3259	*N=29*	
colony size (BP)	27 ± 12	*N=7*	112 ± 152	*N=29*	n.s.
colony growth (λ)	1.15 ± 0.15	*N=11*	1.20 ± 0.17	*N=28*	n.s.
density (geese/ha)	0.5 ± 0.5	*N=5*	1.6 ± 2.3	*N=18*	n.s.
non-breeding sites					
number of sites	9		30		

grazing by different livestock species	**cattle**		**cattle & other**		**significance**
breeding sites					
number of sites	9		10		
total number of geese (BP)	1056	*N=5*	1330	*N=8*	
colony size (BP)	211 ± 204	*N=5*	166 ± 231	*N=8*	n.s.
colony growth (λ)	1.50 ± 0.32	*N=3*	1.14 ± 0.11	*N=9*	**
density (geese/ha)	5.3 ± 7.3	*N=5*	3.4 ± 5.7	*N=6*	n.s.
brood-rearing sites					
number of sites	21		15		
total number of geese (BP)	1044	*N=18*	2162	*N=9*	
colony size (BP)	58 ± 80	*N=18*	240 ± 192	*N=9*	***
colony growth (λ)	1.20 ± 0.18	*N=15*	1.20 ± 0.17	*N=11*	n.s.
density (geese/ha)	1.4 ± 2.4	*N=11*	2.2 ± 2.4	*N=6*	n.s.
non-breeding sites					
number of sites	18		12		

grazing by livestock yearround	**no**		**yes**		**significance**
brood-rearing sites					
number of sites	22		12		
total number of geese (BP)	1903	*N=20*	1028	*N=7*	
colony size (BP)	95 ± 165	*N=20*	147 ± 101	*N=7*	n.s.
colony growth (λ)	1.18 ± 0.16	*N=16*	1.22 ± 0.20	*N=10*	n.s.
density (geese/ha)	1.8 ± 2.7	*N=13*	1.5 ± 1.3	*N=4*	n.s.
non-breeding sites					
number of sites	19		4		

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

Tab. 3.7: Number of breeding, brood-rearing and non-breeding sites, total number of geese, colony size, colony growth and density in relation to mowing and fertilisation according to Oneway-ANOVA test. *p≤ 0.5; **p≤ 0.01; ***p≤ 0.001; n.s.: not significant.

management by mowing	**no**		**yes**		**significance**
breeding sites					
number of sites	43		8		
total number of geese (BP)	2861	*N=30*	1300	*N=7*	
colony size (BP)	95 ± 132	*N=30*	186 ± 243	*N=7*	n.s.
colony growth (λ)	1.21 ± 0.23	*N=26*	1.16 ± 0.08	*N=6*	n.s.
density (geese/ha)	4.3 ± 5.9	*N=22*	3.3 ± 5.8	*N=6*	n.s.
brood-rearing sites					
number of sites	12		32		
total number of geese (BP)	547	*N=5*	1759	*N=27*	
colony size (BP)	109 ± 120	*N=5*	65 ± 75	*N=27*	n.s.
colony growth (λ)	1.09 ± 0.10	*N=9*	1.23 ± 0.17	*N=28*	n.s.
density (geese/ha)	n.i.		1.4 ± 2.2	*N=20*	n.s.
non-breeding sites					
number of sites	15		20		
mowing frequencies (April - October)	**1 - 3x**		**4 - 7x**		**significance**
brood-rearing sites					
number of sites	18		8		
total number of geese (BP)	1179	*N=16*	354	*N=7*	
colony size (BP)	74 ± 78	*N=16*	51 ± 86	*N=7*	n.s.
colony growth (λ)	1.23 ± 0.16	*N=17*	1.17 ± 0.21	*N=6*	n.s.
density (geese/ha)	2.0 ± 2.6	*N=13*	0.1 ± 0.1	*N=5*	***
non-breeding sites					
number of sites	16		0		
time of mowing	**April-June**		**July-October**		**significance**
brood-rearing sites					
number of sites	20		6		
total number of geese (BP)	953	*N=18*	580	*N=5*	
colony size (BP)	953 ± 53	*N=18*	116 ± *124*	*N=5*	n.s.
colony growth (λ)	1.19 ± 0.17	*N=17*	1.23 ± *0.11*	*N=6*	n.s.
density (geese/ha)	22.4 ± 1.6	*N=14*	0.901 ± *0.4*	*N=4*	n.s.
non-breeding sites					
number of sites	14		3		
grazing by livestock yearround	**no**		**yes**		**significance**
brood-rearing sites					
number of sites	22		12		
total number of geese (BP)	1903	*N=20*	1028	*N=7*	
colony size (BP)	95 ± 165	*N=20*	147 ± 101	*N=7*	n.s.
colony growth (λ)	1.18 ± 0.16	*N=16*	1.22 ± 0.20	*N=10*	n.s.
density (geese/ha)	1.8 ± 2.7	*N=13*	1.5 ± 1.3	*N=4*	n.s.
non-breeding sites					
number of sites	19		4		
management by fertilisation	**no**		**yes**		**significance**
brood-rearing sites					
number of sites	29		14		
total number of geese (BP)	2580	*N=17*	667	*N=13*	
colony size (BP)	93 ± 94	*N=17*	51 ± 102	*N=13*	*
colony growth (λ)	1.23 ± 0.18	*N=24*	1.11 ± 0.12	*N=11*	n.s.
density (geese/ha)	2.16 ± 2.58	*N=12*	0.52 ± 1.09	*N=9*	n.s.

3.1.6 Presence of predators

a) Breeding sites

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 (Tab. 3.8). However, colony growth, colony size and density are higher on sites without predation than on sites where predators occur and colony size is very close to significance. The breeding colony of Schiermonnikoog is the only one where predation most likely controls colony growth as none of the young is raised successfully. Predation on this site is assumed but the predator species is unknown.

The fox is the most frequent predator. Questionnaire respondents gave crows as the second most predator species, followed by raptors, large gulls (Herring Gull *Larus argentatus* and Greater black-backed Gull *Larus marinus*, rats, other small mammals. There are no significant differences in the population parameters between sites with a different predator species spectrum and a different predation pressure. Highest predation pressure by fox is known for the areas of Biesbosch and Braakman (89% and 75% of the nests are predated, respectively, Tab. 3.8). There is no relationship found between vegetation height and the presence of foxes at breeding sites (Fig. 3.11.).

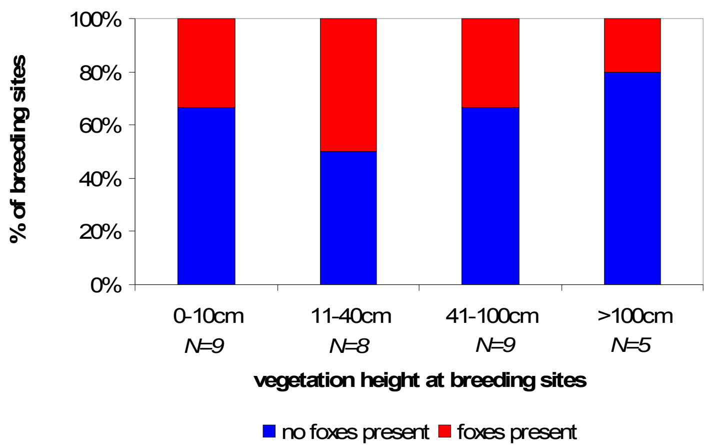

Fig. 3.11: Relationships between vegetation height and presence of foxes at breeding sites (0-10cm: *N=9*, 11-40cm: *N=9*, 41-100cm: *N=9*, >100cm: *N=14*).

On breeding islands, the part of sites where predators occur is 10% less than on the mainland (Fig. 3.12). The predator species spectrum is similar on islands and the mainland. In comparison, islands have 10% fewer sites influenced by predation than the mainland. Islands also have 20% more avian predators, but 20% less ground predators than mainland sites (and vice versa). “Mainland” includes here also sites in wetlands, outside of the seawall and on peninsulas. This takes into account that in the wetlands the short distances from the mainland to the islands can easily be covered by ground predators. A comparison between sites influenced by predation on islands and on the mainland reveals that colony growth and densities are not significantly different (colony $growth_{islands}$: 1.15 $\pm$ 0.22, *N=9*, colony $growth_{mainland}$: 1.18 $\pm$ 0.16, *N=16;* $density_{islands}$: 3.4 $\pm$ 4.3, *N=8*, colony $growth_{mainland}$: 2.8 $\pm$ 2.1, *N=15).* Only colony size shows a statistically significant difference *(*colony $size_{islands}$: 17 $\pm$ 16, *N=8*, colony $size_{mainland}$: 96 $\pm$ 108, *N=11,* $p \geq 0.01$*).* This, however, is more likely explained by the smaller sizes of the breeding sites on islands compared to the mainland (see 4.1.2.).

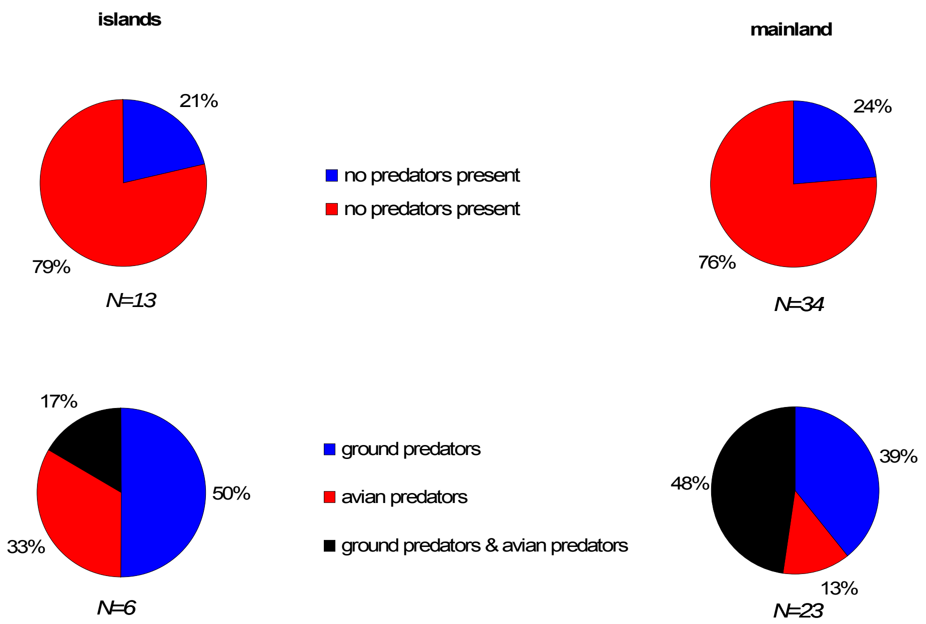

Fig. 3.12: Predator situation depending on the location on islands or on the mainland (mainland includes here also sites in wetlands, outside of the seawall and on peninsulas): above: presence of predators; bottom: predator species.

b) Brood-rearing sites

Predators are present on almost all brood-rearing sites. The predator species spectrum is similar to the breeding sites. Rats and other small mammals appear less frequently than on breeding sites. The fox is the main predator but instead of crows, raptors are second most frequent. Predation pressure is usually low: less than 20% of the geese (adults and chicks) are predated (Tab. 3.8).

c) Non-breeding sites

At non-breeding sites, predators are least frequently present compared to breeding and brood-rearing sites. Only at half of the sites predators appear. It seems that predation does not play any role as respondents – if at all – always gave a very low predation pressure of less than 10% or “a few geese”. At all sites foxes appear and only at a few sites birds are further predators (Tab. 3.8).

Tab.3.8: Number of breeding, brood-rearing and non-breeding sites, total number of geese, colony size, colony growth and density in relation to predation according to Oneway-ANOVA test. *p≤ 0.5; **p≤ 0.01; ***p≤ 0.001; n.s.: not significant; n.i.: not investigated.

predation	**no**		**yes**		**significance**
breeding sites					
number of sites	11		36		
total number of geese (BP)	1236	*N=10*	1581	*N=23*	
colony size (BP)	124 ± 170	*N=10*	69 ± 95	*N=23*	n.s.
colony growth (λ)	1.25 ± 0.18	*N=5*	1.17 ± 0.18	*N=25*	n.s.
density (geese/ha)	8.6 ±11.4	*N=5*	3.1 ± 3.5	*N=19*	n.s.
brood-rearing sites					
number of sites	8		38		
total number of geese (BP)	350	*N=6*	2541	*N=28*	
colony size (BP)	58 ± 49	*N=6*	91 ± 149	*N=28*	n.s.
colony growth (λ)	1.24 ± 0.19	*N=7*	1.18 ± 0.16	*N=30*	n.s.
density (geese/ha)	n.i.		1.1 ± 1.7	*N=19*	n.i.
non-breeding sites					
number of sites	15		15		
predation pressure	**< 20% of the nests/geese are predated**		**>20% of the nests/geese are predated**		**significance**
breeding sites					
number of sites	13		9		
total number of geese (BP)	840	*N=5*	240	*N=6*	
colony size (BP)	168 ± 159	*N=5*	40 ± 25	*N=6*	0.051
colony growth (λ)	1.15 ± 0.15	*N=7*	1.03 ± 0.10	*N=9*	n.s.
density (geese/ha)	6.7 ± 5.6	*N=4*	2.0 ± 1.7	*N=5*	0.053
brood-rearing sites					
number of sites	12		2		
total number of geese (BP)	1374	*N=12*	n.i.		
colony size (BP)	115 ± 118	*N=12*	n.i.		n.i.
colony growth (λ)	1.15 ± 0.04	*N=11*	n.i.		n.i.
density (geese/ha)	2.5 ± 2.7	*N=5*	n.i.		n.i.
non-breeding sites					
number of sites	7		0		
predation exclusively by fox	**no**		**yes**		**significance**
breeding sites					
number of sites	10		8		
total number of geese (BP)	287	*N=7*	520	*N=6*	
colony size (BP)	41 ± 35	*N=7*	87 ± 98	*N=6*	n.s.
colony growth (λ)	1.18 ± 0.22	*N=9*	1.20 ± 0.15	*N=5*	n.s.
density (geese/ha)	0.9 ± 0.7	*N=6*	4.1 ± 6.3	*N=5*	n.s.
brood-rearing sites					
number of sites	12		21		
total number of geese (BP)	1144	*N=12*	1359	*N=13*	
colony size (BP)	95 ± 126	*N=12*	105 ± 183	*N=13*	n.s.
colony growth (λ)	1.14 ± 0.14	*N=9*	1.19 ± 0.19	*N=16*	n.s.
density (geese/ha)	0.7 ± 0.5	*N=7*	1.7 ± 2.3	*N=9*	n.s.
non-breeding sites					
number of sites	3		11		

(Tab. 3.8, contin.)

predation by	avian predators		ground predators		avian & ground predators		significance
breeding sites							
number of sites	6		12		12		
total number of geese (BP)	246	*N=4*	611	*N=10*	724	*N=9*	
colony size (BP)	62 ± 84	*N=4*	61 ± 81	*N=10*	80 ± 121	*N=9*	n.s.
colony growth (λ)	1.17 ± 0.15	*N=5*	1.11 ± 0.18	*N=8*	1.20 ± 0.20	*N=12*	n.s.
density (geese/ha)	n.i.		3.5 ± 4.6	*N=9*	2.3 2.2	*N=8*	n.s.
brood-rearing sites							
number of sites	7		19		8		
total number of geese (BP)	604	*N=5*	659	*N=12*	1222	*N=7*	
colony size (BP)	121 ± 120	*N=5*	55 ± 40	*N=12*	175 ± 268	*N=7*	n.s.
colony growth (λ)	1.19 ± 0.10	*N=6*	1.19 ± 0.20	*N=15*	1.21 ± 0.12	*N=5*	n.s.
density (geese/ha)	n.i.		1.8 ± 2.4	*N=8*	0.7 ± 0.2	*N=4*	n.s.
non-breeding sites							
number of sites	0		11		3		

3.1.7 Human disturbance

a) Breeding sites

Human disturbance occurs on more than half of the breeding sites either never or at a maximum once a week. Colony growth and density decrease with increasing disturbance frequencies, but differences are not statistically significant (Tab. 3.11). Highest disturbance frequencies are found on the mainland compared to islands, peninsulas, wetlands and sites outside the seawall. Sites outside the seawall are the least frequently disturbed sites of all (Tab.3.10). On most of the sites, farmers, researchers and nature wardens are the main source of disturbance. 20% of all breeding sites are part of a recreation area and a few brood-rearing sites are exclusively visited for recreational purposes. At about 20% of the breeding sites, goose chasing takes place (mainly done by shooting of flares). Colony growth is statistically significant higher on sites without chasing.

There is no statistically significant relationship found between the population parameters and the different distances from breeding sites to buildings and settlements. The geese build their nest in close vicinity to buildings (Fig. 3.13) and breeding occurs at a minimal distance of 100m (Tab. 3.12).

Fig. 3.13: Nests in close vicinity to buildings (photo: B. Voslamber).

Disturbance by breeding control occurs on 9 breeding sites of 5 breeding areas. In these breeding areas special permission of breeding control is given to farmers to prevent goose damage. Colony size is significantly higher on sites with breeding control (198 BP) than on sites without breeding control (85 BP, $p \leq 0.05$). Also the density is 3 times higher on these sites (Tab. 3.9). These numbers show that breeding control is a practice in colonies where numbers of geese are very high from the beginning. It is mostly carried out by egg collecting, further methods are egg pricking and shaking. The number of manipulated nests are very high (between 60 an 100%). Nevertheless, there is no significant difference in colony growth between sites with and without breeding control. The manipulated colony of Groote Gat is one of the fastest growing ones of all investigated colonies (λ = 1,45), but the number of breeding pairs only amounts to 63. None of the manipulated colonies shows a negative growth. The number of sites might probably be higher since illegal breeding control at further sites is assumed. For this reason, breeding control is not further investigated and discussed within this study. Detailed investigations about breeding disturbance in Greylag Goose colonies in the Netherlands weres carried out by (HONDHORTS & VOORBERGEN, 2005, VAN DER JEUGD et al., 2006).

Tab. 3.9: Number of breeding sites, total number of geese, colony size, colony growth and density in relation to breeding disturbance by nest manipulation according to Oneway-ANOVA test. *p≤ 0.5; **p≤ 0.01; ***p≤ 0.001; n.s.: not significant.

breeding control	no		yes		significance
breeding sites					
number of sites	40		9		
total number of geese (BP)	2293	*N=27*	1781	*N=9*	
colony size (BP)	85 ± 125	*N=27*	198 ± 227	*N=9*	*
colony growth (λ)	1.21 ± 0.23	*N=24*	1.18 ± 0.15	*N=6*	n.s.
density (geese/ha)	7.7 ± 11.7	*N=23*	28.1 ± 46.9	*N=5*	n.s.

Tab. 3.10: Number of breeding sites in relation to overall disturbance frequency in relation to the location.

site location	frequency of disturbance never up to once a week	2 - 6 days per week	every day / whole day
island	10	5	3
mainland	8	6	5
peninsula	2	1	0
wetland	5	2	0
outsite of seawall	4	0	0

b) Brood-rearing sites

In contrast to breeding geese, the majority of the young families use sites which are disturbed more than once a week. Comparisons reveals significantly highest colony growth on sites where humans are present everyday ($p \leq 0.05$, Tab.3.13). This is connected with the fact, that the sites are farmlands and daily visited by farmers. The presence of farmers, therefore, are the main source of disturbance. At more than half of the sites farmers make use of chasing. The geese are mainly chased away by gas guns and flags or a combination of various chasing techniques. Often used for optical scaring are ropes with metal flares or colour plastic strips and other material which easily moves with the wind. Everyday chasing occurs at 20% of all brood-rearing sites, 70% of all sites are disturbed either never or at a maximum once a week. Significant effects in terms of the population parameters of geese which are chased away were not detected.

There is also no relationship between distances from brood-rearing sites to buildings and settlements and the population parameters. Families feed closer than 100m to a building (Tab. 3.12).

c) Non-breeding sites

At two thirds of the non-breeding sites human disturbance occurs. By this, non-breeding sites are the most frequently disturbed sites compared to breeding and brood-rearing sites. 35% of all non-breeding sites are part of a recreation area. Chasing occurs on more than half of the sites. It is done by the same methods like on brood-rearing sites with a similar frequency. Often chasing takes place on farmland where both, families and non breeders, graze. Also in non-breeders a pattern of site usage depending on the distances from the non-breeding sites to buildings and settlements cannot be detected.

Tab. 3.11: Number of breeding, brood-rearing and non-breeding sites, total number of geese, colony size, colony growth and density in relation disturbance according to Oneway-ANOVA test. *p≤ 0.5; **p≤ 0.01; ***p≤ 0.001; n.s.: not significant; n.i.: not investigated. "Human disturbance wa includes presence of man and chasing/breeding control". "Frequency of human disturbance" indicates the overall disturbance including both chasing and the presence of man.

chasing	**no**		**yes**		**significance**
breeding sites					
number of sites	36		15		
total number of geese (BP)	2146	*N=27*	2015	*N=10*	
colony size (BP)	79 ± 110	*N=27*	202 ± 232	*N=10*	n.s.
colony growth (λ)	1.24 ± 0.22	*N=22*	1.09 ± 0.14	*N=10*	*
density (geese/ha)	4.9 ± 6.7	*N=20*	2.1 ± 2.2	*N=8*	n.s.
brood-rearing sites					
number of sites	23		26		
total number of geese (BP)	2070	*N=18*	1378	*N=18*	
colony size (BP)	115 ± 168	*N=18*	77 ± 107	*N=18*	n.s.
colony growth (λ)	1.22 ± 0.16	*N=18*	1.16 ± 0.16	*N=21*	n.s.
density (geese/ha)	1.9 ± 2.5	*N=15*	0.4 ± 0.5	*N=8*	n.s.
non-breeding sites					
number of sites	18		21		

frequency of chasing	**never up to once a week**		**2 - 6 days per week**	**every day / whole day**		**significance**
breeding sites						
number of sites	41		3	7		
total number of geese (BP)	2714	*N=32*	n.i.	n.i.		
colony size (BP)	85 ± 117	*N=32*	n.i.	n.i.		n.i.
colony growth (λ)	1.23 ± 0.21	*N=25*	n.i.	1.03 ± 0.06	*N=6*	n.s.
density (geese/ha)	4.3 ± 6.1	*N=23*	n.i.	n.i.		n.i.
brood-rearing sites						
number of sites	31		3	9		
total number of geese (BP)	2364	*N=25*	n.i.	270	*N=3*	
colony size (BP)	95 ± 147	*N=25*	n.i.	90 ± 134	*N=3*	n.s.
colony growth (λ)	1.20 ± 0.16	*N=24*	n.i.	1.17 ± 0.22	*N=9*	n.s.
density (geese/ha)	1.6 ± 2.3	*N=18*	n.i.	n.i.		n.s.
non-breeding sites						
number of sites	23		6	6		

(Tab. 3.11, contin.)

frequency of human disturbance	never up to once a week		2 - 6 days per week		every day / whole day		significance
breeding sites							
number of sites	29		14		8		
total number of geese (BP)	2453	*N=31*	1037	*N=8*	671	*N=3*	
colony size (BP)	94 ± 127	*N=26*	130 ± 232	*N=8*	224 ± 199	N=3	n.s.
colony growth (λ)	1.23 ±0.22	*N=19*	1.18 ± 0.13	*N=6*	1.11 ± 0.20	N=7	n.s.
density (geese/ha)	4.1 ± 4.8	*N=19*	4.9 ± 8.2	*N=8*	n.i.		n.s.
brood-rearing sites							
number of sites	17		14		12		
total number of geese (BP)	1032	*N=15*	1462	*N=14*	453	*N=5*	
colony size (BP)	69 ± 79	*N=15*	133 ± 209	*N=11*	91 ± 95	*N=5*	n.s.
colony growth (λ)	1.23 ± 0.12	*N=12*	1.11 ± 0.13	*N=11*	1.21 ± 1.21	*N=12*	n.s.
density (geese/ha)	2.3 ± 2.6	*N=12*	0.54 ± 0.5	*N=7*	n.i.		n.s.
non-breeding sites							
number of sites	12		11		12		

disturbance frequency by presence of man	never up to once a week		2 - 6 days per week		every day / whole day		significance
breeding sites							
number of sites	36		12		3		
total number of geese (BP)	2531	*N=28*	959	*N=6*	671	*N=2*	
colony size (BP)	90 ± 123	*N=28*	160 ± 266	*N=6*	n.i.		n.s.
colony growth (λ)	1.20 ±0.22	*N=25*	1.12 ± 0.03	*N=5*	n.i.		n.s.
density (geese/ha)	3.9 ± 4.6	*N=21*	5.6 ± 9.6	*N=6*	n.i.		n.s.
brood-rearing sites							
number of sites	26		16		6		
total number of geese (BP)	1561	N=21	1704	N=13	n.i.		
colony size (BP)	74 ± 99	N=21	131 ± 197	N=13	n.i.		n.s.
colony growth (λ)	1.17 ± 0.13	N=19	1.12 ± 0.12	N=13	1.35 ± 0.24	N=6	*
density (geese/ha)	2.0 ± 2.5	N=14	0.5 ± 0.5	N=9	n.i.		n.s.
non-breeding sites							
number of sites	18		10		11		

Tab. 3.12: Number of breeding, brood-rearing and non-breeding sites, total number of geese, colony size, colony growth and density in relation to distances to buildings and settlements according to Oneway-ANOVA test. *$p \leq 0.5$; **$p \leq 0.01$; ***$p \leq 0.001$; n.s.: not significant; n.i.: not investigated.

distance to closest building	< 250m		250 - 999m		≥ 1000m		significance
breeding sites							
number of sites	11		16		22		
total number of geese (BP)	666	*N=7*	2277	*N=16*	1218	*N=14*	
colony size (BP)	95 ± 88	*N=7*	142 ± 210	*N=16*	87 ± 115	*N=14*	n.s.
colony growth (λ)	1.18 ± 0.19	*N=10*	1.27 ± 0.17	*N=8*	1.20 ± 0.25	*N=12*	n.s.
density (geese/ha)	1.1 ± 1.0	*N=6*	5.7 ± 8.3	*N=12*	3.9 ± 2.8	*N=10*	n.s.
brood-rearing sites							
number of sites	16		18		13		
total number of geese (BP)	576	*N=12*	1291	*N=12*	881	*N=11*	
colony size (BP)	48 ± 45	*N=12*	108 ± 130	*N=12*	80 ± 91	*N=11*	n.s.
colony growth (λ)	1.16 ± 0.11	*N=13*	1.18 ± 0.20	*N=13*	1.23 ± 0.17	*N=12*	n.s.
density (geese/ha)	2.0 ± 2.2	*N=7*	2.1 ± 3.2	*N=6*	0.5 ± 0.5	*N=9*	n.s.
non-breeding sites							
number of sites	12		10		8		

(Tab. 3.12, contin.)

distance to closest settlement	< 250m		250 - 999m		≥ 1000m		significance
breeding sites							
number of sites	1		13		37		
total number of geese (BP)	n.i.		1418	*N=13*	2736	*N=23*	
colony size (BP)	n.i.		109 ± 192	*N=13*	119 ± 144	*N=23*	n.s.
colony growth (λ)	n.i.		1.22 ± 0.17	*N=8*	1.17 ± 0.21	*N=23*	n.s.
density (geese/ha)	n.i.		5.0 ± 8.4	*N=10*	3.8 ± 4.1	*N=17*	n.s.
brood-rearing sites							
number of sites	14		20		13		
total number of geese (BP)	575	*N=10*	1527	*N=14*	646	*N=11*	
colony size (BP)	58 ± 74	*N=10*	109 ± 120	*N=14*	59 ± 73	*N=11*	n.s.
colony growth (λ)	1.15 ± 0.10	*N=12*	1.18 ± 0.20	*N=14*	1.24 ± 0.18	*N=12*	n.s.
density (geese/ha)	1.0 ±0.7	*N=4*	2.6 ± 3.0	*N=9*	0.4 ± 0.4	*N=9*	n.s.
non-breeding sites							
number of sites	2		7		22		

3.1.8 Nature conservation

a) Breeding sites

Almost all breeding sites are protected. The majority of the sites are protected as nature reserves, some sites are part of a National Park. Often the whole breeding area or a large part of it is protected. At a lot of sites, special regulations are in action even if the site is not protected (Tab. 3.13). Colony growth is significantly lower at breeding sites with special regulations (colony growth $_{\text{without special regulation}}$: λ=1.36 vs. colony growth $_{\text{special regulation}}$: λ=1,13). Principally, these special regulations are “not accessible for the public” “breeding bird management” and “nature development”. Above all, geese breed on sites with special regulation which are managed for breeding birds. A comparison between sites “not accessible to the public” and “nature development” reveals a significant higher colony growth at the latter ones.

b) Brood-rearing sites

Also the majority of the brood-rearing sites is located in protected areas. The remaining sites are mostly intensively managed farmland which is given no protection status. Density is significantly higher on protected sites than on non-protected sites (density $_{\text{protected sites}}$: 1.2 geese/ha vs. density $_{\text{non-protected sites}}$: 0.2 geese/ha, $p \leq 0.5$). At more than half of the brood-rearing sites special regulations are in action, but significant differences in population parameters between sites with and without special regulations are not found. Most of the brood-rearing sites are not accessible for the public and/or breeding bird management is applied to (Tab. 3.13).

c) Non-breeding sites

The majority of the non-breeding sites is protected. Special regulation are in action at about half of the sites wherein “not accessible for the public” predominates (Tab. 3.13).

Tab. 3.13: Number of breeding, brood-rearing and non-breeding sites, total number of geese, colony size, colony growth and density in relation to nature conservation according to Oneway-ANOVA test. *p≤ 0.5; **p≤ 0.01; ***p≤ 0.001; n.s.: not significant; n.i.: not investigated.

within nature reserve	no		yes		significance
breeding sites					
number of sites	4		46		
total number of geese (BP)	312	*N=4*	3834	*N=32*	
colony size (BP)	78 ± 137	*N=4*	120 ± 164	*N=32*	n.s.
colony growth (λ)	n.i.		n.i.		n.i.
density (geese/ha)	n.i.		n.i.		n.i.
brood-rearing sites					
number of sites	12		36		
total number of geese (BP)	531	*N=10*	2890	*N=25*	
colony size (BP)	53 ± 75	*N=10*	116 ± 59	*N=25*	n.s.
colony growth (λ)	1.19 ± 0.19	*N=12*	1.19 ± 0.15	*N=26*	n.s.
density (geese/ha)	0.2 ± 0.2	*N=5*	1.2 ± 2.3	*N=18*	**
non-breeding sites					
number of sites	7		32		

implementation of special regulations	no		yes		
breeding sites					
number of sites	14		30		
total number of geese (BP)	1440	*N=11*	2412	*N=19*	
colony size (BP)	131 ± 166	*N=11*	127 ± 180	*N=19*	n.s.
colony growth (λ)	1.36 ± 0.25	*N=8*	1.13 ± 0.16	*N=21*	*
density (geese/ha)	5.9 ± 6.8	*N=9*	3.8 ± 6.2	*N=15*	n.s.
brood-rearing sites					
number of sites	15		22		
total number of geese (BP)	883	*N=13*	1764	*N=16*	
colony size (BP)	68 ± 80	*N=13*	110 ± 176	*N=16*	n.s.
colony growth (λ)	1.18 ± 0.15	*N=14*	1.20 ± 0.17	*N=16*	n.s.
density (geese/ha)	2.6 ± 3.7	*N=6*	0.9 ± 1.0	*N=11*	n.s.
non-breeding sites					
number of sites	16		18		

type of special regulation	not accessible for the public		breeding bird management		nature development		not accessible for the public & breeding bird management	significance
breeding sites								
number of sites	9		6		6		8	
total number of geese (BP)	196	*N=4*	1174	*N=6*	590	*N=6*	n.i.	
colony size (BP)	49 ± 23	*N=4*	196 ± 270	*N=6*	98 ± 115	*N=6*	n.i.	*n.s.*
colony growth (λ)	1.05 ± 0.05	*N=9*	n.i.		1.13 ± 0.25	*N=6*	n.i.	*
density (geese/ha)	n.i.		1.6 ± 1.8	*N=5*	1.8 ± 2.3	*N=4*	n.i.	*n.s.*
brood-rearing sites								
number of sites	6		4		5		4	
non-breeding sites								
number of sites	6		3		3		3	

3.1.9 Site conversion and changes during the past

a) Breeding sites

Out of 47 sites, at 27 sites habitat conversion took part: a) farmland was designated as a protected area with legal restraints of a decreased management or the application of a special breeding bird management, b) wetlands were drained and c) rivers and coastal areas were embanked (Tab.3.14). The habitat conversion took part either shortly before the geese started using the site or after a colony was established. On sites which were converted Colony growth is higher compared to sites without any conversion.

b) Brood-rearing sites

In contrast, only 30% of the brood-rearing sites were converted from farmland into a protected area, drained or embanked. Colony size is statistically significantly lower on drained or embanked sites compared to sites that were not converted (colony $size_{drained/embanked\ sites}$: 112 pairs vs. colony growth $_{non\ converted\ sites}$: 89 pairs, N=27, $p \leq 0.05$, Tab.3.14).

c) Non-breeding sites

Information for non-breeding sites were too scarce to analyse.

Tab. 3.14: Number of breeding, brood-rearing and non-breeding sites, total number of geese, colony size, colony growth and density in relation to nature site conversion according to Oneway-ANOVA test. *p≤ 0.5; **p≤ 0.01; ***p≤ 0.001; n.s.: not significant; n.i.: not investigated.

conversion of the site	none		farmland declared as protected area		drained or embanked		farmland declared as protected area & drained		significance
breeding sites									
number of sites	20		13		10		4		
total number of geese (BP)	1988	*N=15*	1391	*N=10*	515	*N=4*	132	*N=4*	
colony size (BP)	139 ± 192	*N=15*	139 ± 151	*N=10*	129 ± 177	*N=4*	33 ± 33	*N=4*	n.s.
colony growth (λ)	1.12 ± 0.16	*N=13*	1.20 ± 0.26	*N=9*	1.30 ± 0.12	*N=4*	1.32 ± 0.27	*N=4*	n.s.
density (geese/ha)	3.1 ± 4.4	*N=11*	4.5 ± 5.6	*N=8*	n.i.		n.i.		n.s.
brood-rearing sites									
number of sites	27		3		9		0		
total number of geese (BP)	2457	*N=22*	442	*N=3*	89	*N=5*	0		
colony size (BP)	112 ± 163	*N=22*	n.i.		89 ± 12	*N=5*	n.i.		*
colony growth (λ)	1.21 ± 0.16	*N=21*	n.i.		1.13 ± 0.12	*N=8*	n.i.		n.s.
density (geese/ha)	1.3 ± 2.1	*N=14*	n.i.		n.i.		n.i.		n.i.
non-breeding sites									
n.i.									

Only little information about changes in management, predation situation or human activities was available for the time period prior to goose establishment or colony growth. As far as the few data show, there were no particular changes concerning the management, predation or disturbance during the last 45 years that gave rise to the establishment of breeding colonies. Statistical analyses could not be conducted.

3.1.10 Multivariate linear model

The multivariate linear model reveals that management has a high impact on the site use in geese (Tab.3.15). 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, $p\leq 0.01$), the type of management explains colony growth (R^2= 0.621, $p\leq 0.001$) and mowing frequencies affect density (R^2= 0.623, $p\leq 0.05$). The livestock species spectrum also influences most strongly colony growth at breeding sites (R^2 =0.591, $p\leq 0.05$). Only for colony size at breeding sites another habitat character than management plays a role: the location (mainland versus islands and wetlands) plays the most important role (R^2 =0.401, $p\leq 0.01$). Density at breeding sites was not included into the multivariate linear model since the usage of the variable “distance from the breeding island to the mainland” depends on the location, and “location” was the only habitat character that showed significance within the Oneway-ANOVA analyses.

Tab. 3.15: Multivariate linear model: overview about statistically significant habitat characters. All habitat characters of which revealed significance according to the Oneway-ANOVA analyses are listed and indicated by the p-value (*$p\leq 0.5$; **$p\leq 0.01$; ***$p\leq 0.001$). R^2 indicates the habitat character showing highest significance according to the stepwise multivariate linear model. Density on breeding sites was not included into the multivariate linear model.

	breeding site	brood-rearing sites
colony size (pairs)	location * (R=0.401, p< 0.01) distance from breeding island to mainland * breeding control *	management: grazing by livestock species *** (R=0.642, p< 0.01) fertilisation * conversion of site (none or drainage) *
colony growth (λ)	management: grazing by livestock species ** (R=0.591, p< 0.05) chasing* special nature protection regulations* type of nature protection regulations*	type of management (mowing, grazing, fertilisation)* (R=0.621, p< 0.001) frequency of disturbance by presence of man *
density (geese/ha)	location of feeding site: same site as breeding site or adjacent **	mowing frequency *** (R=0.623, p< 0.05) location in nature reserve ** type of management (mowing, grazing, fertilisation)*

3.2. Barnacle Goose

3.2.1 Present distribution of Barnacle Goose breeding areas outside of Russia

a) Estonia

In Estonia, the first Barnacle Goose pair started to breed in 1981 on Papilaid Islet. None of the first breeders was ringed. LEITO (1996) expected, therefore, that the Estonian breeding birds originate from migrating geese of the Barents Sea population. The breeding numbers continuously increased until 1999 (180 BP). Recently, breeding numbers are declining (Fig.3.22). In 2005 113 pairs were counted (LEITO & TRUU, 2004). Up to 21 breeding sites were confirmed in 2002 (Fig. A.1). In 2005, only 3 breeding areas with at least 4 breeding pairs within the last 4 consecutive years were known (Fig.3.14, Fig.3.17). All these sites are located on small offshore islands (between 2 and 5,5 ha in sizes) along the coast of Saaremaa Island which traditionally is the most important Barnacle Goose breeding area. (LEITO, 1996) gives detailed descriptions about the development of breeding numbers and habitat descriptions of breeding areas in Estonia.

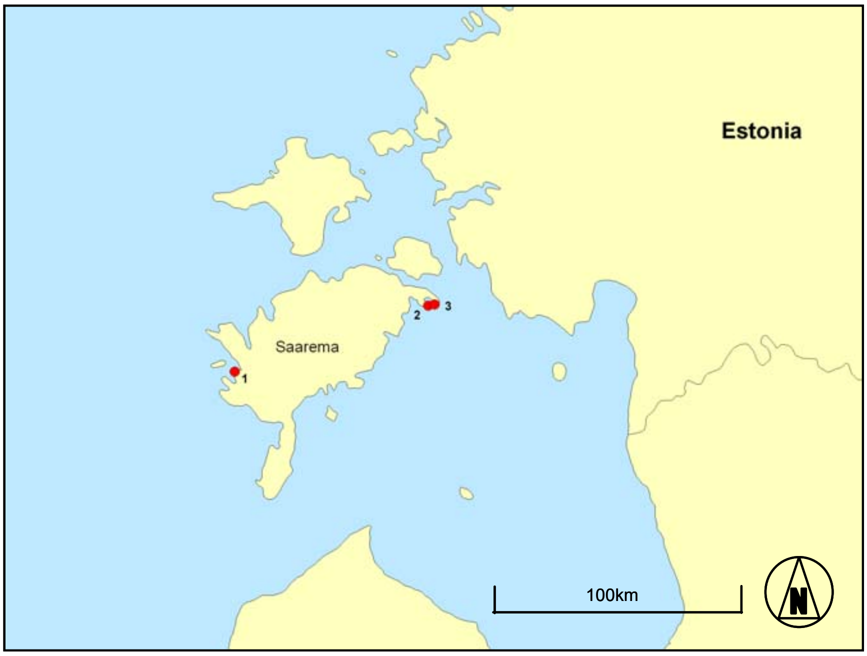

Fig.3.14: Breeding areas in 2005 and study sites of Barnacle Geese in Estonia. 1: Telve, 2: Pihlalaid, 3: Tuumalaid.

b) Finland

The first pair of Barnacle Geese was breeding in the early 1980’s on the Inkoo Archipelago. Ten years later already 18 breeding sites were confirmed and breeding pairs numbered to more than 30 in 1995 (LEITO, 1996). The breeding sites are in close vicinity to the Estonian breeding sites. According to the breeding bird census, in 2006 49 confirmed breeding sites, 2 sites that are very likely and another 28 sites that are only possibly breeding sites were recorded. The main breeding population is in the surroundings of the cities of Helsinki and Turku. An unknown part of the Finnish breeding population originates from zoos in Skansen in Stockholm and Korkeasaari in Helsinki. Also the colony of Lake Vesijärvi near the city of Lahti is not of natural origin. A part of the parent birds have been raised in captivity. After these birds were released to nature they started to breed. However, it seems quite clear that birds born in northern Russia joined the Finnish breeding population (VALKAMA, personal communication).

c) Sweden

In 1971 the first pair of Barnacle Geese started to breed outside from the traditional arctic breeding grounds in Russia. This first breeding site was Laus Holmar, a small off-shore island at the coast of the Swedish Island Gotland. In 1982, two colonies established on the island of Öland in Käreholm and Sillgrund. It is assumed that the founders of the colony on Laus Holmar originated from the Arctic Russian population as the coastal areas around the Baltic Sea have been staging areas in spring and autumn for at least one century (FORSLUND & LARSSON, 1991, LARSSON et al., 1988, LARSSON & VAN DER JEUGD, 1998). Until 2002 the breeding number of Gotland and Öland increased (Fig. 3.222). In 2005, the total numbers amounted to 750 on Öland and 4390 on Gotland and 21 breeding areas are known on these to islands (Fig. 3.15. Fig. 3.17). All breeding sites are situated on small islands mainly off the east coast of Gotland.

BENGTSSON (2007) gives an actual review about breeding Barnacle Geese in the whole country. NILSSON (pers. comm.) estimates the total number of breeding pairs in Sweden between 6500 and 7500.

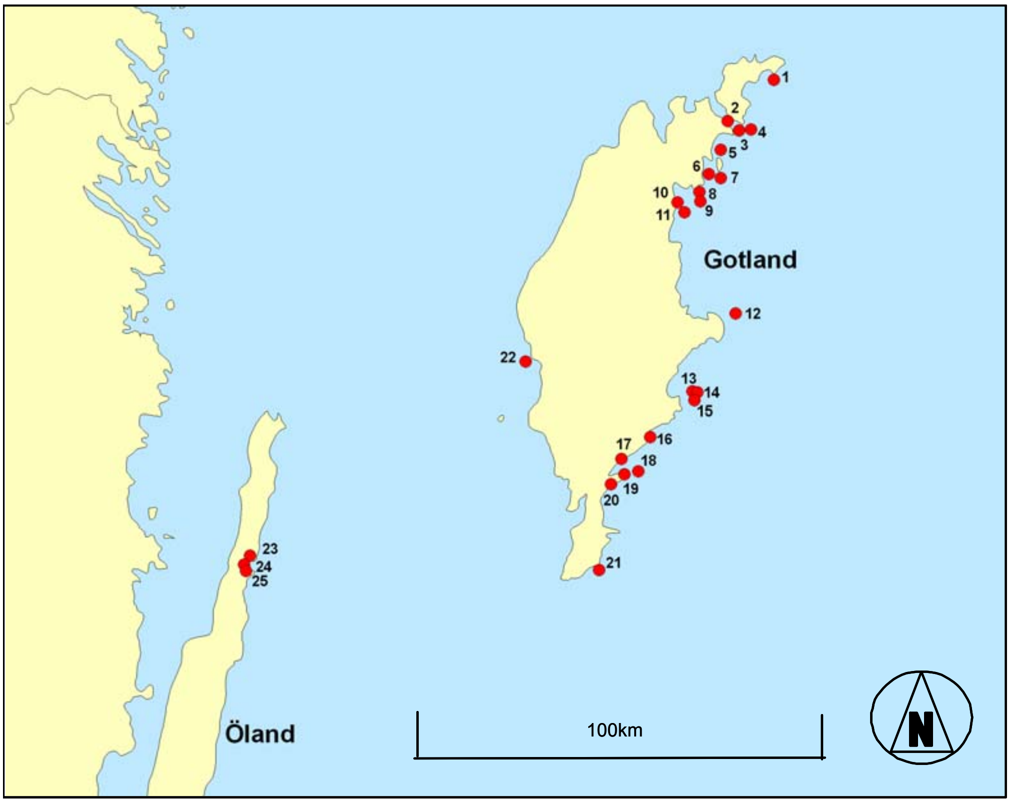

Fig. 3.15: Breeding areas in 2005 and study sites of Barnacle Geese in Sweden.
1: Avagrunn, 2: not investigated , 3: Bunge aur , 4: Dämba Misslauper , 5: Skenholmen, 6: Fjaugen and Klasen , 7: Grauten , 8: not investigated , 9: not investigated , 10: Grunnet , 11: not investigated , 12: Östergarnsholm, 13: Laus holmar, Skarpholmen, 14: Laus holmar, Gräsholmen, 15: Laus holmar, Storholmen, 16: Getorskär , 17: Sigdesholm, 18: Grötlingboudd, Ytterholmen, 19: Grötlingboudd, Koggen, 20: Grötlingboudd, Petsarvegrunn, 21: Heligholmen, 22: Västergarns utholme, 23: Sillgrund , 24: Kåreholm 25: Marskär

d) Denmark

In Denmark there is only one Barnacle Goose breeding area: the island of Saltholm (Fig. 3.16, Fig. 3.17). The breeding colony established in 1992 and probably has its origin in the population in Malmö (Sweden), only less than 20 km away from Saltholm cross open water. Some of the geese have metal and colour rings. Especially the colour rings look "homemade" like rings used on domestic wildfowl (FINK, pers. comm.). It is assumed that the colony originates from feral birds. Number of breeding pairs increased very rapidly and numbered 504 in 2005 (Fig. 3.22). The geese started to colonise the island from the south and expended their breeding range every year a bit northwards (MORTENSEN, pers. comm.). Additionally, up to 3.000 non-breeding Barnacle Geese stay on the island during summer (FINK, pers. comm.).

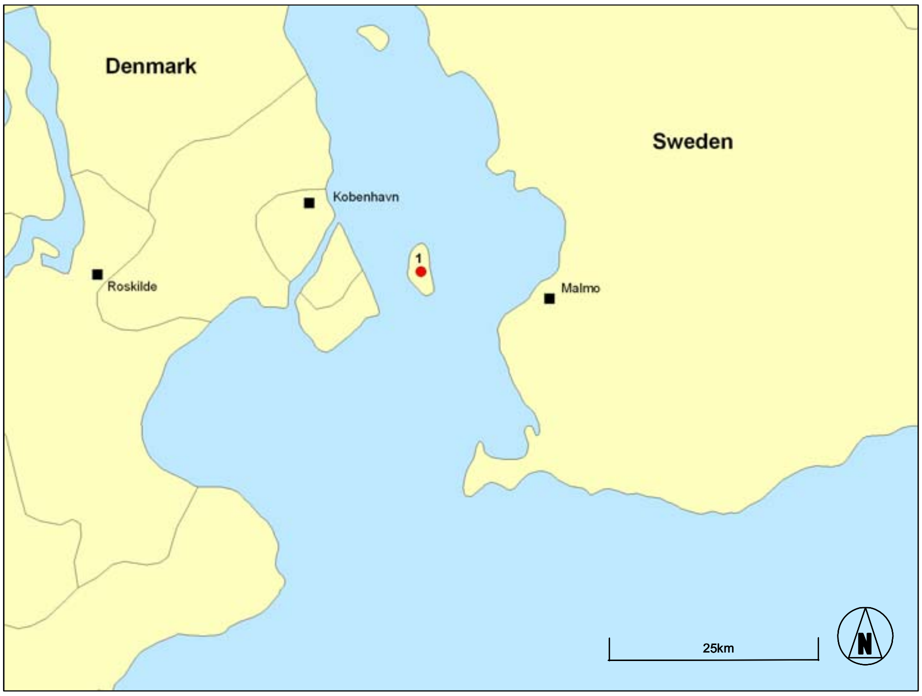

Fig. 3.16: Breeding area in 2005 and study site of Barnacle Geese in Denmark. 1.= Saltholm.

Fig 3.17: Breeding areas in the Baltic region. Top: breeding sites, left: on rather bare soil (Sweden, photo: N. Feige), right: in the shelter of higher vegetation and between trees (Estonia, photo: A. Leito); bottom: brood-rearing sites, left: Denmark (photo: J. Kahlert), right: Sweden (photo: N. Feige). Both sites are managed by livestock grazing.

e) Germany

The first German breeding site was colonised in 1988 on the island Ruhlebener Warder in the lake Großer Plöner See. None of the first German breeding birds was ringed so it is likely that the first breeding colonies originate from the Baltic population (KOOP, 1998). 21 breeding areas were confirmed until 2005 (Fig 3.18. Fig. 3.21). In 2005, numbers of breeding pairs in Germany amounted to 184 (Fig 3.22). The breeding site of the Ruhlebener Warder is the only one close to the Baltic. All other breeding sites are situated along the Wadden Sea coast of Schleswig-Holstein and in Lower Saxony, except for one breeding area inland in the Lower Rhine area. Detailed descriptions of the development of the breeding colonies and habitat use at Hatzumer Sand and Ruhlebener Warder are available at (KRUCKENBERG & HASSE, 2004, LUDWICHOWSKI & BRÄGER, 2003), respectively.

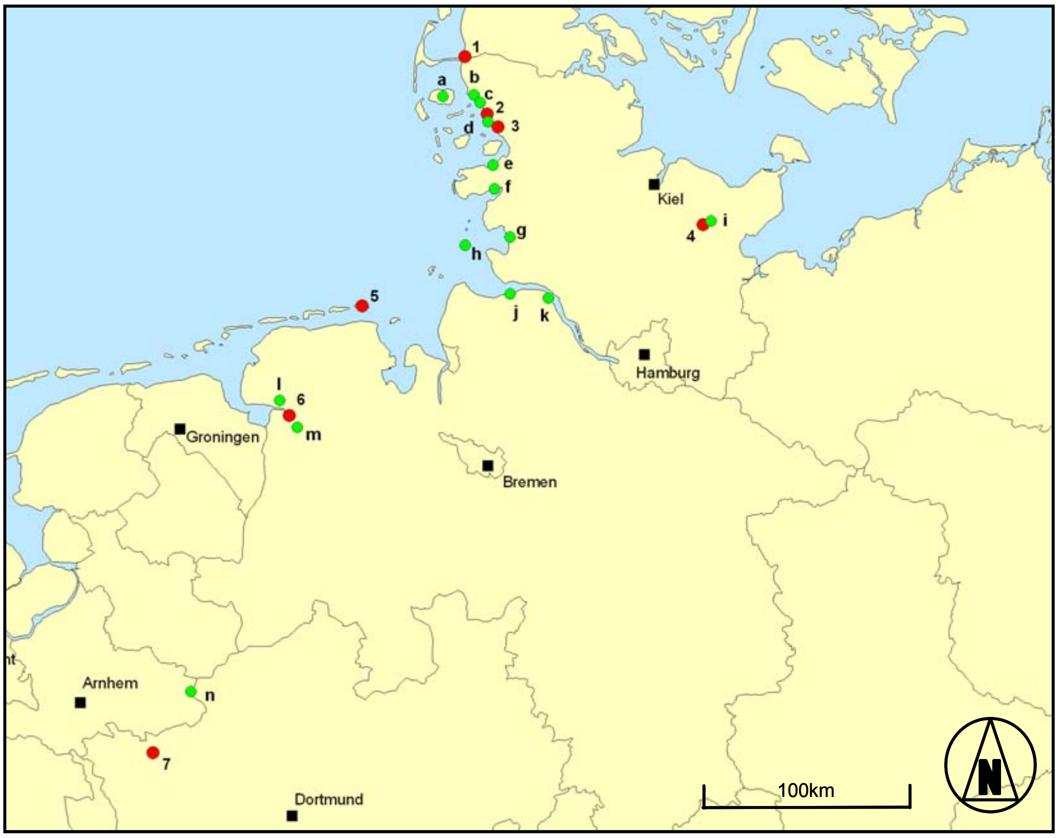

Fig. 3.18: Breeding areas and study sites of Barnacle Geese in Germany. Red dots: at least 4 breeding pairs within the last 4 consecutive years since 2005: 1: Rickelsbüller Koog, 2: Ockholmer Koog, 3: Beltringharder Koog, 4: Ruhlebener Warder (Großer Plöner See), 5: Wangerooge, 6: Hatzumer Sand, 7: Reeser Meer. Green dots: less than 4 breeding pairs within the last 4 consecutive years, colony extinct or singular breedings: a: Föhr, b: Fahretofter Westerkoog, c: Hauke-Haien-Koog, d: Hamburger Hallig, e: Oldensworter Vorland, f: Katinger Watt, g: Meldorfer Speicherkoog, h: Trischen, i: Möweninsel Behler See, j: Hullen, Untererlbe, k: Allwördener Ad, l: Uphuser Meer, m: Bingumer Sand, Ems, n: Zwillbrocker Venn.

f) The Netherlands

In 1982 the first Dutch breeding pair occurred. Some colonies, especially the early established ones, originate in feral birds of water birds collections (MEINGER & VAN SWELM, 1994). In 2005 270 Barnacle Goose breeding areas were known (Fig.3.19)out of which 14 areas harbouring about 70 % of all breeding Barnacle Geese in the Netherlands were included into this study. Number of solitaire breeding pairs were increasing during the last years (VAN DER JEUGD et al., 2006). The total number of breeding pairs amounted to 6,000 in 2005 (fig 3.22). More than the half of the Dutch breeding population is found in Zuid-Holland in areas with plenty of water along the embanked coast. Hellegatsplaten (Fig. 3.21) is the best studied breeding area of Barnacle Geese in the Netherlands. Detailed information about the breeding biology and distribution of the geese in this area can be read in (POUW et al., 2005, VAN DER JEUGD et al., 2006a).

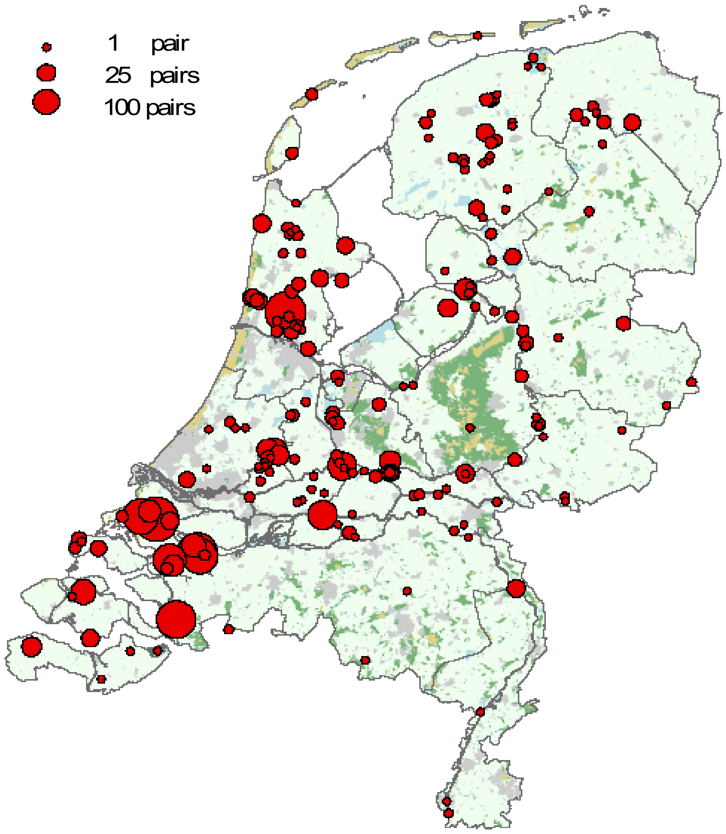

Fig. 3.19: Breeding areas of Barnacle Geese in the Netherlands (VAN DER JEUGD et al., 2006).

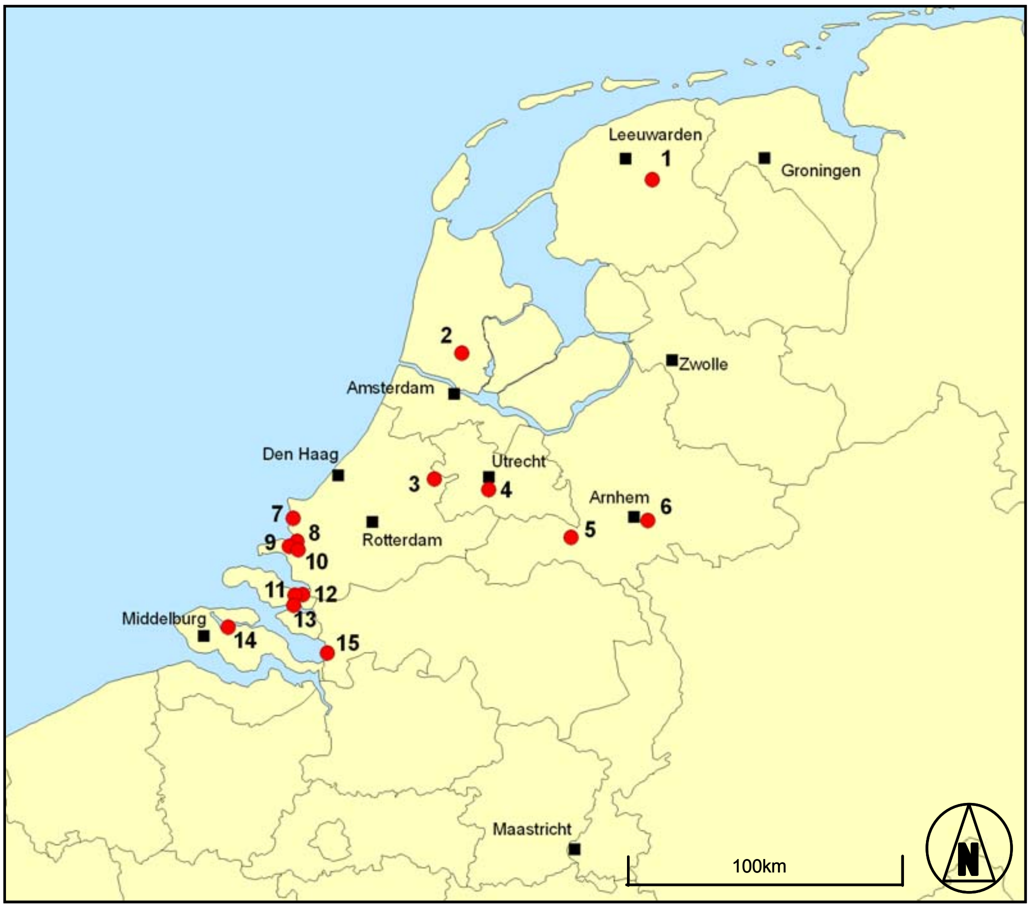

Fig. 3.20: Breeding areas in **2005** and study sites of Barnacle Geese in the Netherlands: 1: Alde Feanen, Jan Durks Polder, 2: Wormer- en Jisperveld, 3: Reeuwijkse Plassen, 4: Stuweiland Driel, 5: Drutensche en Leeuwensche Waarden, 6: Stuweiland Hagesteijn, 7: Beningerslikken, 8: Quarkgors, 9: Scheelhoek, 10: Slijkplaat, 11: Hellegatsplaten, 12: Krib Hellegat 13: Noordplaat, 14: Middelplaten, 15: Markizaat.

g) Belgium

In the 1980's Barnacle Geese started to breed in Belgium in the north of Flanders and along the North Sea coast in the surroundings of the Zwin nature reserve (Knokke). Today, numbers of breeding pairs are assumed to 150-200 or even more. The proximity to the breeding areas in the Netherlands very likely influenced the establishment of the colonies. Escaped and feral birds of water bird collections started to breed in Flanders. Feral birds in Flanders were recorded since the 1960;s.

Recently, numbers of wintering Barnacle Geese started to grow in Belgium. Probably at least a part of these birds originates in the summer population Zeeland. Further it is assumed that some of the breeding birds come from this wild winter population. A goose ringed on Gotland was observed as a breeding bird in Turnhout in 1992. By this, the origin of wild birds is proved for Belgium.

The Flemish landscape is characterised by water and relatively few predators. Nevertheless, adequate breeding islands in higher numbers such as in the Delta do not really exist, except in small park ponds and in the River Scheldt and Meuse. Most of the Barnacle Geese breed in artificial habitats created in the course of harbour expansion in Antwerp, Zeebrugge and Ghent. Number of breeding pairs are especially rapidly increasing in waterfowl collections in private estates (Kuijken, pers. comm., (Anselin & Vermeersch, 2005).

Fig. 3.21: Breeding areas in the North Sea region. Top: breeding area of “Beltringharder Koog” in Schleswig-Holstein, Germany. The geese breed on small islands and use the surrounding managed grasslands for brood rearing (photo: N. Feige). Bottom left: small breeding islands in the Köge of Schleswig-Holstein, Germany (photo: K. Günther); bottom right: the breeding area of Hellegatsplaten in the Netherlands (photo: N. Feige).

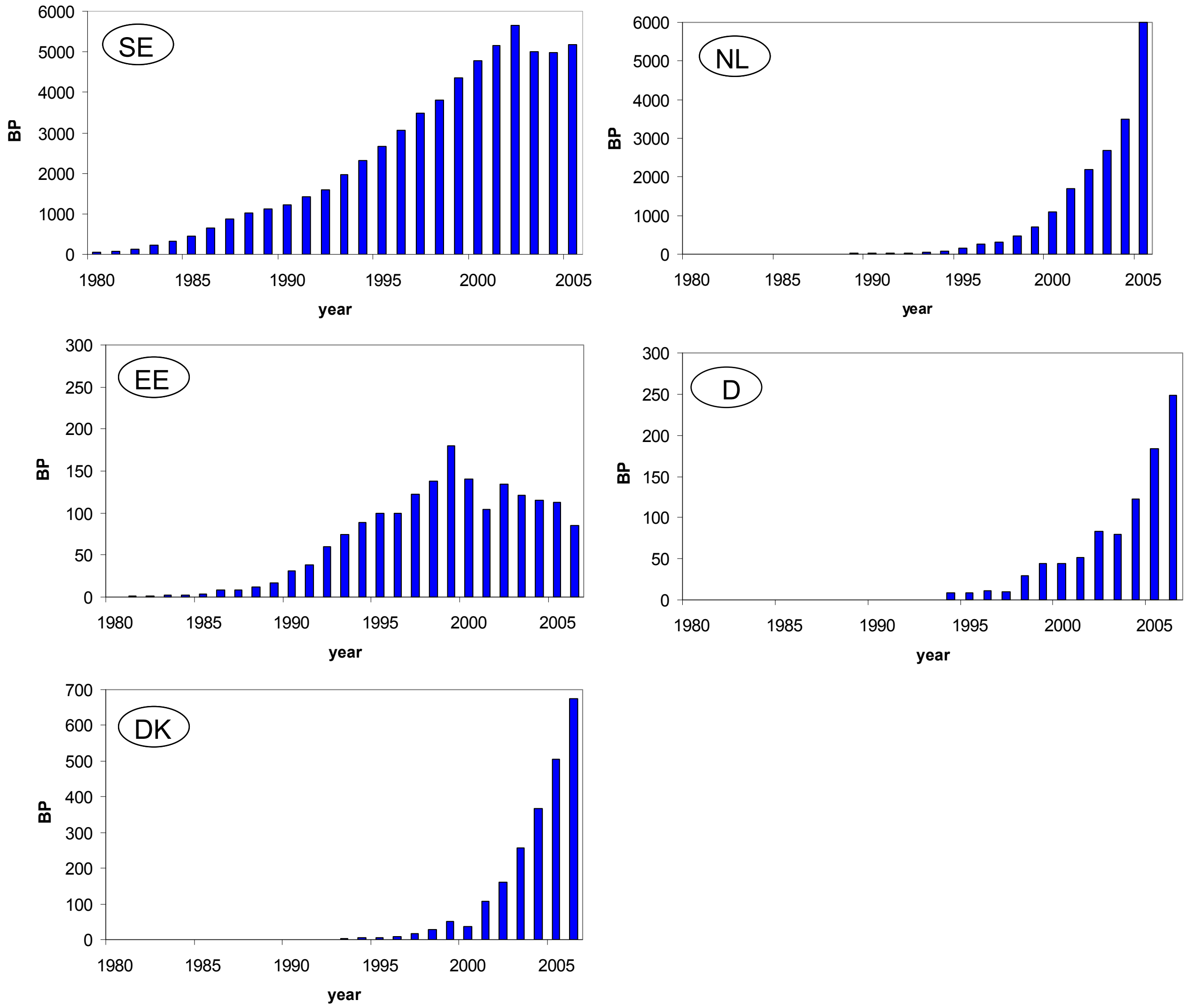

Fig. 3.22: Development of breeding numbers in Sweden (Gotland and Öland only), the Netherlands, Estonia, Germany and Denmark. Note the different scale of the y-axis. Graphs of Estonia, Germany and Denmark include numbers up to 2006.

3.2.2 Comparison between Baltic Sea and North Sea colonies

Multivariate analysis of habitat characters of Barnacle Goose breeding sites revealed significant differences between sites from the Baltic Sea and the North Sea (ANOSIM test, global $R = 0.569$, $p \leq 0.001$). Both the dendrogram of the cluster analysis (Fig. A.2) and the two-dimensional plot of the non-metric MDS (Fig. 3.23) visualise these dissimilarities. The dendrogram shows the tendency of greater similarities of the colonies in Schleswig-Holstein with the colonies in the Baltic than with the remaining colonies in the North Sea.

Contrarily, the ANOSIM test did not reveal any significant differences between brood-rearing sites from the Baltic Sea and the North Sea (global R = 0.111, $p \geq 0.05$). This is also reflected in the dendrogram of cluster analysis (Fig. A.3) and the two-dimensional plot of the non-metric MDS (Fig. 3.23). Most likely, the number of available habitat parameter was too small for a proper analysis.

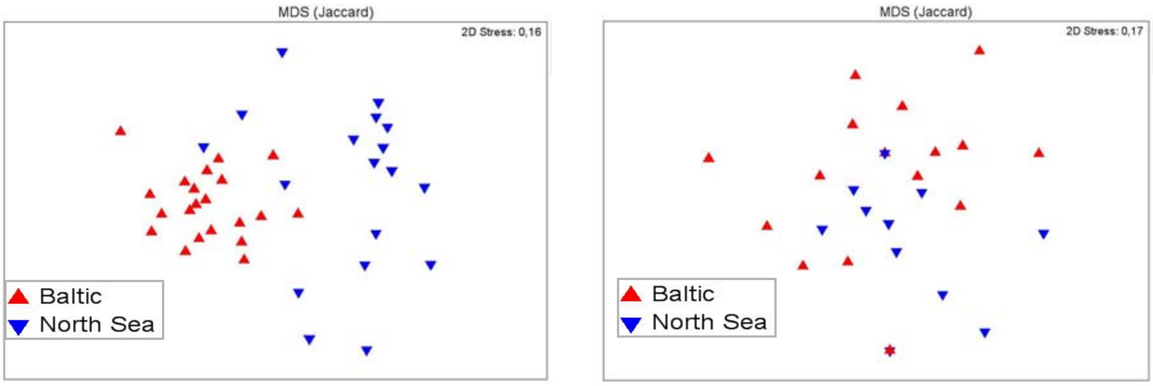

Fig. 3.23: Two-dimensional non-metric MDS configuration of north-western European Barnacle Geese breeding sites (left) and brood-rearing sites (right).

Due to the method of these analyses, the causes for these configurations remain unknown. The results can only be interpreted in the context of the comparisons of every single habitat character and population parameter.

Because of the lack of data or of a very small sample size, it was not possible to conduct comparisons of habitat characters in relation to the population parameters between the two geographical regions. For population parameters, however, the Oneway-Anova revealed significant differences in colony growth between countries (Tab. 3.16), with higher growth rates in The Netherlands and Denmark compared to Germany and Sweden. Colony size is significantly highest in Denmark. If Saltholm would be neglected since sample size for Denmark is only N=1, highest colony sizes would be found in Sweden (Gotland).

Tab. 3.16: Number of sites, total number of geese, colony growth, colony size and density of the analysed sites in the Baltic and North Sea and in relation to the individual countries; according to Oneway-ANOVA test; *p> 0.5; **p> 0.01; ***p> 0.001; n.i.: not investigated, n.s.: not significant.

	Baltic			North Sea			significance
breeding sites							
number of sites	25			29			
total number of geese (BP)	5727	*N=25*		4405	*N=29*		
colony size (BP)	229 ± 374	*N=25*	(15; 1600)	152 ± 217	*N=29*	(4; 935)	n.s.
colony growth (λ)	1.19 ± 0.30	*N=21*	(0.91; 2.14)	1.50 ± 0.32	*N=28*	(0.94; 2.15)	**
density (geese/ha)	17.7 ± 18.6	*N=25*	(0.4; 70)	96.1 ± 147.0	*N=25*	(0.3; 582)	n.s.
brood-rearing sites							
number of sites	24			24			
total number of geese (BP)	n.i.			3447			
colony size (BP)	n.i.			164 ± 274	*N=22*	(4; 1100)	n.i.
colony growth (λ)	n.i.			1.48 ± 0.36	*N=23*	(0,94; 2.15)	n.i.
density (geese/ha)	n.i.			4.7 ± 7.8	*N=20*	(0.1; 32.4)	n.i.

	Estonia		Sweden		Denmark		Germany		Netherlands		Significance
breeding sites											
number of sites	3		14		1		7		22		
total number of geese (BP)	85	*N=3*	5138	*N=21*	504	*N=1*	179	*N=7*	4226	*N=22*	
colony size (BP)	28 ± 15	*N=3*	245 ± 397	*N=21*	504	*N=1*	26 ± 29	*N=7*	192 ± 236	*N=22*	*
colony growth (λ)	n.i.		1.17 ± 0.27	*N=20*	1.68	*N=1*	1.3 ± 0.34	*N=6*	1.5 ± 0.31	*N=22*	**
density (geese/ha)	10.5 ± 7.0	*N=3*	19.4 19.7	*N=21*	1.7	*N=1*	170 ± 178	*N=5*	77.8 ± 137.4	*N=20*	n.i.
brood-rearing sites											
number of sites	6		17		1		10		19		
total number of geese (BP)	85	*N=6*	n.i.		504	*N=1*	179	*N=10*	3431	*N=12*	
colony size (BP)	28 ± 13	*N=6*	n.i.		504	*N=1*	18 ± 23	*N=10*	286 ± 328	*N=12*	***
colony growth (λ)	n.i.		n.i.		1.68	*N=1*	1.37 ± 0.27	*N=9*	1.55 ± 0.41	*N=14*	n.s.
density (geese/ha)	0.8 ± 0.3	*N=6*	n.i.		1.7	*N=1*	6.8 ± 10.6	*N=9*	3.0 ± 4.5	*N=11*	n.s.

3.2.3 Habitat use

a) Description of breeding habitats

Breeding sites

In the Baltic all geese breed on off-shore islands in the Sea. Distances from the mainland rang between 100 and 3500m, whereas the "mainland" is here the large island Gotland, Öland or Saarema, respectively. Breeding sites have a size of 1 - 300ha. Contrarily, in the North Sea region about 30% of the breeding sites are located on the mainland, all of which are in the Netherlands. Islands used for breeding are either in lakes, rivers or in the recently embanked areas (Dutch Delta in the Netherlands and the German "Köge" in Schleswig-Holstein). The only breeding site on an island in the North Sea is on Wangerooge. Most of the islands are artificially created and very seldom have a longer distance than 10 - 500m to the mainland. Largest size of a breeding site is 55ha. In Germany islands mainly have a size of less than 0.02ha.

The breeding sites are predominately characterised by grass. On the North Sea sites, the vegetation is very diverse: in many places, additionally eutrophic herbs, reed and bushes grow (Fig. 4). Bushes are also common on the Baltic sites, but generally vegetation is rather sparse, especially on the Swedish islands.

In Estonia, Denmark and Germany none of the breeding sites is managed. By contrast, in Sweden half of the sites are grazed and in the Netherlands half of the sites are grazed and mown (Fig. 5). Whereas in Sweden islands are predominantly grazed by sheep, in the Netherlands all sites are cattle grazed and half of them in combination with sheep and/or horses.

Breeding sites in the Baltic are mainly influenced by avian predators (Estonia: predominantly White-tailed Eagle *Haliaeetus albicilla*, Sweden: predominantly large gulls *Larus argentatuts, Larus marinus*, Denmark: large gulls and Marsh Harrier *Circus aeruginosus*), in the North Sea additionally the red fox *Vulpes vulpes* as a ground predator occurs. Especially in the Köge in Schleswig-Holstein, predation by foxes can be rather high in years with a low water table which makes breeding islands easily accessible. In years with a low water table such as in 2003/2004 some of the Swedish islands are also accessible to foxes.

Brood-rearing sites

Many of the breeding islands do not provide sufficient feeding habitat to raise goslings so the geese switch to the mainland. Nevertheless, the geese of more than half of the colonies in the Baltic Sea and North Sea each use breeding sites also as brood-rearing sites at least for a while. In the Baltic Sea half of the brood-rearing sites are on the mainland, in the North Sea 80% of the sites are on the mainland. Birds from 12 out of 24 colonies in the Baltic use brood-rearing sites that are located more than 3000m from the breeding site. In the North Sea, the farthest distances are between 1000 and 3000m.

At almost all sites management takes place. Generally, brood-rearing sites are pastures or meadows. Brood-rearing sites in the Baltic are less intensively managed than in the North Sea and only mowing or grazing occurs. In the North Sea additionally fertilisation occurs at some places and many sites are managed by a combination of grazing and mowing. In the Baltic, brood-rearing sites are principally grazed by cattle. On some Swedish islands additionally sheep grazing is common. Conversely, in the North Sea one half of the sites is cattle grazed and the other half is grazed by a combination of cattle, horse and sheep. The pattern of brood-rearing site management between the North Sea countries is similar whereas it differs between the Baltic countries (Fig. 3.24).

Due to the fact that brood-rearing sites in the North Sea are more intensively managed than in Baltic Sea, the vegetation is generally shorter.

The predation situation is only known for the North Sea. There, avian and ground predators occur on half of the sites. All sites in the Baltic Sea and in the North Sea have a clear escape to water as a refuge.

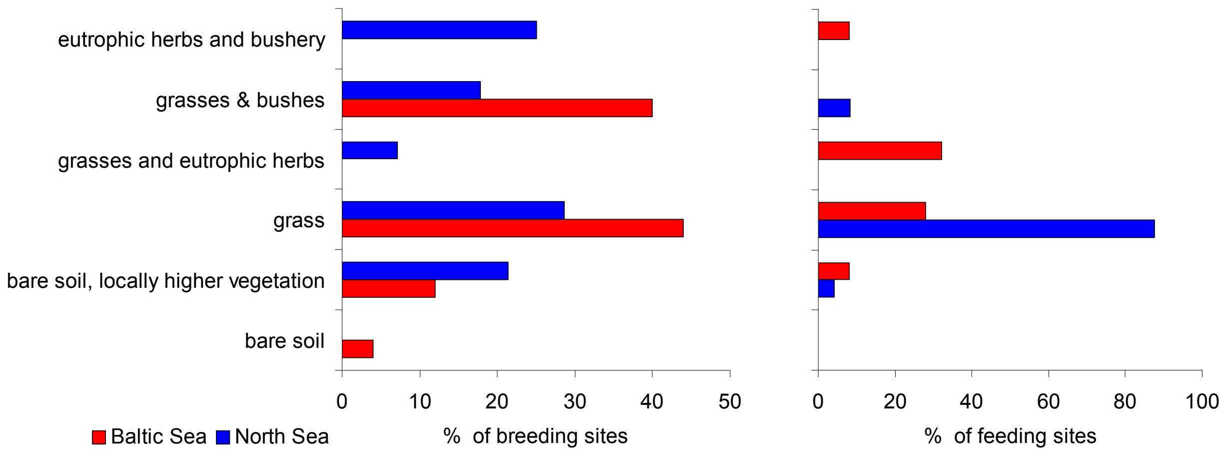

Fig. 3.24: Vegetation at Barnacle Goose breeding and brood-rearing sites (Baltic Sea: breeding sites N=25, brood-rearing sites N=24; North Sea: breeding sites N=28, brood-rearing sites N=19).

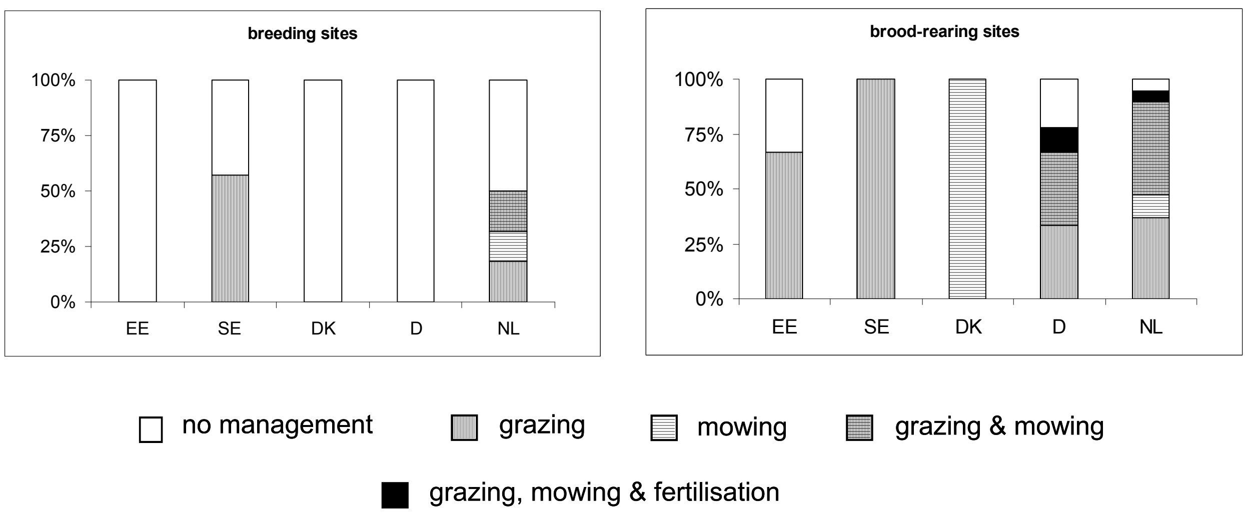

Fig. 3.25: Management at Barnacle Goose breeding and brood-rearing sites in percentages of total number of sites. (Breeding sites: EE: N=3, SE: N=21, DK: N=1, D: N=7, NL: N= 22; brood-rearing sites N=24; EE: N=6, SE: N=17, DK: N=1, D: N=10, the Netherlands: N= 11).

Nature protection

Most of the breeding areas are located in protected areas. About half of the breeding sites in Sweden are part of the Natura 2000 network. The northern breeding islands of Gotland were military restricted area for a long time. As no human activities except military ones were allowed, natural processes could take place. Saltholm has a special status in Denmark: It is probably the most important shore bird area in Eastern Denmark and designated as a Protection area according to the European Council Directive on the Conservation of Wild Birds and the Directive of Habitats. In the North Sea, most of the breeding areas are designated as a nature reserve.

Human disturbance

Though most of all sites are also recreation areas, human disturbance is low. Farmers play the major role of human disturbance. On breeding sites, disturbance generally never occurs except in the Netherlands, but also there disturbance is principally low. Some of the brood-rearing sites are visited by farmers several days a week. Hunting in the surroundings during breeding and brood-rearing time is only known for some areas in the Netherlands. In general, disturbance occurs more seldom in the Baltic.

b) Habitat use in relation to population parameters

Since Baltic Sea sites and North Sea sites showed significant difference in the multivariate analyses, I decided to compare the habitat characteristics in two groups according to their geographical location (Baltic sites and North Sea sites). All results are presented in tables added to the Appendix (tab A3-A6). Here, I only want to amplify on the significant results. For the discussion, I refer to the discussion of the habitat characteristics in the Greylag Goose breeding areas (chapter 4.1.1 - 4.1.7). As the number of geese on brood-rearing sites in the Baltic were not known, the Oneway-Anova tests could not be conducted for these sites.

Spatial distribution of breeding and brood-rearing sites

Colony size in the North Sea is significantly larger if the geese use the breeding site also for brood-rearing (colony size$_{\text{brood-rearing site = breeding site}}$: 368, *N=8* vs. colony size$_{\text{brood-rearing site at a distance <1000m}}$: 50, *N=11*, $p \leq 0.05$).

Vegetation

On the brood-rearing sites in the North Sea, goose density is statistically significant higher on sites where eutrophic vegetation grows than on sites without eutrophic vegetation ($density_{grasses}$: 1.3, *N=11* vs. $density_{grasses\ \&\ eutrophic\ vegetation}$: 12.2, *N=6;* $p \leq 0.05$).

Management

In the North Sea a statistical significant lower density on grazed breeding sites than on ungrazed sites is revealed ($density_{grazed\ sites}$: 10.4, *N=4* vs. $density_{ungrazed\ sites}$: 123.1, *N=13;* $p \leq 0.05$). Further, lower densities are on unmown breeding sites compared to mown breeding sites ($density_{mown\ sites}$: 20.8, *N=19* vs. $density_{unmown\ sites}$: 119.8, *N=6;* $p \leq 0.05$).

Lower densities on mown sites are also found on brood-rearing sites in the North Sea ($density_{mown\ sites}$: 2.3, *N=11* vs. $density_{unmown\ sites}$: 8.3, *N=8;* $p \leq 0.05$).

Human disturbance

On breeding sites in the North Sea, density is statistically significantly lower when hunting occurs, but colony size is higher ($density_{hunting}$: 18.8, *N=9* vs. $density_{no\ hunting}$: 171.3, *N=11*, $p \leq 0.05$; colony $size_{hunting}$: 209, *N=9* vs. colony $size_{no\ hunting}$: 55, *N=13*, $p \leq 0.05$). Also on brood-rearing sites, colony size is higher when hunting occurs (colony $size_{hunting}$: 289, *N=10* vs. colony $size_{no\ hunting}$: 65, *N=11*, $p \leq 0.05$). In this case, the population parameter (here: colony size) influences the presence of the site character.

Nature protection

For breeding sites in the Baltic Sea, the Oneway-ANOVA reveals a significant higher colony size in protected areas compared to non-protected areas (colony $size_{protected\ sites}$: 319, *N=16* vs. colony $size_{non-protected\ sites}$: 68, *N=9*, $p \leq 0.05$). A comparison between protected and non-protected brood-rearing sites in the North Sea also shows higher densities on protected sites ($density_{protected\ sites}$: 5.8, *N=16* vs. $density_{non-protected\ sites}$: 0.1, *N=4*, $p \leq 0.001$).

4. Discussion

4.1 Greylag Goose

4.1.1 Spatial pattern of breeding and brood-rearing sites

The brood-rearing habitat plays an important role for the whole population. Growth rate, body size and survival of the goslings depend strongly on the quality and quantity of the food (VAN DER JEUGD, 1999). Almost all investigated breeding areas harbour a various number of breeding, feeding and non-breeding sites with different habitat characters. This shows that the areas are suitable for geese in all periods of their breeding cycle and provide food for the different needs. Female geese, for instance, need high quality food within a very short time period before the egg laying starts. A study by (VULNIK, 1991) shows, that Greylag Geese prefer dry *Poa/Lolium* grassland grazed year round and summer grazed wet *Alopecurus/Agrostis* grassland in the pre-moulting period. After moulting they forage mainly on summer grazed wet grasslands.

Most of the breeding sites are very close to the brood-rearing sites. Farthest distance of a brood-rearing sites is recorded for the area of Eiland Vijfhoek (almost 10km). (BERNDT & BUSCHE, 1991) report that geese take their young to brood-rearing sites several km away from the nesting site. Brood-rearing sites located far away from the breeding site normally are visited by families with older young (VAN DER JEUGD et al., 2006).
All breeding areas are closely linked with lakes, rivers or other water bodies and almost every breeding and brood-rearing site has a clear access to water. This guarantees a supply of fresh water and an escape in case predators appear. Geese leading young cannot cover greater distances flying and have to stay close to the water until the goslings are fledged. Studies by STAHL & LOONEN, (1998), show that in the Arctic foraging of goose families is limited to sites in the proximity of open water when foxes are present. Additionally, geese need a supply of fresh water. Geese leading young cannot cover greater distances flying and have to stay close to the water until the goslings are fledged.

4.1.2 Breeding sites

a) Location

Statistical analyses revealed significant differences in colony size and density in terms of the breeding site location. A comparison of the site size revealed, that breeding sites in wetlands are significantly larger than sites on the mainland and on islands (wetlands: 306.5ha ± 439.6, *N=6*, mainland: 26.8ha ± 28.0, *N=12,* islands: 9.90ha ± 24.45, *N=17;* p≤ 0.5). Thus, the low density in wetlands can be explained by the geese's distribution over a larger area. As there is no significant difference between the site size on the mainland and on islands, small colony sizes on islands cannot be explained by the smaller site size.

Despite small colony sizes on islands, islands play an important role as breeding sites. They make up one third of all breeding sites. Within the traditional Scandinavian breeding range, islands are used very frequently as breeding sites. In the southern Baltic Greylag Geese mainly breed on inland lakes with extensive areas of reeds. Nests are built either in reed banks or on small islands. Along the east coast of Sweden Greylag Geese breed on the outer islands in the archipelago. Also at the Norwegian coast they mainly nest on islands (NILSSON et al., 1999).

Breeding on islands often is discussed in terms of advantages that come along with the isolated location of these sites. One of these advantages can be less influence of ground predators. According to the results of this study, islands have 20% less ground predators than the mainland. However, especially in years with low water tables, breeding islands situated not far from the mainland can easily be reached by foxes. Another advantage for breeding on an island or in wetland areas might be low human disturbance. Indeed, there is less disturbance on islands and in wetlands compared to sites on the mainland, but my analyses did not reveal any significant difference in colony size, colony growth and or density on sites with different frequencies of disturbances.

b) Vegetation

The vegetation on Greylag Goose breeding sites in North-western European breeding is very diverse. Typically, Greylag geese breed in eutrophic habitats (BAUER et al., 2005). At the Norwegian coast Greylag Geese usually breed in heather, willows or young spruce plantations, and in the southern Baltic they breed in reed banks (NILSSON et al., 1999). In Schleswig-Holstein (Germany) the majority of the breeding sites is found at eutrophic inland lakes and fishponds. Nests are often built in reed beds or on sites with higher eutrophic vegetation, shrubs and trees (BERNDT & BUSCHE, 1991). My study revealed that in the Netherlands, willows and reed are also characteristics of breeding sites: about half of the sites are characterised by reed, and one third is characterised by willows. Further, at one quarter of the breeding sites grows eutrophic vegetation.

c) Grazing and mowing

The majority of the geese breed on sites which are grazed and/or mown, whereas densities are highest on sites without any management at all. Despite of the threat of nest trampling by livestock or nest destruction by mowing machines, it seems that management on breeding sites does not have any negative effects. Locally, mowing may destroy a high number of nests. This is known for the breeding area of Weerribben. The geese build their nests in higher eutrophic vegetation or reed which is mown during breeding time to get rid of it.

Domestic animals may avoid nesting sites when they recognise a nest defending behaviour of the geese. On the other hand, geese rather keep distance to the livestock. They build their nests in vegetation which is not favoured by the farm animals as a food plant or which grows off the most frequently used parts of a pasture (such as along small ditches). Nests are thereby out of reach for livestock. In the breeding areas of Oude Rijn, Erfkamerlingschap, the geese stay close to the horses during breeding time. The geese might profit of the shelter in the close vicinity of livestock in case foxes appear.

Colony growth is significantly higher on sites that are only grazed by cattle compared to sites grazed by a combination of cattle and horse or sheep. According to (AK-FEUCHTWIESENSCHUTZ-WESTNIEDERSACHSEN, 1998), extensive cattle grazing does not have any negative impacts on breeding birds compared to grazing by sheep and horses: horses and sheep mainly stay together in one large herd, while the social units of the cattle herd are separated and grazing pressure is more distributed over the whole area. Thus, disturbance by cattle grazing is less intensive, but continuous and the geese might adapt more easily to it. The impact of livestock species should not be overrated as on many sites the geese mainly breed in parts of pastures where domestic animals do not regularly feed on.

4.1.2 Brood-rearing sites

In the area of Ooijpolder, the geese responded with a lower reproduction rate after intensively used farmland was converted into natural land. As a result of fertilization cessation and the introduction of extensive livestock grazing, brood-rearing sites lost their former attractiveness (VAN DER JEUGD et al., 2006). In the breeding area of Lepelaarsplassen farmland increasingly was converted to building sites. It is likely, that the decrease of goose numbers north of Lepelaarsplassen and additionally the increase in the coastal areas in the Province of Groningen at the same time is connected with changes of food supplies on the farmlands (VAN ROOMEN et al., 2002).
Management obviously influences the site use of feeding geese mostly. Out of 8 habitat characters which revealed significant differences within the Oneway-ANOVA analyses in relation to the population parameters, 5 are concerned with management.

a) Grazing

Geese are exclusively herbivores. Since they have a very simple digestive system and food is retrained only for a short time in the alimentary canal, they have to select food which is high in protein and carbohydrates but low in fibre (GADALLAH & JEFFERIES, 1995, RUTSCHKE, 1997). Especially female geese need high quality food within a very short time period before the egg laying starts (PROP, 2004, PROP & BLACK, 1997). Usually, feeding geese switch between several sites. After a few days when the grass is regrown, they return again to harvest the new growth. At the beginning of the vegetation period, the plants are thereby kept in a young and palatable state with a higher tiller density and much higher in protein than ungrazed plants (OWEN, 1990). Later in season, when the vegetation grows quickly, geese are not able to keep the grass in a young and palatable state by only themselves. Where grassland is managed by livestock grazing, geese benefit from facilitation (BOS, 2002). (BOS & STAHL, 2003) show, that the number of geese can be 4 times higher on livestock-grazed salt marshes than on salt marshes without any grazing at all. According to a study by (BORBACH-JAENE, 2001), in the Leybucht, carrying capacity of Barnacle Geese is even 10 times higher on grazed salt marshes compared to ungrazed marshes. (STOCK & HOFEDITZ, 2000) report 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%. My study shows, that results of the mentioned local studies 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 species (VOSLAMBER et al., 2004). Where livestock is put out to pasture late in season (May or June), the vegetation locally can be short grazed by wild herbivorous waterfowl.

The geese seem to tolerate a certain level of permanent livestock presence. 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 (VULNIK, 1991). Further, compared to cattle, sheep graze the vegetation down to a very short level (WEIGT, 2001). However, domination of cattle grazing very 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).

b) Mowing

The results show, that sites with high mowing frequencies are apparently not favoured by the geese: Meadows mown more than 3 times during the vegetation period are less frequently used and have a significantly lower density as sites with a lower mowing frequency. Whereas continuous livestock grazing keeps the sward permanently at the same height, mowing occurs every six weeks and cuts the grass immediately very short. Until the next cut the grass can regrow to a rather high level. If grassland is used for haymaking, a lot of biomass is taken away which is not available for the geese anymore.

Additionally, livestock grazing and frequent mowing retards vegetation succession by preventing tall plant species from becoming dominant. By this, clear visibility is granted and predators can be detected more easily.

c) *Fertilisation*

Colony size is significantly lower on fertilized sites compared to unfertilised site and only one fifth of the feeding Greylag Goose families use fertilised farming sites. It appears that the geese do not preferably feed on fertilised sites. BLACK et al. (1991) show that reproduction success of Barnacle Geese is not significantly higher in colonies feeding on fertilised farmland compared to geese feeding in natural habitats. Contrarily, (BOS, 2002) report significant higher densities and higher grazing pressures of staging Brent Geese on fertilised sites compared to unfertilised sites in early spring. On heavily fertilised grasslands and arable fields the vegetation can soon reach a height which cannot be overlooked by the geese anymore therefore ((VAN DER JEUGD et al., 2006).

Vegetation is almost everywhere influenced by fertilisation. Nitrogen inputs on the Dutch farmland are the highest ones in Europe and exceed to >250kg fertilizer 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., submitted). The nutrient-enriched water again provided natural grasslands with nitrogen. Besides, aerial nitrogen deposition, which is strongly linked to the intensified dairy cattle industry, influences the vegetation (JEFFERIES & MARON, 1997, VAN EERDEN et al., 2005). As a result, locally differences in food quality and quantity between directly fertilised farmlands and indirectly fertilised vegetation are probably not that big.

d) Feeding on crops

According to (RUTSCHKE, 1997), geese do not prefer specific cereals. A preference could not be found in this investigation either. As a result of crop rotation the supply of crops changes over the years on the individual fields. Geese develop high site fidelity. The same field might be used rather by tradition if food quality and quantity is still granted.

According to the results of the questionnaire in a very few breeding areas families (and non-breeders) exclusively feed on arable fields. It is called into question if they do not use grasslands additionally. In most of the breeding areas the geese switch between meadows, pastures and arable fields. Feeding only on crops does not provide all of the required nutrients (PROP, 2004) and therefore agriculture habitats themselves do not offer the best diet. Additionally, feeding on crops might lead to a more expensive energy budget due to disturbances by farmers like scaring or daily workings (BLACK et al., 2007). Further, within the progress of the vegetation period certain crops like cereals and oil seeds can quickly reach a height which cannot be overlooked by the geese anymore (BERNDT & BUSCHE, 1991). Nevertheless, in some breeding areas geese use farmland very intensively and even cause damage on them (VAN DER JEUGD et al., 2006).

e) Chasing

At more than half of the sites, geese are chased away. Scaring and hunting has negative effects on the geese's energy budget. Flying up in birds due to disturbance causes a 15-fold increase of energy consumption (KRUCKENBERG et al., 1996).

Shooting additionally disturbs geese in the surroundings, where goose damage possibly does not occur. Geese in the surrounding area become very timid and a lot of potential feeding and breeding sites may not be used anymore (MOOIJ, 1991, VAN NUTGEREN, 1997). Without local chasing the geese would spread more over the whole area. Scaring can only be efficient if geese have the opportunity to feed in refuges without disturbance in the neighbourhood (BERGMANN et al., 2002, MOOIJ, 1991).

According to (RUTSCHKE, 1997), geese can get used to scaring methods within a short time which apparently already happened in the Netherlands. this. At least, the geese do not avoid sites where chasing occurs.

4.1.4 Non-breeding sites

For the most part, non-breeding sites have the same characterisation as brood-rearing sites. Non breeders often use sites far away of water bodies compared to breeding birds and foraging families. Predation risk for non-breeders is less than for breeding birds and young families: only during moulting when they are flightless, they are as vulnerable to predators as the families and depend on water bodies as a refuge for predators. For the most part of the summer, they can feed on sites without bodies of water and therefore, are less restricted in site use.

The management of the non-breeding sites is similar to that of the brood-rearing sites. Non-breeders more frequently use farmland (particularly arable fields) and compared to the brood-rearing sites of the families, management on non-breeding sites is more intense: the stocking rates are higher and artificial fertiliser instead of manure is applied more frequently. The higher number of fertilised non-breeding sites and the more frequent use of artificial fertiliser on those can be explained by the higher number of arable fields (crops) the non-breeders feed on (Tab. 3.6).

4.1.5 The influence of predation

Determination of predation is generally not easy. Usually, it is evaluated by the survival rate, and permanent nest and goose observations are necessary. By this (VAN DER JEUGD, 1999) shows that on Gotland 80% of the Barnacle Goose goslings are predated by foxes. A study about Barnacle Geese in the Netherlands reveals that ~50% of the nest are predated or given up (VAN DER JEUGD et al., 2006a). My results do not show any significant differences between population parameters and different predation situations on breeding and brood-rearing sites. However, colony growth, colony size and density are always highest values on breeding sites where predators are absent. Three quarters of all brood-rearing sites are influenced by predation. This shows that the geese do no avoid sites were predation occurs. There is no doubt that survival rates of goslings in the Netherlands are influenced by predation. E.g. in the breeding areas of Biesbosch and Braakman ~90% and ~75% of the nests are predated, respectively. Such detailed information about the influence of predation were generally not available since regular nests controls and goose counts are not carried out in the investigated sites. Nevertheless, according to (LANGGEMACH & BELLEBAUM, 2005), there is no evidence that the overall population of Greylag Geese suffers under predation.

4.1.6 The impact of human disturbance

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 actual response of the geese to it. Nevertheless, it seems that human activities on the studied sites are not a limiting factor in the geese's site choice as the geese do not give them up on the long term. Also (VULNIK, 1991), comes to the result that disturbance on breeding sites does not play any important role. Greylag Geese adapt to a certain level of disturbance (BEZZEL & PRINZINGER, 1990) and when a certain level is reached, foraging geese switch to sites with lower disturbance (BAIRLEIN, 1996).

(SPILLING, 1998) supposed that even if geese show partly high reactions on distances, disturbance by hunters, farmer's activities and walkers do not have any impact on medium-term site usage. Main sources of disturbance in his study are aerial disturbances like planes. By contrast, (KRUCKENBERG et al., 1996) showed that walkers causing 20% of disturbance flights play an important role.

Settlements and buildings block clear visibility and therefore predator detection in open areas. My study reveals that geese do not avoid the vicinity of buildings, and keep only a distance of 100m. According to (SPILLING, 1998) geese can adapt very easily to buildings. On Spitsbergen during brood rearing, higher goose numbers are recorded in the centre of the village of NY Ålesund compared to the surroundings (DROST et al., 2001). Geese have lost their inhibitions towards man and nowadays can be seen in close neighbourhood to buildings and human activities (PERSSON, 1992). Geese possibly would come closer to buildings if the number of individuals is increasing and the border of carrying capacity is reached.

4.1.7 Nature protection and conversion of habitats

Most of the dams along the coast were closed between 1960 and 1987, and during this time, the first breeding colonies of Greylag Geese were established in the Dutch Delta. Between 1950 and 1990, wetland areas in the Netherlands increased at 10%. Although these areas certainly had a positive impact on the increasing numbers of breeding geese in the Netherlands, most of the Greylag Goose sites are situated in wetlands that have been there since ever (VAN DER JEUGD et al., 2006). Nevertheless, one third of the investigated Greylag Geese use small breeding islands and their surroundings, which developed in flooded meadows formerly used for peat cutting. It is obvious, that the geese preferably exploited these man-made wetland areas.

The presence of geese is closely linked with the protection status of an area. New nature reserves were established all over the country during the last decades. Especially areas, which were converted in the course of the big embankments, attracted high numbers of breeding birds shortly after reduction of the tide. By this, they soon gained the status of nature reserves often along with management measures adapted to breeding birds (VAN DER GRAAF et al., submitted). Birds that founded a colony in already existing nature reserves benefited from a favourable breeding habitat a priori. In contrast to the breeding sites, one quarter of the brood-rearing sites are outside of a nature reserve. These sites are all intensively used farmland. Most of the breeding sites are surrounded by an intensively used agriculture area which provides optimal feeding habitats during brood-rearing time in close proximity.

4.2. Barnacle Goose

4.2.1 Shifts of the breeding range

The colonisation of North-western Europe by the Barnacle Goose appeared during a period of high reproductive success on the traditional arctic breeding grounds in NW Russia (GANTER et al., 1999). One can assume that this increase may have led to an increase of density-dependence in the traditional breeding grounds and the need to exploit new breeding sites outside of Russia. But shortly after the first breeding pairs occurred in the Baltic, the geese expanded their breeding area also in Russia. New breeding sites were established westwards and southwest of Novaya Zemlya and Vaigach along the coast of the Barents See and the eastern border of the White Sea (FILCHAGOV & LEONOVICH, 1992, VAN DER JEUGD et al., 2003). The exponential increase in the population started about one decade later (Fig. 4.1), when hunting on north-western European wintering grounds was generally prohibited (GANTER et al., 1999). A spectacular increased occurred on Kolguev Island. Breeding numbers amounted to only several hundred in the late 1980's and were estimated up to 65,000 pairs in 2006 (ANISIMOV, pers. comm.).

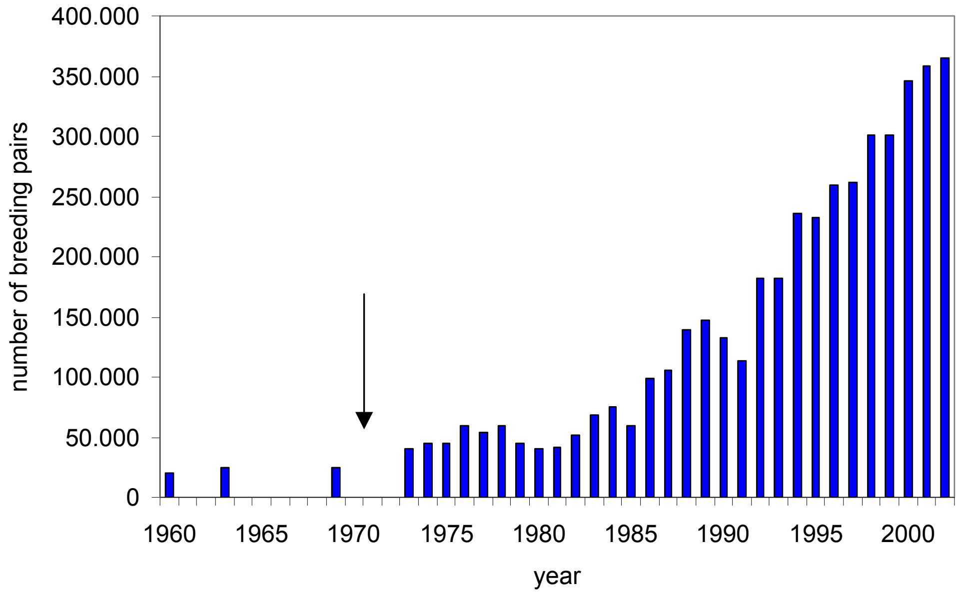

Fig. 4.1: Development of the Barnacle Goose population (Russian, Baltic Sea and North Sea population). The arrow indicates the first breeding outside of the traditional breeding grounds in Russia (data source: SOVON).

Causes for the south-westward breeding range expansion in Europe are heavily discussed. Whereas along the North Sea migration route of Barnacle Geese, landscapes and human land use changed significantly within the last decades, in Sweden and Estonia no particular changes of the landscape surface, management or predator situation occurred prior the establishment of the first colonies and even not during the time of rapid breeding population increase (LARSSON & VAN DER JEUGD, 1998), LEITO, pers.comm.). Knowledge once established can be transferred within the population by tradition (BOS, 2002, STOCK & HOFEDITZ, 2000) and so the geese adapt very quickly to changes.

a) Productive farmland

Farmland provides food of much higher quality than the geese can find in their traditional habitats on salt and fresh-water marshes or pastures along estuaries and natural lakes (MADSEN et al., 1999). This study shows that most of the brood-rearing sites are managed grasslands. During the last decades natural habitats all over Europe have been converted increasingly into pastures and grasslands and these with an increasing tendency into arable fields. In 2005, around 42% of the total area in the EU-25 was utilised agricultural area. This share differs widely between the countries from less than 7% in Sweden to more than 60% in Denmark (Fig. 4.2). About half of the arable land was cultivated by cereals (EUROSTAT, 2007).

Due to improved conditions on brood-rearing sites in their wintering grounds, many geese populations in Europe increased during the last decades (BERGMANN et al., 2002). Also in North America, the increase of goose numbers since the 1950's coincided with the development of intensive agriculture and the increased use of N-based-fertilizers (JEFFERIES, 2000). Big machinery, insecticides, herbicides and artificial fertilization are common today. In western Europe, mineral fertiliser used per ha of cropland in 2001 amounted to 180.7 kg. As a result, tiller density and the length of grasses increased, growing periods during late autumn extended and protein content in the leaves of the plants became higher (VAN EERDEN, 1998). On top of that, aerial nitrogen deposition increases herbivory (JEFFERIES & MARON, 1997, VAN EERDEN et al., 2005). Farmland does not only provide high quality food during the winter: modern mowing schemes, fertilisation and livestock grazing produce forage for geese which remains available in high quality and quantity throughout the whole summer period and provide suitable habitats for brood-rearing.

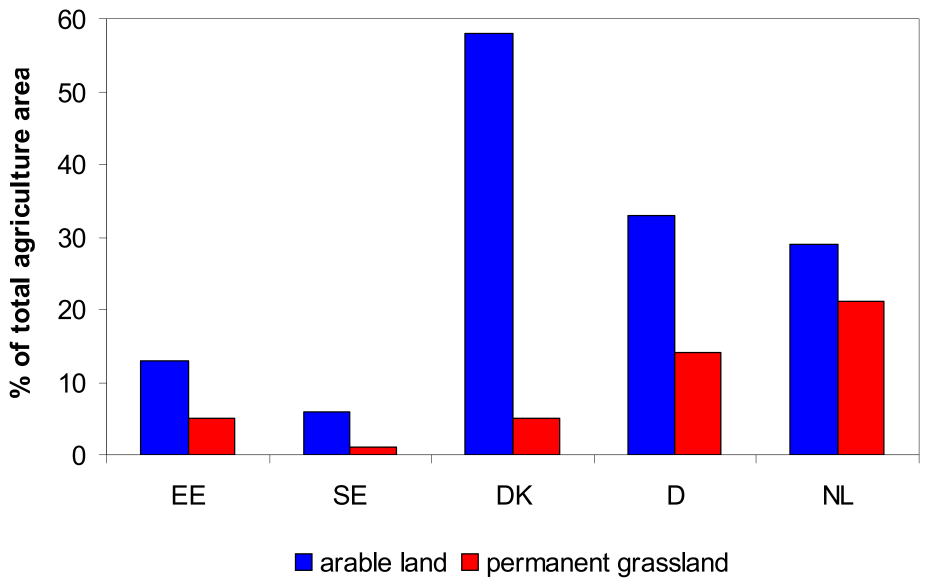

Fig.4.2: Arable land and permanent grasslands in relation to the total agriculture area in Europe (data source: EUROSTAT).

In the eastern and northern Baltic the situation slightly differs from that in the North Sea region: Brood-rearing sites in the Baltic are poorer in nutrients than in western Europe (POUW et al., 2005). Many coastal grasslands are still mown traditionally, and grazing by domestic animals has been common practice for a long time. On Gotland, in 1995 a new EU-development programme aiming in an open landscape and unfertilised but extensively grazed land started. As a result the forest was cleared close to the coast up to 300-400m inland (before: only about 50m) and most of the farmers stopped the use of fertiliser (MAGNUSSEN, pers. comm.). The Coastal grasslands which serve as brood-rearing sites for geese have been expanded by this.

b) Hunting relaxation and nature protection

During the last decades hunting pressure relaxed in many countries. Protection of Barnacle Geese from shooting started in the Netherlands in the 1950s. Until 1970 Barnacle geese could be shot in Baltic staging areas under special licence, and from 1977 on they were also protected from hunting in autumn in Germany (Schleswig-Holstein) (EBBINGE, 1991). Today, the Russian population is protected throughout its range within the EU Bird Directive, the Convention of Migratory Species and the African/Eurasian Water Bird Agreement (BAUER et al., 2005).

In protected areas, site safeguard is guaranteed by restrictions on hunting and other human disturbance. Within the last years protected sites were not only established nationwide: also cross-national legislations gained importance. In 1992, governments of the European Union adopted the legislation designed to protect the most seriously threatened habitats and species across Europe: the Habitat Directive. Together with the

Bird Directive of 1979 it is the basis of the Natura 2000 network and requires the establishment of Special Protection Areas (SPAs) for birds. About 18% of the land surface in Europe are declared as Natura 2000 sites. Also, the Ramsar Convention (1995) is an international treaty for the conservation and sustainable utilization of wetlands.

c) Hydro-engineering measures

Since the last 1000 years, seawalls have been established along the entire Wadden Sea coast. Embankments and drainages were not only necessary for coastal protection but also for reclamation of new agricultural land. The last big changes have occurred only some decades ago: in the Northern Delta, the Krammer-Volkerak and at the German west coast, the Nordstrander Bay was closed in 1987. As a result, former ecosystems characterised by tidal influence disappeared, changed their ecological function and became brackish or were transformed into big inland seas. In that course new water bird habitats and artificial islands turned up. They became popular breeding sites for water birds in a short time and thereby, embanked areas soon gained the status of a protected area (OUWENEEL, 2001, POUW et al., 2005). Today, often special management supports optimal bird habitats. In the Dutch Delta, for instance, management plans aim in a half-open and park-like landscape supported by extensive livestock grazing.

Large water reservoirs constructions, new water bodies and wetlands were also created inland. Today artificial water bodies are important water bird habitats in North-western Europe, and they even have supra-regional importance (VULNIK, 1991).

d) The role of predators

Not only the geese’s distribution but also that of their potential predators is strongly influenced by human activities. Foxes benefit from the modern cultural landscape. They learned to populate croplands where they can reach high reproductively rates (LANGGEMACH & BELLEBAUM, 2005). In addition, foxes benefit from anti-rabies inoculation and increased in numbers during the last decades. Modern agriculture and human waste deposits provide new food resources for avian predators like crows and gulls. Not least, by-catch and fishery waste are a new food source for a great number of gulls (GARTHE, 1993). Raptors profit from changes in hunting legislations and the prohibition of DDT in European countries since the 1970s. As a result, the population of crows, gulls and raptors increased during the last decades (BAUER et al., 2005).

However, in contrast to most other waterfowl species, predation does not seem to limit site use in geese. Though predation has negative impacts on hatching success and goslings survival (VAN DER JEUGD et al., 2006a), almost all colonies are obviously growing due to dispersal.

Further reasons for the establishment of new breeding sites

There are many reasons why Barnacle Geese are present during the summer although they are arctic migratory birds. For one reason, geese that are ill or slightly wounded by bullet-fire are too week to join their group to the northern breeding grounds. They stay in the wintering area or at stop-over sites and finally start to breed. This is proven for the first breeding colonies Schleswig-Holstein (BERNDT & BUSCHE, 1991). Generally, this can be assumed for newly established breeding areas outside of Russia.
Besides, in many places ring findings demonstrate that colony establishment is initiated by birds escaped from breeders or neglected waterfowl collections:

- Finland: surroundings of the cities of Helsinki, Lathi and Turku (VALKAMA, pers. comm.)
- Denmark: Saltholm (FINK, pers. comm.)
- Germany: Wangerooge (HECKROTH, pers. comm.)
- The Netherlands: various region in the Dutch Delta (MEINGER & VAN SWELM, 1994, LENSINK, 1996)
- Belgium: Flandern (ANSELIN & VERMEERSCH, 2005)

Population trend before the establishment of new breeding sites

Prior the establishment of new colonies, often small goose numbers were seen in future breeding areas throughout the entire summer (Ruhlebener Warder: 2 previous years, Hatzumer Sand: 4 previous years, (KRUCKENBERG & HASSE, 2004), 2004, Köge in Schleswig-Holstein, PETERSEN-ANDRESEN, REHM, both pers. comm.). In the Reeser Meer, each year between 1990 and 1994 one unsuccessful breeding pair was observed (HÜPPLER et al., 1998). Same is reported for the breeding areas in the Netherlands (MEINGER & VAN SWELM, 1994, OUWENEEL, 2001).

Most of the new breeding areas outside of Russia were used during migration long time before the first breeding pair occurred. Ever since Gotland was a popular stop-over site (GANTER et al., 1999) and also western Estonia is a traditional staging area (LEITO, 1996). Prior the 1980’s, the island of Saltholm was the only but popular and regular stop-over site in Denmark (up to 1000 birds, MORTENSEN, pers. comm.). Same is reported for the breeding areas in Germany Schleswig-Holstein (Beltringharder Koog 15-20 000 birds, Rickelsbüller Koog 20-25 000 birds during the last years, PETERSEN-ANDRESEN, pers. comm.). Together with the surroundings of the River Ems (Rheiderland, 44 000 bird on average, KRUCKENBERG, pers. comm.) these areas belong to the most important German staging areas. Since a few years, 1000-1500 Barnacle Geese started to use the Lower Rhine area as a wintering site (MOOIJ, pers. comm.). During winter almost the entire Barnacle Goose population is concentrated in the Netherlands.

Mainland versus island - colonisation of non-fox free breeding areas

Until the spectacular population increase Barnacle Geese used to breed on islands. There, they could profit of ground-predator free breeding sites. Nowadays, Barnacle Geese breed also on the mainland which usually does not provide fox-free habitats anymore. Nesting sites in the Arctic north-westerly of Vaygach are almost all accessible by the Arctic Fox *Alopex lagopus* (FILCHAGOV & LEONOVICH, 1992, VAN DER JEUGD et al., 2003). Also the recently colonised islands often do not provide fox-free habitats: In the North Sea and Baltic Sea, islands at short distances to the mainland and surrounded by shallow water can reached easily by foxes. On the non-fox free island Kolguev, Barnacle Geese often breed inland on very steep river slopes, which are not favoured by Artic foxes and visited by them only very seldomly. The geese also use to raise their young on these slopes. Additionally the geese favour sites in the shelter of breeding raptors Rough-legged Buzzard *Buteo lagopus* and Peregrine Falcon *Falco peregrinus (*own observations, (KRUCKENBERG et al., 2007). In other parts of the island the geese seem to minimize the predation pressure by breeding in very dense colonies up to several thousand geese (ANISIMOV, pers. comm.). The flat lowlands on the Barents Sea mainland probably are typical habitats for the Barnacle Goose (SYROECHKOVSKY JR., 1995) and now are repopulated since human disturbance decreased as a result of mass emigration.

Summary

Simultaneously with the population increase landscapes in north-western Europe changed on the long term. Since some decades, the North Sea region offers new breeding opportunities. Breeding habitats are characterised by a combination of breeding islands, freshwater bodies, the declaration as a protected area (often accompanied by special breeding bird management) and the availability of feeding habitats with nutrient rich grasslands in close vicinity. Along the coast, these habitats were mainly developed in the course of embankments, inland water bodies were developed artificially or altered. In contrast, no particular changes in the land use in Sweden and Estonia occurred. There, other reasons must be the main cause of colony establishment.

At many places, birds escaped from water fowl collections or they were released on purpose. These feral birds found themselves in a suitable breeding habitat and soon started to breed. It can be assumed that predation does not seem to limit site use in geese. Though it has negative impacts on hatching success and goslings survival, almost all colonies are growing due to dispersal.

4.2.2 Breeding sub-groups of the Russian Barnacle Goose population

Multivariate analyses of habitat characters of north-western European Barnacle Goose breeding sites revealed significant differences between sites from the Baltic Sea and the North Sea. Additionally, comparisons between colonies in the North Sea and in the Baltic Sea showed significant differences of colony growth, colony size and density in relation to habitat characters. North Sea colonies, Baltic Sea colonies and colonies in Russia distinguish themselves by a different migration strategies and a different breeding biology:

Breeding biology differs in terms of egg laying: At the time Russian birds leave the stop over sites in the North Sea, there geese start already with breeding. On Gotland the first young hatch at the same time the Russian birds start egg-laying. Goslings on Gotland are hatched one week later than in the Netherlands. Clutch decreases with latitudes. Due to nutrient poor vegetation, gosling growth is slowest in the Baltic whereas the young geese in Russia reach fledging time most rapidly. Birds born in Russia have a greater body size and body weight than birds in the North Sea and Baltic Sea. Whereas the North Sea population does not migrate anymore, the Baltic population reaches its first breeding sites after 1000km (Öland, Denmark excluded). By contrast, the Russian birds have to migrate another 2000km to reach their breeding grounds. Non-migratory birds in the Netherlands still show Zugunruhe in spring which is reflected in short visits of other parts of the country (POUW et al., 2005, VAN DER JEUGD et al., 2006a).

On this basis, the Russian Barnacle Goose population can be divided into three breeding sub-groups: the Russian meta-population with breeding sites in Russia, the Baltic meta-population with breeding sites in the Baltic region and the North Sea meta-population with breeding sites in the North Sea. The Baltic group amounts to 21,000 birds and the North Sea group to 25,000 birds (the Netherlands only, (VAN DER JEUGD et al., 2006a). Though all three populations are increasing, colony growth differs significantly. Mean annual growth increases with lower latitudes (POUW et al., 2005): the Russian meta-population increased at 7% since 1960, the total Baltic meta-population at 41% since 1971 and the North Sea meta-population (the Netherlands only) at 48%. Thereby, the Dutch Barnacle Goose colonies are the fastest growing goose colonies of the world (VAN DER JEUGD et al., 2006).

As results of several colour ringing projects show, there is a lively exchange between birds of the three sub-groups (BLACK et al., 2007, VAN DER JEUGD, 2005).

A young bird ringed in 2003 in Zwanenwater (Noord-Holland) was seen during June 2004 in the Ockholmer Koog in Schleswig-Holstein (REHM, pers. comm.). Conversely, a young bird ringed in 1997 in the Ruhlebener Warder was shot in the Russian breeding area on Kanin in 2000 and a young bird of the breeding colony in the city of Malmö (Sweden) was killed two years later by a ground predator in the Russian breeding grounds (LUDWICHOWSKI & BRÄGER, 2003). Out of 4,500 colour ringed birds born on Gotland, 11 were seen as a breeding bird in Russia, 4 in the Netherlands, 3 in Finland, 1 on Spitsbergen and one in Belgium (BLACK et al., 2007, VAN DER JEUGD, 2005). This demonstrates that Barnacle Geese breed in habitats totally different from their place of birth.

Birds of the Russian and the Baltic and the North Sea population use the same wintering areas and mix with the non-migratory population of the Wadden Sea. There, breeding pairs find together from either of the three populations. Female geese are very faithful breeders and return to their own place of birth, since breeding sites are maintained by tradition. Genetic exchanges occur via the male (VAN DER JEUGD & LITVIN, 2006) who follows the female to the breeding area (BLACK et al., 2007).

4.3 Discussion of methods and suggestions for further studies

With the help of a questionnaire I compiled various habitat characters and data of the breeding biology of the two focal goose species. My data therefore strongly depend on the precision with which the questions were answered by the respondents. It is obvious that this method has its limitations, however, the collected data form a unique data set. So far investigations about habitat use in Greylag and Barnacle Geese were carried out at one or only a few study sites usually focussing on one single habitat parameter only. In my study for the first time a large number of different habitat characters were collected for as many study sites as possible.

Information about the predator situation, the impact of human disturbance and changes in the past were not clearly enough. I only could detect the trend, that disturbance and predation have no influence on the investigated population parameter. In example, an important reference parameter for disturbance would be the geese's behavioural reaction. Further, it will be important to record the current changes in agricultural land use and land management in order to be able to analyse the importance of these habitat changes for breeding and staging in more detail than could be done within this study.

More detailed information about goose numbers and population parameters are necessary to get clearly interpretable results. Most of the investigated colonies are growing, though many habitat characters can have negative effects on the survival rate of the goslings. This contradiction is reflected in the comparison of colony growth between sites with and without breeding control: the Oneway-ANOVA-analysis did not reveal any significant difference. Furthermore, even on sites with high predation pressure colonies are growing. The permanent colony growth in the Netherlands very likely originates from immigration of geese. Probably due to high predation pressure in a breeding area, carrying capacity is not reached and density dependence plays no role at present. Fledging rate and survival success of the goslings would describe colony growth more exactly.

More exact data about goose numbers and population parameters require extensive goose observations at every individual site. In addition, ringing programmes and resightings of marked individuals can reveal details on the distribution and usage of feedings sites.

5. Outlook and conclusion

5.1 Future trends effecting Greylag Goose and Barnacle Goose breeding populations

Though recently the number of Greylag Goose breeding pairs has been stabilised in some areas (e.g. the Ooijpolder), the majority of the colonies is still growing. According to a study by VAN DER JEUGD et al. (2006), the Netherlands harbours suitable breeding habitat for up to 90.000 Greylag Goose pairs. For Barnacle Geese breeding numbers of 15.000 - 20.000 pairs are predicted, predominantly depending on the impact of fox predation. In some breeding areas such as Markiezat and Beninger Slikken, colony growth is already stopped by density-depended effects (OUWENEEL, 2001).

In terms of extensively managed grasslands, brood-rearing sites may be available to a great extent. It is more likely, that carrying capacity of breeding areas will be reached by the availability of suitable breeding sites. The future population size and distribution of breeding Barnacle and Greylag Geese is influenced by various human activities.

a) Hydro-engineering measures

According to the Deltaplan numbers of potential goose breeding sites will increase in the coming years and very likely lead to new breeding colony establishment especially of Barnacle Geese (OUWENEEL, 2001). In Germany, further embankments are not planned anymore. In the Netherlands only a very few natural habitats are left and until 2015 it is aimed at the development of 111.741ha “nieuwe natuur”. In that course large restoration projects initiate hydro-engineering measures and create new wetland areas (http://www.mnp.nl/mnc/i-nl-1307.html - 13/05/2007).

b) Protection

Barnacle and Greylag Geese are protected throughout their breeding range by international legislations. Recently, coastal areas have gained an important conservation status in Europe. Seashore meadows are heavily endangered habitats along the Baltic Sea (HELCOM, 1998). Cross-national legislations will become more important within the following years. However until today, the trilateral targets concerning salt marsh management do not include a species-specific management plan (BLEW & SÜDBECK, 2005). Neither specific management policies for geese are included into the European Habitat Directive. In future debates might arise whether the Wadden Sea should be managed in a way to cope with increasing goose populations. If management plans do not support large goose numbers, problems will arise as long as high productive farmland along the coast will attract those (BOS, 2002, KOFFIJBERG & GÜNTHER, 2004).

c) Predation

The development of the future predation situation is not clearly predictable. (VAN DER JEUGD et al., 2006) assume that increasing predation probably limits the number of Greylag Goose breeding pairs to about 60.000 in the Netherlands. Changes of agricultural policy and fisheries agreements, the closing of open waste disposal sites or the cessation of direct persecution as well as breeding bird management in protected areas, may have a deep influence on the predator distribution. Often, predator management does not aim in the hoped-for results e.g. within the Köge of Schleswig-Holstein (PETERSEN-ANDRESEN, pers. comm.).

d) Farming practices

Especially the Easter ward expansion of the European Union resulting in changes of farming practices may effect the future distribution of breeding geese. Large-scale farming such as the production of crops like oilseed rape and winter cereals will increase throughout Europe (STEINFELD et al., 2006). Hence, feeding grounds for summering geese will be expanded. On the other hand, due to genetic engineering, plant species might become unpalatable like in the region of Flevoland in the early 1990's (VAN EERDEN, 1998).

According to a new report from the FAO (STEINFELD et al., 2006), the livestock sector is undergoing a process of technical and geographical change. Production will shift from the countryside to urban and peri-urban areas. Also an accelerating growth in production of pigs and poultry is predicted and in return a slow-down in that of cattle and sheep. Cattle grazed pastures are favourable goose brood-rearing sites. In future, cattle will be raised extensively from which the geese will profit, but in return the area of grasslands will be reduced. This trend is already visible (Fig. 5.1). Owing to those shifts and in connection with increasing urbanisation, livestock will enter into direct competition for scarce land, water and other natural resources and therefore, also for geese. In regions where farming activities will be reduced geese likely will reacted on management changes with decreasing breeding numbers. LEITO (pers. comm.) assumes the cessation of livestock grazing to be one of the reason for decreasing breeding numbers in Estonia.

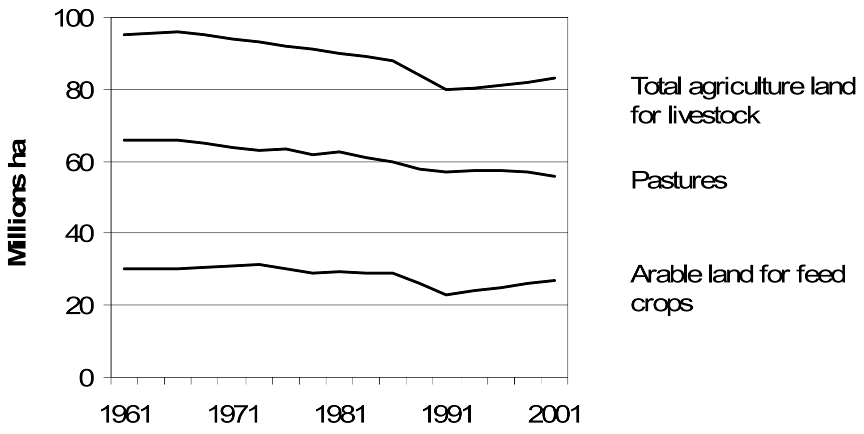

Fig. 5.1: Trends in land-use area for livestock production in the EU (data source: FAO).

e) Goose management

Recently, the conflicts between summering geese and farmers intensify along with the constantly higher economic pressure. Greylag Geese are most responsible for damage (up to 87% of all damages) followed by Domestic Geese, Canada Geese and Barnacle Geese (VAN DER JEUGD et al., 2006). More and more geese tend to feed on farmland. On average, Greylag Geese spend nine months per year in agricultural habitats and only the remaining three months in natural wetlands (VAN DER WAL, 1998).

Debates about how to cope with summering geese are already arising in the Netherlands Agro-environmental schemes like crop rotation can reduce the amount of damage to vulnerable crops. Shooting can be only effective if a very large part of the population is shot annually (MOOIJ, 1991). In refuge areas such as The New Grounds in Slimbridge (U.K.) or in Zeeburg on Texel (NL), geese are supposed to concentrate in small managed areas which provide optimal habitat conditions. Set-aside areas, however, are potentially risky since they might lead to higher carrying capacity and finally to larger populations. An opposing view calls for protection on a lager scale: geese should disperse themselves over extensive areas resulting in a reduced grazing pressure on farmland (BERGMANN et al., 2002, MEIRE & KUJIKEN, 1991).

5.2. Conclusion

Further expansion of goose breeding areas due to far-reaching environmental changes such as farming practices, nature protection and global warming is very likely. Shifts of the migration strategy in terms of arrival and departures times at stop-over sites seem already to be one of the first indications of global weather changes (DRENT et al., 2006, EICHHORN et al., 2006, VAN DER GRAAF et al., 2006). Additionally, climate changes will have an impact on reproduction and survival in the arctic breeding geese (BOYD & MADSEN, 1997, KERY et al., 2006). As a result of specialised behaviours and body designs the current habitat conditions are perfectly suitable for herbivorous waterfowl (BLACK et al., 2007). Yet population growth may become limited by changing habitat conditions along the migration route or in the wintering grounds.

This study showed that land use (farming practices, declarations of protected areas and land surface constructions) has an important impact on the distribution of breeding geese. Today, farming practices and nature protection depend on international developments and European agreements. In the international context our countries have a great responsibility of the Greylag Goose and Barnacle Goose population.

6. Summary

6.1 Summary

Traditional breeding grounds of the Russian Barnacle Goose population (*Branta leucopsis*) are along the coast of the Barents Sea and Kara Sea in the Russian Arctic. During the last decades, the population increased and expanded their breeding area by establishing new breeding colonies not only within the Russian Arctic but also in lower latitudes of the Baltic Sea and North Sea. In 2005, breeding numbers outside Russia amounted to some 12,000 pairs. A considerable increase also occurred in the Greylag Goose (*Anser anser*) population since the mid 1970s. In contrast to the Barnacle Goose, the Greylag Goose is a native breeding bird in several countries of its winter distribution and now repopulates its traditional breeding grounds.

In 2005, information about habitat characteristics and breeding biology of Greylag Geese and Barnacle Geese was collected by means of a questionnaire for various regions along the coasts of the North Sea and the Baltic Sea. For the Greylag Goose, exemplary breeding areas were studied in the Netherlands only. For the Barnacle Goose, all current breeding areas in the North Sea and Baltic Sea regions were described in detail. In the statistical analyses, the influence of habitat characteristics in relation to colony size, colony growth and bird density was investigated.

Breeding sites of the Greylag Goose are predominantly characterised by reed beds and grasslands with higher vegetation whereas brood-rearing mainly takes place on cattle grazed pastures. Statistical analysis revealed that management has a high impact on the use of brood-rearing sites. In a multivariate linear model, colony size correlated most strongly with livestock species on pastures (highest colony size on cattle grazed pastures), colony growth most strongly correlated with the type of management (highest colony growth on grasslands which were mown *and* grazed) and goose density most strongly correlated with the mowing frequency (highest density on meadows which were mown 1-3 times during the vegetation period). In contrast, predation and human disturbance showed less or no correlation at all. Most of the breeding areas are in protected areas.

New established Barnacle Goose breeding areas outside of Russia are located in Finland, Estonia, Sweden, Denmark, Germany, the Netherlands and Belgium. Colonies in the North Sea region are growing rapidly, whereas in the Baltic at least in Sweden carrying

capacity seems to be reached by now. In Estonia numbers are even decreasing. Highest breeding numbers are found in the Netherlands (6,000 pairs), followed by Sweden (5,000 pairs).
Statistical analysis showed significant differences between North Sea and Baltic Sea breeding sites. Compared to the North Sea region, breeding areas in the Baltic region are generally less intensively managed and human disturbance is low. Avian predators are present at all breeding sites in the Baltic region, whereas predation by foxes is rare and usually only occurs at brood-rearing sites. Breeding takes place on off-shore islands. In contrast, around the the North Sea almost all of the breeding sites are located on the mainland where islands in lakes and rivers are used. Besides avian predators, ground predators influence breeding and brood-rearing sites. At almost all sites, Barnacle Geese feed on managed grasslands.
On the basis of their breeding site choice, the flyway population of Barnacle Geese traditionally breeding in the Russian Arctic can be divided into three sub-populations: the Russian population, the Baltic Sea population and the North Sea population. They differ not only in habitat use but also in breeding biology.

The causes for the observed shift in breeding ranges of both species seem to be human activities, especially depended on the land use along the coastal regions. Fertilization, mowing schemes and grazing by livestock produce suitable forage for geese which remains available in high quality and quantity throughout the summer period. Further, the structure of the landscape was altered by human impact: habitats formerly characterised by tidal influence disappeared, became brackish or were transformed into inland wetlands. In those, man-made islands became popular breeding sites for both Barnacle and Greylag Geese and soon gained the status of a protection area (SPA). Today, management measures adapted to breeding birds supports favourable goose habitats. Besides, the establishment of colonies was occasionally supported by the accidental or deliberate release of waterfowl species kept in captivity.

A slow down of the increase in the total breeding numbers of Barnacle and Greylag Geese is not expected in the near future. In contrast, further expansion of breeding areas due to far-reaching environmental changes is likely. Both, Greylag and Barnacle Geese are protected species according to international directives and countries have a high responsibility for their populations.

6. 2 Zusammenfassung

6. Zusammenfassung

Die Ausbreitung der Brutgebiete der Weißwangengans (*Branta leucopsis*) und Graugans (*Anser anser*) in Nordwest-Europa unter besonderer Berücksichtigung von Landnutzungsveränderungen

Die russische Nonnenganspopulation (*Branta leucopsis*) brütet entlang der Küsten der Barentssee und der Kara See. Während der letzten Jahrzehnte wuchs die Population kontinuierlich an und erweiterte ihre Brutgebiete nicht nur innerhalb der russischen Arktis, sondern auch in südlichere Breitengrade der Ost- und Nordsee. 2005 gab es außerhalb Russlands bereits 12.000 Brutpaare. Seit den 1970er Jahren konnte auch in der Graugans-Population (*Anser anser*) ein starker Anstieg beobachtet werden. Im Gegensatz zur Nonnengans ist die Graugans in vielen Ländern ihrer Winterverbreitung auch ein Brutvogel und besiedelt heute einstige Brutgebiete wieder.

2005 wurden Informationen über Brutgebiete der Grau- und Weißwangengans in der Nordsee-Region und im Baltischen Raum gesammelt. Dabei sind Habitatparameter und Brutbiologie mit Hilfe eines Fragebogens erfasst worden. Die Untersuchung der Graugans-Brutgebiete beschränkte sich exemplarisch auf die Niederlande. Die Habitatparameter wurden in Bezug zu Koloniegröße, Koloniewachstum und Vogeldichte statistisch ausgewertet. Für die Nonnengans wurden alle aktuellen Brutgebiete außerhalb Russlands zusammengestellt und deren Entwicklung und besonderen Merkmale beschrieben.

Brutplätze der Graugans sind vorwiegend gekennzeichnet durch Schilf und Grünland mit höherer Vegetation. Zur Jungenaufzucht bevorzugen die Gänse hauptsächlich Weiden. Die statistische Auswertungen zeigten, dass das Management des jeweiligen Gebietes einen hohen Einfluss auf die Nutzung des Gebietes durch Graugänse hat. In einem multivariaten Model korrelierte die Koloniegröße am stärksten mit der Art der Nutztiere, die zur Beweidung eingesetzt wurden (größte Kolonien auf Rinderweiden). Das Koloniewachstum korrelierte am stärksten mit der Art des Managements (höchstes Wachstum auf Grünland, das beweidet *und* gemäht wird) und die Gänsedichte am stärksten mit der Mähhäufigkeit (höchste Gänsedichte bei 1-3maliger Mahd während der

Wachstumsperiode). Im Gegensatz dazu zeigten Prädation und menschliche Störung eine weniger deutliche oder keine Korrelation.

Die Weißwangengans hat außerhalb Russlands neue Brutgebiete in Finnland, Estland, Schweden, Dänemark, Deutschland, den Niederlanden und Belgien erobert. Die Kolonien in der Nordsee-Region zeigen zur Zeit einen sehr starken Zuwachs, während in der Ostsee-Region die Tragfähigkeit der Gebiete zumindest in Schweden erreicht zu sein scheint. In Estland ist sogar ein Abwärtstrend der Brutpaarzahlen zu erkennen. Die höchsten Brutpaarzahlen finden sich in den Niederlanden (ca. 6.000 Brutpaare) und in Schweden (ca. 5.000 Brutpaare).
Statistische Analysen zeigten signifikante Unterschiede zwischen den Brutgebieten der Nordsee und der Ostsee. Die baltischen Gebiete sind allgemein weniger intensiv bewirtschaftet. Auch die menschliche Störung ist niedriger. Vögel sind als Prädatoren an allen baltischen Brutplätzen anwesend, Prädation durch den Fuchs ist dagegen sehr niedrig und kommt hauptsächlich nur in den Aufzuchtsgebieten vor. Zum Brüten nutzen die Gänse kleine Inseln abseits der Küste. In der Nordsee dagegen sind die meisten Brutplätze im Inland zu finden. Hier werden oft Inseln in Flüssen oder Seen besiedelt. Neben Vögeln beeinflussen auch Bodenprädatoren die Brut- und Aufzuchtsgebiete der Nordsee-Region. Fast überall im Nordseeraum nutzen die Nonnengänse extensiv bewirtschaftetes Weidegrünland zur Nahrungssuche.
Die Russische Zugweg-Population kann auf Grund ihrer unterschiedlichen Brutplatzwahl in drei Teil-Populationen aufgeteilt werden: Die russische, die baltische und die Nordsee-Teil-Populationen. Die Teil-Populationen unterscheiden sich nicht nur in der Habitatnutzung, sondern auch in der Brutbiologie.

Die Ausbreitung der Brutgebiete der Grau- und Nonnengans wurde vor allem von menschlichen Aktivitäten beeinflusst. Hierbei spielt insbesondere die heutige Landnutzung entlang unserer Küsten eine große Rolle: Künstliche Düngung, veränderte Mahdrhythmen und beweidetes Grünland bieten den Gänsen den ganzen Sommer über optimale Futterbedingungen in hoher Qualität und Quantität. Auch hat die Landschaftsstrukturveränderung dazu beigetragen, dass sich neue, für die Gänse nutzbare Gebiete entwickelten: So sind einst von der Tide beeinflusste Flächen durch Eindeichungen verloren gegangen und an ihre Stelle sind Brackwasser-Habitate oder süßwasser-beeinflusste Feuchtgebiete entstanden. In diesem Zuge künstlich entstandene Inseln wurden innerhalb kürzester Zeit zu beliebten Brutplätzen, wodurch die Gebiete oft den Status eines Schutzgebietes gewannen. Durch ein auf die Brutvögel abgestimmtes Management werden heute vielerorts optimale Gänsehabitate aufrecht erhalten. Nicht zu vernachlässigen auf die Entstehung neuer Kolonien ist auch der Einfluss von Gefangenschaftsflüchtlingen, die neue Brutkolonien gründeten.

Eine Verlangsamung der Brutpaarzunahme oder gar eine Abnahme ist in naher Zukunft nicht zu erwarten. Im Gegenteil: Es ist sehr wahrscheinlich, dass beide Arten ihre Brutgebiete aufgrund der Umweltveränderungen (Klimawandel, Umgestaltungen in der Landwirtschaft, etc.) weiter ausbreiten.
Sowohl Nonnengänse als auch Graugänse sind europaweit geschützte Arten, und unsere Länder haben eine besondere Verantwortung für den Erhalt ihrer Population.

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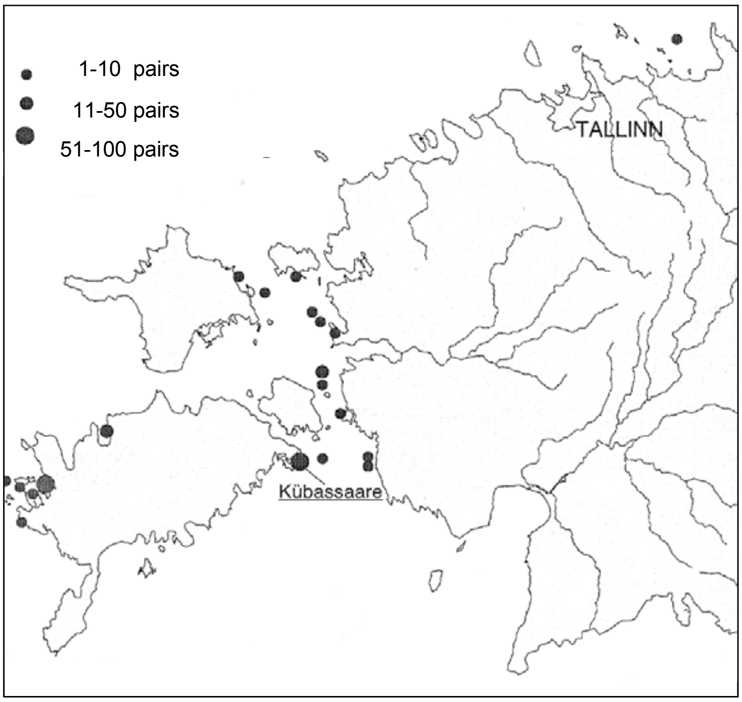

Fig. A1: Breeding sites in Estonia during the 1990s (LEITO & TRUU, 2004).

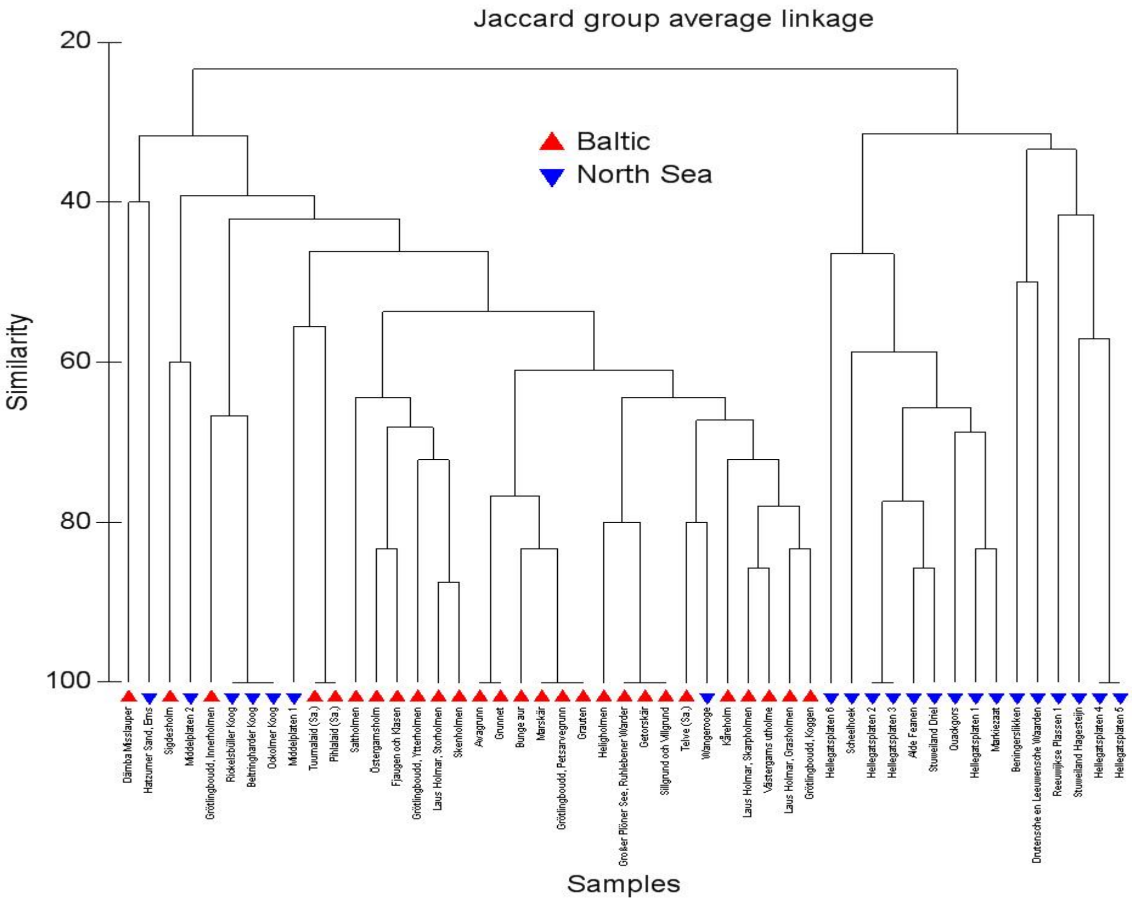

Fig. A2: Dendrogram for hierarchical clustering (group-average linkage) of north-western European Barnacle Geese breeding sites, based on Jaccard similarity matrix.

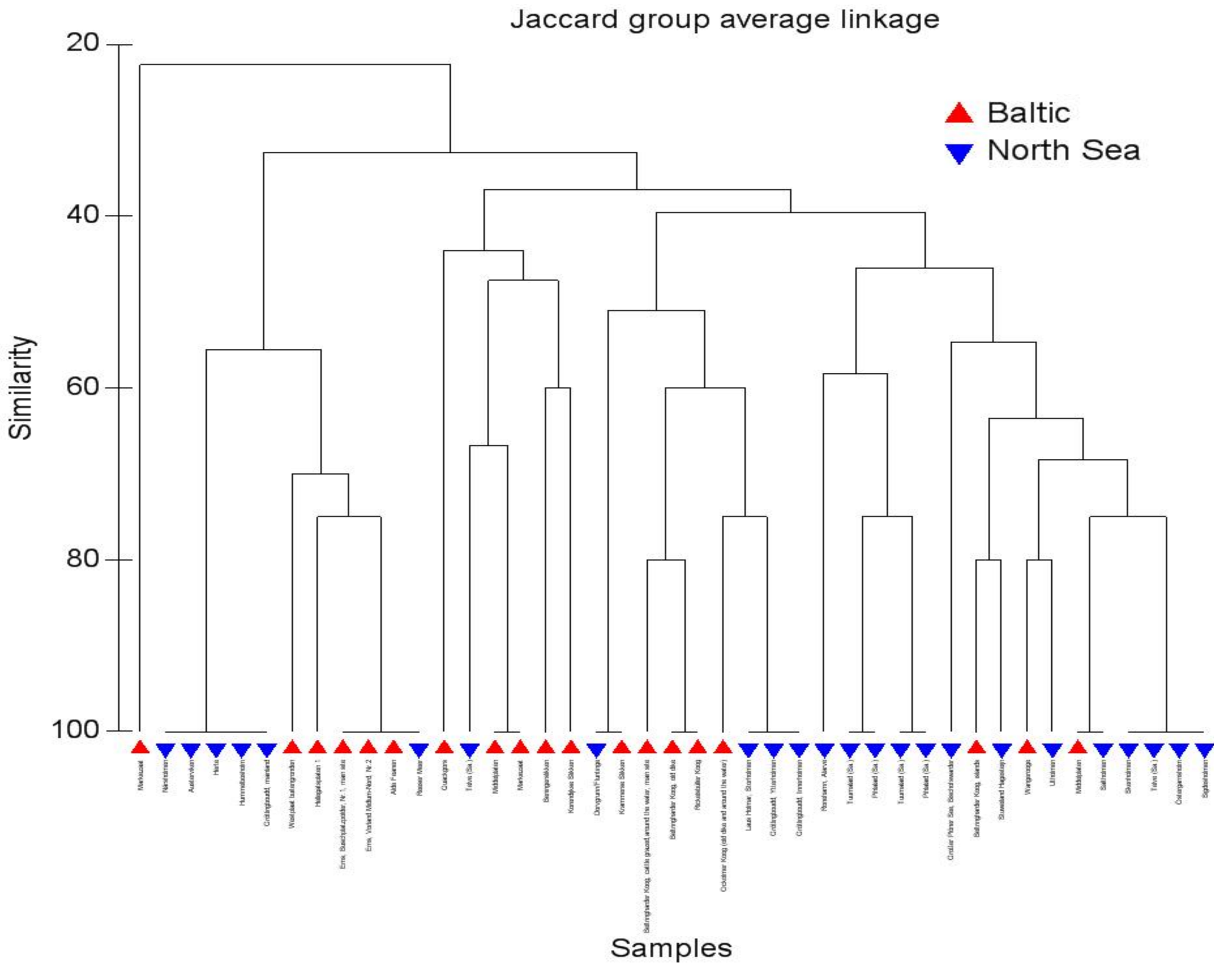

Fig. A3: Dendrogram for hierarchical clustering (group-average linkage) of north-western European Barnacle Geese brood-rearing site sites, based on Jaccard similarity matrix.

Tab. A1: Names of questionnaire respondents.

name of breeding area	data supplied by
Greylag Geese	
Alde Feanen, Jan Durks Polder	Romke Kleefstra
Ankeveense Plassen	Erik de Haan
Beningerslikken Nr.1 GG	Anton Giljam
Biesbosch	Bart A.M. Weel
Braakman	Alex Wieland
De Deelen	Romke Kleefstra
Drutensche en Leeuwensche Waarden	Leo M.F. van den Bergh
Eiland bij Vijfhoek	Frank Visbeen
Grensmaas	Ton Cuijpers
Groot Eiland	Alex Wieland
Groote Gat, Oostburg	Rene Beijersbergen
Hellegatsplaten	Henk van der Jeugd
Het Hol	Erik de Haan
Kiekgat	Jan de Roon
Korendijkse Slikken	Anton Giljam
Lepelaarsplassen	Nico Dijkshoorn
Middelplaten	Andre Hannewijk
Ooijpolder West	Frank Willems, Chris van Turnhout
Oude Rijn, Erfkamerlingschap	Alen Schotman
Oude Rijn, West Bergsehoofd	Hans Quaden
Quackgors	Han Meerman
Reeuwijkse Plassen e.o.	George de Wit
Scheelhoek	Jan de Roon
Schiermonnikoog	Otto Overdijk
Stuweiland Hagesteijn	Wilco Stoopendaal
Vaalwaard	Andre ten Hoedt
Verdronken Land van Saeftinghe	Rene Beijersbergen
Weerribben	Jeroen Breedenbeek
Wieden	Natuurmonumenten De Wieden
Wormer- en Jisperveld	Jan G.P. van der Geld
Barnacle Geese	
Alde Feanen	Romke Kleefstra
Beningerslikken	Anton Giljam
Drutensche en Leeuwensche Waarden	Leo M.F. van den Bergh
Hellegatsplaten	Henk van der Jeugd
Hellegatsplaten Krib hellegat	Alexander J. van der Graaf
Korendijkse Slikken	Anton Giljam
Markiezaat	Ton Bakker
Middelplaten	Andre Hannewijk
Noordplaat	Alexander J. van der Graaf
Quackgors	Han Meerman
Reeuwijkse Plassen	George de Wit
Scheelhoek	Jan de Roon
Slijkplaat	Alexander J. van der Graaf
Slikken v.d. Heen	Alexander J. van der Graaf
Stuweiland Driel	Ton Bakker
Stuweiland Hagesteijn	Wilco Stoopendaal
Uiterwaarden Lek	Alexander J. van der Graaf
Westplaat buitengronden	Alexander J. van der Graaf
Wormer & Jisperveld	Jan G.P. van der Geld
Beltringharder Koog	Walther Petersen-Andresen
Großer Plöner See, Ruhlebener Warder	Bernd Koop
Hatzumer Sand, Ems	Kees Koffijberg
Ockolmer Koog	Walther Petersen-Andresen
Reeser Meer	Stefan Sudmann
Rickelsbüller Koog	Walther Petersen-Andresen
Wangerooge	Mathias Heckroth
Saltholmen	Christian Ebbe Mortensen
all Swedish sites	Kjell Larsson
all Estonian sites	Aivar Leito

Tab. A2 Overview of Greylag Goose breeding areas in 2005 included in the analysis.

Name of breeding area	**total number of BP**	**first year of breeding**	**colony growth (λ)**	**number of breeding sites**	**number of BP at breeding sites**	**number of brood-rearing sites**	**number of BP at brood-rearing sites**	**number of non-breeding sites**
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
	5269			**51**	**4161**	**49**	**3448**	**32**

Tab. A3: Number of Barnacle Goose breeding and brood-rearing site sites, total number of geese, colony size, colony growth and density in relation to the location (Oneway-ANOVA test. *p> 0.5; **p> 0.01; ***p> 0.001; n.s.: not significant; n.i.: not investigated). 1): “mainland” = Gotland/Öland and Saaremaa, BRS= brood-rearing site site, BS= breeding site

	Baltic Sea			North Sea		
location	**islands**	**mainland 1)**	**significance**	**islands**	**mainland**	**significance**
breeding sites						
number of sites	25	0		21	8	
total number of geese (BP)				3389 *N=21*	1016 *N=8*	
colony size (BP)				161 ± 222 *N=21*	127 ± 217 *N=8*	n.s.
colony growth (λ)				1.51 ± 0.32 *N=20*	1.47 ± 0.33 *N=8*	n.s.
density (geese/ha)				109.7 ± 158.5 *N=19*	53.0 ± 101.9 *N=6*	n.s.
brood-rearing sites						
number of sites	12	11		6	22	
total number of geese (BP)				310 *N=5*	2934 *N=16*	
colony size (BP)				62 ± 82 *N=5*	183 ± 311 *N=16*	n.s.
colony growth (λ)				1.40 ± 0.46 *N=6*	1.51 ± 0.35 *N=16*	n.s.
density (geese/ha)				1.7 ± 1.7 *N=5*	5.7 ± 8.9 *N=15*	n.s.
distance from breeding island to mainland	**0 - 500m**	**> 500m**	**significance**	**0 - 500m**	**> 500m**	**significance**
breeding sites						
number of sites	3	22		15	4	
total number of geese (BP)	340 *N=3*	5387 *N=22*		1268 *N=15*	1590 *N=4*	
colony size (BP)	n.i.	n.i.		85 ± 108 *N=15*	398 ± 394 *N=4*	n.s.
colony growth (λ)	n.i.	n.i.		1.55 ± 0.35 *N=14*	1.32 ± 0.28 *N=4*	n.s.
density (geese/ha)	n.i.	n.i.		134.3 ± 182.4 *N=13*	64.8 ± 90.6 *N=4*	n.s.

	Baltic Sea				North Sea				
closest distance from BRS to BS	**BS same as FS**	**> 1000m**	**1000-3000m**	**>3000m**	**BS same as FS**	**> 1000m**	**1000-3000m**	**>3000m**	**significance**
number of sites	15	0	5	4	10	12	6	0	
total number of geese (BP)	674 *N=7*				2947 *N=8*	550 *N=11*	n.i.		
colony size (BP)	96 ± 180 *N=7*				368 ± 381 *N=8*	50 ± 58 *N=11*	n.i.		*
colony growth (λ)					1.52 ± 0.42 *N=9*	1.52 ± 0.31 *N=12*	n.i.		n.s.
density (geese/ha)	0.9 ± 0.4 *N=7*				3.0 ± 5.3 *N=8*	7.6 ± 10.1 *N=9*	n.i.		n.s.
farthest distance from BRS to BS	**BS same as FS**	**> 1000m**	**1000-3000m**	**>3000m**	**BS same as FS**	**> 1000m**	**1000-3000m**	**>3000m**	**significance**
number of sites	1	1	10	12	4	10	11	0	
total number of geese (BP)						396 *N=9*	2260 *N=8*		
colony size (BP)					n.i.	44 ± 63 *N=9*	283 ± *380* *N=8*		n.s.
colony growth (λ)					1.75 ± 0.50 *N=4*	1.46 ± 0.31 *N=10*	1.46 ± 0.36 *N=7*		n.s.
density (geese/ha)					n.i.	8.2 ± 10.7 *N=8*	4.2 ± 5.7 *N=6*		n.s.

Tab. A4: Number of Barnacle Goose breeding and brood-rearing site sites, total number of geese, colony size, colony growth and density in relation to management (Oneway-ANOVA test. *p> 0.5; **p> 0.01; ***p> 0.001; n.s.: not significant; n.i.: not investigated).

	Baltic Sea					North Sea				
grazing	**no**		**yes**		**significance**	**no**		**yes**		**significance**
breeding sites										
number of sites	15		10			21		8		
total number of geese (BP)	1378	*N=15*	4349	*N=10*		3272	*N=21*	1133	*N=8*	
colony size (BP)	92 ± 105	*N=15*	435 ± 527	*N=10*	*	156 ± 224	*N=21*	142 ± 215	*N=8*	n.s.
colony growth (λ)	1.16 ± 0.18	*N=11*	1.23 ± 0.40	*N=10*	n.s.	1.49 ± 0.32	*N=20*	1.51 ± 0.34	*N=8*	n.s.
density (geese/ha)	18 ± 15.7	*N=15*	17.2 ± 23.2	*N=10*	n.s.	123.1 ± 159.9	*N=19*	10.4 ± 10.0	*N=6*	*
brood-rearing sites										
number of sites	5		17			4		25		
total number of geese (BP)								3382	*N=19*	
colony size (BP)						n.i.		178 ± 291	*N=19*	n.i.
colony growth (λ)						1.42 ± 0.53	*N=4*	1.49 ± 0.34	*N=19*	n.s.
density (geese/ha)						5.2 ± 8.4	*N=17*			n.i.
mowing	**no**		**yes**		**significance**	**no**		**yes**		**significance**
breeding sites										
number of sites	25		0			22		7		
total number of geese (BP)						3025	*N=22*	1380	*N=7*	
colony size (BP)						138 ± 216	*N=22*	197 ± 234	*N=7*	n.s.
colony growth (λ)						1.46 ± 0.29	*N=21*	1.59 ± 0.41	*N=7*	n.s.
density (geese/ha)						119.8 ± 161.6	*N=19*	20.8 ± 28.8	*N=6*	*
brood-rearing sites										
number of sites	23		1			12		14		
total number of geese (BP)						1167	*N=10*	1703	*N=11*	
colony size (BP)						117 ± 165	*N=10*	163 ± 328	*N=11*	n.s.
colony growth (λ)						1.48 ± 0.34	*N=11*	1.52 ± 4.2	*N=10*	n.s.
density (geese/ha)						8.5 ± 10.4	*N=8*	2.3 ± 4.6	*N=11*	*

North Sea

grazing by different livestock species	**cattle**		**cattle & horse**		**cattle & sheep**		**significance**
brood-rearing sites							
number of sites	9		6		6		
total number of geese (BP)	715	*N=7*	1759	*N=4*	775	*N=5*	
colony size (BP)	102 ± 194	*N=7*	440 ± 454	*N=4*	155 ± 278	*N=5*	n.s.
colony growth (λ)	1.43 ± 0.32	*N=6*	1.38 ± 0.47	*N=5*	1.59 ± .014	*N=5*	n.s.
density (geese/ha)	1.3 ± 1.5	*N=6*	4.7 ± 7.4	*N=4*	11.7 ± 12.4	*N=5*	n.s.

Tab. A5: Number of Barnacle Goose breeding and brood-rearing site sites, total number of geese, colony size, colony growth and density in relation to predation, hunting and nature protection (Oneway-ANOVA test. *p> 0.5; **p> 0.01; ***p> 0.001; n.s.: not significant; n.i.: not investigated).

	Baltic Sea					North Sea				
predation	**no**		**yes**		**significance**	**no**		**yes**		**significance**
breeding sites										
number of sites	0		25			8		17		
total number of geese (BP)						1460	*N=8*	1370	*N=17*	
colony size (BP)						183 ± 230	*N=8*	81 ± 102	*N=17*	n.s.
colony growth (λ)						1.37 ± 28	*N=8*	1.55 ± 0.36	*N=17*	n.s.
density (geese/ha)						55.9 ± 92.4	*N=8*	130.6 ± 179.6	*N=14*	n.s.
brood-rearing sites										
number of sites	1		7			9		12		
total number of geese (BP)						1701	*N=9*	1624	*N=10*	
colony size (BP)						189 ± 360	*N=9*	162 ± 236	*N=10*	n.s.
colony growth (λ)						1.43 ± 0.25	*N=8*	1.60 ± 0.43	*N=11*	n.s.
density (geese/ha)						6.4 ± 6.0	*N=7*	4.4 ± 9.4	*N=11*	n.s.
hunting	**no**		**yes**		**significance**	**no**		**yes**		**significance**
breeding sites										
number of sites						13		9		
total number of geese (BP)						715	*N=13*	1879	*N=9*	
colony size (BP)						55 ± 82	*N=13*	209 ± 213	*N=9*	*
colony growth (λ)						1.39 ± 0.23	*N=12*	1.69 ± 0.42	*N=9*	n.s.
density (geese/ha)						171.3 ± 191.6	*N=11*	18.8 ± 26.3	*N=8*	*
brood-rearing sites										
number of sites						11		13		
total number of geese (BP)						715	*N=11*	2888	*N=10*	
colony size (BP)						65 ± 158	*N=11*	289 ± 340	*N=10*	*
colony growth (λ)						1.38 ± 0.26	*N=10*	1.64 ± 4.01	*N=11*	n.s.
density (geese/ha)						6.5 ± 10.0	*N=10*	3.2 ± 4.9	*N=9*	n.s.
nature reserve	**no**		**yes**		**significance**	**no**		**yes**		**significance**
breeding sites										
number of sites	9		16			4		25		
total number of geese (BP)	616		5111			551	*N=4*	3854	*N=25*	
colony size (BP)	68 ± 82	*N=9*	319 ± 443	*N=16*	*			154 ± 227	*N=25*	
colony growth (λ)	1.31 ± 0.38	*N=8*	1.12 ± 0.22	*N=13*	n.s.			1.50 ± 0.33	*N=25*	
density (geese/ha)	12.3 ± 11.2	*N=9*	2.7 ± 21.4	*N=16*	n.s.			101.2 ± 152.2	*N=23*	
brood-rearing sites										
number of sites	7		13			7		21		
total number of geese (BP)						184	*N=6*	3426	*N=16*	
colony size (BP)						31 ± 37	*N=6*	214 ± 308	*N=16*	n.s.
colony growth (λ)						1.42 ± 0.26	*N=5*	1.5 0.39	*N=18*	n.s.
density (geese/ha)						0.1 ± 0.0	*N=4*	5.8 8.4	*N=16*	***

Tab. A6: Number of Barnacle Goose breeding and brood-rearing site sites, total number of geese, colony size, colony growth and density in relation to frequency of human disturbance and vegetation (Oneway-ANOVA test. *p> 0.5; **p> 0.01; ***p> 0.001; n.s.: not significant; n.i.: not investigated).

	Baltic Sea				North Sea			
frequency of human disturbance	**never up to once a week**	**2-6 days a week**	**every day**	**significance**	**never up to once a week**	**2-6 days a week**	**every day**	**significance**
breeding sites								
number of sites	22	2	1		13	11	1	
total number of geese (BP)	3943 *N=22*	1280 *N=2*	504 *N=1*		1263 *N=13*	929 *N=11*		
colony size (BP)	179 ± 336 *N=22*	n.i.	n.i.		97 ± 136 *N=13*	84 ± 87 *N=11*		n.s.
colony growth (λ)	1.18 ± 0.30 *N=18*	n.i.	n.i.		1.48 ± 0.41 *N=12*	1.53 ± 0.28 *N=11*		n.s.
density (geese/ha)	18.6 ± 19.3 *N=22*	n.i.	n.i.		90.5 ±145. *N=10*	124.5 ± 173.4 *N=11*		n.s.
brood-rearing sites								
number of sites	6		2		9	14	1	
total number of geese (BP)					1007 *N=9*	2596 *N=12*		
colony size (BP)					112 ± 211 *N=9*	216 ± 322 *N=12*		n.s.
colony growth (λ)					1.39 ± 0.29 *N=9*	1.61 ± 0.4 *N=12*		n.s.
density (geese/ha)					8.2 ± 10.6 *N=8*	2.6 ± 4.6 *N=11*		n.s.

	Baltic Sea			North Sea					
vegetation	**grass**	**grass & bushes**	**significance**	**grass**	**grass & bushes**	**eutrophic herbs & bushery**	**bare soil with higher vegetation**	**grasses & eutrophic herbs**	**significance**
breeding sites									
number of sites	11	10		8	5	7	6	2	
total number of geese (BP)	4103 *N=11*	1036 *N=10*		1012 *N=8*	721 *N=5*	1052 *N=7*	1436 *N=6*		
colony size (BP)	373 ± 520 *N=11*	104 ± 93 *N=10*	n.s.	127 ± 218 *N=8*	144 ± 162 *N=5*	150 ± 144 *N=7*	239 ± 367 *N=6*		n.s.
colony growth (λ)	1.16 ± 0.36 *N=11*	1.20 ± 0.18 *N=8*	n.s.	1.50 0.22 *N=8*	1.55 ± 0.50 *N=4*	1.41 ± 0.33 *N=7*	1.56 ± 0.40 *N=6*		n.s.
density (geese/ha)	19.3 ± 21.5 *N=11*	18.4 ± 19.3 *N=10*	n.s.	129.1 ± 160.5 *N=7*	33.9 ± 37.5 *N=3*	155.1 ± 206.8 *N=7*	16.0 ± 16.8 *N=6*		n.s.
brood-rearing sites									
number of sites	21	2		17	0	2	2	8	
total number of geese (BP)	674 *N=7*			1944 *N=10*				1363 *N=8*	
colony size (BP)	96 ± *180* *N=7*			194 ± *240* *N=10*				170 ± *377* *N=8*	n.s.
colony growth (λ)				1.51 ± 0.39 *N=12*				1.51 ± 0.32 *N=8*	n.s.
density (geese/ha)	0.9 ± 0.4 *N=7*			1.3 ± 1.4 *N=11*				12.2 ± 11.4 *N=6*	*

EIDESSTATTLICHE ERKLÄRUNG

Ich erkläre hiermit an Eides statt, dass ich die vorliegende Diplomarbeit selbst und nur unter Verwendung der angegebenen Hilfsmittel und Quellen angefertigt habe.

Die Arbeit ist in gleicher oder ähnlicher Form noch keiner anderen Prüfungsbehörde vorgelegt worden.